PRETREATMENT AND POSTTREATMENT CHANGE OF CLINICAL DENTAL ARCH FORM IN ANGLE'S CLASSIFICATION II DIVISION 1 IN THAI

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ABSTRACT

The purpose of the present study was to define a generalized equation describing a Thai person's dental arch form as specified in Angle's classification II, Division 1. This was done by applying a computer-curve fitting program to compare the pretreatment and posttreatment clinical dental arch form, and to determine arch wire selection for treatment in Angle's classification II, Division1 malocclusion in Thais. The study was comprised of 22 sets (8 males and 14 females) of pretreatment and posttreatment dental models which initially expressed Angle's Classification II, Division 1 malocclusion. The following describes the pretreatment and posttreatment clinical dental arch form : Fourteen and twelve dental landmarks on the bracket positions from the buccal surface of molars, premolars, the labial surface of the canines and incisors of each dental models were triggered and recorded using the Coordinate Measuring Machine and reported into their corresponding coordinates (X-, and Y- direction). These coordinates were processed through a computer curve-fitting program to define the parameter of beta function in order to describe their dental arches.

The dental arch forms of Thai people who had a Class II, Division 1 malocclusion were shown to be accurately represented mathematically by the beta function. The coefficient of the determination between the measured arch-shape data and the mathematical arch shape was expressed by the beta function. The average coefficient was 0.97 with a standard deviation of 0.02. When pretreatment and posttreatment Class II were compared, there was a statistically significant decrease in a-parameter (arch depth) and intermolar width both in maxillary and mandibular arches, but the remaining parameters were not statistically significant different. When sexual dimorphism was examined, males showed a larger arch form than the females but only in pretreatment maxillary arch depth (a-parameter) maxillary and mandibular intermolar width. The results revealed that gender seemed to have little influence on arch form differences. For the arch wires selection, Class I and Class II, Division 1 dental arch form fitted quite nicely with the OrthoForm tapered-shaped preformed arch wire.

KEY WORDS: BETA FUNCTION / DENTAL ARCH FORM / COORDINATE MEASURING MACHINE / CLASS II DIVISION1 / PRETREATMENT / POSTTREATMENT / ARCH WIRE

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แนวความโค้งการเรียงตัวของฟันในคนไทยที่มีการสบฟันชนิดที่ 2 ดิวิชั่น 1 ก่อนและหลังการรักษาทางทันตกรรมจัดฟัน (PRETREATMENT AND POSTTREATMENT CHANGE OF CLINICAL DENTAL ARCH FORM IN ANGLE’S CLASSIFICATION II DIVISION 1 IN THAI)

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บทคัดย่อ

วัตถุประสงค์ของการศึกษาครั้งนี้เพื่อค้นหาสมการทั่วไปทางคณิตศาสตร์ที่จะใช้ในการอธิบายถึงแนวความโค้งการเรียงตัวของฟันในขากรรไกรในคนไทยที่มีการสบฟันชนิดที่ 2 ดิวิชั่น 1 เพื่อเปรียบเทียบแนวความโค้งการเรียงตัวของฟันในทางคลินิกก่อนและหลังการรักษาทางทันตกรรมจัดฟัน และเพื่อใช้ในการตัดสินใจเลือกลวดจัดฟันในการรักษาความผิดปกติของการสบฟันชนิดที่ 2 ดิวิชั่น 1 ในคนไทย ข้อมูลมีจำนวน 22 ชุด (เพศชาย 8 ชุด, หญิง 14 ชุด) ในแต่ละชุดจะมีวิธีการวัดแนวความโค้งการเรียงตัวของฟันในทางคลินิก ก่อนและหลังการรักษาทางทันตกรรมจัดฟันโดยการถอนฟันกรามน้อยซี่ที่ 1 เป็นจำนวน 4 ซี่ ร่วมกับการจัดฟัน การวัดแนวความโค้งการเรียงตัวของฟันในทางคลินิกจะวัดที่ตำแหน่งที่ติดเบรกเกต จำนวน 14 จุด (ก่อนรักษา) และ 12 จุด (หลังรักษา) ในการวัดจะใช้เครื่องวัดพิกัดสามมิติและรายงานผลการวัดเป็นพิกัดความสัมพันธ์ในแนวระนาบแกนเอกซ์และวาย ข้อมูลจะถูกนำมาใช้เพื่อหาค่าสัมประสิทธิ์ของสมการเบต้า ฟังก์ชันเพื่อใช้ในการอธิบายแนวความโค้งของการเรียงตัวของฟัน

ผลการศึกษาพบว่า เบต้าฟังก์ชันเป็นสมการทางคณิตศาสตร์ที่อธิบายถึงแนวความโค้งการเรียงตัวของฟันในคนไทยที่มีการสบฟันแบบที่2 ดิวิชั่น 1 ได้ถูกต้องแม่นยำสูง แสดงด้วยค่าสัมประสิทธิ์แห่งการกำหนดเฉลี่ย 0.97 เมื่อเปรียบเทียบผลก่อนและหลังการรักษาทางทันตกรรมจัดฟัน ในการรักษาความผิดปกติของการสบฟันชนิดที่ 2 ดิวิชั่น 1 ในคนไทย พบว่าภายหลังการรักษาจะมีแนวโค้งการเรียงตัวของฟันที่สั้นลง และมีระยะห่างระหว่างฟันกรามซี่แรกที่แคบลง ทั้งในขากรรไกรบน และล่าง

เมื่อเปรียบเทียบความแตกต่างระหว่างเพศ ก่อนและหลังการรักษาทางทันตกรรมจัดฟัน จะพบว่าเพศชายมีขนาดของแนวความโค้งการเรียงตัวของฟันที่ใหญ่กว่าเพศหญิงเพียงบางค่า ดังนั้น เพศจึงมีอิทธิพลต่อรูปร่างของแนวความโค้งการเรียงตัวของฟันน้อย

ในการตัดสินใจเลือกลวดจัดฟันเพื่อการรักษาความผิดปกติของการสบฟันชนิดที่ 1 และ ชนิดที่ 2 ดิวิชั่น 1 ในคนไทยนั้น สามารถเลือกใช้ลวดจัดฟันรูปร่าง tapered ของ OrthoForm ในการรักษาผู้ป่วยที่มีความผิดปกติรูปแบบดังกล่าวได้

120 หน้า

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CHAPTER 1

INTRODUCTION

Dental arch width and form are important factors for determining the success and stability of orthodontic treatment. Arch shape affects both the functional and the esthetics of the occlusion. Preservation of dental arch shape during growth is an indicator of equilibrium between tongue and circumoral muscle forces[1]. Dimensional changes of dental arches might affect arch form as well. Arch width changes during growth and after orthodontic therapy have been examined in various studies[2-5]. A general tendency toward an increase in intermolar width was noted during the change from deciduous to permanent dentition. This expansion is generally accompanied by a decrease in arch depth[6, 7].

In arch form studies, attempts have been made to define an ideal arch shape[6, 8, 9], but considerable individual variability existed. Studies of untreated subjects showed a pentamorphic arch system, which included 5 different types of arch form : normal, ovoid, tapered, narrow ovoid, narrow tapered[10]. Various methods have been used to define these arch forms mathematically, including geometric curves, such as ellipses[1, 11, 12], parabolas[13], caternary curves[14, 15], and equations, such as polynomial functions[8, 13, 16], cubic splines[17, 18], conic sections[19], β-functions[16, 20, 21], and the Bezier cubic equation[22].

Few studies have been conducted to evaluated longitudinal dental arch form changes in orthodontically treated subjects. The commonly held view has been that the original arch form should be maintained to ensure stability. However, in certain patients, arch form is purposely changed with orthodontic treatment. In Class II Division 1 patients with a tapered maxillary arch form and flared incisors, the maxillary arch is frequently expanded to accommodate the mandibular arch during the antero-posterior correction of the jaw relationship[19, 23].

Little[24] based on more than 35 years of research, recommended as a clinical guideline that the patient's pretreatment arch form be used as a guide to posttreatment arch shape. The application of a single ideal arch form to every member of an ethnic group, despite individual variations, may adversely affect posttreatment occlusal stability.

Meanwhile, with the recent advancements in superelastic wire materials and preadjusted appliance systems, preformed arch wires have been commercially available and frequently used, mainly in the leveling and alignment stages. However, their superelastic property makes customization of arch form and sized difficult. After more than 20 years with the preadjusted appliance, it is apparent to the authors that some customizing of the arch form for individual patients is important. In-out is built into the preadjusted appliance, and this eliminates the need for first order bends. It thus simplifies arch form, but it does not eliminate the need to use different shapes for different individuals.

Failure to do some customization will create the probability of relapse in some cases, and can lead to unnatural esthetics. If a broad arch form is used for an individual with a narrow facial appearance, for example, there will be a risk of relapse and an unnatural look to the smile. A return to the concept of customizing arch form for each patient, but without the need for needless wire bending, is a desirable and sensible approach. Clinically, it seems more reasonable to have several types of preformed arch wire available and to select the shape that most closely match the patient's arch form according to their ethnicity and type of malocclusion.

For several years, researchers have been trying to define the ideal arch form, frequently using the concept that the dental arch form is similar to the mathematical formulas as well as the catenary curve. Several studies of the shapes of dental arches have received both praise and criticism, and several have formed the basis for commercially produced arch form, but this is more appropriate to Caucasian.

In several studies, it also holds that people form different ethnic groups present different modal conditions. Furthermore, the previous study showed that different types of Angle's classification presented different arch forms, and the clinician should anticipate the differences in size and form rather than treating all cases to a single ideal.

In the present day, superelastic preformed arch wire are used widely but there are many problems about a wide variety of shape and size of arch form.

Kmolvisit[25] studied arch form of Angle’s classification II, Division 1 in Thais that exhibited generalized reduced arch width and depth compared with the Class I arches and found that the beta function accurately describes it.

This study aim to compare the dental arch width changes of Angle’s classification II, Division 1 malocclusion after four first premolars extraction therapies and to determine the changes in arch widths and arch depth because of treatment in Angle’s classification II, Division 1 malocclusion in Thai samples.

The purposes of the study

1. To determine the dynamic relationships between clinical arch depth and arch width the pretreatment and posttreatment clinical dental arch form in Angle classification II, Division 1 in Thais by the application of a computer curve – fitting program which may yield important clinical applications.

2. To compare the clinical dental arch form changes between pretreatment and posttreatment in Angle classification II, Division1 malocclusion after four first premolars extraction therapies.

3. To compare the pretreatment and posttreatment clinical dental arch form parameters (a-, c-, d-parameter, intercanine, and intermolar width) according to sexual dimorphism.

4. To determine whether samples of Angle classification I and classification II, Division1 malocclusion cases display similar arch form characteristics.

5. This present work can be used as a database for further studies in arch wire selection for treatment in Angle’s classification II, Division1 malocclusion in Thais.

The expected benefits of this study

1. The deduction of the equation will be useful in determining the dynamic relationships between arch depth and arch width and may yield important clinical applications.

2. The clinician could use the differences between the norm of Angle’s classification I and classification II, Division1 malocclusion in Thais for the dental arch widths, arch depths, and arch taperedness measurements in the diagnosis and treatment planning.

3. It is an appropriated database useful for selection of the commercial arch wires that are fitting for treatment in Angle’s classification II, Division1 malocclusion in Thais.

Statement of hypothesis

1. There are no correlation between the recorded coordinates and the calculated coordinates from the equation.

2. The beta function fits the Thai clinical dental arch form in the pretreatment and posttreatment in Angle’s classification II, Division 1.

3. There are no difference between the pretreatment and posttreatment clinical dental arch forms in Angle’s classification II, Division1 malocclusion after four first premolars extraction therapies.

4. There are no difference in the pretreatment and posttreatment clinical dental arch forms changes among sexual dimorphism.

5. There are no differences between clinical dental arch forms in Angle’s classification I and classification II, Division1 malocclusion both the pretreatment and posttreatment after four first premolars extraction therapies.

CHAPTER 2

LITERATURE REVIEW

The form of human dental arches has been widely studied from several points of view. Human anatomy, physical anthropology and dentistry have all investigated the size and shape of arches, together with qualitative, and sometimes quantitative determinations of dental morphology[1].

A literature review reveals that arch form has been discussed in dental and orthodontic publications for over a century. Four contradictory themes have dominated the clinical observations and research[2]:

- A persistent search for the ideal arch form for the human dentition.
- Awareness that there is great variation among human arch forms.
- Archwires selection during different stages of treatment.
- Observations that changes from the initial arch form lead to a proportionate amount of subsequent relapse.

The historical search for the ideal arch form

In the early 1900s numerous authors described shapes for the dental arches. For example in 1902 Broomell[3] wrote that “...the teeth are arranged in the jaws in the form of two parabolic curves, the superior arch describing the segment of a larger circle than the inferior, as a result of which the upper teeth slightly overhang the lower”.

However, Bonwill and Hawley were the most influential early writers, leading to the Bonwill-Hawley arch form. In 1885, Bonwill[4], whose work was concerned with full dentures, had noted the tripod shape of the lower jaw and declared that it formed an equilateral triangle with the base extending from condyle to condyle and the sides extending from each condyle to the midline of the central incisors. He stated that this triangle existed for the proper functioning of the teeth. Importantly, the noted that the premolars and molars formed a straight line from the canines to the condyles.

In 1905, Hawley[5] employed some of Bonwill's principles in proposing a geometric method for constructing the ideal arch form. Hawley suggested that the lower six anterior teeth be made to lie along a circle whose radius equaled their combined widths. From this circle he created an equilateral triangle, the base of which represented the intercondylar width. It was proposed that the premolars and molars should be aligned along these extended straight lines. Hawley did, however, advise against the strict use of this method for determining arch form, stating that it should be used only as a guide in establishing arch form.

In 1907, Angle[6]discussed in detail the “line of occlusion”. The form of this line was said to resemble a parabolic curve but one that varied greatly due to race, type, and temperament, of the individual. Because of these variables, Angle did not consider the Bonwill-Hawley arch form to be useful for anything more than a general approximation of the true line of occlusion. Angle objected particularly to the straight line proposed from canine to third molar. He stated that a straight line existed from canine to the mesio-buccal cusp of the first molar, but that there was a need for a natural curvature in the molar region.

In 1934, Chuck[7] noted the variation in human archform and pointed out that archforms had been referred to as square, round, oval, tapering, etc. He stated that while the Bonwill-Hawley archform was not suitable for every patient, it could be used as a template for the construction of individualized arch forms. Chuck superimposed this arch form on a millimeter grid and used this template for archwire construction according to Angle's method. Chuck suggested that the premolar regions should be wider than the canines to prevent excessive expansion of the canines.

In 1963, Boone[8] proposed a similar superimposition of the Bonwill-Hawley arch form on a millimeter template for construction of the individualized edgewise arch form (figure 1). Thus, over the years the Bonwill-Hawley archform has been the most consistently used arch form as a beginning template for edgewise orthodontists. It is the “standard” arch form offered by most orthodontic manufacturers today.

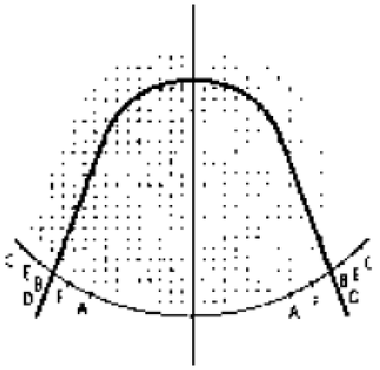


Figure 1: Traditional edgewise wire bending and Boone arch form.

The 1942 edition of Gray's Anatomy[9] stated “The maxillary dental arch forms an elliptical curve ... the mandibular dental arch forms a parabolic curve”. MacConaill[10] disagreed, pointing out that it would be impossible for an ellipse and a parabola to meet one another at every point. He concluded that the ellipse-parabola description of the two dental arches, although elegant, had no immediate relation to function. He stated that a certain simple and well known curve, the catenary curve, fitted so many cases with exactness that it could be taken as the “ideal curve” of common occlusions. The catenary curve is formed simply by suspending a chain of appropriate length from two points of varying width for example width of the most distal molars in the arch form (figure 2). The precise shape depends on the weight of each link of the chain, and the distance between the suspension points. Many of the tapered arch forms provided by orthodontic manufacturers today are based on the catenary curve.

Figure 2: The catenary curve is formed by extending a chain from two fixed points.

In 1957, Scott[11] also supported the concept of the catenary curve as the shape of the human arch based on the developmental anatomy of the dental arches and surrounding anatomic structures.

Burdi and Lillie[12] in 1966 further stated that the basic bony arch is established by ten weeks in utero, in the form of a catenary curve. However, their research actually showed not only the catenary form, but numerous other arch forms also. Musich and Ackerman[13], in 1973, further supported the concept of the catenary curve as the ideal arch form, and suggested the use of the catenometer as a reliable device for construction of arch form. However, in 1977 White[14] evaluated the suitability of the catenary curve, and found it was a “good fit” in only 27% of cases.

The catenary curve creates a rather tapered arch form. Many of the “tapered” arch forms from orthodontic manufacturers today are based on the catenary curve.

In 1972 a major publication attempting to establish the “ideal” archform was presented by Brader[15]. He considered the teeth to be in soft tissue balance. He thus stated that dental arch form is made up of teeth which assume positions along a compound curve, with equilibrium at all points, due to the balancing forces of the tongue and circumoral tissues.

Brader recommended an arch guide with five arch forms. The selection of the proper arch form was based on arch width at the second molars as measured at the buccal, gingival surface. The maxillary arch form was selected one size larger than the mandibular arch form. While the Brader arch form provided a convenient method of archwire selection, clinicians found that this arch form caused narrowing in the canine region of many patients and led to excessive canine wear.

Braun S, Hnat WP, Kusnoto B, Hnat FW.[16] proved that the beta function most closely represents the human dental arch. The data were obtained by recording the coordinates of the cusp tips locations of forty sets of casts (15 Class I, 16 Class II, and 9 Class III). Subdivision occlusions were not included in the study. Casts exhibiting incisal or cuspal atrrition, fracture of teeth, ectopically erupted teeth, or deciduous teeth were excluded from this study; only casts of fully developed adult dentitions (including second molars) were included. A precision machine tool device (Coordinate

Measuring Machine; CMM) was used to record the X-,Y-, and Z-coordinates of selected dental landmarks on all casts to 0.001 mm. accuracy.

Coordinates were recorded at the center of each incisor incisal edge, at the cusp tips of the canines and premolars, and at the mesiobuccal and distobuccal cusp tips of each molar. Eighteen points were recorded in each dental arch. The coordinates were processed through a computer curve-fitting program.

The dental arch described by the beta function, was given by

$$Y = 3.031\ D\ \{x/\ w + ½\ \}^{0.8}\{1/2 - x/\ w\}^{0.8}$$

W represents the cross – arch distance between the second molar contact points.

D represents the perpendicular distance form the most anterior point between the two central incisors to the molar cross-arch dimension, as illustrated in figure 3.

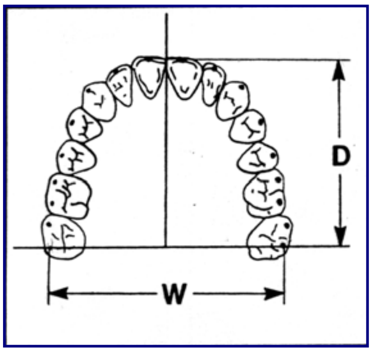


Figure 3: The dental landmarks and parameters in Braun et. al.'s study: W = arch width, D = arch depth.

The beta function has been shown to be an accurate representation of the human dental arches. The mean correlation coefficient of curve fit was found to be 0.98, with a standard deviation of 0.02, for the complete sample of 80 casts. From these study, they concluded that the beta function more accurately described the dental arch form than representations previously reported.

Braun and Hnat[17] studied the dynamic relationships of the mandibular anterior segment. Twenty-one mandibular casts of untreated patients that showed to minimal anterior segment irregularities were selected. Measurements were made at each canine cusp tip, the center of each incisor incisal edge, and the normal contact between the first bicuspids and canines.

An analytical equation of the anterior segment shape was required to describe the relationships between the intercanine width, anterior segment depth, anterior arch perimeter, and incisor angulation.

Thus the generalized equation of the mandibular anterior segment shape may be expressed as

$$Y = -\cos h \{x/ b \cos h^{-1} (h+1)\} +1.0+h$$

b represents half the cross arch distance between the normal distal contacts of the right and left canines, as illustrated.

h represents the distance measured along a line form the contacts of the central incisors perpendicular to a line connecting the distal contacts of the canine, as illustrated in figure 4.

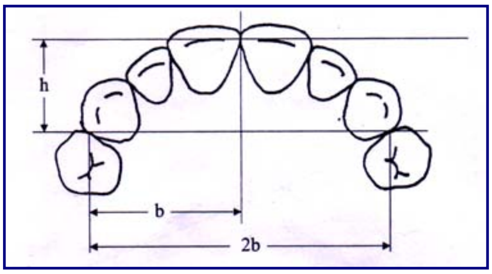


Figure 4: The parameters (h) and (b) used in Braun et. al.'s study.

The arch perimeter may then be calculated using

$$L = \int_{-w}^{+w} \sqrt{1+\left(\frac{dy}{dx}\right)^{2}}\, dx$$

Where W represents the cross arch distance from the normal canine/first premolar contact on one side to the opposite side in milimeters, and L is the anterior segment arch perimeter from the canine/first premolar normal contact along the arch to the opposite side in millimeters.

The related angular change for a typical mandibular incisor was given by the formula

$$\Delta\theta = \tan^{-1}\frac{\Delta D}{14.2}$$

Where ΔD was the change in depth of the anterior segment in millimeter.

The above relationships were of value in treatment planning. The outcome in anterior arch perimeter, depth, and incisor angular change can be forecast with accuacy (r = 0.951) without resorting to trail and error or doing a wax-up.

The variation in human arch form

Most authors have acknowledged that there is variability in the size and shape of human arch form. Angle[6] had noted that individual arch forms varied, and he therefore did not consider Hawley's method to be useful for anything more than a general approximation. Over the years, however, the majority of edgewise orthodontists used the Bonwill-Hawley arch form as a beginning template for the construction of the edgewise arch wire. These construction methods were described by Angle[6], Chuck[7], Boone[8], Stoner[18], and others. Hellman[19] investigated the skulls of apes and human beings, and found no relation between the size of teeth and the form and shape of the dental arches. Therefore, he did not accept the theories of arch predetermination based on measurements of certain teeth. He concluded that mathematical methods for dealing with the question of arch form were unsatisfactory.

Stanton[20] carried out extensive investigations on arch form and pointed out the error in the Bonwill- Hawley method of arch predetermination. He used “arthrographic map makers” to study occlusions, and concluded that arch forms are open and closed, that is elliptical, parabolic, and other curves. Izard[21] based his method of arch predetermination on ratios between arch width and facial depth. He concluded that approximately 75% of arch forms were represented by an ellipse, and the rest by a parabola or a U shape. Wheeler[22] observed that dental arches generally conform to the shapes of parabolic curves, but he stated that anatomical structures could not be reduced to the mathematical precision of geometrical terms.

Sicher[23] wrote that the shapes of the dental arches vary considerably, but that the upper arch generally took on the appearance of an ellipse, and the lower arch a parabola.

White[24] compared the accuracy of various standardized arch designs with 24 untreated ideal adult occlusions. He found:

- The Bonwill-Hawley arch form had a good fit with 8% of the cases, a moderately good fit with 40% of the cases, and a poor fit with 52% of the cases.
- The Brader arch form had a good fit with 12% of the cases, a moderately good fit with 44% of the cases, and a poor fit with 44% of the cases.
- Catenary curve showed a good fit with 27% of the cases, a moderately good fit with 46% of the cases, and a poor fit with 27% of the cases.
- The Rocky Mountain Data computer-derived arch design, which is based on measurements of intermolar width, inter-canine width and arch depth, showed a good fit with 8% of the cases, and a moderately good fit with 92% of the cases. No cases showed a poor fit.

Most theories consider arch form to be symmetrical. White observed that there was a great deal of asymmetry in the arches and felt that this should be considered in arch design. Because of the variability that he found among arch form, he suggested that an occlusal “map maker” should be used to construct the shape of the arch for each individual and then used throughout orthodontic treatment.

To find out whether an ideal orthodontic arch form could be identified, Felton et al.[25] studied the mandibular models of 30 untreated normal cases, 30 Class I non-extraction cases, and 30 Class II nonextraction cases. After computerized digitizing and the use of a mathematical function called a “polynomial of the fourth degree”, they found that no particular arch form predominated in any of the three samples. They therefore stated that customizing arch forms appeared to be necessary in many cases to obtain optimum long term stability, because of the great variability in arch form observed in the study.

Furthermore comparing mandibular arch shapes (figure 6), it was evident that the dental arches associated with Class III occlusions exhibit a smaller arch depth than the Class I occlusions. Additionally, the mandibular dental arches associated with Class III occlusion were wider than the Class I mandibular arches. When Class II mandibular arches were compared with Class I arches, reduced arch width and arch depth were evident. This could be explained by the fact that some Class II relationships result from a small mandibular body. When comparing maxillary arch shapes (figure 5), it was apparent that arch depths for all Angle Classifications were essentially the same. However, Class III dental arch widths were greater than Class I widths. This begins in the lateral incisors-canines area and proceeds distally. When Class II maxillary arch widths were compared with Class I widths, they were found to be narrower, beginning in the lateral incisors-canines area.

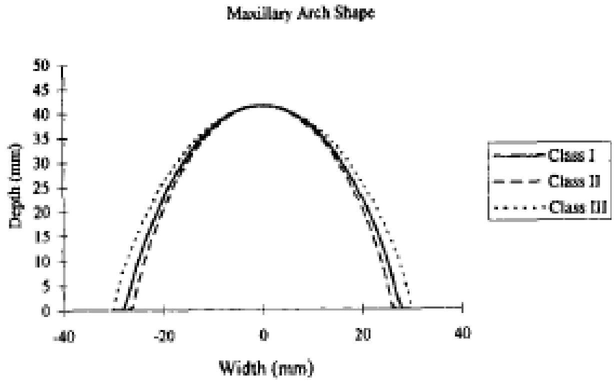


Figure 5: Average (typical) maxillary arch shapes for Class I, II, and III occlusion in Braun et. al.'s study.

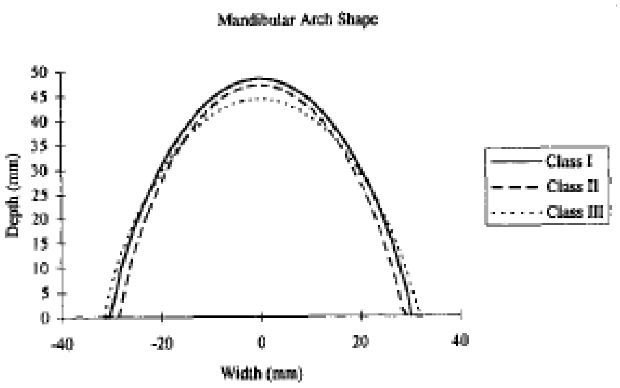


Figure 6: Average (typical) mandibular arch shapes for Class I, II, and III occlusion in Braun et. al.'s study.

Lu[26] has used the multiple regression, correlation, and the coefficient of determination to define how well-fit of the fourth order polynomial equation in the analysis of the form, symmetry and asymmetry of the dental arch. In his research, however, the observed values were (except for small errors of measurement) the truth, while the calculated values were only the approximations to the truth. Resulting from his efforts to obtain an effective representation, neither can properly be regarded as a random variable, which loosed their more time. While Bookstein's algorithm for fitting conic sections to data, or Sampson's modification of that algorithm[27] was well-suited to modeling the shape of the dental arch. Previous approaches to modeling the outline of the dental arch have used fitting algorithms which depend on the exact specification of a coordinate system.

Many of the algorithms are classic least-squares methods, minimizing the sum of squared distances from data points to a fitted curve in the direction parallel to an arbitrarity chosen Y-axis.

The present work aims at defining the mathematical equation of the dental arch's shape in the post-orthodontic treatment in the Angle classification II, Division 1 that best fit to Thai and clearly clarify differences between pre-orthodontic and post-orthodontic treatment in class II, Division 1 malocclusion in Thais.

Kmolvisit[28] studied in sample of 40 subjects (20 males and 20 females) with class II division 1 malocclusion was selected from patient records at the Department of

Orthodontics, Faculty of Dentistry, Mahidol University and from private dental clinics. The models included the full permanent teeth (excluded the third molar).

In this study, the measurement was done by using the CMM (Coordinate Measuring Machine) to record the landmarks on dental model and report these landmarks in the corresponding X-,Y-,and Z- coordinates. CMM is used extensively in the precision machine tool industry. As previously described, Braun et. al.[16] and Qiong et. al.[29] have used CMM to record the X-,Y- coordinates of dental landmarks for the study of human dental arch forms and the comparison of intermaxillary tooth size discrepancies among different malocclusion groups. The study of the reliability of CMM in measuring dental models[30] had concluded that the Coordinate Measuring Machine can be applied to measuring dental casts in three dimensions with highly accurate, reliable and reproducible results.

This study used the evolution algorithm, a good optimization method[31], to calculate the parameters of the beta function from the collected data of each dental arch. It was based on the minimized sum of squared errors of the calculated values to the measurement values (details about the estimation of its parameters from a sample of data were given by Department of Mathemetics, Faculty of Science, Mahidol university). The goal was to obtain the measure of the closeness of agreement between the true arch form and the approximation. The total sums of squares accounted for by the regression was a measure of closeness of an approximation. The ratio

$$R^2 = 1 - \frac{\sum_{i=1}^{n} e_i^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2} = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}$$

(where y_i is the Y-coordinate of the data point and $\hat{y}_i$ is the computed Y-coordinate of the point on the beta function curve corresponding to the original X_i)

was equivalent to the coefficient of determination in the multiple-correlation sense. As a rule, the beta function will fit the arch form quite nicely, the investigation may require that $R^2 \geq a$; for $0 < a < 1$ to suit this purpose[32].

From the results show the goodnesss of fit of the beta function to represent each of the 40 maxillary and mandibular arches, as also verified by the high coefficient of determination (r), average 0.97 with a standard deviation of 0.03. This is in agreement with Braun et. al.[16] who has been the first to offer the beta function to describe the dental arch, with an average correlation coefficient of 0.98 with a standard deviation of 0.02.

According to the geographic mathematic, the beta function describing the human arch form, the general formula (the relationship between the width and depth of the dental arch) can be expressed as:

$$Y = a\left(1-\frac{4X^{2}}{c^{2}}\right)^{d-1}$$

As described earlier, If the a-parameter (arch depth) and c-parameter (arch width) were set to 40 mm. and 55 mm. respectively while the d-parameter was put into the different value, the resulting curve would express into different arch forms, as illustrated in figure 7.

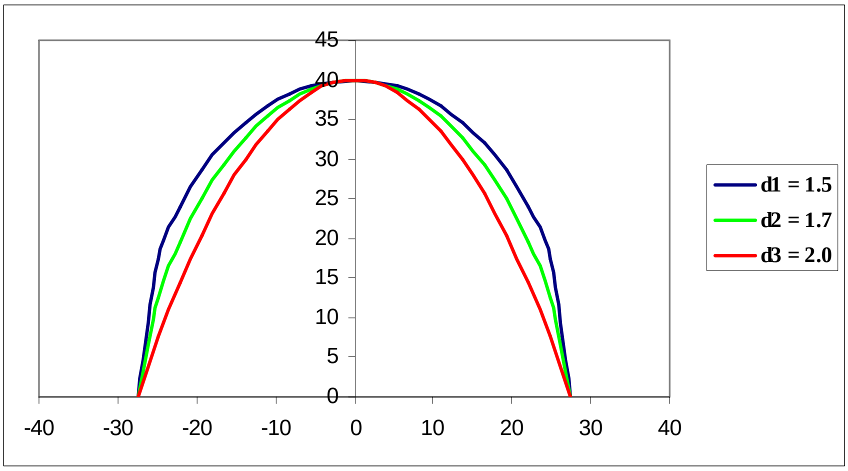


Figure 7: The curves expressed different arch forms according to the difference in d-values.

Since the d-parameter measures the quadratic portion, the larger the magnitude of d-parameter, the more the arch would assume the form of a taper; roughly, we may say it is the measuring of "taperedness". The consequence of small d-parameter in physical terms would tend to give the arch a more square-like look. In this description, we may say that d-parameter is a description of the form of dental arch. The more the values of the d-parmeter, the narrower the arch form is to be. The less the values of the d-parameter , the wider the arch form is to be.

According to the d-parameter, we found that the arch form of the Thai subjects have a more wider-like look than that of the Caucasian subjects in the study of Braun both the Angle Classification I and II, Division 1. Because the maxilla d-parameter of class I and II are 1.67 and 1.78 respectively, the mandibular d-parameter of Class I and II are 1.77 and 1.75 respectively, meanwhile the d-parameter of the Caucasian subjects in the study of Braun equal to 1.8 in both maxillary and mandibular arches[16]. The superimposition has shown in figures 8-11. It is agreed by Nojima and MaLaughlin[33] who compared the Caucasian and Japanese mandibular clinical arch forms. Their study has concluded that the Caucasian have a statistically significant decreased arch width and increased arch depth compared with the Japanese. While the subjects were regrouped by arch form, no statistically significant difference in arch dimension was observed between the two ethnic groups in any of the arch form samples. As a result, it is suggested that there was no single arch form specific to any of the Angle Classifications or ethnic groups.

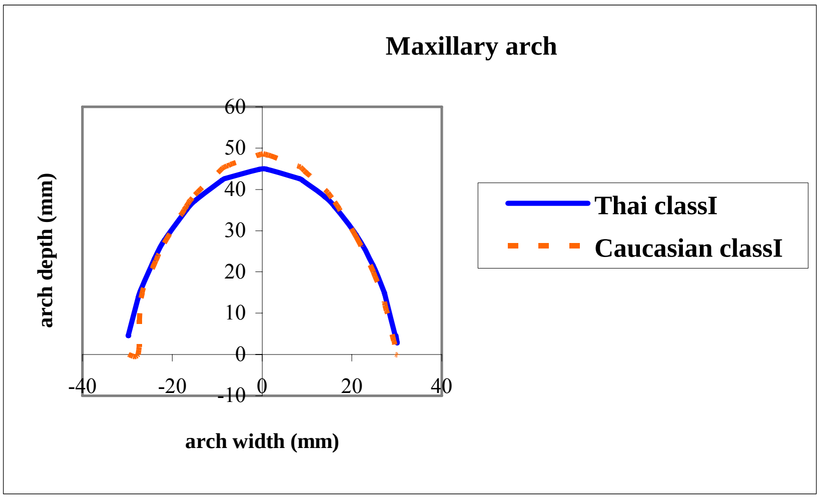


Figure 8: The superimposition of Class I maxillary arch form that were calculated from formula of Braun's and Kmolvisit's study.

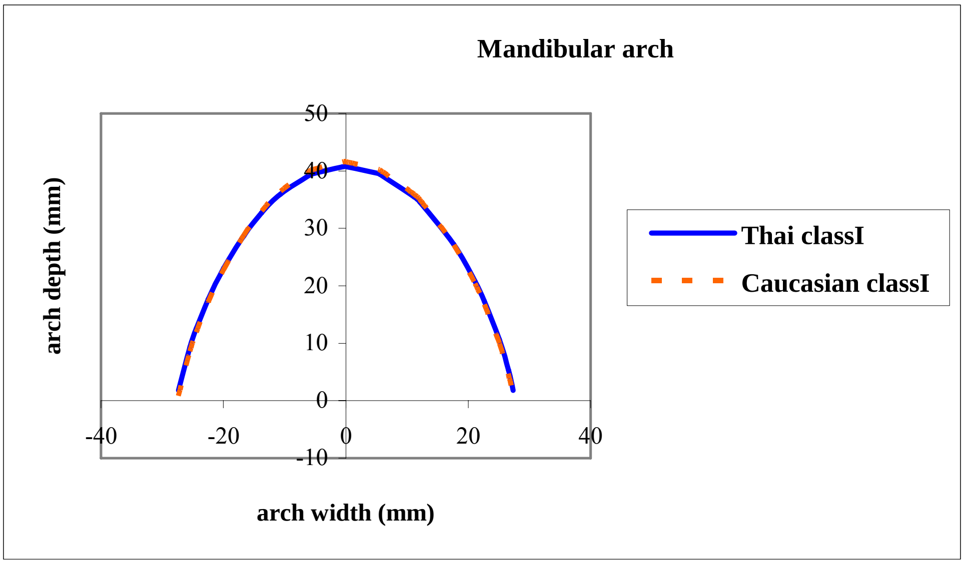


Figure 9: The superimposition of Class I mandibular arch form that were calculated from formula of Braun's and Kmolvisit's study.

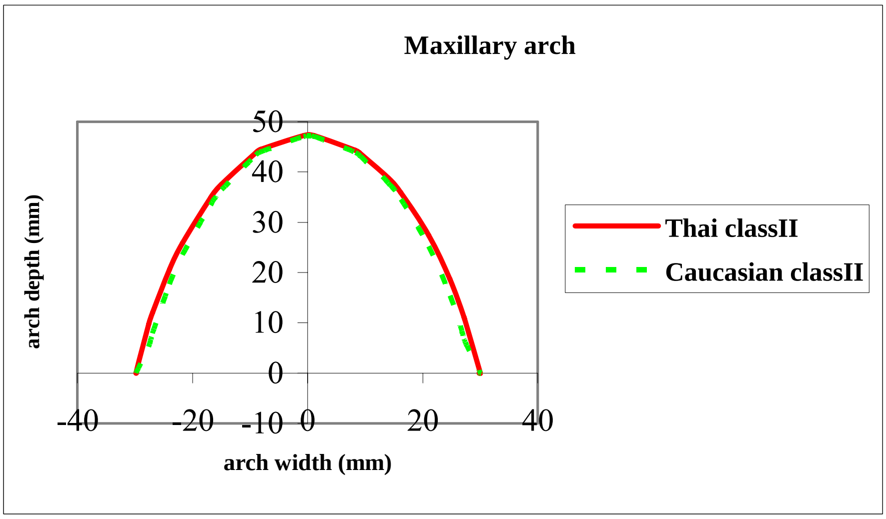


Figure 10: The superimposition of Class II maxillary arch form that were calculated from formula of Braun's and Kmolvisit's study.

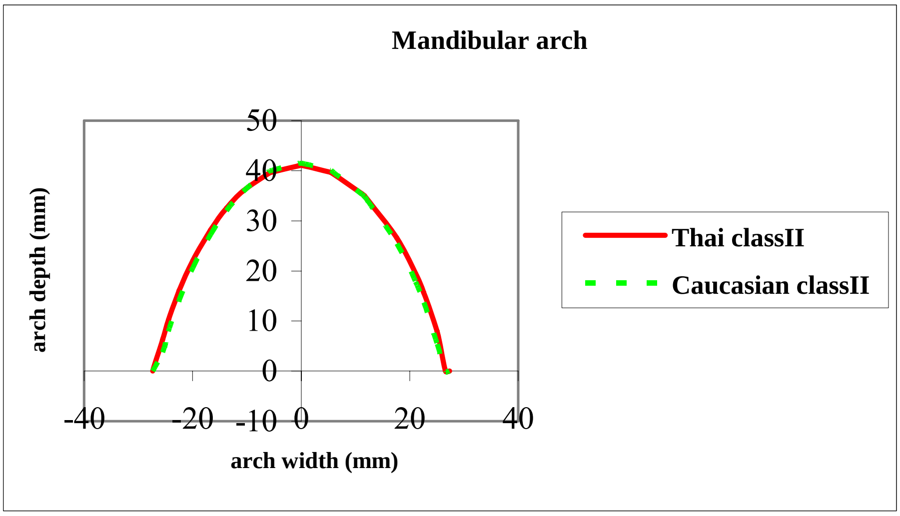


Figure 11: The superimposition of Class II mandibular arch form that were calculated from formula of Braun's and Kmolvisit's study.

As a result from Aukvongseree's[34] and Kmolvisit's[28] that show the comparison of Class I and Class II, when the Class II mandibular arches(figure 13), are compared to the Class I mandibular arches, an average generalized reduced arch width of 2 mm. is observed and it is apparent that arch depth and taperedness are essentially the same.

Comparing Class II maxillary arches to Class I arches (figure 12), an average generalized reduced arch width of 1.4 mm. is evident, and an average increased arch depth of 2.4 mm. is observed. Perhaps this can be explained by the fact that some Class II relationships are resulted from a large maxillary body. The d-parameter of Class II is more than that of Class I, which means that arch form of Class II is more tapered than that of Class I. Clinicians have speculated on the reasons for this difference—nasal obstruction, finger habits, tongue thrusting, low tongue position, abnormal swallowing and sucking behaviors.

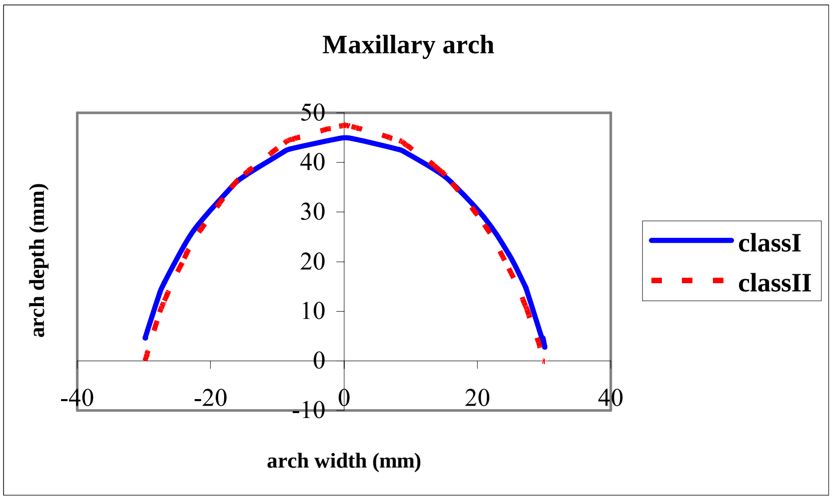


Figure 12: The superimposition of the calculating data from the beta function of Class I from Aukvongseree's study (blue line) and Class II from Kmolvisit's study (red point) are showing in this figure.

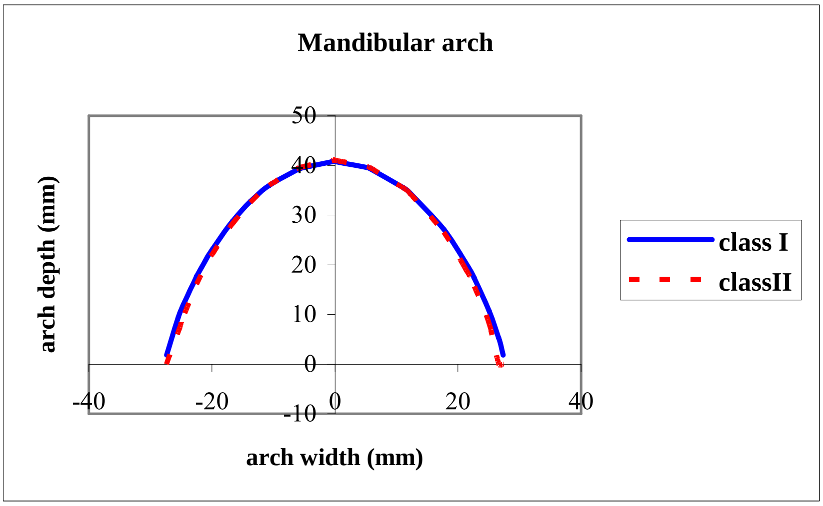


Figure 13: The superimposition of the calculating data from the beta function of Class I from Aukvongseree's study (blue line) and Class II from Kmolvisit's study (red point) are showing in this figure.

There are important differences between "Research arch form" and "Clinical arch form". For example, the recent work of Braun et al.[16] reported that the human arch form could be represented by a complex mathematical formula, known as the beta function. This was calculated by entering measurements of dental landmarks on orthodontic models into a computer curve-fitting program. Braun et al.[16] measured "the center of each incisor incisal edge, the cusp tips of the canines and premolars, and the mesiobuccal and distobuccal cusp tips of the molars". The resulting arch form can be surprisingly tapered (figure 14), but this is a "Research arch form". It is not useful for the clinician, and it is not appropriate to use this shape as a basis for the construction of arch wires.

Figure 14: Research measurement points and research arch form.

In contrast, the clinician's arch wire shape must be based on the points where the wire will lie in the bracket slots of correctly positioned brackets. This "Clinical arch form" relates to the mid-points on the labial surface of the clinical crowns of the teeth (figure 15), and should include an estimation for the in-out which is built in to the bracket system. The "Clinical arch form" is not related to the incisal edges or the cusp tips which are used to establish "Research arch form". Two different arch forms are obtained when the two measurement methods are used for the same dental model.

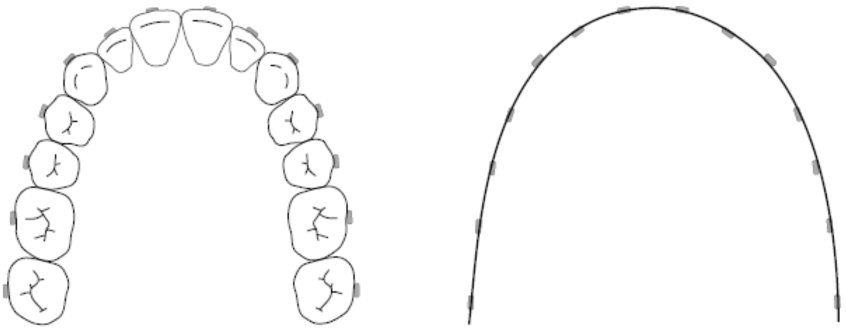


Figure 15: Clinical measurement points and clinical arch form.

Ferrario et. al.[35], who defined the mathematical formulas (Euclidean-distance matrix analysis) applied to the selected 50 men and 45 women in permanent healthy dentitions. The maxillary and mandibular arches were described by center of gravity (centroids). The results show that the maxillary arch were wider than the mandibular arch regardless of gender. Gender differences were found majorly in the maxillary arch, where they reflected more of a size discrepancy than a shape difference. Gender seemed to have some influence on arch sized differences (men has shown larger differences than women). The differences of the arch depth are because of differences of samples' overjet.

Kook et. al.[36] has compared Korean and North American white clinical arch forms. The result has shown that, among the Korean, the most frequent arch form is square, whereas among the white, the tapered arch form has been predominated. Therefore the current preformed superelastic wires are too narrow for many patients in the Asian and should be modified when they are being treated.

Therefore, from Kmolvisit's study[28], there were two measurement methods. The comparison of the two measurement methods has shown that the a-parameter (arch depth) in both arches as recorded on the cups tips were significantly greater than that on the bracket positions at p-value <0.05. The c-parameter (arch width) in both arches as recorded on the bracket positions were significantly greater than that on the cusp tips at p-value <0.05. The d-parameter (taperedness) as recorded on the cusp tips were significantly greater than that on the bracket positions only in the mandibular arch at p-value <0.05 (figure 16,17). This agreed with McLaughlin[2] who has shown that the research arch form is more tapered than the clinical arch form. Due to the superimposition between maxillary and mandibular arches, there were no co-ordination between two arches in the research arch form but there were co-ordination between two arches in the clinical arch form. Therefore, it is appropriated to use clinical arch form as a basis for the construction of arch wire but it should include the thickness of bracket's base.

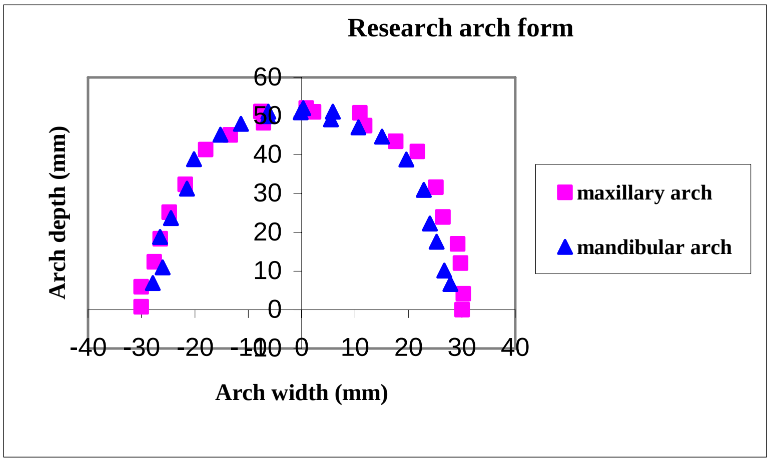


Figure 16: Superimposition of maxillary and mandibular research arch form.

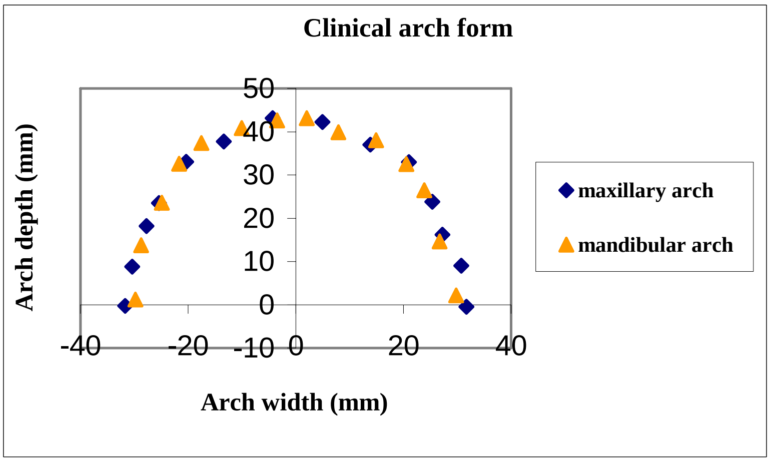


Figure 17: Superimposition of maxillary and mandibular clinical arch form.

The overall messages from these clinical observations and research papers are:

- There are extensive variations in human arch forms.
- Because of these variations there does not seem to be any single arch form that can be used for all orthodontic cases.
- If the patient's original arch form is changed during treatment, there is a strong tendency (in as much as 70% of cases) for the arch form to return to its original shape after appliances are removed[25].

The relapse tendency after changing arch form

Some researchers have documented that arch dimensional changes occur both with the orthodontic treatment after the extraction of teeth and with the nonextraction therapy[37, 38]. The maintenance of the pretreatment values for intercanine and intermolar distances was suggested as the key to posttreatment stability because these values were believed to represent a position of muscular balance for the patient[39]. It has been suggested that in extraction cases the canines could be moved to the buccal if they were moved distally into the extraction sites, thereby occupying a wider part of the arch[40]. It is well accepted that, during orthodontic treatment involving the extraction of teeth, arch dimensional changes occur and that these dimensions continue to change after active treatment[37, 38, 41-43].

In 1969, in a chapter on retention in Graber's text, Riedel[44] reviewed the literature on previous studies concerning stability of arch form. He cited numerous authors who had reported that when intercanine and intermolar width had been changed during orthodontic treatment, there was a strong tendency for these teeth to return to their pre-treatment position. He cited only one author, Walter[45, 46], who reported the maintenance of a slight increase in mandibular inter-canine width after all retention had been removed for what was termed an adequate period. Riedel postulated that “arch form, particularly in the mandibular arch, cannot be permanently altered during appliance therapy”.

The above comments are made primarily in reference to non-extraction cases. Concerning extraction cases, Strang[40] and Howes[47] felt that inter-molar width was normally decreased during extraction treatment. However, if canines were moved distally into extraction sites, they could be expanded buccally to limits offered by their new distal location. Contrary to this, other author[48] reached the conclusion that in extraction cases, intermolar width decreased posttreatment, but the intercanine width did not show an increased arch width as was previously thought.

In 1974 Shapiro[49] studied changes in arch length, intercanine width and intermolar width in 22 nonextraction cases and 58 extraction cases after treatment and post-retention. He concluded:

- Mandibular intercanine width showed a strong tendency to return to its pretreatment dimension in all groups, with the exception of Class II, Division 2 cases. Expansion of intercanine width in treated Class II, Division 2 cases showed significantly greater stability than Class I or Class II, Division 1. (This interesting finding could possibly be due to the fact that Class II, Division 2 cases normally show a deep bite, with lower canines inclined lingually in relation to the palatal surface of the upper canines. When the bite is opened, the incisal edges of the lower canines may move labially, but the apices of the roots of these teeth may actually move lingually, with the body of the tooth remaining in the same position.)
- Mandibular arch length decreased substantially in every group during the post-retention period.
- Arch length reduction in the Class II, Division 2 group was significantly less than in the Class I and the Class II, Division 1 groups.
- From pretreatment to post-retention, mandibular intermolar width decreased more in extraction case s than in non-extraction cases. In the nonextraction group much of the treatment intermolar width expansion was stable, although the trend was to return to the pretreatment width. In the extraction group intermolar width was decreased during treatment and continued to decrease during the post-retention period.

In 1976 Gardner[50] studied inter-canine, inter-first premolar, inter-second premolar and intermolar widths, as well as arch length changes in 103 cases. 74 were nonextraction, and 29 were treated with extraction of four first premolars. Among his conclusions were the following:

- Intercanine width increased during treatment, but had a strong tendency to return to (or close to) its original pre-treatment width, in both nonextraction and extraction cases.
- Inter-first premolar width showed the greatest treatment increase, with only a minimal amount of posttreatment width decrease.

- Second premolar width in nonextraction cases showed a significant amount of increase, with a slight tendency for post-retention decrease.
- Second premolar width in extraction cases showed a decrease during treatment and a slight continued decrease post-retention.
- The intermolar width in nonextraction cases showed a significant increase in width during treatment, but the extraction cases showed a significant decrease during treatment. However, there were no changes in inter-molar width in either extraction or non-extraction cases post-retention.
- The incisor to intermolar distance decreased with treatment and had a slight tendency to continue to decrease post-retention.

In 1987 Felton et al.[25] carried out a computerized analysis of the shape and stability of mandibular arch forms in 30 Class I and 30 Class II cases. They concluded that 70% of the dental arches returned to their original shape during the posttreatment period.

In 1995 de La Cruz et al.[38] studied the long term changes in arch form of 45 , Class II, Division 1 cases after orthodontic treatment and a minimum of 10 years post-retention. They concluded that arch form tended to return toward the pretreatment shape after retention and that the greater the treatment change, the greater the tendency for post-retention change. Individual variations were considerable in the study. They suggested that the patient's pretreatment arch form appeared to be the best guide for future arch form stability, but emphasized that minimizing treatment change was no guarantee of post-retention stability.

Burke et al.[51] recently used the meta-analysis technique to review 26 previous studies of mandibular intercanine width. They concluded that “regardless of patient diagnostic and treatment modalities, mandibular intercanine width tends to expand during treatment in the order of about one or two millimetres, and to contract post-retention to approximately the same dimension”. Thus, there is overwhelming support in the orthodontic literature confirming that when arch form is changed during orthodontic treatment, in many cases there is a strong tendency for relapse to the original dimensions. This is particularly true of intercanine width. The most recent evidence does indicate that changes in inter-molar width seem to be more stable than those of intercanine width.

The changes which occur following expansion of the dental arches have also received considerable interest from a number of investigators. In general, they have observed that any increase in mandibular intercanine width during treatment tends to relapse after treatment[52, 53]. Even in cases where the canines move distally in the arch, their width still tends to decrease following treatment[54]. Intermolar expansion does not fare much better[52, 53], although the increases tend to be relatively more stable in the maxilla than in the mandible[55]. Other investigators found that lower incisor crowding recurs after treatment[52, 55, 56], accompanied by a decrease in arch length. Among the explanations offered for this crowding are: large tooth size[55]; canines expanding during treatment; and excessive proclination of the lower incisors and/or late skeletal growth[52]. Other investigators have been unable to find a relationship between lower incisor crowding before treatment and relapse after treatment[57]. In some cases, the lower incisors were proclined considerably and remained stable in their new positions, particularly if they were initially retroclined[58]. Furthermore, recrowding has often been noted even in cases treated with lower incisor extraction[59].

In the study of Boley et. al.[60] the interarch changes of four premolar extraction cases were evaluated. According to their findings, maxillary intercanine widths increased 1 mm and the corresponding mandibular arch width increased 1.7 mm during treatment. Maxillary and mandibular intermolar widths decreased 1.7 and 2.1 mm, respectively. The study shows that in either extraction- or nonextraction-treated cases, the intercanine widths increased significantly.

Luppanapornlarp and Johnston[42] also evaluated the postreatment results of extraction and nonextraction therapy in Class II patients and showed that mandibular intercanine width was greater in the extraction group than in the nonextraction group.

Gianelly[61] studied the interarch changes of extraction and nonextraction groups. He found that the changes in the maxillary and mandibular arch widths indicated that extraction treatment does not result in narrower dental arches than nonextraction treatment. However, the group included in that study was not homogenous and the distribution of malocclusions was not the same in the extraction or nonextraction groups. Thus, the results reported in Gianelly's study might be influenced by the wide range of individual variation.

Instability in dental arch changes can result in periodontal breakdown, recurrence of crowding of the buccal segments, or increased crowding of the labial segments particularly where the lower intercanine width has been expanded. Bishara et. al.[43] studied the long-term stability of extraction and nonextraction orthodontic treatment and found that during the treatment the maxillary intercanine width of the males increased significantly in the extraction group because of the alignment of the crowded anterior segment. However, they did not mention the initial tooth size arch length discrepancies of the study group. The maxillary and mandibular intermolar widths increased in the nonextraction group and decreased in the extraction group.

Subsequently, Little et al.[56] reported on the long-term follow-up of 65 cases with extraction of first premolars. The lower intercanine width had been increased by more than 1 mm. during treatment in 60% of the cases but, after treatment , constriction in the intercanine width occurred in 60 – 65 cases, usually more than 2 mm.

In summary, several studies showed that when the dental arch form was changed with orthodontic treatment, there was a postretention tendency for it to change back toward its pretreatment shape. It might imply that, if patient's original arch form is maintained during treatment, it will tend to remain stable after retention. Long term stability is not necessarily ensured by minimally altering the patient's original pretreatment arch form. The high degree of variability observed in the postretention responses to treatment changes make it difficult for the clinician to predict the consequences, if any, of altering or not altering the shape of the dental arch.

Archwires selection during different stages of treatment

While there have been attempts to find the perfect arch form for all patients, many researches indicate that there is a great deal of variation in human arch form.

Therefore, the use of a single arch form in three different sizes does not take into account for this variation in human arch form.

It is necessary to identify the components of arch form, and to accept that in the literature three basic forms have been repeatedly described. These are tapered, ovoid, and square. It is also helpful to examine the importance of arch wire shape during different stages of treatment.

The four components of arch form

Evaluation of the following four components (figure 18) provides a basis for the design of a preformed arch wire system.

(i) Anterior curvature

(ii) Intercanine width

(iii) Posterior curvature

(iv) Intermolar width

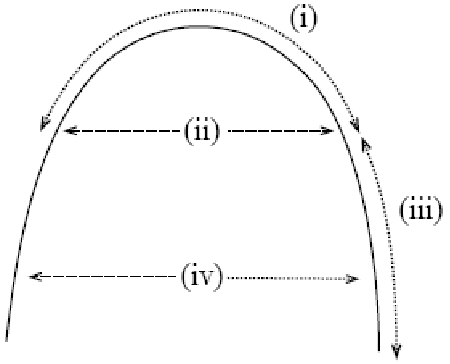


Figure 18: Four components of arch form; intercanine width (ii) is the most important. The other components are anterior curvature (i), posterior curvature (iii), and intermolar width (iv).

- **The anterior curvature**

This curvature is based primarily on intercanine width, with its shape being more tapered when intercanine width is narrow and more flattened or square when the intercanine width is wide. Arch forms have been generally classified as tapered, ovoid and square based primarily on the anterior curvature. Superimposition of these arch forms is shown in figure 20.

- **The intercanine width**

This appears to be the most critical aspect of arch form, because significant relapse occurs if this dimension is changed. In a group of individuals the average intercanine width will vary by about 6 mm, and if an arch form system can cover this range, then it is suitable for most cases in an orthodontic practice. A suitable preformed arch wire can then be selected, based on the planned width of the canines in the bracket slot area.

- **The posterior curvature**

The posterior shape of the dental arch has been described in the literature as a straight line (the Bonwill-Hawley arch form)[4] and a rather dramatic curvature (the Brader arch form)[15]. The bicuspids could be slightly wider than the intercanine width to provide better function during protrusive movement as Roth has described. The consensus seems to favour a gradual (but not significant) curvature between canines and second molars with the bicuspids being slightly wider than the cuspids.

- **Intermolar width**

There is obviously a great deal of variation in intermolar width from patient to patient. However, the minor adjustment in this dimension appear to be slightly more stable than changes in intercanine width, especially if molar expansion is carried out at an early age and retained for a number of years. It is easy wire bending to widen or narrow the molar region of an arch wire. Arch form width in this dimension can therefore be standardized in a preformed system, and individual wires can be widened or narrowed, depending on the needs of the case.

- **Tapered, square and ovoid arch forms**

Felton et. al.[25] evaluated a wide range of manufactured arch wires from orthodontic companies. It was found that the arch forms fell quite closely into tapered, square, or ovoid groupings. The three basic shapes are shown below (figure 19). When superimposed they vary mainly in intercanine width, giving a range of approximately

6 mm (figure20). Intermolar widths of the three shapes are quite similar, but the molar areas of wires can be widened or narrowed as needed, by easy wire bending

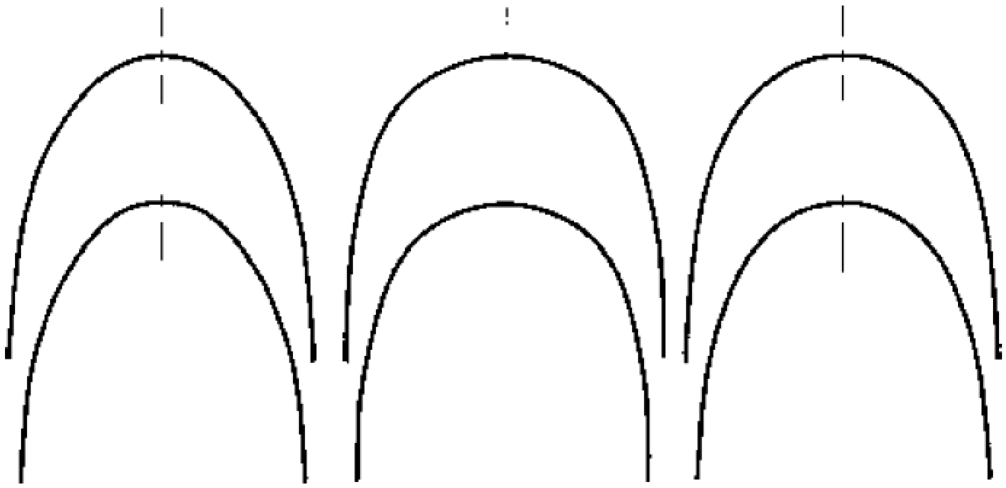


Figure 19: Tapered arch form Square arch form Ovoid arch form

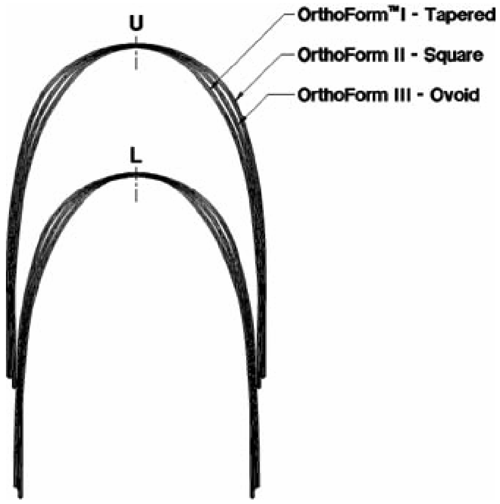


Figure 20: Tapered, square and ovoid arch forms superimposed.

Nowadays in Thailand, the clinician always use preformed arch wires, which are based on Caucasian arch forms, and choose the one that closely match their patient's arch form. Based on the previous studies on stability and relapse[62, 63], it's agreed that preservation of the mandibular intercanine width and original arch form during orthodontic treatment will be resulted in the good post-treatment occlusal stability. In the study of Nojima and McLaughlin[33], it appears that the frequency of a particular arch form varies among ethnic groups. Benjamin et. al.[64] has found that the differences of ethnic (American Blacks and Whites) also seem to correlate with those of arch form. Clinically, it seems more reasonable to have several types of preformed arch wire available and then select the shape that closely matches the most with the patient's pretreatment arch form based on his or her ethnicity and type of malocclusion.

Summary of review

There are the difference of arch form in different type of occlusion. For this reason, study of arch form in other type of occlusion is essential. Using pretreatment arch form as a guide to posttreatment arch shape will create natural esthetic and occlusal stability.

Contribution of variation in arch size and shape is defined in the fetus as genetic influence, variability in eruption paths of the teeth, growth of the supporting bone and movement of the teeth after emergence due to habits and unbalanced muscular pressure. The result of genetic and environment factor make the difference of arch shape in the differences in ethnic and the difference type of occlusion.

According to the gerneral method, the error of measurement was happen in the process of transfering three-dimensions of dental casts to two-dimensions. In the present day, a highly accurate measuring device (CMM) used in the machine tool industry can be applied to record specific landmarks directly on dental models[30]. The dental landmarks are reported in the corresponding of X, Y, Z. Therefore the processing of collecting and recording the data times were reduced.

The beta function with the feasibility coefficient proved to have a high correlation with the dental arch[16]. The data were obtained by recording the coordinates of the center of each incisal edge, at the cusp tips of the canines and premolars, and at the mesiobuccal and distobuccal cusp tips of each molar. But due to limitation about research arch form in the former study[16, 34]. In the present study, we want to solve this problem by add clinical arch form. Clinical arch form was measured from the points where the wire will lie in the bracket slots of correctly positioned brackets. The bracket position need to be considered from the following variable 1) mesiodistal location , 2) vertical height on the crown, 3) angulation of the bracket, 4) labio-lingual positioning[33, 64].

A number of factors have been suggested as important for enhancing the stability of the treatment results, including establishment of a good functional occlusion in harmony and balance with muscle function[15, 44, 65], attainment of good interdigitation with normal axial inclination of the teeth[44, 65], providing a healthy environment for the periodontium[65], having proper mandibular incisor position and angulation[44, 65] achieving a normal jaw relationship and the presence of favorable growth[65]. On the other hand, the major factors that have been suggested as enhancing relapse include poor treatment results[44, 65, 66], expanding the arches and changing their shape[44], the inability to eliminate etiology e.g. persistent habit[44], and insufficient retention period[44].

The present findings indicate that the extraction of premolars as a part of orthodontic treatment significantly improves the discrepancy between tooth size and arch length. On the other hand, extractions do not significantly alter the direction of the overall posttreatment trends observed in most dental arch parameters, e.g., interincisor and intercanine width, arch length and tooth size-arch length discrepancies. For other parameters, e.g., intermolar width, the trends are different in the extraction and nonextraction groups. In general, the posttreatment trends are similar in both males and females as well as in the maxillary and mandibular arches.

In summary, the severity and characteristics of the malocclusion[53], the magnitude of the changes achieved during treatment[53] the length of time the malocclusion existed before treatment[67] and the functional demands of the stomatognathic system[67] are all factors that need to be considered when planning the length of the retention period and the design of the retention appliance.

CHAPTER 3

MATERIALS AND METHODS

Determining sample size

All patients involved in this study were treated for Angle’s classification II, Division 1 malocclusions in the graduate orthodontic clinic at the Orthodontics Department, Mahidol University. Twenty-two subjects (8 males and 14 females) subjects were treated with the extraction of four first premolars.

The following criteria were used in the selection:

1. At the start of treatment, all subjects were in the permanent dentition without any missing permanent teeth or congenitally absent teeth.
2. Skeletal type II relationship (ANB > 4^o)
3. None of the subjects had any adjunctive appliance such as a Quad Helix, a functional appliance, or a rapid palatal expander used as part of their orthodontic treatment.
4. The subjects had undergone routine edgewise orthodontic treatment that included maxillary and mandibular first premolar extractions.
5. Model was exhibited Angle’s classification II, Division 1 malocclusion (without molar shifted).
    a. bilateral Class II molar relationship in centric occlusion with the mesial groove of the mandibular first permanent molar articulates posteriorly (1/4 cusp width – full cusp width) to the mesiobuccal cusp of the maxillary first permanent molar.
    b. protrusive maxillary incisors (overjet > 4 to 9 mm.).
6. Absence of cuspal attrition, fracture of teeth, restoration extending to contact areas, cusp tips or incisal edge

7. Permanent dentition including second molar with normal tooth size and shape
8. The initial record was between the aged of 17 – 25 years.
9. At the posttreatment, model was exhibited bilateral Class I molar relationship and well-aligned arches with normal overjet and overbite (1 – 2 mm.).

Dental arches of the 22 subjects were selected (the typical dental models was show in figure 21). In all models have the landmarks that labeled on each dental model as follow:

- The bracket position: the point on buccal and labial surfaces of teeth that derived from cross section of long axis of teeth and line which was perpendicular with long axis of teeth. The last line was measured from incisal edge for incisors and the cusp tip for other teeth. The distance is 3.5 mm. for upper lateral incisors and lower incisors. Furthermore, 4 mm. for the remaining teeth[83]. These points represented position in bonding bracket. Fourteen points were labeled on each dental cast (figure 21).
- A bracket height gauge was used to suitably mark the labial and buccal surfaces of the teeth and then a black 2H automatic pencil with a 0.3 mm tip was used to mark the following anatomic landmarks on the maxillary and mandibular dental models. The bracket positions points on the teeth’s labial surfaces were used for digitization from the right second molar to the left second molar. The 14 points (pretreatment stage; T_0) and the 12 points (posttreatment stage; T_1) were digitized and recorded from each dental arch.

Figure 21: The dental landmarks used in this study. Fourteen points were marked on each dental model.

During the measurement of dental models using Coordinate Measuring Machine (LK G 90C), each cast was oriented in the Coordinate Measuring Machine (CMM). The device was used extensively in the precise machine tool in the Faculty of Engineering, Mahidol university (figure 22). Measurements of dental casts using CMM in this study was done by technician who was trained to use CMM. A frictionless air bearing probe recorded the coordinates of a point in space in each of the three orthogonal axes to 10^{-6} meters. The casts were secured to a fixed plane. The touch trigger probe was used to identify each of the measurement points (figure 25).

The touch trigger probe was used to identify each of the following measurement points respectively from the

Maxillary dental models:

1. point on buccal surface of right second molar
2. point on buccal surface of right first molar
3. point on buccal surface of right second premolar
4. point on buccal surface of right first premolar
5. point on labial surface of right canine
6. point on labial surface of right lateral incisor
7. point on labial surface of right central incisor
8. point on labial surface of left central incisor
9. point on labial surface of left lateral incisor

10. point on labial surface of left canine
11. point on buccal surface of left first premolar
12. point on buccal surface of left second premolar
13. point on buccal surface of left first molar
14. point on buccal surface of left second molar

Mandibular dental models:

1. point on buccal surface of right second molar
2. point on buccal surface of right first molar
3. point on buccal surface of right second premolar
4. point on buccal surface of right first premolar
5. point on labial surface of right canine
6. point on labial surface of right lateral incisor
7. point on labial surface of right central incisor
8. point on labial surface of left central incisor
9. point on labial surface of left lateral incisor
10. point on labial surface of left canine
11. point on buccal surface of left first premolar
12. point on buccal surface of left second premolar
13. point on buccal surface of left first molar
14. point on buccal surface of left second molar

B

A

C

Figure 22: The coordinate measuring machine(CMM): A) CMM (LK G-90C), B) Touch trigger probe, C) A hand stick was used to control the direction of trigger probe.

Fourteen points (pretreatment stage; T_0) and twelve points (posttreatment stage; T_1) were recorded in each dental model while the X-and Y-coordinates of each landmark were projected to the Z-plane. The coordinates of the landmarks in three dimensional space for each of the 22 sets of dental casts were recorded in the corresponding X-, Y-, Z-coordinates automatically by using the LK Camio suit 5.5 program.

Before recording the dental landmarks, the datum (X, Y, and Z plane) was set at the point on buccal surface of the right second molar on each maxillary dental model and at the point on buccal surface of the left second molar on each mandibular model. The coordinates (X and Y) at these points were defined as zero. A planar projection of each cast was subsequently obtained by setting the Z-plane from three-point contact between wire that was bent along arch form and buccal surface of each dental model(figure23). The Z-axis was then perpendicular to this plane (figure24).

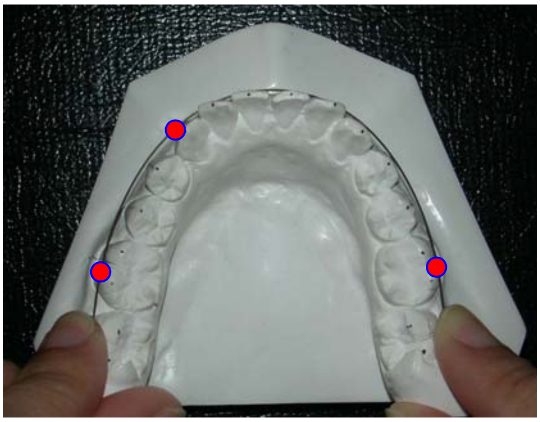


Figure 23: The construction of the Z-axis: the Z- axis was set from the three–point contact between wire and labial or buccal surface of each dental model. The Z axis was perpendicular to this plane.

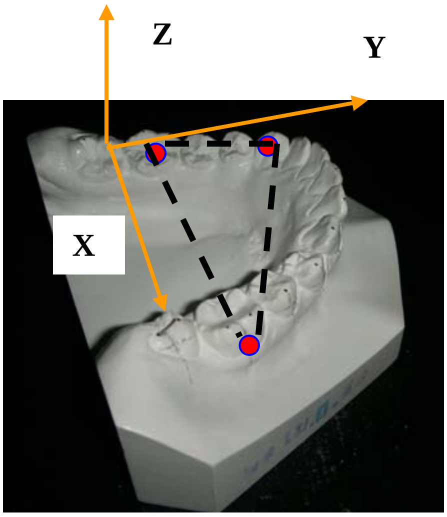


Figure 24: Three points contacted used in constructed of the Z-axis. A planar projection of the Z plane was constructed from the three points (in red) which contacted the wire on the buccal surface of the model.

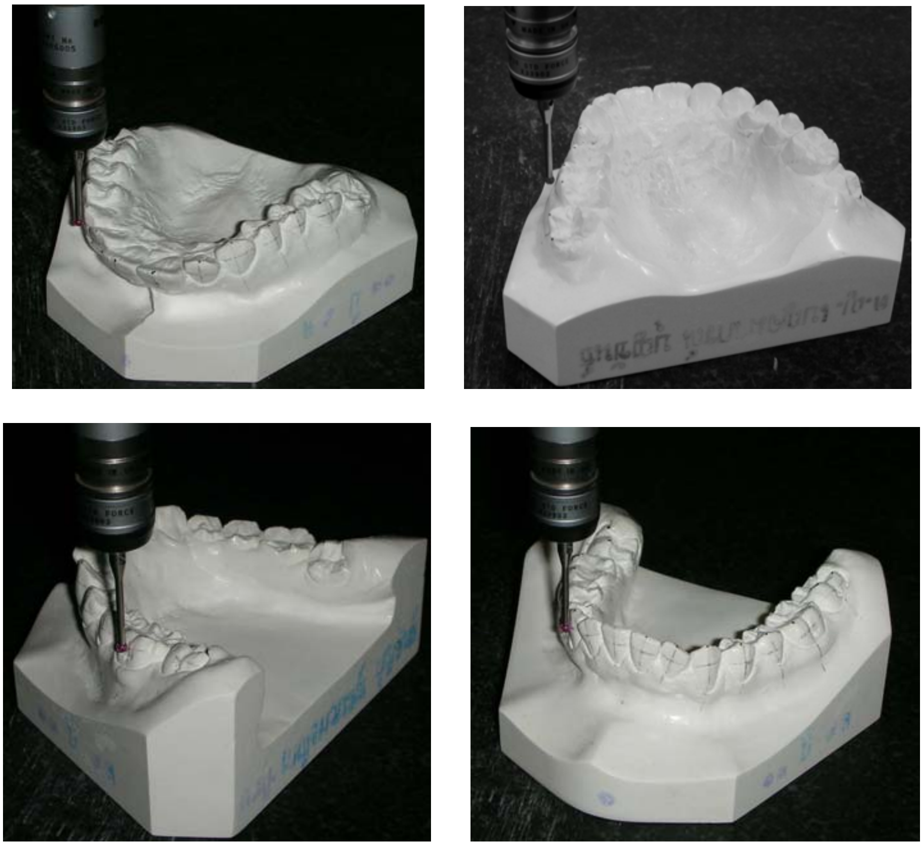


Figure 25: The processing of measuring the dental casts: dental casts were placed on a fixed plane during the recording of the dental landmarks with the Coordinate Measuring Machine.

Error of measurement

Replicate measurement by the same single examiner were made on 5 sets of randomly selected dental casts after a 4 weeks interval. The X-, and Y- coordinates of each landmark were compared between two separate of measurements.

The method errors for each of the categories of measurement were calculated according to Dahlberg’s equation.

$$\text{Method error (ME)} = \sqrt{\frac{\sum_{i=1}^{n} d^2}{2(n-1)}}$$

d = difference between two successive measurements

n = number of double determinations

Arch interpolation

An analytical equation of the dental arch shape was neccessary to describe the relationships between the arch width (X-coordinate) and arch depth (Y-coordinate). Many mathematical functions were investigated as to fit. The beta function most closely represents the dental arch shape[21]. Two measurements (molar width and arch depth) were required to generate the dental arch shape. The beta function representing the dental arch shape is given by the general formula[21].

$$Y = \frac{a\left(\frac{X-b+cm}{c}\right)^2\left(1-\frac{X-b+cm}{c}\right)}{m^{d-1}n^{e-1}}$$

$$m = \frac{d-1}{d+e-2};\ n = \frac{e-1}{d+e-2}$$

Where Y is the arch depth at arch width (X).

Parameter (a) represents the arch depth measured by the perpendicular distance from the most anterior point between two central incisors to the molar cross-arch dimension (figure 26).

The parameter (b) is a offset and is set to zero so the arch centerline is at zero, our reference position.

The parameter (c) is the arch width measured by the cross-arch distance between the second molar distobuccal cusp tips. The parameters (d) and (e) are factors the control the symmetry (figure 26).

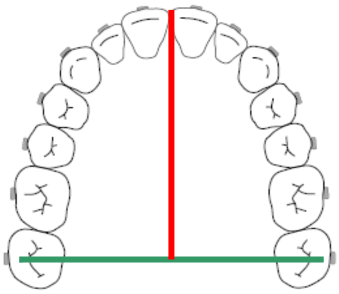


Figure 26: The parameter of beta function: diagram showed the parameter, a; Arch depth (red line), c; Arch width (green line).

If parameter b = 0, and d = e, the beta function becomes symmetrical about the centerline of the teeth. The beta function then become

$$m = \frac{d-1}{d+e-2} = \frac{d-1}{d+d-2} = \frac{d-1}{2(d-1)} = \frac{1}{2}$$

$$n = \frac{e-1}{d+e-2} = \frac{d-1}{d+d-2} = \frac{d-1}{2(d-1)} = \frac{1}{2}$$

$$Y = \frac{a\left(\frac{X+\frac{c}{2}}{c}\right)^{d-1}\left(1-\frac{X+\frac{c}{2}}{c}\right)^{d-1}}{\left(\frac{1}{2}\right)^{d-1}\left(\frac{1}{2}\right)^{d-1}}$$

$$= \frac{a\left(\frac{X}{c}+\frac{1}{2}\right)^{d-1}\left(\frac{1}{2}-\frac{X}{c}\right)^{d-1}}{\left(\frac{1}{4}\right)^{d-1}}$$

$$= a\left(4\left(\frac{1}{4}-\frac{X^2}{c^2}\right)\right)^{d-1}$$

$$Y = a\left(1-\frac{4X^2}{c^2}\right)^{d-1}$$

For the beta function, the coefficients were estimated using a dedicated computer program, (the computer program was created by Department of Mathemetics, Faculty of science, Mahidol university) based on the Differential Algorithm. These also fit standard beta function equations to the data points for each of the 88 dental arches. The curve with a minimal deviation from all data points is desired. This *best-fitting curve* can be obtained by the least square error methods. That is, the computer was instructed to approximate the coefficients of the beta function of each such that:

$$\sum_{i=0}^{n}(Y_i-\hat{Y}_i)^2 \text{ is minimal}$$

Where n is the number of data points, Y_i is the Y-coordinates of the data point (X_i, Y_i) on the common line of occlusion and $\hat{Y}_i$ is the computed Y-coordinate of the point on the beta function curve corresponding to the original X_i and the sum of squared distances from the bracket position coordinates to the fitted curve in the Y direction.

Following this process, each parameter (a, c, d and e) of the beta function were reported for the individual dental arch curvature.

Dental arch measurements

Various definitions of the dental arch have been used in studies of arch form. Arch form will thus vary according to the landmarks chosen to represent the teeth. This study represented the landmarks at an bracket position points as in previous studies[25, 52, 55]. The digitized maxillary and mandibular landmarks also enabled for calculate the following distances:

Intercanine width; The distance between bracket position points of the right and left canines.

Intermolar width; The distance between the bracket position points of the right and left first permanent molars.

Arch depth (a-parameter)

Arch width (c-parameter)

Manual measurements

Visual inspection evaluated the types of dental arch form at the pretreatment stage: T_0 and posttreatment stage: T_1 by superimposing the computer-generated arch curves with morphologic arch system (OrthoForm, 3M Unitek, Calif; figure 19) by the Photoshop software program (Adobe Systems, San Joe, Calif).

Intercentral width was used for registration during superimposition of the scanned images of the arch system to the computer-generated arch curves because this distance remained relatively stable in maxillary and mandibular models in all time periods[22]. The capability of the arch forms to fit these cases was then analyzed. One operator assessed the arch form change at two different times. The subjective evaluation of the operator revealed no intraexaminer variability.

Statistical analysis

1. The mathematics function and coefficient of determination were used to describe the relationship between the recorded and calculated independent variable.

2. Paired t-test was used to describe the mean difference of each coordinate landmark between the first and the second measurement.

3. Student t-test was used to describe the mean difference of the parameters (a, c, d, e, intercanine, and intermolar widths) between pretreatment and posttreatment clinical dental arch form.

4. Student t-test was used to describe the mean difference of the parameters (a, c, d, e, intercanine, and intermolar widths) among the sex.

5. Student t-test was used to describe the mean difference of the parameters (a, c, d and e) between Class II from Kmolvisit’s study and Class II clinical dental arch form from this study.

6. Student t-test was used to describe the mean difference of the parameters (a, c, d and e) between Class I from Chantarasmee’s unpublished study and Class II pretreatment and posttreatment clinical dental arch form from this study.

All statistical analysis were performed using the Statistical Package for Social Sciences for windows (SPSS) software package (version 11.5, SPSS Inc., Chicago). And the significant level was predetermined at p-value < 0.05.

This study used student t-test for the comparison between pretreatment and posttreatment clinical dental arch form. Although the pretreatment and posttreatment models were from similar subject, the present study did not used paired t-test to compare. Because the landmarks on pretreatment and posttreatment models were not similar and the data were independent (14 points on pretreatment models and 12 points on posttreatment models).

CHAPTER 4

RESULTS

With the least squares method, the curve-fitting program would calculate for every existed. The results were categorized by the type of landmarks as follows:

1) landmarks on the bracket positions (pretreatment). The results were as shown in Table 1 and 2.

2) landmarks on the bracket positions (posttreatment). The results were as shown in Table 3 and 4.

The a-parameter represented the arch depth, and the c-parameter represented the arch width at the bracket position of the second molar. While the b-parameter was automatically set to null value by the curve fitting program, the d- and e-parameters were equal. Finally, the beta function became symmetrical at about the centerline of the teeth.

1) landmarks on the bracket positions (pretreatment).

The maxillary arch table (table 1) shows the values of each parameter in each individual maxillary dental arch based on the beta function. The mean value of the arch depth (a-parameter) was 41.72 mm. with a standard deviation of ± 2.87 mm. The maximum dimension was 46.89 mm. and the minimum dimension was 36.97 mm. The mean value of the arch width (c-parameter) was 62.95 mm. with a standard deviation of ± 3.47 mm. The maximum width was 70.85 mm. and the minimum width was 57.20 mm. The mean value of the d- and e-parameters were 1.70 with a standard deviation of ± 0.22. The maximum value was 2.51 and the minimum value was 1.49.

The mandibular arch table (table 2) shows the values of each parameter in the individual mandibular dental arch based on the beta function. The mean value of the arch depth (a-parameter) was 38.21 mm. with a standard deviation of ± 2.57 mm. The maximum dimension was 42.17 mm. and the minimum dimension was 32.64 mm. The mean value of the arch width (c-parameter) was 57.66 mm. with a standard deviation of ± 2.96 mm. The maximum width was 63.01 mm. and the minimum width was 51.94 mm. The mean value of the d- and e-parameters were 1.56 with a standard deviation of ± 0.09 The maximum value was 1.78 and the minimum value was 1.42.

2) landmarks on the bracket positions (posttreatment).

The maxillary arch table (table 3) shows the values of each parameter in each individual maxillary dental arch based on the beta function. The mean value of the arch depth (a-parameter) was 35.60 mm. with a standard deviation of ± 1.61 mm. The maximum dimension was 39.83 mm. and the minimum dimension was 32.93 mm. The mean value of the arch width (c-parameter) was 61.89 mm. with a standard deviation of ± 3.37 mm. The maximum width was 67.58 mm. and the minimum width was 55.22 mm. The mean value of the d- and e-parameters were 1.67 with a standard deviation of ± 0.08. The maximum value was 1.84 and the minimum value was 1.50.

The mandibular arch table (table 4) shows the values of each parameter in the individual mandibular dental arch based on the beta function. The mean value of the arch depth (a-parameter) was 32.66 mm. with a standard deviation of ± 1.42 mm. The maximum dimension was 34.93 mm. and the minimum dimension was 28.67 mm. The mean value of the arch width (c-parameter) was 57.44 mm. with a standard deviation of ± 2.34 mm. The maximum width was 62.03 mm. and the minimum width was 53.83 mm. The mean value of the d- and e-parameters were 1.63 with a standard deviation of ± 0.07. The maximum value was 1.77 and the minimum value was 1.42.

As shown in Tables 5 – 8, all values – the measured values, calculated values of maxillary and mandibular dental arches has been well-fit based on the beta function. According to this based sample used, the maxillary and mandibular arches were considered to fit the data well, especially when taking the coefficients of determination average 0.97 in the maxillary arch (pretreatment and posttreatment) and mandibular arch (posttreatment), and average 0.96 in the mandibular arch (pretreatment) with a standard deviation of 0.02.

Table 1. The values of each parameter in individual maxillary dental arch (pretreatment) based on the beta function. (landmarks on the bracket positions)

Sample	**Maxillary Parameter**			
	a-parameter	**c-parameter**	**d-parameter**	**e-parameter**
1	46.46	64.96	1.73	1.73
2	45.87	67.05	1.70	1.70
3	46.89	62.92	1.62	1.62
4	42.36	67.78	1.61	1.61
5	40.96	58.48	1.51	1.51
6	43.27	60.90	1.54	1.54
7	38.31	62.77	1.80	1.80
8	43.00	63.09	1.62	1.62
9	36.97	67.79	2.51	2.51
10	40.08	58.48	1.58	1.58
11	42.46	62.85	1.52	1.52
12	42.15	57.20	1.70	1.70
13	37.22	61.58	1.62	1.62
14	42.24	63.24	1.49	1.49
15	40.93	60.57	1.64	1.64
16	39.92	64.81	1.70	1.70
17	37.37	58.87	1.86	1.86
18	43.61	59.47	1.54	1.54
19	41.56	70.85	2.05	2.05
20	44.37	63.89	1.74	1.74
21	38.81	62.51	1.75	1.75
22	43.12	64.92	1.68	1.68
Mean	**41.72**	**62.95**	**1.70**	**1.70**
SD	**2.87**	**3.47**	**0.22**	**0.22**
Max	**46.89**	**70.85**	**2.51**	**2.51**
Min	**36.97**	**57.20**	**1.49**	**1.49**

Table 2. The values of each parameter in individual mandibular dental arch (pretreatment) based on the beta function. (landmarks on the bracket positions)

Sample	**Mandibular Parameter**			
	a-parameter	**c-parameter**	**d-parameter**	**e-parameter**
1	37.85	58.90	1.47	1.47
2	42.17	60.95	1.61	1.61
3	41.38	57.53	1.56	1.56
4	40.28	62.50	1.67	1.67
5	41.66	56.50	1.52	1.52
6	40.44	53.95	1.52	1.52
7	34.68	55.19	1.42	1.42
8	37.35	57.32	1.56	1.56
9	38.47	51.94	1.45	1.45
10	36.87	56.18	1.53	1.53
11	40.16	60.94	1.75	1.75
12	34.62	53.76	1.60	1.60
13	34.92	54.39	1.52	1.52
14	39.67	61.05	1.50	1.50
15	37.89	56.62	1.58	1.58
16	37.89	63.01	1.58	1.58
17	32.64	56.45	1.78	1.78
18	39.17	55.48	1.54	1.54
19	37.02	57.96	1.46	1.46
20	41.33	59.40	1.65	1.65
21	36.31	59.34	1.65	1.65
22	37.87	59.17	1.50	1.50
Mean	**38.21**	**57.66**	**1.56**	**1.56**
SD	**2.57**	**2.96**	**0.09**	**0.09**
Max	**42.17**	**63.01**	**1.78**	**1.78**
Min	**32.64**	**51.94**	**1.46**	**1.46**

Table 3. The values of each parameter in individual maxillary dental arch (posttreatment) based on the beta function. (landmarks on the bracket positions)

Sample	**Maxillary Parameter**			
	a-parameter	**c-parameter**	**d-parameter**	**e-parameter**
1	35.29	65.98	1.84	1.84
2	36.52	67.58	1.75	1.75
3	39.83	63.43	1.68	1.68
4	36.54	67.41	1.70	1.70
5	34.42	59.03	1.63	1.63
6	33.34	62.65	1.72	1.72
7	36.54	58.59	1.59	1.59
8	35.82	62.71	1.62	1.62
9	32.96	59.54	1.69	1.69
10	36.05	57.18	1.61	1.61
11	36.96	62.38	1.66	1.66
12	32.93	55.22	1.57	1.57
13	33.65	59.69	1.66	1.66
14	36.27	63.79	1.64	1.64
15	36.16	59.70	1.58	1.58
16	33.68	62.04	1.63	1.63
17	35.88	59.05	1.79	1.79
18	36.95	58.54	1.50	1.50
19	35.75	65.85	1.79	1.79
20	36.32	64.94	1.69	1.69
21	36.11	62.05	1.67	1.67
22	35.26	64.27	1.76	1.76
Mean	**35.60**	**61.89**	**1.67**	**1.67**
SD	**1.61**	**3.37**	**0.08**	**0.08**
Max	**39.83**	**67.58**	**1.84**	**1.84**
Min	**32.93**	**55.22**	**1.50**	**1.50**

Table 4. The values of each parameter in individual mandibular dental arch (posttreatment) based on the beta function. (landmarks on the bracket positions)

Sample	**Mandibular Parameter**			
	a-parameter	**c-parameter**	**d-parameter**	**e-parameter**
1	32.42	59.96	1.71	1.71
2	33.96	61.25	1.76	1.76
3	34.93	56.78	1.63	1.63
4	33.15	62.03	1.63	1.63
5	32.62	56.65	1.68	1.68
6	32.70	55.19	1.62	1.62
7	33.15	55.86	1.54	1.54
8	32.28	57.34	1.63	1.63
9	32.08	55.21	1.62	1.62
10	32.89	54.83	1.67	1.67
11	34.66	57.25	1.63	1.63
12	28.67	53.83	1.58	1.58
13	32.75	55.64	1.64	1.64
14	33.86	59.82	1.60	1.60
15	31.31	55.04	1.65	1.65
16	30.31	59.10	1.69	1.69
17	32.08	56.47	1.77	1.77
18	34.41	54.78	1.42	1.42
19	33.16	60.21	1.63	1.63
20	33.36	58.68	1.58	1.58
21	32.03	59.42	1.56	1.56
22	31.64	58.42	1.64	1.64
Mean	**32.66**	**57.44**	**1.63**	**1.63**
SD	**1.42**	**2.34**	**0.07**	**0.07**
Max	**34.93**	**62.03**	**1.77**	**1.77**
Min	**28.67**	**53.83**	**1.42**	**1.42**

Table 5. The measured values, calculated value, and the coefficient of determinant of maxillary arches arch (pretreatment); in all instances of maxillary arch are judged to fit the data well. (landmarks on the bracket positions)

Sample	**Measured values (mm.)**		**Calculated values (mm.)**		
Maxillary arch	**Depth**	**Width**	**Depth**	**Width**	**R^2**
1	45.74	64.95	46.46	64.96	0.94
2	44.95	67.05	45.87	67.05	0.96
3	45.25	62.92	46.89	62.92	0.98
4	41.42	67.78	42.36	67.78	0.95
5	40.30	58.48	40.96	58.48	0.98
6	42.70	60.90	43.27	60.90	0.91
7	38.56	61.75	38.31	62.77	0.96
8	42.09	63.09	43.00	63.09	0.95
9	36.04	67.79	36.97	67.79	0.98
10	39.28	58.48	40.08	58.48	0.98
11	42.87	62.85	42.46	62.85	0.97
12	41.16	57.20	42.15	57.20	0.99
13	36.70	61.57	37.22	61.58	0.97
14	42.59	63.24	42.24	63.24	0.95
15	38.37	60.57	40.93	60.57	0.99
16	39.42	64.81	39.92	64.81	0.99
17	36.14	58.86	37.37	58.87	0.95
18	43.07	59.47	43.61	59.47	0.98
19	39.71	70.64	41.56	70.85	0.96
20	43.88	63.89	44.37	63.89	0.99
21	38.85	61.87	38.81	62.51	0.97
22	41.03	64.92	43.12	64.92	0.99
Average	**40.91**	**62.87**	**41.72**	**62.95**	**0.97**
SD	**2.85**	**3.46**	**2.87**	**3.47**	**0.02**
Max	**45.74**	**70.64**	**46.89**	**70.85**	**0.99**
Min	**36.04**	**57.20**	**36.97**	**57.20**	**0.91**

Table 6. The measured values, calculated value, and the coefficient of determinant of mandibular arches arch (pretreatment); in all instances of mandibular arch are judged to fit the data well. (landmarks on the bracket positions)

Sample Mandibular arch	**Measured values (mm.)**		**Calculated values (mm.)**		R^2
	Depth	**Width**	**Depth**	**Width**	
1	37.55	58.90	37.85	58.90	0.97
2	41.40	60.94	42.17	60.95	0.99
3	40.91	56.40	41.38	57.53	0.97
4	39.96	62.50	40.28	62.50	0.95
5	41.23	56.50	41.66	56.50	0.97
6	39.72	52.68	40.44	53.95	0.96
7	35.10	52.54	34.68	55.19	0.91
8	37.41	57.32	37.35	57.32	0.99
9	39.26	51.94	38.47	51.94	0.96
10	36.62	56.18	36.87	56.18	0.99
11	39.80	58.80	40.16	60.94	0.97
12	34.61	53.76	34.62	53.76	0.94
13	34.93	54.39	34.92	54.39	0.97
14	39.85	61.05	39.67	61.05	0.98
15	37.57	56.62	37.89	56.62	0.94
16	36.79	63.01	37.89	63.01	0.93
17	32.12	55.58	32.64	56.45	0.96
18	38.91	52.99	39.17	55.48	0.93
19	37.48	56.35	37.02	57.96	0.93
20	40.19	59.40	41.33	59.40	0.98
21	35.49	59.34	36.31	59.34	0.98
22	37.54	59.17	37.87	59.17	0.97
Average	**37.93**	**57.11**	**38.21**	**57.66**	**0.96**
SD	**2.45**	**3.25**	**2.57**	**2.96**	**0.02**
Max	**41.40**	**63.01**	**42.17**	**63.01**	**0.99**
Min	**32.12**	**51.94**	**32.64**	**51.94**	**0.91**

Table 7. The measured values, calculated value, and the coefficient of determinant of maxillary arches (posttreatment); in all instances of maxillary arch are judged to fit the data well. (landmarks on the bracket positions)

Sample	**Measured values (mm.)**		**Calculated values (mm.)**		
Maxillary arch	**Depth**	**Width**	**Depth**	**Width**	**R^2**
1	34.23	65.96	35.29	65.98	0.98
2	35.47	67.58	36.52	67.58	0.98
3	38.66	63.43	39.83	63.43	0.96
4	35.59	67.41	36.54	67.41	0.98
5	33.59	59.03	34.42	59.03	0.96
6	32.72	62.65	33.34	62.65	0.98
7	35.56	58.59	36.54	58.59	0.95
8	35.15	62.70	35.82	62.71	0.96
9	32.22	59.54	32.96	59.54	0.98
10	35.48	57.18	36.05	57.18	0.92
11	36.22	62.37	36.96	62.38	0.96
12	32.36	55.22	32.93	55.22	0.94
13	33.07	59.68	33.65	59.69	0.97
14	35.56	63.79	36.27	63.79	0.96
15	35.43	59.70	36.16	59.70	0.97
16	33.02	62.03	33.68	62.04	0.98
17	34.44	59.04	35.88	59.05	0.99
18	36.17	58.54	36.95	58.54	0.98
19	34.29	65.84	35.75	65.85	0.96
20	35.75	64.94	36.32	64.94	0.98
21	35.00	62.05	36.11	62.05	0.96
22	34.34	64.27	35.26	64.27	0.96
Average	**34.74**	**61.89**	**35.60**	**61.89**	**0.97**
SD	**1.52**	**3.36**	**1.61**	**3.37**	**0.02**
Max	**38.66**	**67.58**	**39.83**	**67.58**	**0.99**
Min	**32.22**	**55.22**	**32.93**	**55.22**	**0.92**

Table 8. The measured values, calculated value, and the coefficient of determinant of mandibular arches (posttreatment); in all instances of mandibular arch are judged to fit the data well.(landmarks on the bracket positions)

Sample Mandibular arch	**Measured values (mm.)**		**Calculated values (mm.)**		R^2
	Depth	**Width**	**Depth**	**Width**	
1	32.06	59.13	32.42	59.96	0.96
2	33.62	61.25	33.96	61.25	0.99
3	34.46	56.78	34.93	56.78	0.98
4	33.02	62.03	33.15	62.03	0.94
5	32.41	56.65	32.62	56.65	0.98
6	32.40	55.19	32.70	55.19	0.92
7	32.71	55.86	33.15	55.86	0.97
8	31.69	57.34	32.28	57.34	0.97
9	31.44	55.21	32.08	55.21	0.96
10	32.59	54.82	32.89	54.83	0.98
11	34.36	57.25	34.66	57.25	0.98
12	28.28	53.83	28.67	53.83	0.99
13	32.40	55.64	32.75	55.64	0.98
14	33.68	59.82	33.86	59.82	0.95
15	30.85	55.03	31.31	55.04	0.98
16	29.63	59.09	30.31	59.10	0.97
17	31.54	56.47	32.08	56.47	0.99
18	34.26	54.78	34.41	54.78	0.97
19	32.86	60.21	33.16	60.21	0.97
20	33.09	58.68	33.36	58.68	0.94
21	31.80	59.42	32.03	59.42	0.99
22	31.33	58.42	31.64	58.42	0.98
Average	**32.30**	**57.40**	**32.66**	**57.44**	**0.97**
SD	**1.49**	**2.30**	**1.42**	**2.34**	**0.02**
Max	**34.46**	**62.03**	**34.93**	**62.03**	**0.99**
Min	**28.28**	**53.83**	**28.67**	**53.83**	**0.92**

A sample of the beta function , which has landmark on the bracket positions (pretreatment), was calculated from the measured data points of maxillary and mandibular arches as shown in figures 27 and 28 respectively. Arch width was measured by the gap between the coordinate distance of the second molar bracket position. Then arch depth was measured by height from the peak of the arch to the arch width's line. As seen from the curve fit analysis, the measured values of the arch width underestimated the calculated values, by approximately 0.81 mm. in the maxillary and 0.28 mm. in the mandibular arches. The measured values of the arch depth underestimated the calculated values, by approximately 0.08 mm. in the maxillary and 0.55 mm. in the mandibular arches (table 5 and 6).

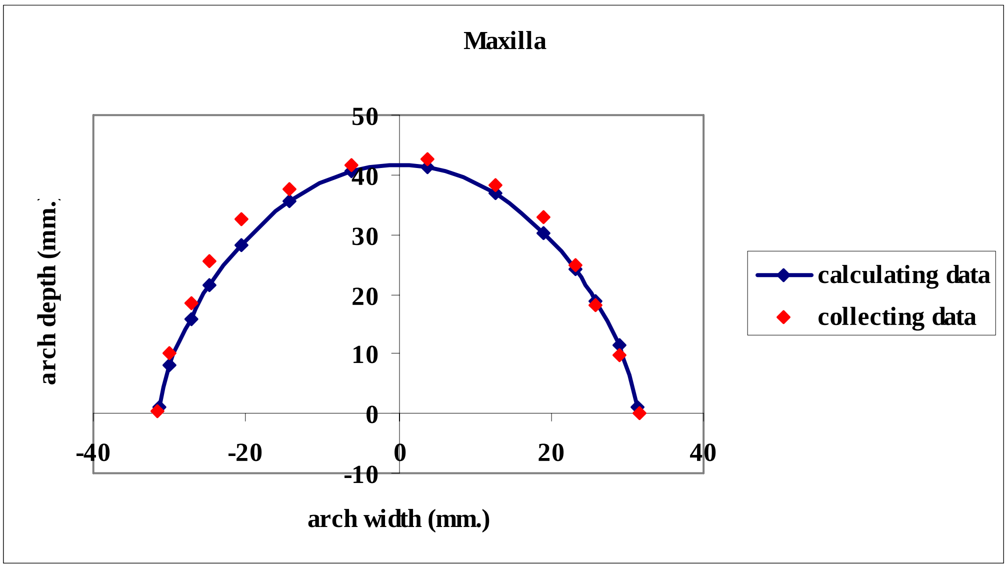


Figure 27: Coordinates were plotted at the bracket positions of maxillary dental arch (pretreatment) as data collected in this study. The superimposition of the collected data (red dot) and the calculated data from the beta function (blue line) are as shown in this figure.

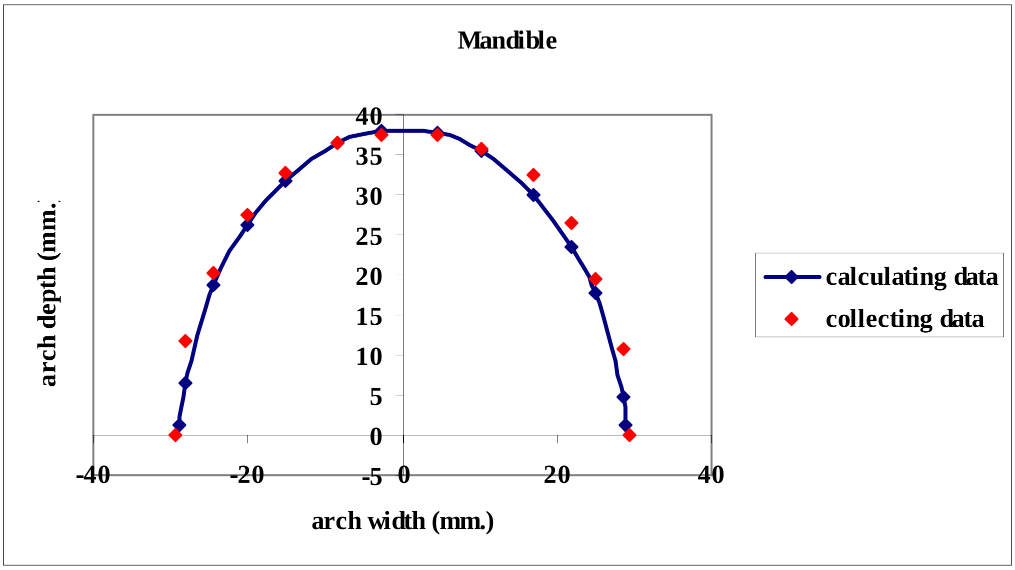


Figure 28: Coordinates were plotted at the bracket positions of mandibular dental arch (pretreatment) as data collected in this study. The superimposition of the collected data (red dot) and the calculated data from the beta function (blue line) are as shown in this figure.

A sample of the beta function , which has landmark on the bracket positions, was calculated from the measured data points of maxillary and mandibular arches as shown in figures 29 and 30 respectively. Arch width was measured by the gap between the coordinate distance of the second molar bracket position. Then arch depth was measured by height from the peak of the arch to the arch width’s line. As seen from the curve fit analysis, the measured values of arch width underestimated the calculated values, by approximately 0.86 mm. in the maxillary arches. But in the mandibular arches the measured values of arch width absolutely fitted the calculated values. The measured values of arch depth underestimated the calculated values, by approximately 0.36 mm. in the maxillary arches and 0.04 mm. in the mandibular arches (table 7 and 8).

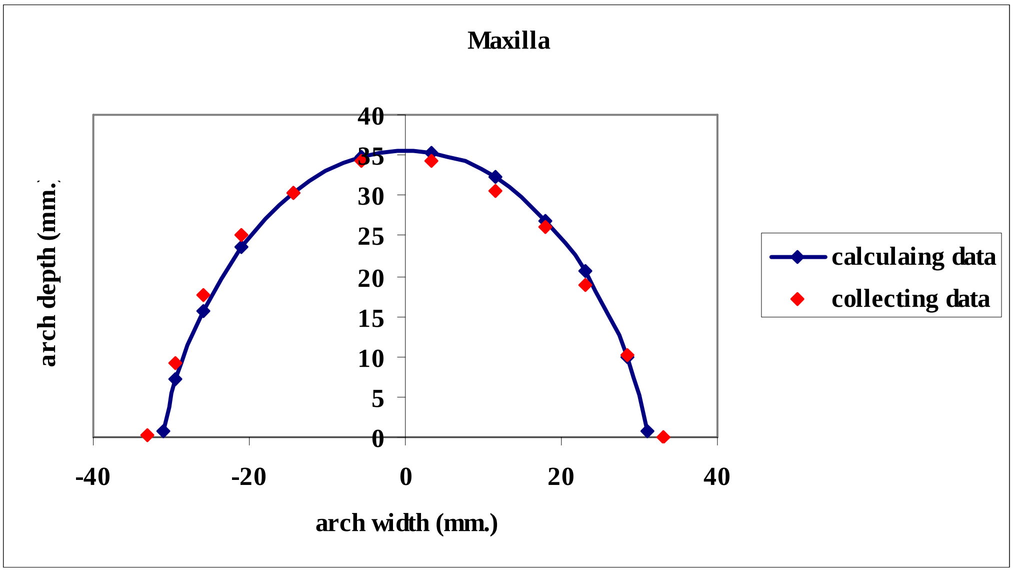


Figure 29: Coordinates were plotted at the bracket positions of maxillary dental arch (posttreatment) as data collected in this study. The superimposition of the collected data (red dot) and the calculated data from the beta function (blue line) as shown in this figure.

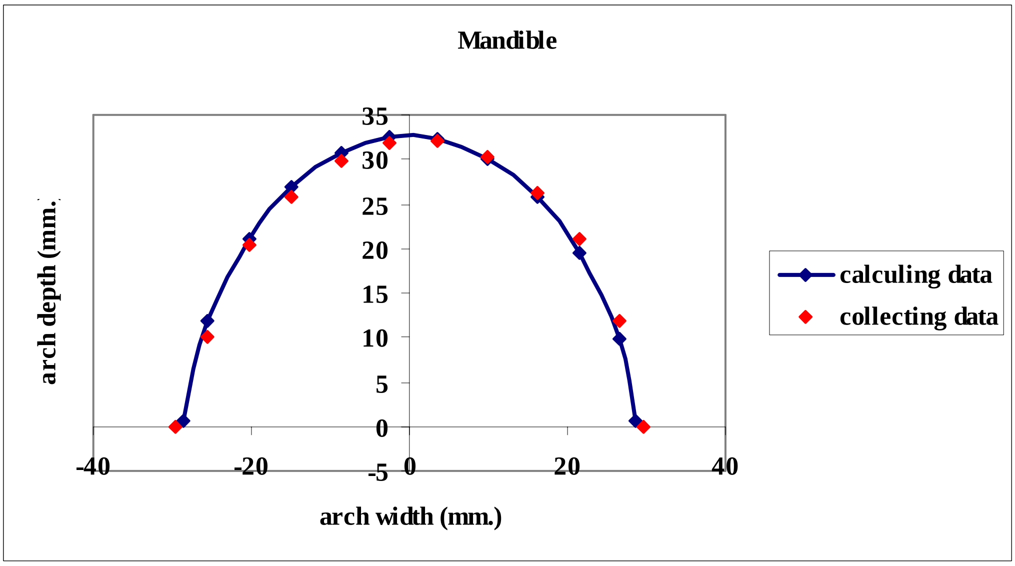


Figure 30: Coordinates were plotted at the bracket positions of mandibular dental arch (posttreatment) as data-collected in this study. The superimposition of the collecting data (red dot) and the calculated data from the beta function (blue line) as shown in this figure.

Table 9. The pretreatment and posttreatment intercanine width of maxillary and mandibular arches. (The distance between landmarks on the bracket positions from the right canine to the left canine)

Sample	**Pretreatment values (mm.)**		**Posttreatment values (mm.)**	
	Maxilla	**Mandible**	**Maxilla**	**Mandible**
1	41.27	32.23	39.02	30.93
2	41.52	32.15	42.91	31.44
3	43.39	32.84	42.94	33.53
4	42.39	34.57	42.07	32.73
5	39.39	31.63	39.29	28.87
6	39.13	29.95	38.62	30.61
7	39.15	32.32	40.49	32.15
8	39.75	30.62	40.37	31.82
9	33.46	26.55	38.10	31.14
10	37.27	30.92	37.76	29.70
11	41.72	32.62	42.35	33.82
12	37.44	26.86	36.85	28.03
13	38.66	29.28	39.29	31.68
14	41.10	31.35	39.67	31.69
15	36.19	30.82	39.30	30.17
16	37.11	29.50	39.39	30.11
17	37.28	23.31	37.49	29.52
18	42.32	30.98	41.85	32.42
19	42.30	29.85	42.44	34.11
20	37.22	32.69	40.94	33.79
21	38.20	30.07	40.84	32.10
22	40.11	31.52	40.46	30.06
Average	**39.38**	**30.57**	**40.11**	**31.38**
SD	**2.48**	**2.47**	**1.80**	**1.66**
Max	**43.39**	**34.57**	**42.94**	**34.11**
Min	**33.46**	**23.31**	**36.85**	**28.03**

Table 10. The pretreatment and posttreatment intermolar width of maxillary and mandibular arches. (The distance between landmarks on the bracket positions from the right molar to the left molar)

Sample	**Pretreatment values (mm.)**		**Posttreatment values (mm.)**	
	Maxilla	**Mandible**	**Maxilla**	**Mandible**
1	61.07	56.72	58.01	52.15
2	61.37	54.97	59.74	52.16
3	59.04	53.46	57.38	50.70
4	64.39	57.84	60.11	54.70
5	57.21	54.94	54.88	48.96
6	56.91	50.26	54.09	48.18
7	55.96	52.87	54.30	50.86
8	58.88	53.42	57.05	50.54
9	54.14	50.29	53.94	48.63
10	56.27	51.72	52.97	48.35
11	60.27	54.26	56.85	50.58
12	53.14	49.22	50.95	47.31
13	56.91	51.73	53.54	49.21
14	60.26	56.63	57.99	53.03
15	56.25	51.57	53.94	48.26
16	58.41	57.75	56.40	51.07
17	52.72	49.41	51.92	48.96
18	57.37	53.50	54.96	51.65
19	60.85	55.19	58.55	53.13
20	59.70	54.09	58.14	52.75
21	57.32	53.08	55.69	51.85
22	61.04	55.58	56.22	50.91
Average	**58.16**	**53.57**	**55.80**	**50.63**
SD	**2.88**	**2.54**	**2.47**	**1.95**
Max	**64.39**	**57.84**	**60.11**	**54.70**
Min	**52.72**	**49.22**	**50.95**	**47.31**

Table 11. Descriptive statistics (Means and SD) of each parameter both in the maxillary and mandibular arches between males and females (pretreatment).

Parameter	**Male (n=8)**		**Female (n=14)**	
	Mean (mm)	**SD**	**Mean (mm)**	**SD**
Maxilla				
a-parameter	43.39	2.94	40.77	2.45
c-parameter	63.49	3.07	62.65	3.75
d-parameter	1.64	0.10	1.74	0.27
Intercanine width	40.75	1.63	38.60	2.59
Intermolar width	59.35	2.80	57.47	2.79
Mandible				
a-parameter	39.48	2.60	37.49	2.34
c-parameter	57.85	2.85	57.55	3.13
d-parameter	1.54	0.08	1.58	0.10
Intercanine width	32.04	1.40	29.74	2.59
Intermolar width	54.31	2.36	53.15	2.63

Table 12. Statistical difference of each instance between males and females (pretreatment).

Parameter	**Mean diff (mm)**	**t**	**p-value**
Maxillary arch			
A	2.62	2.24*	0.04
C	0.84	0.54	0.59
D	-0.10	-1.28	0.22
Intercanine width	2.15	2.11*	0.04
Intermolar width	1.88	1.52	0.15
Mandibular arch			
A	1.99	1.84	0.08
C	0.30	0.23	0.82
D	-0.04	-0.87	0.39
Intercanine width	2.30	2.31*	0.03
Intermolar width	1.16	1.03	0.31

* Significant at p-value < 0.05

Table 11 was the descriptive statistics (Means and SD) of each parameter, which came from recording at the bracket positions (pretreatment), both in the maxillary and mandibular arches between males and females. All of the parameters indicated the small difference in values between the sex dimorphism. The comparison of each instance between males and females are as shown in table 12. No statistically significant difference of any parameter was found between males and females at p-value < 0.05 both in the maxillary and mandibular arches except at the a-parameter in the maxillary arch and intercanine widths in both maxillary and mandibular arches. It was found that the arch depth in maxillary arch from males were significantly greater than females average 2.62 mm. at p-value < 0.05. The intercanine width of maxillary arch from males were significant greater than females average 2.15 mm. in maxilla and 2.30 mm. in mandible at p-value <0.05.

Table 13. Descriptive statistics (Means and SD) of each parameter both in the maxillary and mandibular arches between males and females (posttreatment).

Parameter	**Male (n=8)**		**Female (n=14)**	
	Mean (mm)	**SD**	**Mean (mm)**	**SD**
Maxilla				
a-parameter	36.04	1.91	35.35	1.42
c-parameter	63.42	3.45	61.02	3.10
d-parameter	1.69	0.08	1.66	0.08
Intercanine width	40.71	1.73	39.77	1.80
Intermolar width	56.94	2.35	55.15	2.37
Mandible				
a-parameter	33.15	0.90	32.37	1.60
c-parameter	58.13	2.59	57.05	2.19
d-parameter	1.65	0.07	1.62	0.08
Intercanine width	31.51	1.43	31.31	1.83
Intermolar width	51.03	2.03	50.41	1.95

Table 13 was the descriptive statistics (Means and SD) of each parameter, which came from recording at the bracket positions (posttreatment), both in the maxillary and mandibular arches between males and females. All of the parameters indicated the small difference in values between the sex dimorphism. The comparison of each instance between males and females are as shown in table 14. No statistically significant difference of any parameter was found between males and females at p-value < 0.05 both in the maxillary and mandibular arches.

Table 14. Statistical difference of each instance between males and females (posttreatment).

Parameter	Mean diff (mm)	t	p-value
Maxillary arch			
A	0.69	0.96	0.35
C	2.40	1.68	0.11
D	0.03	0.96	0.35
Intercanine width	0.94	1.20	0.24
Intermolar width	1.79	1.72	0.10
Mandibular arch			
A	0.78	1.26	0.22
C	1.08	1.05	0.31
D	0.03	0.98	0.34
Intercanine width	0.20	0.26	0.79
Intermolar width	0.62	0.72	0.48

Table 15 and 16 were the comparisons of the parameters from data-recording on bracket positions (pretreatment) compared between Kmolvisit’s study and this study. All of the parameters indicated the small difference in values between two studies. There was no statistically significant difference of every parameters between two studies at p-value <0.05.

Table 15. Descriptive statistics (Means and SD) of each parameter both in the maxillary and mandibular arches between recorded on the bracket positions compared between Kmolvisit's study and this study.

Parameter	**Kmolvisit's study (n=40)**		**This study (n=22)**	
	Mean (mm)	**SD**	**Mean (mm)**	**SD**
Maxilla				
a-parameter	41.72	2.93	41.72	2.87
c-parameter	62.56	3.19	62.95	3.47
d-parameter	1.76	0.14	1.70	0.22
Mandible				
a-parameter	37.48	3.32	38.21	2.57
c-parameter	57.32	3.39	57.66	2.96
d-parameter	1.60	0.13	1.56	0.09

Table 16. Statistical difference of each instance between recorded on the bracket positions compared between Kmolvisit's study and this study.

Parameter	**Mean diff (mm)**	**t**	**p-value**
Maxillary arch			
A	0.00	0.00	1.00
C	-0.39	-0.45	0.66
D	0.06	1.03	0.31
Mandibular arch			
A	-0.73	-0.89	0.37
C	-0.34	-0.39	0.70
D	0.04	1.31	0.19

The descriptive statistics (Means and SD) of the pretreatment and posttreatment parameters in the maxillary and mandiblular arches (table 17 and 18). The pretreatment of both maxillary and mandibular arches are statistically significant greater than posttreatment at p-value < 0.05.

Table 17. Descriptive statistics (Means and SD) of each parameter both in the maxillary and mandibular arches between pretreatment and posttreatment stages.

Parameter	**Pretreatment (n=22)**		**Posttreatment (n=22)**	
	Mean (mm)	**SD**	**Mean (mm)**	**SD**
Maxilla				
a-parameter	41.72	2.87	35.60	1.61
c-parameter	62.95	3.47	61.89	3.37
d-parameter	1.70	0.22	1.67	0.08
Intercanine width	39.38	2.48	40.11	1.80
Intermolar width	58.16	2.88	55.80	2.47
Mandible				
a-parameter	38.21	2.57	32.66	1.42
c-parameter	57.66	2.96	57.19	1.98
d-parameter	1.56	0.09	1.63	0.07
Intercanine width	30.57	2.47	31.38	1.66
Intermolar width	53.57	2.54	50.63	1.95

Table 18. Statistical difference of each instance between pretreatment and posttreatment.

Parameter	**Mean diff (mm)**	**t**	**p-value**
Maxillary arch			
A	6.12	8.72**	0.00
C	1.06	1.03	0.31
D	0.03	0.66	0.52
Intercanine width	-0.73	-1.12	0.27
Intermolar width	2.36	2.92**	0.01
Mandibular arch			
A	5.56	8.88**	0.00
C	0.47	0.62	0.54
D	-0.07	-1.66	0.05
Intercanine width	-0.81	-1.28	0.21
Intermolar width	2.94	4.29**	0.00

** Significant at p-value < 0.01, * Significant at p-value < 0.05

Table 17 shows the comparison of the maxillary arch width changes during treatment ($T_1 - T_0$). During orthodontic treatment, the maxillary intercanine width increased but not significantly (mean value of 0.73 mm., p-value > 0.05). The great decrease was between the intermolar with a mean value of 2.36 mm. (p-value < 0.01). A significant decrease in arch depth was also found during orthodontic treatment (mean value of 6.12 mm., p-value < 0.01).

A comparison of the mandibular arch width changes at the two time periods is shown in Table 18. No statistically significant increase in intercanine width during orthodontic treatment (mean value of 0.81 mm., p-value > 0.05). The great decrease was found in the intermolar with a mean value of 2.94 mm. (p-value < 0.01). A significant decrease in arch depth was also found during orthodontic treatment (mean value of 5.56 mm., p-value < 0.01).

Table 19. Descriptive statistics (Means and SD) of each parameter both in the maxillary and mandibular arches between recorded on the bracket positions compared between Chantarasmee's study and the pretreatment dental arch of this study.

Parameter	**Chantarasmee 's study (n=40)**		**This study (n=22)**	
	Mean (mm)	**SD**	**Mean (mm)**	**SD**
Maxilla				
a-parameter	41.39	2.17	41.72	2.87
c-parameter	64.03	2.48	62.95	3.47
d-parameter	1.70	0.09	1.70	0.22
Mandible				
a-parameter	38.57	1.76	38.21	2.57
c-parameter	59.47	2.17	57.66	2.96
d-parameter	1.68	0.10	1.56	0.09

Table 20. Statistical difference of each instance between recorded on the bracket positions compared between Chantarasmee's study and the pretreatment dental arch of this study.

Parameter	Mean diff (mm)	t	p-value
Maxillary arch			
A	-0.33	-0.51	0.61
C	1.07	1.41	0.16
D	-0.01	-0.06	0.95
Mandibular arch			
A	0.36	0.59	0.56
C	1.81	2.75*	0.01
D	0.12	4.71**	0.00

** Significant at p-value < 0.01, * Significant at p-value < 0.05

Table 19 and 20 were the comparisons of the parameters from data-recording on bracket positions compared between the Angle Classification I from Chantarasmee's unpublished study and the Angle Classification II, Division 1 (pretreatment) from this study. There was no statistically difference of every parameters in the maxillary arch between two Angle Classifications at p-value <0.05. The results has shown that the c- and d-parameter in mandibular arch of Class II were significantly lesser than those of Class I at p-value <0.05.

Table 21. Descriptive statistics (Means and SD) of each parameter both in the maxillary and mandibular arches between recorded on the bracket positions compared between pretreatment dental arch of Chantarasmee's study and the posttreatment dental arch of this study.

Parameter	**Chantarasmee 's study (n=40)**		**This study (n=22)**	
	Mean (mm)	**SD**	**Mean (mm)**	**SD**
Maxilla				
a-parameter	41.39	2.17	35.60	1.61
c-parameter	64.03	2.48	61.89	3.37
d-parameter	1.70	0.09	1.67	0.08
Mandible				
a-parameter	38.57	1.76	32.66	1.42
c-parameter	59.47	2.17	57.19	1.98
d-parameter	1.68	0.10	1.63	0.07

Table 22. Statistical difference of each instance between recorded on the bracket positions compared between pretreatment dental arch of Chantarasmee's study and the posttreatment dental arch of this study.

Parameter	**Mean diff (mm)**	**t**	**p-value**
Maxillary arch			
A	5.79	10.94**	0.00
C	2.14	2.85*	0.01
D	0.03	1.28	0.20
Mandibular arch			
A	5.92	13.53**	0.00
C	2.28	4.07**	0.00
D	0.05	2.17*	0.03

** Significant at p-value < 0.01, * Significant at p-value < 0.05

Table 21 and 22 were the comparisons of the parameters from data-recording on bracket positions compared between the Angle Classification I from Chantarasmee's unpublished study and the Angle Classification II, Division 1 (posttreatment) from this study. All of the parameters except d-parameter in the maxillary arch indicated the statistically difference in values between two Angle Classifications at p-value <0.05. The results has shown that every parameters except d-parameter in the maxillary arch of Class II were significantly lesser than that of Class I at p-value <0.05.

Manual measurements

According to superimpositions with the morphologic arch system (OrthoForm, 3M Unitek, Calif.), maxillary arch forms were tapered at the pretreatment stage; T_0. During orthodontic treatment, maxillary arch form were not change.

The mandibular arch forms were tapered at the pretreatment stage; T_0. During orthodontic treatment, pretreatment tapered mandibular arch form remained tapered.

The curves were generated by putting the values of the mean arch widths, the mean arch depth (table 5 - 8) and the mean of d-parameter (table 1 - 4) received from the samples into the equation as follows:

$$Y = a\left(1 - \frac{4X^2}{c^2}\right)^{d-1}$$

The maxillary and mandibular dental arch equations for each arch are as shown below:

The maxillary arch

Landmarks on the bracket positions (pretreatment)

$$Y = 41.72\left(1 - \frac{4x^2}{62.95^2}\right)^{0.7}$$

Landmarks on the bracket positions (posttreatment)

$$Y = 35.60\left(1 - \frac{4x^2}{61.89^2}\right)^{0.67}$$

The mandibular arch

Landmarks on the bracket positions (pretreatment)

$$Y = 38.21\left(1 - \frac{4x^2}{57.66^2}\right)^{0.56}$$

Landmarks on the bracket positions (posttreatment)

$$Y = 32.66\left(1 - \frac{4x^2}{57.44^2}\right)^{0.63}$$

Error of measurement

The method error was calculated by repeating the registration of dental landmarks randomly with 5 sets of study models by keeping the period of timing 4 weeks. Double determination reveal errors in the measurements, including mean and standard deviations. Tables 23 to 30 were the summaries of these measurements. No statistically significant difference (at p-value < 0.05) was found between the two series of recording. Table 31 and 32 has shown the errors of measurement which were small and acceptable. The maxillary and mandibular dental arch equations for each arch are as shown below:

Table 23. The statistical differences of the X-coordinate from maxillary dental landmarks between two measurements (pretreatment).

CMM-recorded	**First measure (n=5)**	**SD**	**Second measure (n=5)**	**SD**	**Mean diff (mm)**	**p-value**
Maxillary arch						
X-coordinate						
X1	-0.02	0.03	-0.01	0.02	-0.01	0.85
X2	3.20	2.48	3.22	2.48	-0.02	0.59
X3	5.90	2.21	6.00	2.15	-0.10	0.15
X4	8.45	2.50	8.44	2.50	0.01	0.92
X5	12.43	2.90	12.43	2.98	0.00	1.00
X6	18.98	2.63	19.02	2.66	-0.04	0.33
X7	26.15	2.18	26.20	2.19	-0.05	0.39
X8	36.14	2.18	36.16	2.12	-0.02	0.70
X9	44.31	2.54	44.21	2.52	0.10	0.07
X10	50.62	2.98	50.67	2.90	-0.05	0.48
X11	54.87	3.60	54.85	3.45	0.02	0.82
X12	57.53	3.57	57.52	3.58	0.01	0.98
X13	60.39	4.05	60.41	3.95	-0.02	0.79
X14	63.08	4.92	63.06	4.96	0.02	0.80

Table 24. The statistical differences of the X-coordinate from maxillary dental landmarks between two measurements (posttreatment).

CMM-recorded	**First measure (n=5)**	**SD**	**Second measure (n=5)**	**SD**	**Mean diff (mm)**	**p-value**
Maxillary arch						
X-coordinate						
X1	-0.01	0.01	-0.01	0.01	0.00	1.00
X2	3.23	0.84	3.24	0.74	-0.01	0.75
X3	6.72	1.50	6.69	1.49	0.03	0.67
X4	11.16	1.62	11.15	1.61	0.01	0.98
X5	18.03	2.16	17.93	2.11	0.10	0.11
X6	26.07	2.80	26.03	2.68	0.04	0.61
X7	35.33	3.04	35.37	2.95	-0.04	0.55
X8	43.47	3.25	43.40	3.24	0.07	0.33
X9	50.18	3.82	50.23	3.80	-0.05	0.32
X10	54.34	3.77	54.32	3.87	0.02	0.80
X11	58.35	4.38	58.39	4.37	-0.04	0.42
X12	61.09	5.43	61.00	5.33	0.09	0.19

Table 25. The statistical differences of the Y-coordinate from maxillary dental landmarks between two measurements (pretreatment).

CMM-recorded	**First measure (n=5)**	**SD**	**Second measure (n=5)**	**SD**	**Mean diff (mm)**	**p-value**
Maxillary arch						
Y-coordinate						
Y1	0.05	0.10	0.03	0.03	0.02	0.63
Y2	9.53	0.96	9.58	0.90	-0.05	0.32
Y3	16.71	2.49	16.77	2.52	-0.06	0.45
Y4	24.72	1.61	24.74	1.56	-0.02	0.77
Y5	31.65	1.96	31.69	1.86	-0.04	0.61
Y6	38.80	2.88	38.89	2.87	-0.09	0.06
Y7	44.75	4.77	44.73	4.82	0.02	0.60
Y8	44.57	5.14	44.55	5.31	0.02	0.85
Y9	38.89	3.03	38.93	3.05	-0.04	0.49
Y10	33.59	4.09	33.55	4.11	0.04	0.61
Y11	24.79	1.57	24.88	1.46	-0.09	0.24
Y12	16.64	2.18	16.57	2.26	0.07	0.26
Y13	9.27	0.99	9.29	1.00	-0.02	0.59
Y14	-0.02	0.04	0.00	0.06	-0.02	0.27

Table 26. The statistical differences of the Y-coordinate from maxillary dental landmarks between two measurements (posttreatment).

CMM-recorded	**First measure (n=5)**	**SD**	**Second measure (n=5)**	**SD**	**Mean diff (mm)**	**p-value**
Maxillary arch						
Y-coordinate						
Y1	0.04	0.06	0.02	0.05	0.02	0.11
Y2	10.29	0.98	10.25	1.08	0.04	0.53
Y3	18.11	1.39	18.03	1.38	0.08	0.20
Y4	25.23	1.37	25.31	1.33	-0.08	0.09
Y5	30.58	1.56	30.63	1.55	-0.05	0.40
Y6	33.99	1.59	34.02	1.60	-0.03	0.54
Y7	33.99	1.64	34.02	1.68	-0.03	0.58
Y8	29.56	3.00	30.31	1.44	-0.75	0.41
Y9	25.43	1.21	25.32	1.10	0.11	0.18
Y10	18.29	1.25	18.33	1.24	-0.04	0.30
Y11	9.87	1.13	9.91	1.15	-0.04	0.56
Y12	0.03	0.05	0.04	0.05	-0.01	0.60

Table 27. The statistical differences of the X-coordinate from mandibular dental landmarks between two measurements (pretreatment).

CMM-recorded	**First measure (n=5)**	**SD**	**Second measure (n=5)**	**SD**	**Mean diff (mm)**	**p-value**
Mandibular arch						
X-coordinate						
X1	0.20	0.27	0.16	0.18	0.04	0.51
X2	2.16	0.66	2.11	0.68	0.05	0.53
X3	4.85	1.09	4.87	1.06	-0.02	0.71
X4	8.62	0.99	8.59	0.95	0.03	0.67
X5	13.78	0.90	13.66	0.88	0.12	0.11
X6	20.30	1.50	20.30	1.53	0.00	1.00
X7	25.78	1.52	25.85	1.55	-0.07	0.07
X8	31.39	2.32	31.50	2.20	-0.11	0.43
X9	37.30	2.29	37.33	2.25	-0.03	0.67
X10	44.52	2.28	43.62	3.26	0.90	0.44
X11	48.36	3.13	48.38	3.19	-0.02	0.77
X12	51.43	3.09	51.48	3.06	-0.05	0.27
X13	54.57	3.19	54.49	3.16	0.08	0.20
X14	56.50	3.80	56.53	3.73	-0.03	0.81

Table 28. The statistical differences of the X-coordinate from mandibular dental landmarks between two measurements (posttreatment).

CMM-recorded	**First measure (n=5)**	**SD**	**Second measure (n=5)**	**SD**	**Mean diff (mm)**	**p-value**
Mandibular arch						
X-coordinate						
X1	0.00	0.00	0.01	0.02	-0.01	0.18
X2	4.03	1.04	4.00	0.90	0.03	0.74
X3	8.06	1.08	8.12	1.08	-0.06	0.29
X4	13.24	1.52	13.27	1.49	-0.03	0.64
X5	19.56	1.77	19.50	1.74	0.06	0.48
X6	25.49	1.90	25.45	1.89	0.04	0.37
X7	31.15	1.99	31.19	2.05	-0.04	0.51
X8	37.40	1.96	37.34	1.89	0.06	0.23
X9	43.51	2.07	43.55	1.94	-0.04	0.52
X10	48.51	2.62	48.62	2.54	-0.11	0.32
X11	53.18	2.86	53.26	2.86	-0.08	0.14
X12	56.85	3.18	56.84	3.03	0.01	0.94

Table 29. The statistical differences of the Y-coordinate from mandibular dental landmarks between two measurements (pretreatment).

CMM-recorded	**First measure (n=5)**	**SD**	**Second measure (n=5)**	**SD**	**Mean diff (mm)**	**p-value**
Mandibular arch						
Y-coordinate						
Y1	0.15	0.20	0.15	0.19	0.00	1.00
Y2	11.77	0.90	11.76	1.02	0.01	0.87
Y3	19.66	1.39	19.70	1.42	-0.04	0.56
Y4	27.10	1.59	27.16	1.63	-0.06	0.18
Y5	32.39	2.20	32.40	2.16	-0.01	0.85
Y6	36.15	2.78	36.17	2.82	-0.02	0.62
Y7	37.96	2.71	37.93	2.72	0.03	0.65
Y8	37.93	2.59	37.99	2.61	-0.06	0.27
Y9	35.96	2.89	35.93	2.88	0.03	0.46
Y10	32.34	2.44	32.39	2.46	-0.05	0.39
Y11	26.73	1.55	26.79	1.58	-0.06	0.33
Y12	19.56	1.44	19.58	1.44	-0.02	0.59
Y13	12.09	1.60	12.13	1.62	-0.04	0.28
Y14	-0.01	0.06	-0.04	0.08	-0.03	0.54

Table 30. The statistical differences of the Y-coordinate from mandibular dental landmarks between two measurements (posttreatment).

CMM-recorded	**First measure (n=5)**	**SD**	**Second measure (n=5)**	**SD**	**Mean diff (mm)**	**p-value**
Mandibular arch						
Y-coordinate						
Y1	-0.01	0.03	0.02	0.05	-0.03	0.24
Y2	11.28	0.83	11.27	0.73	0.01	0.90
Y3	20.20	0.68	20.29	0.73	-0.09	0.20
Y4	26.41	1.06	26.44	1.07	-0.03	0.73
Y5	30.07	1.84	30.09	1.83	-0.02	0.62
Y6	31.60	2.01	31.62	2.04	-0.02	0.77
Y7	31.62	2.09	31.55	2.01	0.07	0.42
Y8	30.03	1.89	30.03	1.81	0.00	1.00
Y9	25.97	1.10	26.10	1.19	-0.13	0.21
Y10	20.33	1.11	20.32	1.14	0.01	0.90
Y11	12.04	0.90	12.04	0.91	0.00	1.00
Y12	0.04	0.07	0.01	0.03	0.03	0.14

Table 31 and 32 showed the method errors, describing random measurement error for each of the categories of measurement that were calculated according to Dahlberg’s equation. The difference between the first and second measurements of the 5 model sets was insignificant. The recorded-data indicated the range of method error between 0.006 and 0.218 mm. and were within acceptable limits.

Table 31. The measurement errors (pretreatment) calculated using Dahlberg's equation.

Dental landmark	**Maxillary arch**		**Mandibular arch**	
	X-coordinate (mm)	**Y-coordinate (mm)**	**X-coordinate (mm)**	**Y-coordinate (mm)**
1	0.012	0.071	0.082	0.040
2	0.074	0.081	0.113	0.106
3	0.114	0.124	0.068	0.137
4	0.114	0.121	0.103	0.066
5	0.104	0.115	0.135	0.094
6	0.066	0.090	0.089	0.062
7	0.092	0.081	0.080	0.096
8	0.082	0.142	0.218	0.084
9	0.097	0.102	0.100	0.058
10	0.109	0.055	0.115	0.098
11	0.108	0.121	0.111	0.093
12	0.077	0.104	0.063	0.105
13	0.111	0.108	0.102	0.055
14	0.083	0.023	0.191	0.046

Table 32. The measurement errors (posttreatment) calculated using Dahlberg's equation.

Dental landmark	**Maxillary arch**		**Mandibular arch**	
	X-coordinate (mm)	**Y-coordinate (mm)**	**X-coordinate (mm)**	**Y-coordinate (mm)**
1	0.006	0.018	0.015	0.042
2	0.076	0.095	0.117	0.109
3	0.106	0.100	0.093	0.114
4	0.154	0.089	0.097	0.104
5	0.010	0.097	0.126	0.069
6	0.117	0.096	0.084	0.108
7	0.101	0.092	0.102	0.143
8	0.110	0.114	0.139	0.094
9	0.134	0.145	0.100	0.166
10	0.125	0.068	0.164	0.119
11	0.078	0.104	0.092	0.053
12	0.118	0.010	0.119	0.041

CHAPTER 5

DISCUSSION

It is well established that the changes in dental arch length and width during orthodontic treatment tend to return toward pretreatment values after retention[3, 72]. These dimensional changes may affect arch form as well.

Traditionally, change in arch form has been analyzed in terms of the behavior of various linear dimensions such as arch width, depth, and circumference. However, many authors have cautioned that analyses of this type are incomplete and limited in description. Lavelle[84] stressed that single variable analysis involving the use of intertooth dimensions tends to treat the dental arch as a collection of discrete entities rather than a biological unit, not to mention the possibility of cross correlation between the variates. Sampson[11] declared that changes in intertooth dimensions fail to distinguish size and shape changes and provide only a fraction of the information embodied in the changing curvature of an arch form. The majority of studies pertaining to arch form have focused on attempts to find the single shape that would best describe the dental arches of a particular sample.

More recently, arch form has been describe with a variety of mathematical equations[1, 11, 12, 14, 18, 47, 85]. The present work aims at defining the mathematical equation of the dental arch forms in the pretreatment and posttreatment of Angle Classification II, Division 1 that best fit to Thais.

A sample of 22 subjects (8 males and 14 females) with Class II, Division 1 malocclusion was selected from patient records at the Orthodontics Department, Faculty of Dentistry, Mahidol University. The models included the full permanent teeth (excluded the third molar).

In this study, the measurement was done by using the CMM (Coordinate Measuring Machine) to record the landmarks on dental model and report these landmarks in the corresponding X-,Y-,and Z- coordinates. CMM is used extensively in the precision machine tool industry. As previously described, Braun et al.[21] and Qiong et al.[48] have used CMM to record the X-,Y- coordinates of dental landmarks for the study of human dental arch forms and the comparison of intermaxillary tooth size discrepancies among different malocclusion groups. The study of the reliability of CMM in measuring dental models[53] had concluded that the Coordinate Measuring Machine can be applied to measuring dental casts in three dimensions with highly accurate, reliable and reproducible results.

Replicated measurements by the same single examiner were made on five sets of study models with a time lapse of one week each. The paired t-test, which was used to assess any systematic error of the machine, was reliable and reproducible. The method error of the coordinates's measurements of dental landmarks were calculated based on Dahlberg's equation. As a result, very small error range has been shown (0.006 - 0.218 mm.). Intraexamination has also reconfirmed that the results were accurate and well-calibrated. It would be seem fair to state, with careful recording of data for this purpose, the integration of data from the dental models is reasonably accurate. Although the technique developed to assess the dental arch form was more accurate than any thus far available.

In the present, we used the evolution algorithm, a good optimization method [21, 25, 53], to calculate the parameters of the beta function from the collected data of each dental arch. It was based on the minimized sum of squared errors of the calculated values to the measurement values (details about the estimation of its parameters from a sample of data were given by Department of Mathemetics, Faculty of Science, Mahidol university). The goal was to obtain the measure of the closeness of agreement between the true arch form and the approximation. The total sums of squares accounted for by the regression was a measure of closeness of an approximation. The method is not concerned with the change in position of any specific tooth or group of teeth or arch segment. The entire configuration of the arch form is evaluated.

The beta function has been shown to be an accurate representation of the human dental arches. The goodnesss of fit of the beta function for the complete sample of the 22 maxillary and mandibular arches, as also verified by the high coefficient of determination (R^2), average 0.97 in the maxillary arch (pretreatment and posttreatment) and mandibular arch (posttreatment), and average 0.96 in the mandibular arch (pretreatment) with a standard deviation of 0.02. This is in agreement with Braun et.al.[21], who has been the first to offer the beta function to describe the dental arch, with an average correlation coefficient of 0.98 with a standard deviation of 0.02.

The resulting equation, the beta function is an excellent representation of the dental arch form, including the second molars. Geometric parameters that describe and distinguish the size and the shape of the beta function curve can be easily computed and used to quantify and achieved better understanding of both the maxillary and mandibular as well as the pretreatment and posttreatment dental arch form for the Angle's classification II, Division 1 malocclusion in Thais.

In a study comparing arch widths in adults with normal occlusion and adults with Class II, Division 1 malocclusions, Staley et al.[86] observed that in five of six arch width measurements, normal male adults were significantly larger than normal female adults. On the other hand, among the subjects with Class II, Division 1 malocclusions, the male subjects had no statistically significant different in any dimensional parameters from the female subjects in both maxillary and mandibular dental arch widths. They suggested that the malocclusion might tend to minimize or eliminate the differences normally found between the genders.

This is suggested by the greater frequency of variables that are significantly different between male and female subjects with Class II, Division 1 pretreatment as compared with the corresponding posttreatment changes in the subject with Class II, Division 1 malocclusions treated with four first premolars extraction. In general, the current findings tend to support this hypothesis and confirm with the presence of such differences in only pretreatment maxillary a-parameter, and maxillary and mandibular intercanine widths that the male subjects showed greater values than the females. The investigation also indicated that the posttreatment parameter values were similar in male and female subjects in the various dental arch parameters evaluated. As an example, there were no significant differences in any of the absolute posttreatment dental arch parameter values such as arch depth, arch taperedness, intercanine and intermolar widths.

In the present study, when evaluated at the pretreatment stage (T_0), the study exhibited a statistically significant difference only in the maxillary pretreatment arch depth (a-parameter) between the sex dimorphism. It was found that the arch depth in maxillary arch from males were significantly greater than females average 2.62 mm. at p-value < 0.05.

When compared pretreatment and posttreatment changes in the intercanine and intermolar widths between males and females. The findings from these dental arch measurements indicated that at the pretreatment stage (T_0), males had statistically significant greater intercanine width than females both in maxilla and mandible, but no statistically significant different in intermolar width between males and females at p-value < 0.05.

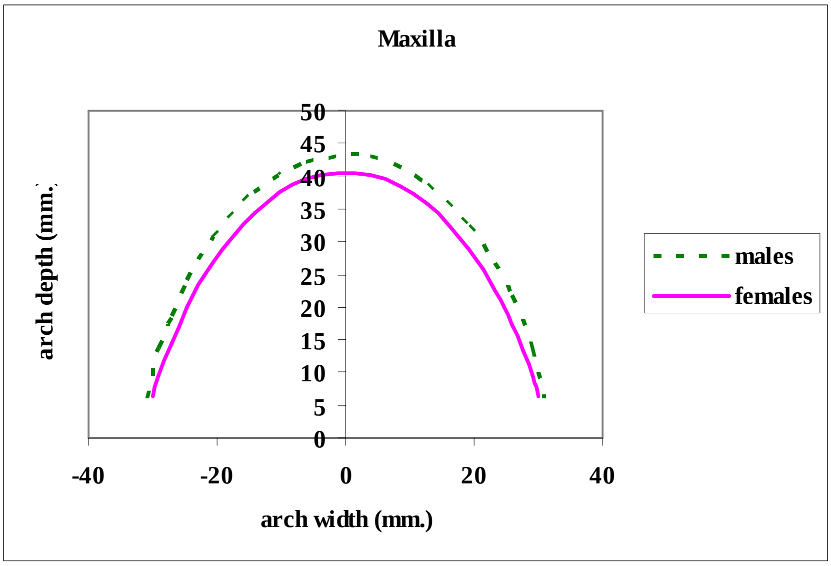


Figure 31: The superimposition of pretreatment maxillary arch form that were compared between males (green point) and females (pink line).

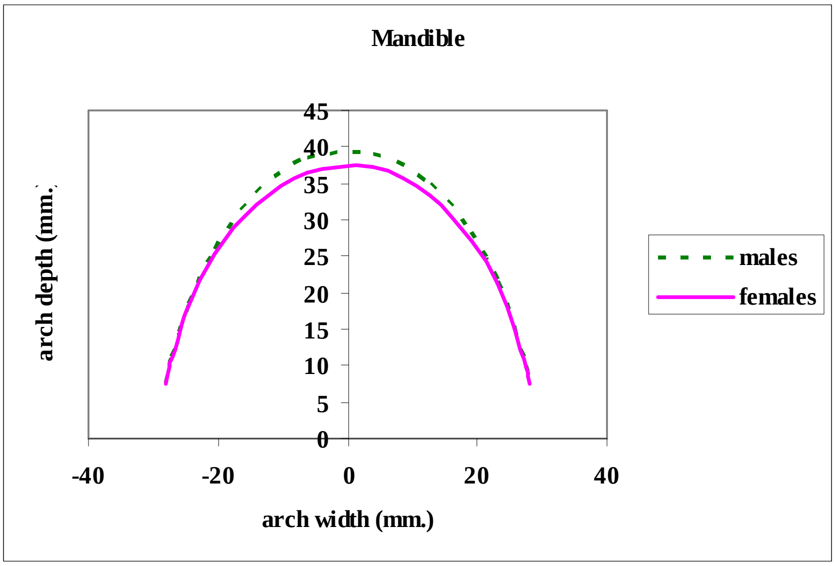


Figure 32: The superimposition of pretreatment mandibular arch form that were compared between males (green point) and females (pink line).

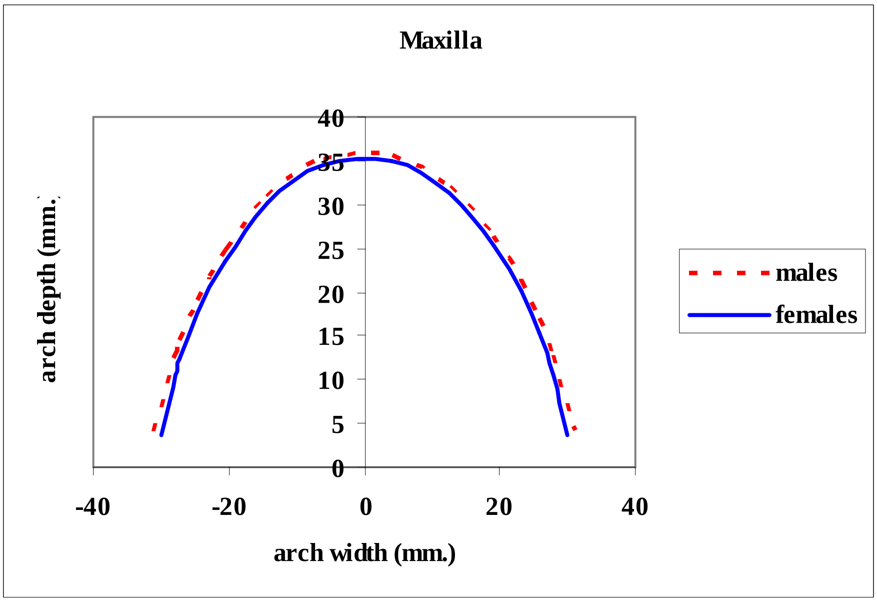


Figure 33: The superimposition of posttreatment maxillary arch form that were compared between males (red point) and females (blue line).

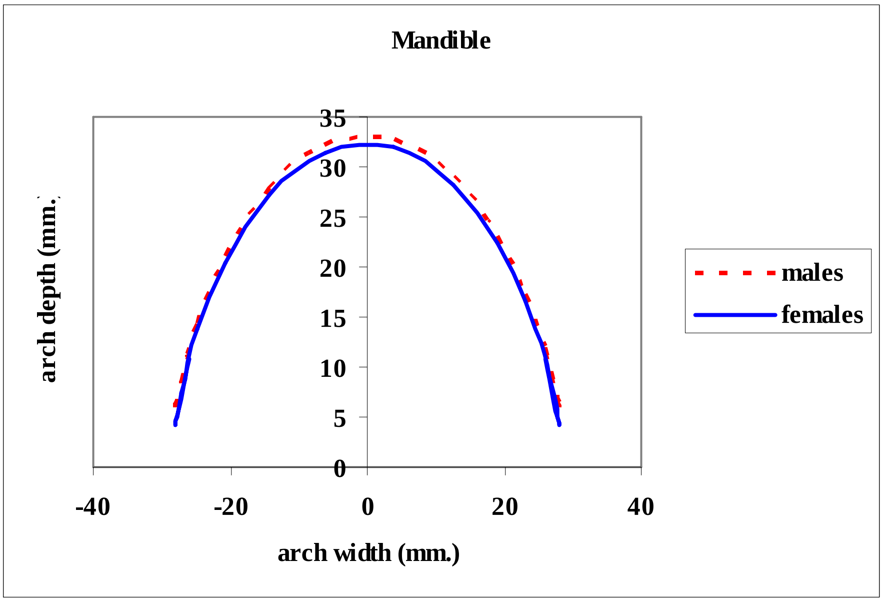


Figure 34: The superimposition of posttreatment mandibular arch form that were compared between males (red point) and females (blue line).

At the posttreatment stage (T_1), the current findings indicated that the direction of the posttreatment trends were similar in male and female subjects in the various dental parameters evaluated. There were no significant differences in any of the absolute posttreatment dental arch parameters such as arch depth (a-parameter), arch widths (c-parameter, intercanine width, and intermolar width), and arch taperedness (d-parameter).

A possible explanation for this result is that in Angle's classification II, Division 1 malocclusions patients, the maxillary arches are tapered shapes, flared incisors, and the mandibular arches are tapered and constricted intercanine widths that are often changed during orthodontic treatment. The reader should be aware that the results of this study are based on a sample of patients treated with extraction of premolars. Space closure rather than expansion may have been the major cause of the change in arch form during treatment. While after successful completion of treatment, the maxillary and mandibular arch form is usually expanded and this expansion is generally accompanied by a decrease in arch depth to accommodate each other during the antero-posterior correction of the dental relationship. Because the occlusion was changed from large overjet to normal overjet, it is possible to become no statistically significant difference of the posttreatment arch forms between sex dimorphism.

Knott[2] found that in normal populations, males have larger dental arch dimension than females in absolute size of the different linear parameters. Similar differences[87] were observed between the two genders in the absolute and incremental changes in normal persons with various facial types. These differences in the cephalometric skeletal and dental parameters were observed in both the longitudinal as well as the cross-sectional comparisons. The study also found that for some parameters, the changes were different between male and female subjects. There is sufficient evidence to indicate that male and female subjects differ in absolute size, incremental changes, and timing of growth, but there is a scarcity of information regarding whether male and female subjects respond similarly to the orthodontic forces. As important it needs to be determined whether they express similar trends in their posttreatment dental arch parameters. When differences are observed, they can be a result of variations in the original size of the parameters, the severity of the original malocclusion, or gender related. In the latter case, the clinician might have to develop treatment and retention protocols that take into consideration such a variation. Therefore clinicians should design the treatment plan in both male and female subjects, on the basis of the characteristics as well as the severity of the original malocclusion rather than on any gender differences.

It is surprising that the findings of pretreatment dental arch form in Angle’s classification II, Division 1 malocclusions in this study was essentially the same as from Kmolvisit’s study even though the samples were differed. This findings may imply that can be used the beta function curves from this study as a template to construct preformed arch wire for the treatment of patients with Angle’s classification II, Division 1 malocclusions in Thais.

The size and shape of the arches have considerable implications in orthodontic diagnosis and treatment planning, affecting the space available, dental esthetics, and stability of the dentition. Investigators have studied the growth of arch widths in persons with normal occlusion, arch widths in adults with normal occlusion, and compared these values with those of different malocclusion samples[6]. However, there is considerable controversy among the results presented in the literature.

Staley et al.[86] compared arch widths of 36 normal occlusion occlusion subjects (19 males and 17 females) with 39 Class II, Division 1 subjects (20 males and 19 females), and they stated that the maxillary dental arch as a whole is narrower in adults with Class II, Division 1 malocclusion than it is in adults with normal occlusion. When we compare the dental and alveolar arch widths of Class II, Division 1 malocclusion samples with the normal occlusion samples, statistically significant lower values were found in most of the upper arch widths in Class II, Division 1 patients. All upper alveolar width and interpremolar width measurements were greater in the normal occlusion sample. However, the intermolar dental arch width was larger in the Class II, Division 1 sample. But no differences were found in mandibular canine widths and intermolar widths.

Bishara et al.[87] compared dental arch width differences of 37 Class II, Division 1 malocclusion subjects (15 males and 22 females) with 55 Class I subjects (28 males and 27 females) at three dentition stages (deciduous, mixed, and permanent dentition), and cross-sectionally, in permanent dentition stage they reported no differences in maxillary and mandibular intercanine width measurements between the groups. Mandibular intercanine widths were significantly larger in Class II, Division 1 group than Class I group, whereas no significant differences were found between maxillary intercanine width measurements of two groups. This finding may be the cause or result of the excessive overjet in Class II, Division 1 patients. As an expected result, intercanine widths difference was significantly greater in Class I group than Class II, Division 1 group. Intermolar widths were the most commonly evaluated measurement in previous studies that found no difference in molar widths between normal and Class II subjects. While evaluating alveolar widths, they reported that maxillary alveolar widths and mandibular alveolar widths of the males were larger in the Class I group. Again, alveolar width differences were found to be greater in the Class I group. They suggested that palatal movement of maxillary posterior teeth in Class II patients was needed to compensate for the increased overjet and to have good posterior interdigitation.

Sayin and Turkkahraman[88] compared the arch and alveolar widths of 30 subjects with Class II, Division 1 malocclusion and 30 subjects with Class I ideal occlusion in the permanent dentition. Mandibular intercanine widths were significantly larger in Class II, Division 1 group than Class I group (Class I 25.64 mm., Class II 26.80 mm.), whereas no significant differences were found between maxillary intercanine width measurements of the two groups (Class I 33.87 mm., Class II 33.56 mm.). Maxillary intermolar widths were significantly larger in Class I group than Class II, Division 1 group (Class I 40.34 mm., Class II 39.46 mm.), however, mandibular intermolar widths I and II did not differ significantly between groups (Class I 43.87 mm., Class II 43.70 mm.). They suggested that the narrow widths of the dental arch in Class II, Division 1 patients appeared to be caused by palatally tipped teeth and also by narrower bony bases of the dental arch.

Uysal[89] claimed that most of previous studies presented a limited sample size resulting in questionable validity. The large sample size in this study might have increased its power. This study compared the transverse dimensions of the dental arches and alveolar arches in the canine, premolar, and molar regions of Class II, Division 1 and Class II, Division 2 malocclusion groups with untreated normal occlusion subjects. This study was performed using measurements on dental casts of 150 normal occlusion, 106 Class II, Division 1, and 108 Class II, Division 2 malocclusion subjects. Width measurements described in this article will help clinicians diagnose and plan the treatment of patients with Class II, Division 1 and Class II, Division 2 malocclusions. These findings indicate that the maxillary interpremolar width, maxillary canine, premolar and molar alveolar widths, and mandibular premolar, molar alveolar widths and intermolar widths were significantly narrower in subjects with Class II, Division 1 malocclusion than in the normal occlusion sample. Therefore, they concluded that in subjects with Class II, Division 1 malocclusions tend to have the maxillary molar teeth incline to the buccal to compensate the insufficient alveolar base.

As a result from the comparison of Class I from Chantarasmee’s unpublished study and Class II, Division 1 from this study, comparing Class II maxillary arches to Class I arches. At the pretreatment stage (T_0), there were no statistically significant different in any of parameters between the two Angle classifications. But when compared in the mandible, there was an average generalized reduced arch width of

1.81 mm. is evident, and an average decreased arch taperedness of 0.12 mm. is observed. Perhaps this can be explained by the fact that some Class II relationships are resulted from a small mandibular body. The d-parameter of Class II is more lesser than that of Class I, which means that mandibular arch form of Class I is more tapered than that of Class II. Clinicians have speculated on underlying bony morphology that is the reasons for this difference of dental arch form between Angle classifications.

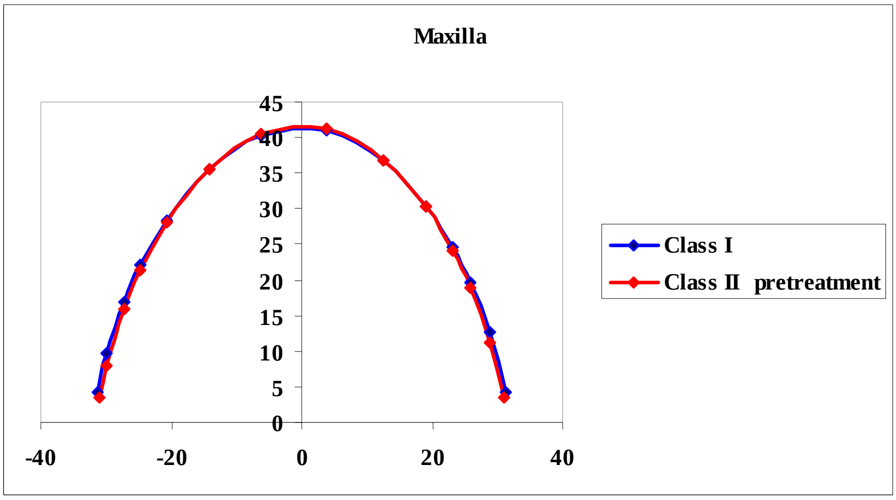


Figure 35: The superimposition of the calculating data from the beta function of Class I in maxillary arch from Chantarasmee's unpublished study (blue line) and pretreatment Class II from this study (red line).

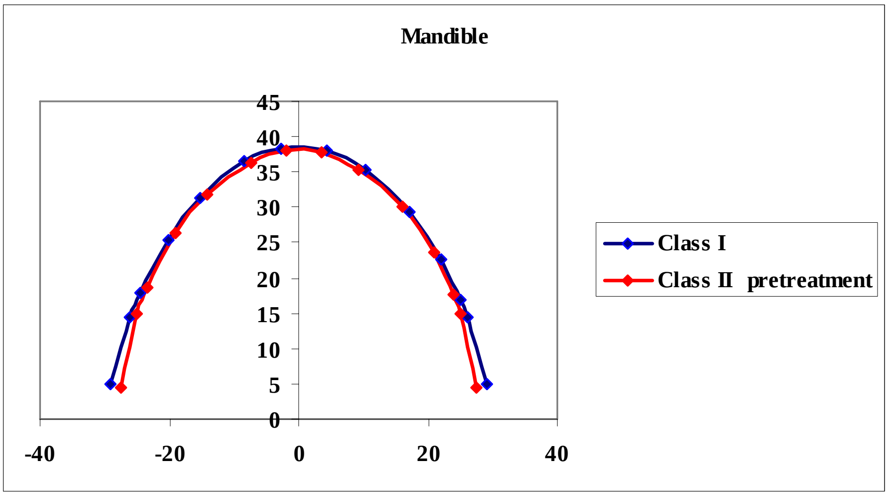


Figure 36: The superimposition of the calculating data from the beta function of Class I in mandibular arch from Chantarasmee's unpublished study (blue line) and pretreatment Class II from this study (red line).

At the posttreatment stage (T_1), comparing Class II, Division 1 posttreatment dental arch from this study with Class I pretreatment dental arch from from Chantarasmee’s unpublished study. It found that Class I had statistically significant greater than Class II in all parameters except maxillary d-parameter (arch taperedness). Given that the dimensions of the two samples were nearly the same before the treatment but very different after the treatment.

Several studies have evaluated the magnitude and direction of posttreatment dental arch changes in an attempt to help the clinicians understand these changes and to improve the stability of the orthodontic correction obtained. It was also observed that the degree of posttreatment changes vary significantly between different persons. This variation reflects the complexity of the factors that interact within the dentofacial complex to achieve an equilibrium between the various structural and functional demands.

Walter[63] determined the changes in mandibular intercanine width (distance between central-labial lobe of each canine) and first molar widths (distance between mesiobuccal cusp tip) during and following treatment of 50 nonextraction cases (16 Class I, 25 Class II, Division 1, 9 Class II, Division 2) and 50 four first premolars extraction cases (36 Class I, 12 Class II, Division 1, 2 Class II, Division 2). Intercanine width would have to be increased during treatment both nonextraction and extraction cases. The mean intercanine increase was 3.2 mm. in nonextraction cases and 3.1 mm. in extraction cases. In this investigation, most extraction cases the mandibular canines are moved somewhat distally. This places them in a wider area of the arch than there original positions. For the intermolar width 72 percent of nonextraction cases showed the mean 2.4 mm. increase, 70 percent of extraction cases showed the mean 1.9 mm. decrease. So the Class I cases behave no differently from Class II, Division 1 and Class II, Division 2 cases.

Hernandez[90] analyzed 83 Class II, Division 1 cases, 58 nonextraction and 25 four first premolars extraction cases to determine lower intercanine width (distance between canine cusp tip) changes during and following treatment. A net increase in intercanine width was seen in 100 percent of the extraction cases and 50 percent of the nonextraction cases. The mean intercanine increase was 1.9 mm. in extraction cases and 1.0 mm. in nonextraction cases.

Bishara[66] investigated the stability of maxillary and mandibular intercanine width (distance between canine cusp tip) of 30 orthodontically treated cases, all requiring four first premolars extraction. Maxillary intercanine width increased from 31.68 mm. to 34.78 mm. following treatment, an increase of 9.78 percent. Mandibular intercanine width increased from 25.38 mm. to 26.15 mm. after treatment, this represent a 3.0 percent increase.

Shapiro[3] determined the changes in mandibular intercanine width (distance between canine cusp tip) and first molar widths (distance between mesiobuccal cusp tip) during and following treatment of 22 nonextraction cases (5 Class I, 14 Class II, Division 1, 3 Class II, Division 2) and 58 four first premolars extraction cases (23 Class I, 29 Class II, Division 1, 6 Class II, Division 2). This study confirm Walter's observations[63] that during treatment, intercanine width increased during treatment both nonextraction and extraction cases. For all Angle classification were acted in similarly manner. So that in Class II, Division 1, the mean intercanine increase was 0.2 mm. in nonextraction cases and 1.2 mm. in extraction cases. While the intermolar width responded differently in extraction and nonextraction cases. In the nonextraction cases, the intermolar width showed the mean 1.6 mm. increase. In contrast, intermolar width in the extraction cases showed the mean 1.3 mm. decrease during treatment.

Gardner[5] This study was to identify the arch changes that occurred during treatment. This was done by measuring the arch widths of canines (distance between canine cusp tip), premolars, and molars (distance between most convex buccal surface at buccal groove of the first molars) and an arch depth. These measurements were obtained from the mandibular models only. The material of this study consisted of the clinical records of 103 cases. Of these, 74 were treated nonextraction and 29 were treated with extraction of four first premolars. There were 62 females and 41 males. All were classified in the Angle classification with 33 Class I, 52 Class II, Division 1, 5 Class II, Division 2. In extraction cases, the intercanine width was increased significantly with treatment to 1.92 mm. but the intermolar width is decrease of 1.46

mm. which is expected. In nonextraction cases, the intercanine width was significantly increased with treatment to 1.23 mm. and the intermolar width is increase of 2.04 mm.

Uhde[91] studied the long-term stability of dental relationships after orthodontic treatment in 36 Class I (18 four first premolars extraction and 18 nonextraction cases) and 36 Class II, Division 1 sample (9 four first premolars extraction and 27 nonextraction cases). The maxillary intercanine width tended to decrease in all sample groups, with no statistically differences. Mean decreases were 1.98 mm. in Class I, 1.17 mm. in Class II, 1.84 mm. with extraction and 1.42 mm. without extraction. Greater decreases were found in the mandibular intercanine width but again no statistically differences. Mean decreases were 2.30 mm. in Class I, 2.12 mm. in Class II, 2.13 mm. with extraction and 2.26 mm. without extraction. The tendency for the maxillary intermolar width to decrease was similar in all sample groups. Mean decreases were 1.21 mm. in Class I, 1.56 mm. in Class II, 1.48 mm. with extraction and 1.33 mm. without extraction and the largest decrease was found in Class II. The mandibular intermolar width also decreased after treatment with no statistically differences. Mean decreases were 1.98 mm. in Class I, 1.25 mm. in Class II, 1.22 mm. with extraction and 1.02 mm. without extraction.

Paquette[59] compared the long-term effects of extraction and nonextraction edgewise treatments in 63 Class II, Division 1 samples (33 four first premolars extraction and 30 nonextraction cases). This study confirm Walter’s and Shapiro’s studies[3, 63] that during treatment, intercanine width increased during treatment both nonextraction and extraction cases but the changes were generally small. In nonextraction cases, the mean intercanine increase was 0.8 mm. in maxilla and 1.1 mm. in mandible. In extraction cases, the mean intercanine increase was 0.9 mm. in maxilla and 2.2 mm. in mandible. For the intermolar width, also responded differently in extraction and nonextraction cases. In the nonextraction cases, the intermolar width showed the mean increase of 2.9 mm. in maxilla and 1.8 mm. in mandible. In contrast, intermolar width in the extraction cases showed the mean decrease of 0.1 mm. in maxilla and 0.6 mm. in mandible.

de La Cruz[19] evaluated the long-term stability of orthodontically induced changes in maxilla and mandibular arch form in 45 Class I and 42 Class II, Division 1 malocclusions who received four first premolars extraction treatment. Findings demonstrated that changes in intermolar width, and intercanine width were in agreement with findings of previous studies[63, 72]. Class I cases showed the similar results as Class II, Division 1 cases. For Class I cases, the mean intercanine increase was 1.7 mm. in maxilla and 1.4 mm. in mandible. The intermolar width showed the mean decrease of 0.5 mm. in maxilla and 0.6 mm. in mandible. In Class II, Division 1 cases, the mean intercanine increase was 2.2 mm. in maxilla and 0.9 mm. in mandible. The intermolar width showed the mean decrease of 0.1 mm. in maxilla and 1.3 mm. in mandible.

Bishara[92] evaluated the treatment and posttreatment changes in the facial and dental parameters in two groups of patients with Class II, Division 1 malocclusions. In one group (n = 46), the patients were treated with a nonextraction approach, whereas in the second group (n = 45), the treatment included the extraction of four first premolars. The findings from the dental arch measurements indicate that during treatment both the nonextraction and extraction groups experienced similar trends in an increase of the intercanine widths, but significantly increased in the extraction groups. This is the result of the alignment of the crowded anterior segment. In nonextraction cases, the mean intercanine increase was 0.7 mm. in maxilla and 0.4 mm. in mandible. In extraction cases, the mean intercanine increase was 3.1 mm. in maxilla and 1.4 mm. in mandible. The posttreatment changes in the intermolar widths of nonextraction and extraction groups showed the different trends that in nonextraction cases the intermolar width showed the mean increase of 1.5 mm. in maxilla and 0.6 mm. in mandible. In contrast, intermolar width in the extraction cases showed the mean decrease of 0.5 mm. in maxilla and 1.6 mm. in mandible. The posttreatment trends in the cephalometric and dental arch changes were similar in male and female subjects, as well as in the maxilla and the mandible.

From the present study, compared the pretreatment and posttreatment changes due to extraction orthodontic treatment. There were statistically significant decrease in a-parameter (arch depth) and intermolar width both in maxillary and mandibular arches. But the remaining parameters were no statistically significant different at p-value < 0.05. According to Angle classification, Figure 37 - 44 showed superimposed arch forms for the Class I and Class II, Division 1 groups. These superimpositions clearly illustrate the differences between Angle classifications.

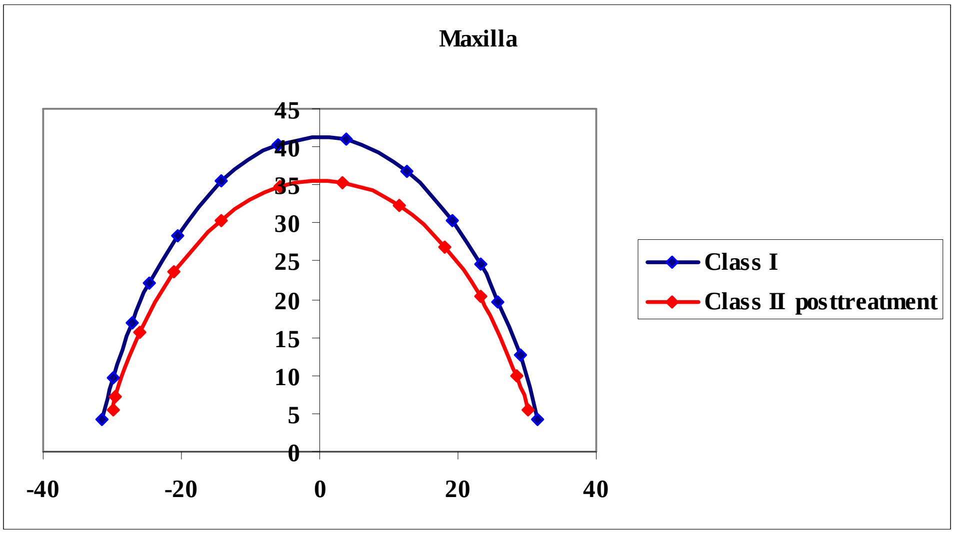


Figure 37: The superimposition of the calculating data from the beta function of Class I in maxillary arch from Chantarasmee's unpublished study (blue line) and posttreatment Class II from this study (red line).

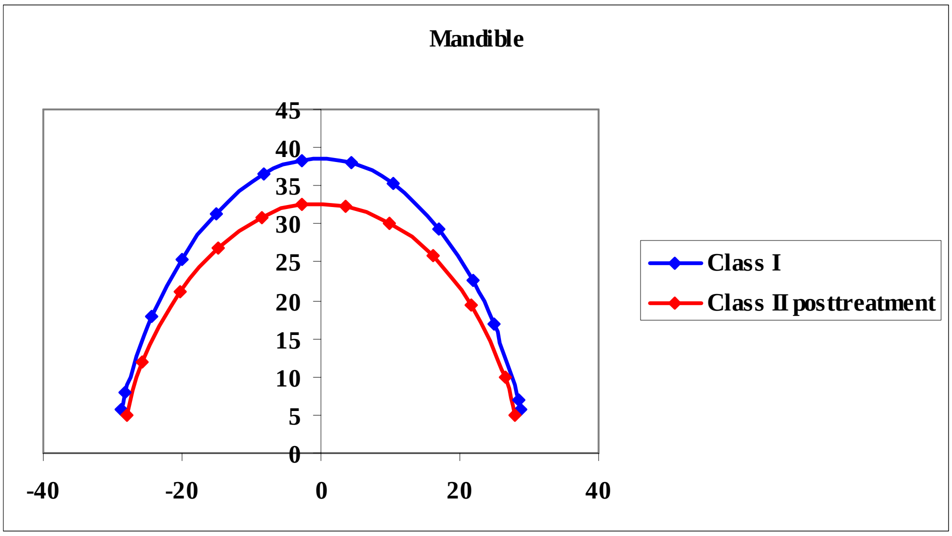


Figure 38: The superimposition of the calculating data from the beta function of Class I in mandibular arch from Chantarasmee's unpublished study (blue line) and posttreatment Class II from this study (red line).

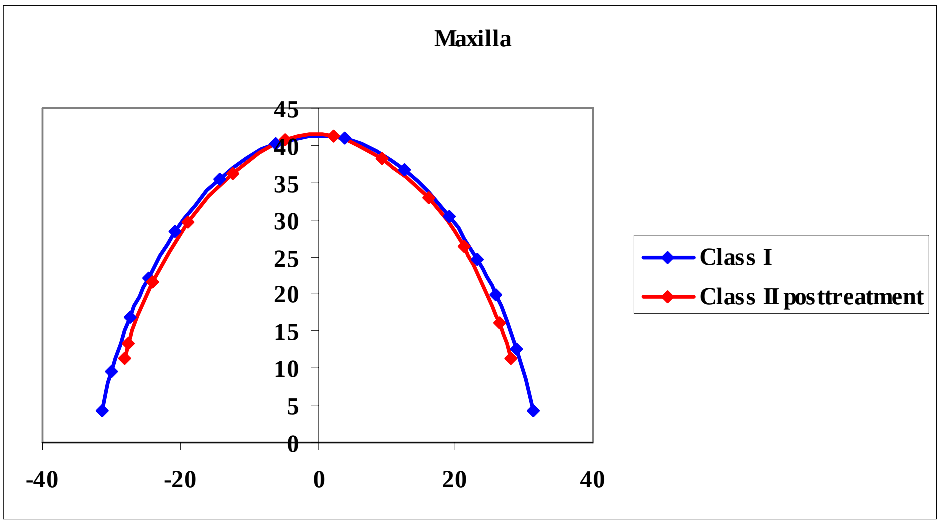


Figure 39: The superimposition of the calculating data from the beta function of Class I in maxillary arch from Chantarasmee’s unpublished study (blue line) and posttreatment Class II from this study (red line) registration at intercentral width.

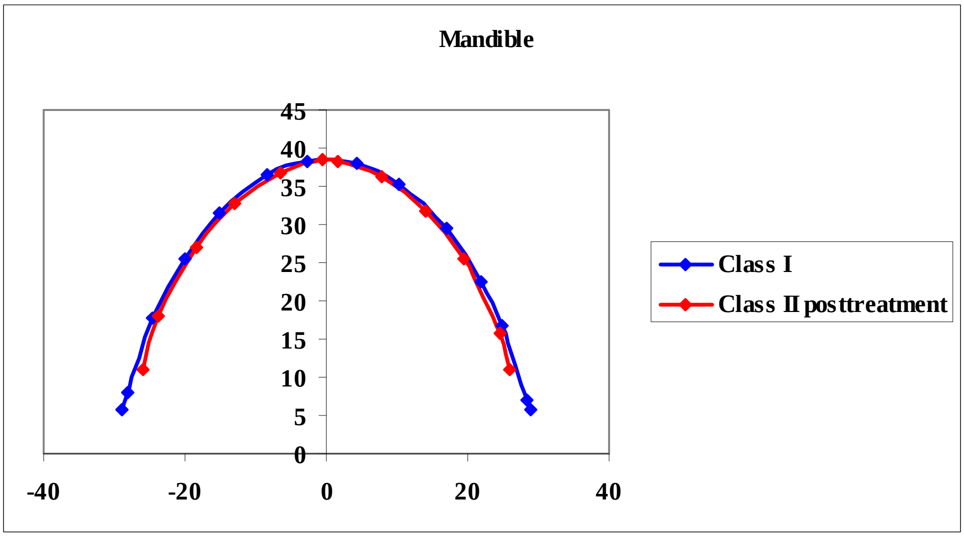


Figure 40: The superimposition of the calculating data from the beta function of Class I in mandibular arch from Chantarasmee’s unpublished study (blue line) and posttreatment Class II from this study (red line) registration at intercentral width.

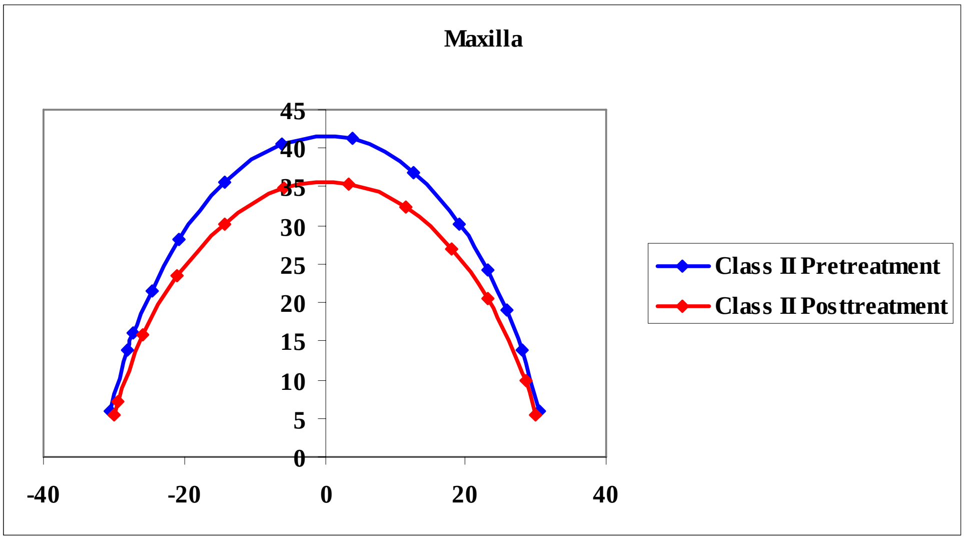


Figure 41: The superimposition of the calculating data from the beta function of pretreatment Class II in maxillary arch (blue line) and posttreatment Class II from this study (red line).

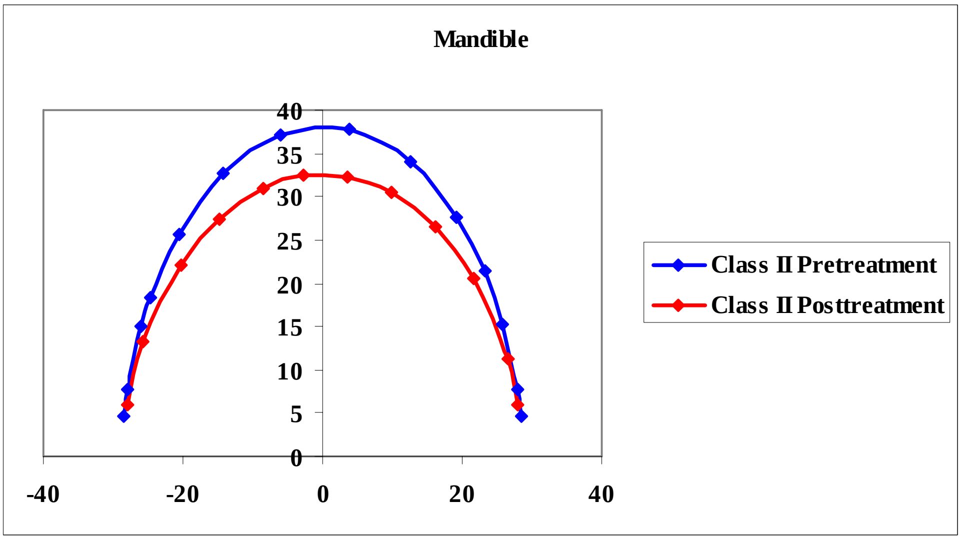


Figure 42: The superimposition of the calculating data from the beta function of pretreatment Class II in mandibular arch (blue line) and posttreatment Class II from this study (red line).

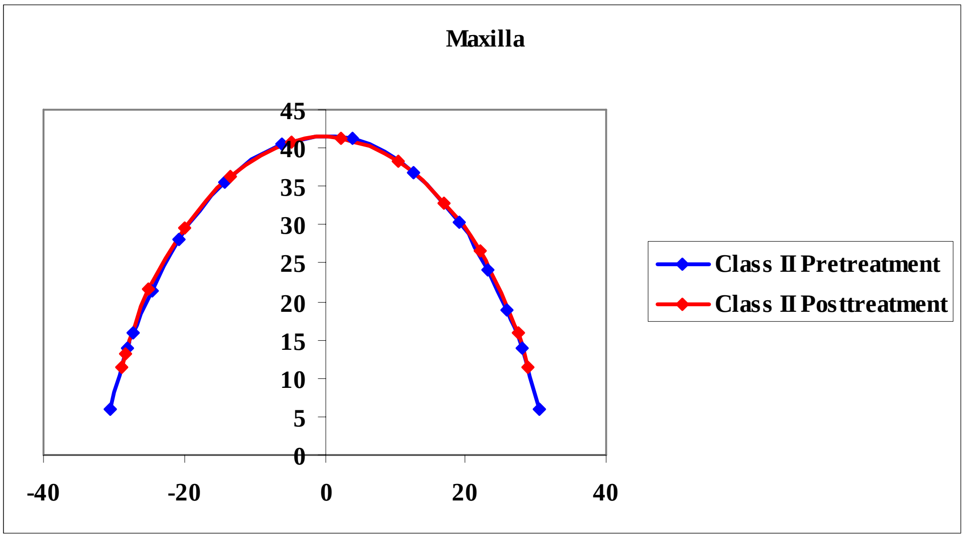


Figure 43: The superimposition of the calculating data from the beta function of pretreatment Class II in maxillary arch (blue line) and posttreatment Class II from this study (red line) registration at intercentral width.

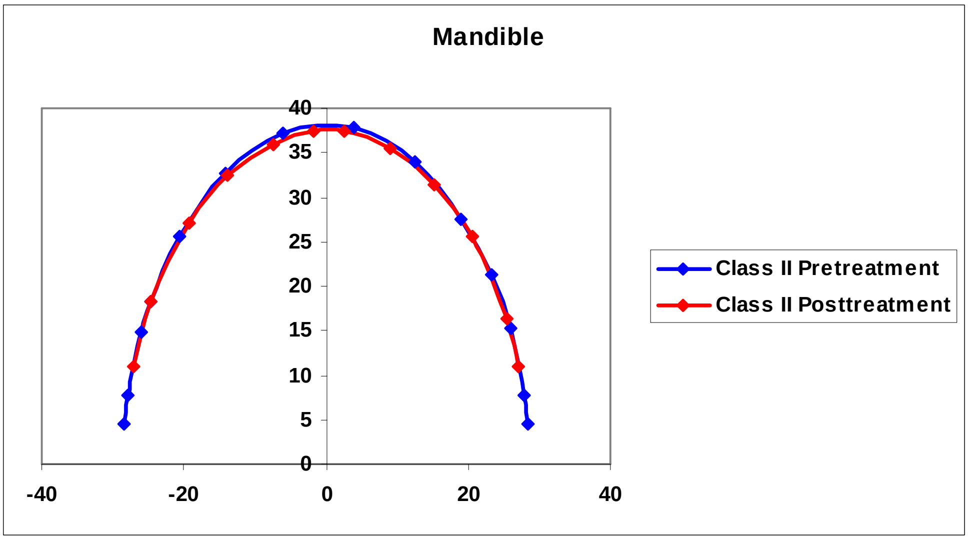


Figure 44: The superimposition of the calculating data from the beta function of pretreatment Class II in mandibular arch (blue line) and posttreatment Class II from this study (red line) registration at intercentral width.

It may argued that the current results appear to support the conclusion of previous studies[19, 59] that in the changes of intercanine width appears to remain absolutely unchanged. And the changes in intermolar width of this study support to those all of previous studies[63, 92]. Although, our interdental distances measurement can not be compared to the measurements of the published previously because other studies have measured the different dimensions. As a result, it is suggested that their maxillary and mandibular arch forms change during orthodontic treatment might be due to different treatment needs and growth change between Angle classifications[87].

The subjects in this study were not exhibited severely Class II malocclusion, so the machanics to solve this problem needed the moderate anchorage. It might be the possible explanation that intercanine widths were not statistically changed at the posttreatment.

For the comparison between pretreatment and posttreatment c-parameters (the distance between the bracket position points of the right and left second permanent molars) and the intermolar widths (the distance between the bracket position points of the right and left first permanent molars), this study revealed statistically significant changed between pretreatment and posttreatment c-parameters but the intermolar widths were not changed. It might be due to in the past decades, the second permanent molar were not bonded and not simultaneously aligned with other teeth in the arch. So that created the discrepancy between position of first and second molars at the posttreatment.

The identification of a suitable arch form for treating each malocclusion is a key aspect of achieving a stable, functional, and esthetic arch form. Failure to customize the arch form creates the probability of relapse and can lead to an unnatural smile[93].

Recent articles[21, 25, 94] have reported that a clinical bracket point seems to be of great clinical value in modern orthodontic techniques, in which preformed superelastic archwires are frequently used. Clinically, instead of one preformed archwire, it is more reasonable to have several types of preformed arch wires available and to identify the patient’s pretreatment arch form according to race and malocclusion.

With the widespread use of superelastic wires, it might be more clinically appropriate and accurate to select the most suitable arch form according to each patient’s pretreatment arch form, ethnicity, and type of malocclusion to achieve a stable, functional, and esthetic goal. Clinical bracket points corresponding to a bracket slot were used in this study, according to a method described in a recent report[25].

With the advent of nickel-titanium highly elastic preformed arch wires, the clinician often fails to recognize a particular patient's uniqueness of arch form and size, because of the great and confusing variability in arch form classification encountered in clinical practice[94]. The present study followed OrthoForm methodology by classifying maxillary and mandibular arches into square, ovoid, and tapered arch forms to determine the frequency distribution of the 3 arch forms for each Angle classification group according to the previous studies[9].

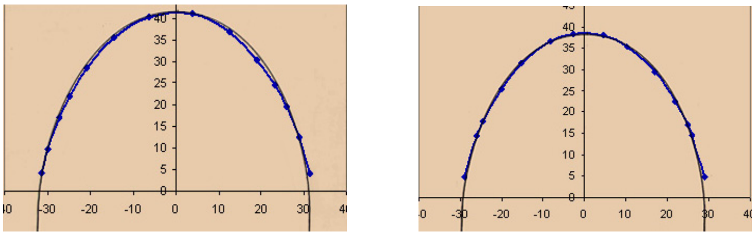
The form of the arch wire is designed to move teeth into an optimal arch form. the arch wire is engaged into channels of the orthodontic attachments located on the most facial crown points to move the teeth. The assumption supporting this paradigm is that the form of the arch wire represents an optimal dental arch form. There is, however, no consensus on the optimal dental arch form to be achieved as the result of treatment. In orthodontic practice, therefore, a fundamental question is how clinicians select the appropriate form from arch wire. Though each patient should be given individualized normal dental arch forms at the end of treatment, it would be reasonable to group arch wire from individuals dental arch forms into a few sets of patterns according to their geometric similarities classified dental arch forms from individuals with various types of occlusions and arch wire with a specific arch form is chosen. And then can be predict the dental arch form that should be achieved at the end of orthodontic treatment.

Recently, the idea of individualizing arch forms has become more popular. With the continuing development of computer-assisted analysis, this approach of custom designing arch forms may provide the optimum solution for accurately describing the ideal arch form for each case.

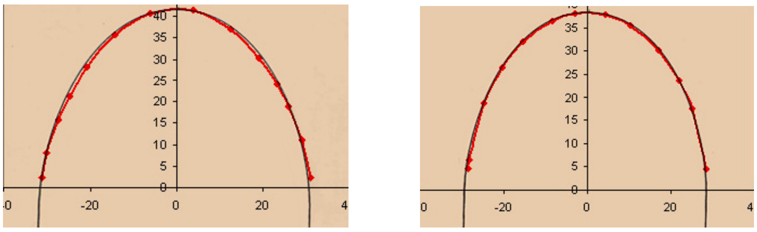
Nojima[52] clarified morphological differences between Caucasian and Japanese mandibular clinical arch forms in Class I, II, and III malocclusions. The study included 60 Class I, 50 Class II, and 50 Class III cases from each ethnic group. The dental arches from clinical bracket positions were classified into square, ovoid, and tapered forms to determine and compare the frequency distributions between the 2 ethnic groups. Sixty percent of the Caucasian Class II arches displayed a tapered arch form, with most of the 36% showing an ovoid arch form and 4% were squared arch form. The frequency of the ovoid arch form among the Japanese Class II arches was over 50%, with square and tapered shapes accounting for approximately 25% each.

Kook[55] evaluated morphologic differences in the mandibular arches of Korean and North American white subjects. The subjects were grouped according to arch form (tapered, ovoid, and square) to compare the frequency distribution of the 3 arch forms between the ethnic groups in each Angle classification. The sample included 160 white (60 Class I, 50 Class II, and 50 Class III) and 368 Korean (114 Class I, 119 Class II, and 135 Class III) subjects. In the Class II samples, the white incidence of 36% ovoid and 60% tapered arch forms, whereas the Korean incidence frequency of square arch forms was 40.3% but in the white group was only 4%, and the remaining was 29.4% ovoid and 30.3% tapered arch forms.

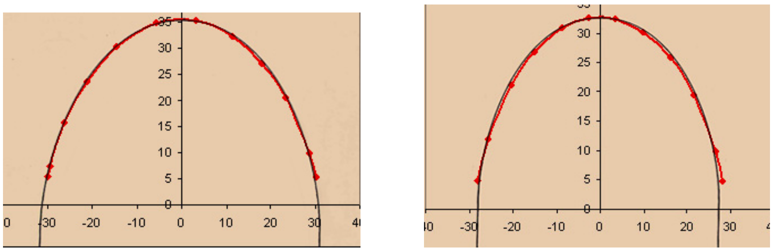
In this study, there were a general shape of arch forms that would characterize for the Angle Class I and Class II, Division 1 malocclusions in Thais and the shape were tapered. Though, the study showed statistically significant different between the arch forms of the two groups, but there was little clinically difference between the arch forms (figure 45). The results from this study was differed from previous findings, it might be suggested that the materials and methods from this study was differed from previous studies and it can not be comparable.



Class I maxilla Class I mandible



Class II pretreatment maxilla Class II pretreatment mandible



Class II posttreatment maxilla Class II posttreatment mandible

Figure 45: Determination of arch form type by superimposition of geographic arch template (OrthoForm) on computer-generated arch curves.

Finally, the mean parameters of the twenty-two treated maxillary and mandibular dental arches were compared to the three arch forms derived above and the results are shown in Figure 45. It seen that the cases fit at least one arch form to within 1.0 mm. average distance from each curve. According to superimpositions with the morphologic arch system, maxillary arch forms were tapered at the pretreatment stage. During orthodontic treatment, maxillary arch form were not show much change. The mandibular arch forms were tapered at the pretreatment stage. During orthodontic treatment, pretreatment tapered mandibular arch form remained tapered.

Considerable individual variation in arch form occurring with normal growth. In addition, it is also important to consider that changes, although statistically significant, would be imperceptibly small on examination, and such a change is only detectable on measurement, not visual comparison.

The changes in the dental arch dimensions that occur as a result of growth and treatment are of interest to the orthodontist and require careful consideration during treatment planning. A greater understanding of these changes could influence the patient's expectations from treatment as well as the formulation of the treatment and retention plans by the clinician. Many studies of untreated subjects reveal little change in arch width after the age of 13 years.

Moorrees and his colleagues[95] found that in the maxilla there is little further increase in arch width in girls after the age of 12 years, but in boys the maxillary intercanine width may continue to increase until the age of 17 years.

Sillman[96] noted that arch width remains fairly stable from 13 through 20 years of age. The study looked at 65 normal white children from birth to over 25 years of age, including those with malocclusions, and found a progressive increase in arch width especially in males. Sinclair et al.[4] have confirmed that the increase in molar width after the age of 12 is statistically different in males and females, without an increase in arch length or perimeter. Arch width continues to increase to a lesser extent in the third and fourth decades, but this is associated with arch length shortening[97]. It seems therefore that:

- Male arches grow wider than female arches.
- The lower intercanine width increases significantly in the changeover dentition but does not increase in the permanent dentition after 12 years of age.
- The upper and lower intermolar widths increase spontaneously to a considerable extent between ages of 7 and 17 especially in males.
- Little change in arch width occurs in the premolar region after the age of 12.
- Changes in arch width may not be accompanied by changes in arch depth; there is a tendency toward a decrease in arch depth in the third and fourth decades.

Researchers who studied growth changes in the arch widths of subjects in the Iowa Facial growth study found that intermolar and intercanine widths did not change after age 13 in females and age 16 in males[2, 98].Other researcher who studied growth of dental arch reported similar findings[96].

DeKock[98] investigated the changes in dental arch depth (median distance computed from the formula) and width (maximum transverse diameter at the first molars) for the persons of each sex with good occlusion in 46 male, 10 female North American Caucasians subjects. The study discussed for interval 12 to 15, 12 to 26, 25 to 26, and 17 to 26 years of age. The findings found that means for both maxillary and mandibular arch depth decrease with age throughout the period studied in each sex, with the rate of change being less after the age of 15 years. The mean decrease in mandibular arch depth from 12 to 26 years of age was 3.2 mm.(10 percent decrease) for male subjects, and 2.6 mm. (9 percent decrease) for female subjects. The arch width did not change statistically significant from 12 years to 26 years of age. For male subjects, there was small statistically significant increase in arch width from 12 to 15 years of age (0.74 mm.). Mean arch width in each arch revealed no significant change from 12 years of age to adulthood (females decrease 0.06 mm. in maxilla and increase 0.31 mm. in mandible, males increase 1.43 mm. in maxilla and increase 0.89 mm. in mandible).

Knott[2] evaluated longitudinal study of dental arch widths at four stages of dentition to individual who had no orthodontic treatment. Twenty-one males and fourteen females dental models were obtained for the three width of each dental arch, specific for sex at four stages of dentition deciduous, mixed, early permanent, and later permanent (25.9 year). Findings on mean size include average size of the dental arch was greater for males than females; the differences in mean widths range from 0.5 to 3.0 mm. Findings from analyses of changes for individuals include change between stages in the six width of the dental arch were distributed similarly for male and female subjects. For most individuals, maximum intercanine width of both arches showed little change after stage of permanent dentition was attained and ranged from 0.00 to 0.09 mm. decrease. The maximum intermolar width of both arches also showed little change that ranged from 0.29 to 0.44 mm. decrease.

Lee[6] apparent that changes in arch width vary between males and females and that more growth in width occurs in the upper than the lower arch; this growth occurs mainly between the ages of 7 and 12 years of age and is approximately 2 mm in the lower arch and 3 mm in the upper. After the age of 12, growth in arch width is seen only in males.

Henrikson[7] observed of longitudinal changes in dental arch dimensions, it carried out on 30 subjects (11 males and 19 females) of Swedish origin by the used of a computer-assisted method for the description and analysis of maxillary and mandibular arch form in sample of normal occlusion, and to evaluate the long-term stability in dental arch form from the age of 13 to 31 years. Age change occurred in arch form, although with large individual variations. Arch form changes occurred both in the maxilla and in the mandible. A significant pattern only found in the mandible, a tendency change to a more rounded arch form with age was found. But no gender differences could be found with regard to arch form change with age in the maxilla or in the mandible. Linear arch dimensional changes showed that a statistically significant reduction in maxillary as well as mandibular intercanine widths and arch depths was found. The maxillary intercanine width decreased 0.4 mm., mandibular intercanine width decreased 0.7 mm. The maxillary intermolar width decreased 0.2 mm., mandibular intercanine width increased 0.4 mm. The maxillary arch depth decreased 1.8 mm., mandibular arch depth decreased 1.6 mm.

The minimum ages of the subjects measured in this study were chosen on the basis of these prior study[22]. Therefore, can be assumed that the arch widths and arch depth of the subjects in this study were fully developed.

Clinical application

According to the mean of d-parameter, the general formula which represent the maxillary arch are as follows:

Landmarks on the bracket positions (pretreatment)

$$Y = a\left(1 - \frac{4x^2}{c^2}\right)^{0.7}$$

Landmarks on the bracket positions (posttreatment)

$$Y = a\left(1 - \frac{4x^2}{c^2}\right)^{0.67}$$

The general formula which represent the mandibular arch are as follows:

Landmarks on the bracket positions (pretreatment)

$$Y = a\left(1 - \frac{4x^2}{c^2}\right)^{0.56}$$

Landmarks on the bracket positions (posttreatment)

$$Y = a\left(1 - \frac{4x^2}{c^2}\right)^{0.63}$$

The a-(arch depth) and c-(arch width) parameter are varies depending on the arch dimension of the individual. If that patient has maxillary arch depth of 42 mm. and arch width of 63 mm., the arch form of these patient can be predicted by putting the a-parameter with 42 mm. and the c-parameter with 63 mm. in the equation. In addition, the arch form can be proposed as the baseline for posttreatment dental arch forms, comparing to another Angle classification malocclusions.

The useful dynamic relationships between arch depth, arch width, and arch perimeter may yield important clinical applications by the used of mathematical equation from this study as a template to construct preformed arch wire for the treatment of Angle’s classification II, Division 1 in Thais.

Due to the differences between Class I and II arch form especially in the mandibular arch, this knowledge for selection of arch wires can be applied as follows:

- In all stages of treatment, their could be selected the similar preformed arch wire type in Class I and Class II, Division 1 malocclusions for both maxillary and mandibular dental arch.
- Preformed arch wire currently available are suitable for many orthodontic cases. Based upon the data from this study, their suggested that Class I and Class II, Division 1 dental arch form fitted quite nicely with the OrthoForm tapered-shaped preformed arch wire.

Limitations and Suggestions

This study was designed primarily to examine the pretreatment and posttreatment dental arches form of orthodontically treated patients. The sample size of 22 was reasonably adequate, although a larger sample would have been desired in that the results would be more meaningful. An increased sample size leads to a greater probability to establishing statistical significant for the observed trends in all dental parameters measurements.

In this study, the arch size can not be categorized into small, medium, and large like in the Augvongseree's study[53] because the samples of this study are classified in Angle's classification II, Division 1 which express protrusive maxillary incisors. Therefore, a-parameter (arch depth) should be more concentrated than c-parameter (arch width). Due to the small sample sizes in each group when categorized into 3 different sizes, the further studies is needed to fit the curves of the beta function of dental arches and to examine the variability from average shapes in a population.

It should be noted that this may be a biased outcome because models exhibiting ectopically positioned dental units were excluded from the sample.

The present study were not decided to measure alveolar widths and vertical alveolar arch parameters. For the further studies, a researching in the point of stability and relapse should be included that parameters.

Finally, previous studies[52, 55] have been focused on the variation of the dental arches form among the different types of Angle’s classification. Hence additional studies to compare arch form between Angle’s classification malocclusion in Thais would be desirable to provide better understanding of the Thai dental arch forms and will be the evidence base for a treatment plan.

CHAPTER 6

CONCLUSIONS

The samples is comprised of twenty-two sets of dental models (8 males and 14 females), which were treated for Angle's classification II division 1. The results have been concluded that:

1. From the current study, the beta function accurately described Thai dental arch forms with the high coefficient of determination, reveal an average correlation coefficient of 0.97 in the maxillary arch (pretreatment and posttreatment) and mandibular arch (posttreatment), and average 0.96 in the mandibular arch (pretreatment) with a standard deviation of 0.02.

The general formula are generated as follows:

The maxillary arch

Landmarks on the bracket positions (pretreatment)

$$Y = a\left(1 - \frac{4x^2}{c^2}\right)^{0.7}$$

Landmarks on the bracket positions (posttreatment)

$$Y = a\left(1 - \frac{4x^2}{c^2}\right)^{0.67}$$

The mandibular arch

Landmarks on the bracket positions (pretreatment)

$$Y = a\left(1 - \frac{4x^2}{c^2}\right)^{0.56}$$

Landmarks on the bracket positions (posttreatment)

$$Y = a\left(1 - \frac{4x^2}{c^2}\right)^{0.63}$$

The equations represent the maxillary and mandibular arches based on the difference in arch width and arch depth, as follows:

The maxillary arch

Landmarks on the bracket positions (pretreatment)

$$Y = 41.72\left(1 - \frac{4x^2}{62.95^2}\right)^{0.7}$$

Landmarks on the bracket positions (posttreatment)

$$Y = 35.60\left(1 - \frac{4x^2}{61.89^2}\right)^{0.67}$$

The mandibular arch

Landmarks on the bracket positions (pretreatment)

$$Y = 38.21\left(1 - \frac{4x^2}{57.66^2}\right)^{0.56}$$

Landmarks on the bracket positions (posttreatment)

$$Y = 32.66\left(1 - \frac{4x^2}{57.44^2}\right)^{0.63}$$

2. The d-parameter of beta function is a description of the form of dental arch. The higher the values of d-parameter, the more taperness the arch form, and the less the values of d-parameter, the more squared the arch form.

3. Class II pretreatment arch form in this study was essentially the same as from Kmolvisit’s study even though the samples were differed. This findings may imply that can be used the beta function curves from this study as a template to construct preformed arch wire for the treatment of patients with Angle’s classification II, Division 1 malocclusions in Thais.

4. There were no statistically significant different in any of maxillary parameters between the Angle's classification I and pretreatment Class II.

But in the mandible, pretreatment Class II has average reduced arch width of 1.81 mm. is evident, and average decreased arch taperedness of 0.12 mm.

5. Class I had statistically significant greater than posttreatment Class II in all parameters except maxillary d-parameter (arch taperedness)

6. When compared pretreatment and posttreatment Class II: there were statistically significant decrease in a-parameter (arch depth) and intermolar width both in maxillary and mandibular arches. But the remaining parameters were no statistically significant different at p-value < 0.05.

7. When compared between sexual dimorphism: There were fewer significant differences in the pretreatment and posttreatment dental arch parameter. The males showing larger size than the females but only in pretreatment maxillary arch depth (a-parameter) maxillary and mandibular intermolar width.

It revealed that gender seemed to have little influences on arch form differences.

8. For the arch wires selection, Class I and Class II, Division 1 dental arch form fitted quite nicely with the OrthoForm tapered-shaped preformed arch wire.

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