INTERMAXILLARY TOOTH SIZE DISCREPANCIES AMONG CLASS I, II, III OCCLUSION IN A GROUP OF THAI

ARUNEE TIPTAWONNUGUL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE (ORTHODONTICS)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2004

ISBN 974-04-4799-6

Thesis

Entitled

INTERMAXILLARY TOOTH SIZE DISCREPANCIES AMONG CLASS I, II, III OCCLUSION IN A GROUP OF THAI

A. Tiptawonnugul

Ms.Arunee Tiptawonnugul
Candidate

Jiraporn Chaiwat

Assoc. Prof. Jiraporn Chaiwat
D.D.S., Training in Ortho. (Bergen)
Diplomate Thai Board of Orthodontics
Major advisor

P. Sawaengkit

Assoc. Prof. Pornrachanee Sawaengkit
B.Sc., D.D.S., M.S. (Orthodontics)
Diplomate Thai board of Orthodontics
Co-advisor

Assoc. Prof. Rassmidara Hoonsawat
Ph.D
Dean
Faculty of Graduate Studies

P. Sawaengkit

Assoc. Prof. Pornrachanee Sawaengkit
B.Sc., D.D.S., M.S. (Orthodontics)
Diplomate Thai Board of Orthodontics
Chair
Master of Science Program in Orthodontics
Faculty of Dentistry

Thesis

Entitled

INTERMAXILLARY TOOTH SIZE DISCREPANCIES AMONG CLASS I, II, III OCCLUSION IN A GROUP OF THAI

was submitted to the Faculty of Graduate Studies, Mahidol University

for the degree of Master of Science (Orthodontics)

on

May 11, 2004

A. Tiptawonnugul

Ms.Arunee Tiptawonnugul
Candidate

Jiraporn Chaiwat

Assoc. Prof. Jiraporn Chaiwat
D.D.S., Training in Ortho. (Bergen)
Diplomate Thai Board of Orthodontics
Chair

Sunsanee Anansakulwat

Mrs.Sunsanee Anansakulwat
B.Sc.,D.D.S., M.S.(Orthodontics)
Diplomate Thai board of Orthodontics
Member

P. Sawaengkit

Assoc. Prof. Pornrachanee Sawaengkit
B.Sc., D.D.S., M.S.(Orthodontics)
Diplomate Thai Board of Orthodontics
Member

Rassmidara Hoonsawat

Assoc. Prof. Rassmidara Hoonsawat
Ph.D.
Dean
Faculty of Graduate Studies
Mahidol University

Jurai Nakaparksin

Assoc.Prof. Jurai Nakaparksin
D.D.S., M.S.
Dean
Faculty of Dentistry
Mahidol University

ACKNOWLEDGEMENT

I would like to express my deep appreciation and gratitude to my advisory committee: Associate Professor Jiraporn Chaiwat and Associate Professor Pornrachanee Sawaengkit for their guidances, supervision, encouragement, comments, suggestions, understanding and patience.

My special thanks to Associate Professor Jiraporn Chaiwat for providing me the study models used in this study and Associate Professor Sumalee Singhaniyom and Assistant Professor Sumol Yuthasanprasit for the helpful on statistical analyses.

Thanks to my colleagues in Orthodontics for all their assistances. I have learned much from them and hope to repay in kind.

Finally, a very special thank to my parents and family who provide me the time and supports needed to complete my study.

Arunee Tiptawonnugul

INTERMAXILLARY TOOTH SIZE DISCREPANCIES AMONG CLASS I, II, III OCCLUSION IN A GROUP OF THAI .

ARUNEE TIPTAWONNUGUL 4536421 DTOD/M

M.Sc. (ORTHODONTICS)

THESIS ADVISORS : JIRAPORN CHAIWAT, THAI BOARD OF ORTHODONTICS, PORNRACHANEE SAWAENGKIT, THAI BOARD OF ORTHODONTICS

ABSTRACT

The purpose of this study was to determine whether there was a prevalent tendency for intermaxillary tooth size discrepancies among different malocclusion groups and genders in a group of Thai people. The samples consisted of 360 pretreatment orthodontic models with Class I, Class II and Class III malocclusions. Tooth size measurements were performed on these models by electronic digital calipers to an accuracy of 0.01 mm. Tooth size ratios were analyzed as described by Bolton. The incidence of mesio-distal tooth size discrepancies in the malocclusion groups was analyzed and compared between males and females. The ratios from this study were compared with the ratios from various studies, principally, Bolton's study.

The results of the study showed no significant sexual dimorphism for the tooth size discrepancies in each of three malocclusion groups. Further, ANOVA indicated that, no significant difference was determined in the anterior ratio but there were significant differences between Class II and both Class I, III malocclusion groups for posterior and overall ratios. When the anterior and overall ratios of the present study were compared to that of Bolton's, no significant difference was found in all malocclusion classes, except for the anterior ratio in Class III malocclusion.

This study suggests that the differences in intermaxillary tooth size discrepancy among the three malocclusion groups should be considered during orthodontic diagnosis and therapy.

KEY WORDS: INTERMAXILLARY TOOTH SIZE DISCREPANCIES / BOLTON RATIOS / TOOTH SIZE RATIOS / MALOCCLUSION

79 pp. ISBN 974-04-4799-6

ความแตกต่างของขนาดของฟันระหว่างขากรรไกรบนและขากรรไกรล่างกับลักษณะการสบฟันแบบที่ 1,2,3 ในคนไทยกลุ่มหนึ่ง(INTERMAXILLARY TOOTH SIZE DISCREPANCIES AMONG CLASS I,II,III OCCLUSION IN A GROUP OF THAI)

อรุณี ทิพย์ถาวรนุกูล 4536421 DTOD/M

วท.ม. (ทันตกรรมจัดฟัน)

คณะกรรมการควบคุมวิทยานิพนธ์ : จิราภรณ์ ชัยวัฒน์, THAI BOARD OF ORTHODONTICS, พรรัชนี แสวงกิจ, THAI BOARD OF ORTHODONTICS

บทคัดย่อ

การศึกษานี้มีจุดประสงค์เพื่อศึกษาความแตกต่างของขนาดของฟันระหว่างขากรรไกรบนและล่างในกลุ่มการสบฟันผิดปกติชนิดต่างๆและในเพศที่ต่างกันในคนไทยกลุ่มหนึ่ง กลุ่มตัวอย่างประกอบด้วยแบบจำลองฟันก่อนการรักษาทางทันตกรรมจัดฟันจำนวน 360 คู่ ซึ่งมีลักษณะการสบฟันผิดปกติแบบที่ 1,แบบที่ 2,และแบบที่ 3 การวัดขนาดฟันจากแบบจำลองฟันทำโดยใช้อิเล็คโทรนิคดิจิตอลคาลิเปอร์ซึ่งละเอียดถึง 0.01 มม.และใช้วิธีของบอลตัน(Bolton)ในการวิเคราะห์สัดส่วนขนาดของฟัน เพื่อเปรียบเทียบความแตกต่างระหว่างกลุ่มการสบฟันผิดปกติชนิดต่างๆ และระหว่างเพศชายและเพศหญิง นอกจากนี้ยังเปรียบเทียบค่าสัดส่วนจากการศึกษานี้กับค่าสัดส่วนจากการศึกษาอื่นๆ เช่น การศึกษาของบอลตัน

ผลการศึกษาไม่พบความแตกต่างอย่างมีนัยสำคัญของสัดส่วนขนาดของฟันระหว่างเพศในแต่ละกลุ่มของลักษณะการสบฟันที่ผิดปกติและจากการวิเคราะห์ความแปรปรวนไม่พบความแตกต่างอย่างมีนัยสำคัญในสัดส่วนของขนาดฟันหน้า แต่พบความแตกต่างอย่างมีนัยสำคัญในสัดส่วนของฟันหลัง และในสัดส่วนของฟันโดยรวม ระหว่างกลุ่มการสบฟันผิดปกติแบบที่ 2 กับทั้งกลุ่มการสบฟันผิดปกติแบบที่ 1 และ 3 เมื่อเปรียบเทียบค่าเฉลี่ยของการศึกษานี้กับการศึกษาของบอลตันไม่พบความแตกต่างระหว่างค่าของบอลตันกับค่าจากการศึกษานี้ในกลุ่มการสบฟันผิดปกติ ยกเว้นค่าสัดส่วนของขนาดฟันหน้าในกลุ่มการสบฟันผิดปกติแบบที่ 3 ที่แตกต่างอย่างมีนัยสำคัญจากค่าเฉลี่ยของบอลตัน การศึกษานี้เสนอแนะว่าความแตกต่างของขนาดของฟันระหว่างขากรรไกรบนและล่างระหว่างลักษณะการสบฟันที่ผิดปกติ 3 แบบควรพิจารณาในการวินิจฉัยและการรักษาทางทันตกรรมจัดฟัน

79 หน้า ISBN 974-04-4799-6

CONTENTS

LIST OF TABLES

LIST OF TABLES (CONT.)

LIST OF TABLES (CONT.)

LIST OF TABLES (CONT.)

LIST OF FIGURES

LIST OF FIGURES (CONT.)

CHAPTER 1

INTRODUCTION

One of the goals in a comprehensive orthodontic treatment is to obtain an optimal final occlusion, overbite, and overjet. There are many factors that influence the attainability of this goal, i.e. arch size, tooth size, number of tooth.

Tooth needs space for aligning in the arch. If there is lack of space for tooth alignment, undesirable effect appears, for example: tooth crowding, tooth impaction. The causes may come from large tooth, small arch or both. In the other hand, if small tooth aligns in normal or large arch, tooth spacing appears. Thus, the tooth size must be in harmony with the arch size in order to obtain well-aligned teeth on arch. In order to obtain an excellent occlusion that has the optimal overjet and overbite, the tooth size must be in harmony between the maxillary and mandibular arches so that the case is successful with the proper occlusal interdigitation or coordination of arches. If a tooth is not missing or extracted before an orthodontic treatment, the case finishes as Class I canine and molar relationship. Patients, who have intermaxillary tooth size discrepancies, require a correction such as removal e.g., interdental stripping (1,2) or addition e.g., composite build-ups, porcelain veneers of tooth structure to open or close spaces in the opposite arch. These treatments should be planed before initiation of an orthodontic treatment. Therefore, the evaluation of abnormal tooth size or location of abnormality is important for deciding the treatment planning.

There are many methods that evaluate the relative tooth masses of the maxillary and mandibular teeth and forecast the potential tooth mass discrepancies and related overjet. A common forecasting method is either diagnostic set up casts or the mathematical formula. The well-known mathematical formula is Bolton's tooth size analysis (3,4).

Bolton (3,4), in 1958, developed a method of analyzing a relationship between maxillary and mandibular teeth from the right first molar to the left first molar by

the ratio. The ratio between the two is the percentage relationship of mandibular arch length to maxillary arch length:

$$\frac{\text{Sum mandibular 6-6}}{\text{Sum maxillary 6-6}} \times 100 = \text{Overall ratio}$$

The same procedure was carried out to analyze the six anterior teeth from the right canine to the left canine:

$$\frac{\text{Sum mandibular 3-3}}{\text{Sum maxillary 3-3}} \times 100 = \text{Anterior ratio}$$

In order to seek optimal value for those ratios, he studied 55 cases with excellent occlusion, forty-four cases had been treated orthodontically (non-extraction) and eleven cases had not received any prior orthodontic treatment. He concluded that an overall ratio of 91.3 and an anterior ratio of 77.2 were necessary for proper coordination of maxillary and mandibular teeth.

Crosby and Alexander (5) suggested that the Bolton analysis was the important diagnostic tool and should be used before initiating a treatment, as well as Fields (6) who suggested the Bolton tooth size analysis is important to determine the amount and the location of a tooth size discrepancy before starting a treatment.

However, the Bolton tooth size analysis has had some limitations. The Bolton's estimates of variation were underestimated because his samples were derived from the perfect Class I occlusion. The population and the gender composition of the Bolton's samples were also not specified, which implied the potential selection bias. Therefore, the Bolton's tooth size ratios may be limited to some variables such as sexes, races and malocclusion classes. Some studies had been done to evaluate whether Bolton's tooth size ratios extend across genders, population and occlusal categories, such as the studies of Smith et al. (7), Nie and Lin (8), Alkofide and Hashim (9).

Smith et al. (7) determined whether Bolton's ratios extended across population and genders. They suggested that the relationships between the sizes of the mandibular and maxillary teeth were dependent on population and gender, and Bolton's ratios applied properly to white females; this ratio should be used with caution to white males, blacks or Hispanics who have been anthropologically related to Mongoloids.

To determine whether a different exists in intermaxillary tooth size among different malocclusion groups, Nie and Lin (8) had studied China patients, whereas Alkofide and Hashim (9) had studied Saudi patients. The results of both studies showed a significant difference in mean values of some ratios among different malocclusion groups.

In Thailand, however, there had been no study that determined whether a difference exists in intermaxillary tooth size among different malocclusion groups.

Thus, the present study would be undertaken in an effort to determine whether a difference does exist in the tooth size ratios among the different malocclusion classes and to determine if in fact sexual dimorphism occurs in Thai population. If the ratios are different by these variables, the exact values can help making a proper decision in the orthodontic treatment.

The Purposes of this Study are as Follows:

1. To determine whether there are significant differences in the anterior, posterior and overall tooth size ratios among Class I, II and III malocclusion groups in Thai population.

2. To determine whether there are significant differences in the anterior, posterior and overall tooth size ratios between the groups of males and females in the samples of Thai population.

3. To compare the anterior, posterior and overall tooth size ratios of Class I, Class II and Class III received from the present study to the anterior, posterior and overall tooth size ratios of normal occlusion.

4. To compare the anterior and overall tooth size ratios of Class I, Class II and Class III received from the present study to the anterior and overall tooth size ratios from the Bolton's study.

5. To compare the results of the present study to other studies on whether there are significant differences in the anterior, posterior and overall tooth size ratios among classifications in different groups of population.

The Expected Benefits of this Study

1. This investigation will elucidate whether there are significant differences in the anterior, posterior and overall tooth size ratios among 3 classifications: Class I, II and III occlusion in Thai patients. Those different tooth size ratios among any types of occlusion (if any) would be taken into account for an appropriate decision in planning for the orthodontic treatment in Thai population.

2. This study will determine whether there are significant differences in the anterior, posterior and overall tooth size ratios between the groups of males and females in the sample of Thai population. The results can be used as a guideline for diagnosis and treatment in different gender.

3. The results from this study will confirm whether the Bolton tooth size ratios would be compatible to Thai population.

4. The results from this study will be a guideline for the use of the Bolton tooth size ratio in diagnosis and treatment.

CHAPTER 2

REVIEW OF THE LITERATURES

Methods of Recording Mesiodistal Tooth dimension

There were many available methods that were used for recording the mesiodistal tooth size in many studies.

Nance (10), Neff (11), Hixon and Oldfather (12), and Barrett et al. (13) used basically similar techniques in recording the mesiodistal tooth dimension. The majority of these investigators used plaster models poured from alginate impressions of upper and lower arches.

Hunter and Priest (14) reported that cast measurements were slightly larger than direct measurements made in the mouth. But measurements made from dental casts were more consistent and more accurate than direct measurements taken from the mouth, particularly in the posterior segments where measuring becomes unwieldy.

Methods of Measuring Mesiodistal Tooth dimension

In the past, the mechanics of measuring tooth size has been carried out with either of two basic instruments: the sliding calipers with a vernier scale and a pair of engineer dividers used in conjunction with a millimeter ruler. With the latter, holes were punched on a card and the distances were then measured with the millimeter ruler. Hunter and Priest (14) found the sliding calipers to be more accurate, while the dividers gave a consistently higher mean reading.

Electronic digimatic calipers were developed for convenient usage. Electronic digimatic calipers were combined between the sliding calipers and microcomputer. The microcomputer would show the length of the vernier scale as digital data. Proffit (2) stated that an advantage of digitizing tooth dimensions in conjunction with the computer was that the computer could quickly provide tooth size values

Moorrees and Reed (15) pioneered the effort to standardize the location of measurement on the models. The measuring the greatest mesiodistal diameter at the

contact point parallel to the occlusal surface of the teeth and also parallel to the vestibular surface of the model.

Differences of Tooth Size in the Different Genders or Population

The size of the teeth is dependent upon race and sex. Lavelle (16) measured the mesiodistal tooth sizes in a total of 120 sets of casts from Caucasoids, Mongoloids, and Negroids in males and females samples. Lavelle showed that there was sexual dimorphism in tooth dimensions, in those males had somewhat larger teeth than females. Furthermore, the average mesiodistal crown diameter appeared larger in Negroids than in Caucasiods, with that for Mongoloids being intermediate.

Santoro et al. (17) studied mesiodistal crown dimensions of Dominican Americans and compared mesiodistal crown dimensions of Dominican Americans to those of African Americans. Their results showed that the Dominican American samples presented maxillary and mandibular tooth dimensions slightly smaller than those of the African American samples.

The Study of Intermaxillary Tooth Size Discrepancies

To obtain the excellent results in orthodontic treatments, there are many factors of which orthodontists should be concerning. A major factor in coordinating posterior interdigitation, overbite, and overjet in a neutroclusion is the relative harmony in mesiodistal width of the maxillary and mandibular dentitions. The importance of this geometric relationship becomes apparent to orthodontists, especially in the finishing stages of a treated case. The mesiodistal tooth size of the maxillary and mandibular arch must be related to each other in order to obtain an excellent occlusion. The tooth size discrepancies have conventionally been described as a relative excess of teeth structure in one arch in relation to the other arch (6). A significant variation in the harmony will lead to malocclusion and difficulties in obtaining an occlusion with optimal overjet, overbite and Class I canine and molar relations (18). It would seem prudent for clinicians to routinely include a tooth-size analysis in their initial case analysis. Identifying such a discrepancy before final tooth alignment would prove beneficial in both treatment planning and final expectations of both the clinician and the patient (19).

In 1945, Kesling (20) advocated a procedure as a diagnostic aid in which duplicate models were made, and the teeth cut off and reset in ideal occlusion. However, a substantial amount of time was necessary to make this setup.

Before 1949, differences in tooth size between the upper and lower arch in a ratio had not yet been expressed. Neff (11) was the first one who expressed the ratio of anterior maxillary tooth structure to anterior mandibular tooth structure on the basis of cumulative measurements of the maximum mesiodistal crown widths, and defined it as "anterior coefficient". The relationship between this ratio and the final overbite status was stressed. An ideal overlap of 20% of the lower incisor crown height was associated with a coefficient of 1.20 to 1.22. If a case had a less than ideal "anterior coefficient," a less than ideal result could be expected in the anterior segment of the finished case.

Bolton (3,4), in 1958, developed a method of analyzing mesiodistal tooth size ratio between maxillary and mandibular teeth. In his study, he concluded that it would be difficult for proper occlusal interdigitation or coordination of arches in the finishing stage of orthodontic treatment without the proper mesiodistal tooth size ratio between the maxillary and mandibular teeth.

Bolton conducted a study on the relationship of tooth size discrepancy to the occlusion. He studied 55 cases with excellent occlusion, forty-four had been treated orthodontically (non-extraction) and eleven had not received any prior orthodontic treatment. The mesiodistal width measurements of the 12 maxillary teeth (first molar to first molar) were totaled and compared with the sum derived by the same procedure carried out on the 12 mandibular teeth. The ratio between the two is the percentage relationship of mandibular arch length to maxillary arch length:

$$\frac{\text{Sum mandibular 6-6}}{\text{Sum maxillary 6-6}} \times 100 = \text{Overall ratio}$$

The same procedure was carried out to analyze the six anterior teeth (canine to canine) and the six posterior teeth:

$$\frac{\text{Sum mandibular 3-3}}{\text{Sum maxillary 3-3}} \times 100 = \text{Anterior ratio}$$

Bolton concluded that an overall ratio of 91.3 and an anterior ratio of 77.2 were necessary for proper coordination of maxillary and mandibular teeth.

Stifter (21) replicated Bolton's study on Class I occlusion and reported similar results. For the overall and anterior ratios, Stifter respectively reported a mean value of 91.04 and 77.55.

Ho and Freer (22) summarized the results of various studies about interarch tooth size relationships as shown in Table 1. They concluded that the differences between tooth width ratios in the studies might be a reflection of the underlying populations from which the samples were selected. Bolton (3,4) used excellent occlusions. Tonn (23) used cases with anatomically correct occlusion. Stifter (21) selected normal Angle's Class I adult dentitions, which were separated into 'ideals' and 'normals'. Lundstrom (24,25) selected cases at random from a school population. While Neff (11), Crosby and Alexander (5), and Ho and Freer (22) used cases with malocclusions.

Table 1 Comparison of the anterior, posterior and overall ratios from various studies

Ratio	Study	n	mean	SD	SE	range	CV
MD 3-3	Lundstrom (1954)	264	78.5	2.07	0.13	73.0-84.5	2.64
MX 3-3	Neff. (1957)	300	79.0	-	-	73.5-84.7	
	Bolton (1958)	55	77.2	1.65	0.22	74.5-80.4	2.14
	Stifter ideals	22	77.6	2.72	0.58	72.5-81.7	3.51
	(1958) normals	34	78.6	2.37	0.41	73.9-83.3	3.02
	Crosby and	109	77.5	3.40	0.33	65.3-90.5	4.39
	Alexander (1989)						
	Ho and Freer	60	78.7	2.10	0.27	74.8-84.1	2.67
	(1994)						
MD 654	Lundstrom (1954)	68	104.9	3.08	0.37	99.5-113.0	2.94
MX 654	Ho and Freer	60	104.6	2.86	0.37	97.6-112.0	2.73
	(1994)						
MD 6-6	Tonn (1937)	50	93.0	1.80	0.25		1.94
MX 6-6	Lundstrom (1954)	63	92.3	2.07	0.26	88.0-97.5	2.24
	Bolton (1958)	55	91.3	1.91	0.26	87.5-94.8	2.09
	Stifter ideals	23	90.9	2.08	0.43	87.2-94.2	2.29
	(1958) normals	34	91.1	1.79	0.31	87.9-94.6	1.96
	Crosby and	109	91.4	2.40	0.23	86.6-99.8	2.63
	Alexander (1989)						
	Ho and Freer	60	92.0	1.58	0.20	88.0-95.6	1.72
	(1994)						

Source: Ho and Freer, 1994 (22)

MD – Sum mandibular

MX – Sum maxillary

Differences of Tooth Size Ratios in the Different Malocclusion Classes

In Bolton's study (3,4), the difference of tooth size ratios in the different malocclusion classes had not been studied resulting in that his tooth size analysis might have some limitations. Firstly, his estimates of variation were underestimated because his samples were derived from the perfect Class I occlusion. Secondly, the population and gender composition of his sample were not specified, which implied a potential selection bias. That leaded to a question -- whether Bolton's ratios extend across classes of occlusion, gender and populations.

Some studies gave interest in classes of occlusion differences in interarch tooth size relationships, such as:

Lavelle (16) compared the maxillary and mandibular tooth dimensions between the various occlusal categories. The over-all tooth dimensions were Class I > Class II, Division 1 > Class II, Division 2 >Class III for the maxillary dentition. In contrast, the relationship for the mandibular teeth was Class III > Class I > Class II, Division 1 > Class II, Division 2.

Sperry et al. (18) analyzed the Bolton ratios in the groups of Class I, Class II and Class III cases. They investigated the frequency of excess mandibular tooth structure that affected the tooth size ratios. They found that the frequency of mandibular tooth size excess was greater in the cases of Angle's class III than in the cases of Angle's Class I and Class II malocclusions.

Crosby and Alexander (5) analyzed the Bolton ratios in the different occlusal categories. They did not differentiate between sexes, and did not include Class III patients. The relationship of malocclusion to skeletal pattern was not mentioned. They did not find a statistically significant difference in the prevalence of tooth size discrepancies among the different malocclusion groups.

Nie and Lin (8) analyzed the Bolton ratio for the different malocclusion groups in 360 Chinese patients (120 for each Class). They used a YM-2115 Three Dimension Measuring Machine to orient each model. The results showed no significant sexual dimorphism, and no significant difference between subcategories of malocclusion. However, a significant difference was found for both anterior and overall ratios between the groups of occlusion. The results showed that the ratio in Class III malocclusion was greater than in Class I and Class II.

Alkofide and Hashim (9) determined a difference existing in intermaxillary tooth size among different malocclusion groups in Saudi patients. The study consisted of 240 pretreatment orthodontic casts (60 cases in each malocclusion class, in addition to normal occlusion). The results of the study showed no significant difference in the incidence of tooth size discrepancies for the overall ratio and anterior ratio among the different malocclusion groups, except for the anterior ratio in Class III malocclusion. Furthermore, no statistical significant difference was observed between males and females.

The results from 3 studies (i.e. Crosby and Alexander (5), Nie and Lin (8), Alkofide and Hashim (9)) were summarized in Table 2.

Table 2 Comparison of sample size, mean, and standard deviation of the anterior, posterior and overall ratios from 3 studies

Ratio	Study	classification	n	Mean	SD
MD 3-3	Crosby and	Class I	30	77.20	2.7
MX 3-3	Alexander (1989)	Class II, Division 1	30	78.20	3.1
		Class II, Division 2	29	76.80	5.3
		Class II surgery	20	77.50	2.7
	Nie and Lin (1999)	Class I	120	81.54	2.75
		Class II	120	80.79	3.15
		Class III	120	82.75	2.91
	Alkofide and	Class I	60	78.77	2.74
	Hashim (2002)	Class II	60	78.70	2.45
		Class III	60	78.50	2.53
MD 654	Nie and Lin (1999)	Class I	120	104.45	3.17
MX 654		Class II	120	102.60	3.36
		Class III	120	107.60	3.73
MD 6-6	Crosby and	Class I	30	91.3	2.4
MX 6-6	Alexander (1989)	Class II, Division 1	30	91.7	2.3
		Class II, Division 2	29	91.5	3.1
		Class II surgery	20	91.3	2.2
	Nie and Lin (1999)	Class I	120	93.39	2.46
		Class II	120	92.06	2.47
		Class III	120	95.59	2.58
	Alkofide and	Class I	60	92.24	2.04
	Hashim (2002)	Class II	60	92.80	2.20
		Class III	60	92.71	2.12

Source: Crosby and Alexander, 1989 (5)
Nie and Lin, 1999 (8)
Alkofide and Hashim, 2002 (9)

MD – Sum mandibular

MX – Sum maxillary

Differences of Tooth Size Ratios in the Different Genders or Population

Concerning gender or ethnic differences in interarch tooth size relationships, Lavelle (16) showed the degree of sexual dimorphism for the overall ratio averaged 0.98% in Caucasoids, 0.64% in Negroids, and 0.54% in Mongoliods. Similarly, the anterior ratio was greater in males than in females, averaging 0.90% for Caucasoids, 1.01% for Negroids, and 0.63% for Mongoloids. In addition, there was racial dimorphism between Negroids, Mongoloids and Caucasians. Both overall and anterior ratios were greater in Negroids than in Caucasoids, those of Mongoloids being intermediate.

However, there was no significant difference for both overall and anterior ratios in sexual dimorphism in the studies of Crosby and Alexander (5), Nie and Lin (8) and Alkofide and Hashim (9), except the value of anterior ratio for the Class III female samples in Alkofide and Hashim's study.

Richardson and Malhotra (26) found significant differences in overall ratio between blacks (94%) and whites (91%). Surprisingly, their anterior ratio was similar to Bolton's value, suggesting that blacks differ markedly in the posterior arch segment relationship.

Smith et al. (7) concluded that interarch tooth size relationships were population and gender specific. The Bolton ratios were the most appropriate to apply to white females; the tooth size ratios should not be indiscriminately applied to white males, blacks, or Hispanics. Their results in Table 3 showed significant ethnic group differences in interarch ratios. Whites displayed the lowest overall ratio (92.3%), followed by Hispanics (93.1%), and blacks (93.4%). The overall and posterior ratios were also significantly larger in males than in females.

Table 3 Population differences in overall, anterior and posterior ratios

Ratio	F-test	Significance	Population		
			White (n=60)	Black (n=60)	Hispanic (n=60)
Overall	4.53	0.012	92.3	93.4	93.1
Anterior	3.24	0.041	79.6	79.3	80.5
Posterior	9.65	<0.001	104.8	107.2	105.3

Source: Smith et al., 2000 (7)

Studies about Tooth Size in Thailand

Srisopak (27) measured the tooth size from the skull of sampled Thai population about 40 teeth without classifying the occlusion type. Bijaphala (28) measured the tooth size from the sample of Thai population. The samples were 950 extracted teeth with the proper shape. Kiatpongsan (29) measured the tooth size of the model from Thai Bangkokian with the naturally excellent occlusion. Her results of the study was compatible with Srisopak‘s study. In three studies, the Bolton tooth size analysis was not taken into consideration.

Patanaporn (30) measured tooth size of the model from Thai Bangkokian with the naturally excellent occlusion about 40 samples. He found that almost all of the tooth size was smaller than the one in Srisopak’s study, however the average values of both anterior and overall ratios were almost equal to the Bolton’s values with the anterior ratio being 76.1% and the overall ratio being 91.5%.

Boondej and Sirinavin (31) studied permanent tooth size in Northern Thai with normal occlusion. They found that many tooth sizes were statistically different between side and sex. Individual tooth size of Northern Thai was not different from another Thai group (comparing with Patanaporn’s study) . The sums of the width of 12 maxillary and 12 mandibular teeth of Northern Thai were greater than White Americans but less than Black Americans. The tooth size ratios of this study were shown in Table 4. These tooth size ratios were statistically larger than the tooth size ratios from Patanaporn’s study and the Bolton ratios.

Table 4 Sample size, means and standard deviations for the overall and the anterior ratios in both sexes

Ratio	Gender			
	Male (n=35)		Female (n=35)	
	Mean	SD	mean	SD
Anterior ratio	78.56	2.18	78.19	1.93
Overall ratio	92.38	1.37	92.06	1.51

Source: Boondej and Sirinavin, 1990 (31)

Dechkunakorn et al. (32) studied a group of Thai population (Bangkok) with normal occlusion. There was a statistically significant difference of tooth size in some teeth between males and females. There was no significantly sexual difference in the tooth size ratios (anterior ratio = 78.53% ,overall ratio =92%).

The tooth size ratios from 3 studies (i.e. Patanaporn (30), Boondej and Sirinavin (31), Dechkunakorn et al. (32)) were summarized in Table 5.

Table 5 Comparison of sample size, mean, standard deviation, range and coefficient of variation (CV) of the anterior, posterior and overall ratios from 3 studies in Thai population

Ratio	Study	n	mean	SD	Range	CV
Anterior ratio	Patanaporn (1983)	40	76.7	1.6	71.4 – 79.9	2.1
	Boondej (1990)	70	78.4	2.1	74.2 – 83.9	2.6
	Dechkunakorn (1995)	100	78.53	2.34	73.4 – 84.31	2.98
Posterior ratio	Dechkunakorn (1995)	100	104.9	2.17	100.12 – 109.38	2.07
Overall ratio	Patanaporn (1983)	40	91.5	1.2	88.7 – 93.6	1.3
	Boondej (1990)	70	92.2	1.4	88.6 – 96.0	1.6
	Dechkunakorn (1995)	100	92.0	1.68	87.33 -96.47	1.83

Source: Patanaporn, 1983 (30)
Boondej and Sirinavin, 1990 (31)
Dechkunakorn et al., 1995 (32)

There was no study or report on whether there was a prevalent tendency for intermaxillary tooth size discrepancies among different malocclusion groups in Thai population.

Hypotheses

1. There are no significant differences between the genders in the anterior, posterior and overall tooth size ratios in Thai patients.
2. There are no significant differences in the anterior, posterior and overall tooth size ratios among Class I, II, and III occlusions in Thai patients.
3. There are no significant differences in the anterior and overall tooth size ratios between Thai tooth size ratios and the Bolton's tooth size ratios.

CHAPTER 3

MATERIALS AND METHODS

Materials

Collection and Selection of the Samples

The pretreatment casts have been selected from the orthodontic clinic of the dental department, Mahidol University and the private clinics in Bangkok.

All samples are Thai and live in Thailand.

The following selection criteria are used:

1. Good quality pre-treatment models
2. All permanent teeth erupt and present from right first molar to left first molar
3. No severe mesiodistal and occlusal tooth abrasion
4. No residual crown or crown-bridge restoration
5. No tooth deformity for example conic-form lateral incisor teeth, questionable articulation, malformed teeth that can affect the mesiodistal crown width
6. Tooth size of the model that cannot be measured such as severe crowding that can affect the mesiodistal crown width are not included in the sample.

The samples consists of 360 pretreatment casts with both sexes evenly distributed in each class (Table 6).

Table 6 The sample sizes for all groups of the study

Angle classification	Males (n)	Females (n)	Total (n)
Class I	60	60	120
Class II	60	60	120
Class III	60	60	120
Total	180	180	360

Occlusion categories have been classified by the Angle's classification (Fig. 1). Definitions are (33,34,35):

Molar Angle's classification

Angle's classification is used to assess anteroposterior position of upper right first molar relative to lower right first molar. Class I is defined as that position where mesio-buccal (M-B) cusp of upper first molar fits exactly into buccal groove of lower first molar. Any deviation from Class I is measured to the nearest half cusp width. Class II tendency is defined as M-B cusp of upper first molar moving mesial relative to buccal groove of lower first molar. Class III tendency is defined as M-B cusp of upper first molar moving distal relative to buccal groove of lower first molar.

Canine Angle's classification

Angle's classification is used to assess anteroposterior position of upper right canine relative to lower right canine. Class I is defined as position where cusp of upper canine fits exactly into embrasure formed by lower canine and first premolar. If there is space distal to lower canine, Class I is defined as position where cusp tip of upper canine pointed directly at distal surface of lower canine. Any deviation from Class I is measured to the nearest half cusp width. Class II tendency is defined as cusp of upper canine moving mesial relative to embrasure formed by lower canine and first premolar. Class III tendency is defined as cusp of upper canine moving distal relative to embrasure formed by lower canine and first premolar.

Pretreatment casts have been classified by the Angle's classification. Occlusion classification has been examined again by the experienced orthodontist (Chaiwat J.). Name, sex, overbite, overjet and Angle's classification of each pretreatment cast was recorded on a recording form (Fig. 2).

A. Angle's Class I

B. Angle's Class II

C. Angle's Class III

Figure 1. Samples were classified by the Angle's classification: A. Angle's Class I, B. Angle's Class II, and C. Angle's Class III

Information data from casts

Page No…….

No	Name	Sex	OB	OJ	Criterian													
					Class I				Class II				Class III				Angle Class	Note
					Canine		Molar		Canine		Molar		Canine		Molar			
					L	R	L	R	L	R	L	R	L	R	L	R		

Figure 2. A form for recording name, sexes, overbite, overjet and Angle's classification of pretreatment cast

Methods

Measurement and Analysis of the Samples

A total of 48 mesiodistal contact points (2 points per tooth for each arch) were marked on the maxillary and mandibular models (Fig. 3).

Figure 3. Mesiodistal contact points were marked on models

The measurements were made directly on the dental casts. Electronic digital caliper (Mitutoyo Digimatic caliper. Mitutoyo Corporation, Japan) (Fig. 4) accuracy of 0.01 mm. with fine tips to improve the access interproximally was used for the measurements. All measurements were taken under natural and neon light by one examiner.

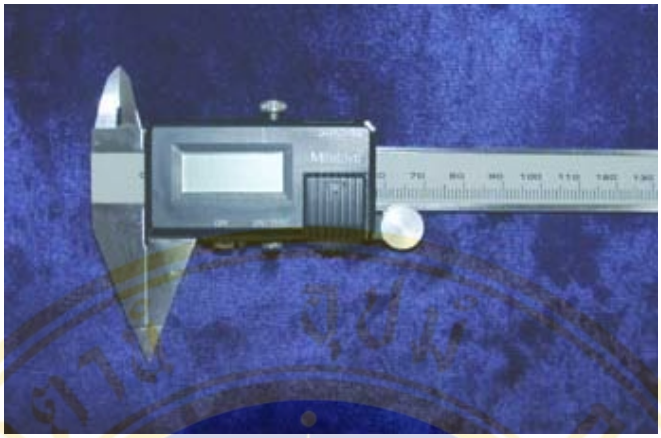

Figure 4. Mitutoyo Digimatic Callipers used for the measurement of mesiodistal tooth widths

The procedure of measuring the mesiodistal tooth width was performed as described herein. The caliper beaks inserted from the buccal (labial), and held occlusally parallel to the long axis of the tooth. The beaks were then closed until gentle contact to the contact points of the tooth has been felt (Fig. 5).

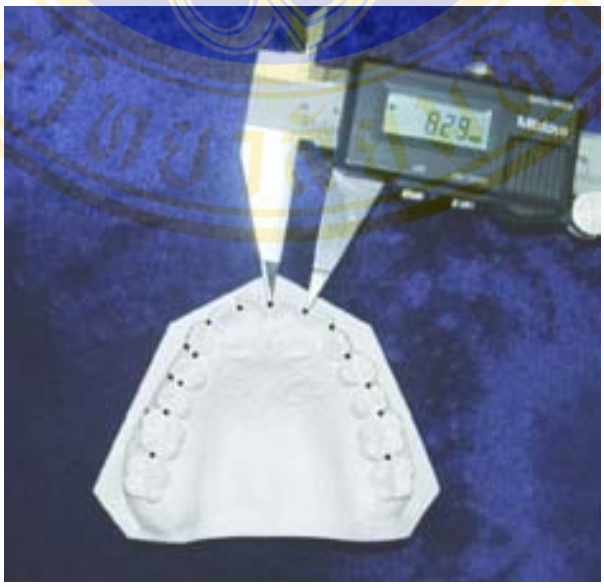

Figure 5. Tooth size measurement

The measurements included the maximum mesiodistal width of all the twelve maxillary and mandibular teeth from the right first permanent molar to the left first permanent molar. The measurements were carefully made to avoid any damages on beaks contact. The measurement values were recorded on a form of measurements (Fig. 6).

FORM OF MEASUREMENTS

Cast No….. **Class** –Norm , I , II , III **Sex** – M / F

UPPER MODEL			LOWER MODEL		
Measure No.			Measure No.		
Right first molar	#16		Right first molar	#46	
Right second premolar	#15		Right second premolar	#45	
Right first premolar	#14		Right first premolar	#44	
Right canine	#13		Right canine	#43	
Right lateral incisor	#12		Right lateral incisor	#42	
Right central incisor	#11		Right central incisor	#41	
Left central incisor	#21		Left central incisor	#31	
Left lateral incisor	#22		Left lateral incisor	#32	
Left canine	#23		Left canine	#33	
Left first premolar	#24		Left first premolar	#34	
Left second premolar	#25		Left second premolar	#35	
Left first molar	#26		Left first molar #36		
Σ 3-3			Σ3-3		
Σ 4-6			Σ 4-6		
Σ 6-6			Σ 6-6		
Anterior ratio					
Posterior ratio			Overall ratio		

Figure 6. A form for recording the measurements

Collection and Analysis of the Data

Tooth size ratios were analyzed as described by Bolton. [Use the spreadsheets – The Microsoft Excel version 97 program for the calculation]

$$\frac{\text{Sum mandibular 6-6}}{\text{Sum maxillary 6-6}} \times 100 = \text{Overall ratio}$$

$$\frac{\text{Sum mandibular 3-3}}{\text{Sum maxillary 3-3}} \times 100 = \text{Anterior ratio}$$

$$\frac{\text{Sum mandibular } P_1 + P_2 + M_1}{\text{Sum maxillary } P_1 + P_2 + M_1} \times 100 = \text{Posterior ratio}$$

The spreadsheets (36) of the Microsoft Excel version 97 program were created for calculating tooth size ratios (Fig. 7).

	A	B	C	D	E	F	G
1	Upper Arch		Lower Arch				
2	Right Central Incisor	8.8	Right Central Incisor	5.6			
3	Right Lateral Incisor	6.8	Right Lateral Incisor	5.6			
4	Right Canine	8.0	Right Canine	7.0			
5	Left Central Incisor	8.8	Left Central Incisor	5.6			
6	Left Lateral Incisor	6.8	Left Lateral Incisor	5.6			
7	Left Canine	8.0	Left Canine	7.0			
8	Total	47.2	Total	36.4			
9							
10	Bolton Index:	77.1%					
11							
12							
13							
14	Ideal value:	77.2%					
15	Upper arch:	47.2					
16	Lower arch:	36.4					
17							
18							
19							
20							

Totals are calculated by entering the formulas: =SUM(B2:B7) and =SUM(D2:D7)

Bolton index calculated from the above values: =D8/B8 (Percent Style is used here)

Upper total width should be equal to this value if the upper arch is assumed to be at fault. =D8/B14

Lower total width should be equal to this value if the lower arch is assumed to be at fault. =B8*B14

Figure 7. An example of spreadsheets used for Bolton Index calculator. Values for mesiodistal widths of anterior teeth were entered into cells B2 to B7 and D2 to D7. Totals were calculated with SUM function. Bolton Index was found by dividing lower total length by upper total length. Ideal upper and lower total widths were calculated in cells B15 and B16, based on ideal value entered in B14. Treatment options could be easily evaluated by using this part of spreadsheet.

Error of the Measurements

In order to test reproducibility of the measuring technique, 30 sets of the models were randomly selected from the whole samples. Measurements were performed again in 10 days later by the same examiner. For each replicated measurement, the method error statistic: Pair T-test and Dahlberg's method were used for testing the error of the measurements (37, 38).

The error of the measurements were calculated by the Dahlberg's modified method for small samples:

$$\text{Error of measurements} = \sqrt{\frac{\Sigma (x_1 - x_2)^2}{2n}}$$

where

x_1 = the original measurement

x_2 = the replicated measurement

n = the replication sample size

Statistic Analysis

1. Descriptive statistics: The mean and standard deviation were calculated for each tooth measurement.

2. To determine whether there was sexual dimorphism in the incidence of tooth size ratios, a Student t-test was performed for each malocclusion group.

3. To compare tooth size ratios among Class I, II and III malocclusion groups, ANOVA and Student Newman-Keuls Multicomparisons were performed.

The SPSS (version 10) was used for all the statistical analysis with the level of significance $p < 0.05$ and $p < 0.001$.

CHAPTER 4

RESULTS

Error of the Measurements

In order to determine the measurement error, Pair T-test and Dahlberg's method were computed on 30 sets of measurements from the models randomly selected to measure again 10 days later.

Dahlberg's equation modified for small samples was used in the calculation as defined by:

$$\text{Error of measurement} = \sqrt{\frac{\Sigma (x_1 - x_2)^2}{2n}}$$

where

x_1 = the original measurement

x_2 = the replicated measurement

n = the replication sample size

The results of Pair T-test and Dahlberg's method were shown in Table 7 and Table 8, respectively. The Pair T-test results (Table 7) showed no significant difference between the two measurements. The results from Dahlberg's method (Table 8) showed that measurement errors of the mesiodistal diameters for the individual teeth ranging between 0.04 mm. and 0.13 mm. The molars showed the largest errors (0.13 mm.)whereas the upper premolars, the upper right central incisor and the lower left central incisor showed the smallest errors (0.04 mm.). None of the measures displayed significant systematic errors.

Table 7 Paired t-test for all measurements between the first and second measurements

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean (mm.)	Std. Deviation (mm.)	Std. Error Mean (mm.)	Lower (mm.)	Upper (mm.)	t	df	Sig. (2-tailed)
#16	-0.040	0.159	0.029	-0.099	0.019	-1.386	29	0.176
#15	0.025	0.097	0.017	-0.010	0.061	1.449	29	0.158
#14	0.020	0.058	0.010	-0.001	0.042	1.905	29	0.067
#13	0.026	0.088	0.016	-0.006	0.059	1.623	29	0.115
#12	0.020	0.097	0.017	-0.016	0.056	1.129	29	0.268
#11	0.003	0.064	0.011	-0.020	0.027	0.309	29	0.760
#21	0.007	0.122	0.022	-0.038	0.052	0.313	29	0.756
#22	0.028	0.076	0.013	-0.001	0.057	1.969	29	0.059
#23	0.002	0.145	0.026	-0.051	0.056	0.088	29	0.931
#24	0.020	0.058	0.010	-0.001	0.042	1.913	29	0.066
#25	0.020	0.095	0.017	-0.014	0.056	1.190	29	0.244
#26	-0.034	0.190	0.034	-0.106	0.036	-0.994	29	0.328
sum of #13-23	0.088	0.337	0.061	-0.037	0.213	1.430	29	0.163
sum of upper posterior teeth	0.012	0.345	0.063	-0.117	0.141	0.190	29	0.851
sum of #16-26	0.100	0.535	0.097	-0.100	0.300	1.022	29	0.315
#46	0.037	0.157	0.028	-0.021	0.095	1.290	29	0.207
#45	0.027	0.160	0.029	-0.032	0.087	0.934	29	0.358
#44	0.026	0.098	0.017	-0.010	0.062	1.471	29	0.152
#43	0.009	0.105	0.019	-0.029	0.049	0.500	29	0.621
#42	0.018	0.092	0.016	-0.016	0.053	1.081	29	0.288
#41	0.017	0.090	0.016	-0.016	0.051	1.071	29	0.293
#31	-0.002	0.071	0.013	-0.029	0.024	-0.204	29	0.840
#32	-0.008	0.083	0.015	-0.039	0.022	-0.544	29	0.590
#33	0.009	0.145	0.026	-0.044	0.063	0.352	29	0.727
#34	0.019	0.136	0.024	-0.031	0.070	0.788	29	0.437
#35	0.030	0.112	0.020	-0.011	0.072	1.472	29	0.152
#36	0.027	0.195	0.035	-0.045	0.100	0.767	29	0.450
sum of #33-43	0.044	0.289	0.052	-0.064	0.152	0.832	29	0.412
sum of lower posterior teeth	0.168	0.469	0.085	-0.007	0.343	1.959	29	0.060
sum of #36-46	0.212	0.615	0.112	-0.017	0.441	1.886	29	0.069
anterior ratio	-0.052	0.790	0.144	-0.347	0.243	-0.360	29	0.721
posterior ratio	0.316	0.975	0.178	-0.048	0.680	1.775	29	0.086
overall ratio	0.122	0.626	0.114	-0.111	0.355	1.067	29	0.295

Table 8 Error of the measurement for the mesiodistal diameters for the individual teeth using Dahlberg's method

No. of teeth	Error of measurement (mm.)	No. of teeth	Error of measurement (mm.)
#16	0.11	**#36**	0.13
#15	0.06	**#35**	0.08
#14	0.04	**#34**	0.09
#13	0.06	**#33**	0.10
#12	0.06	**#32**	0.05
#11	0.04	**#31**	0.04
#21	0.08	**#41**	0.06
#22	0.05	**#42**	0.06
#23	0.10	**#43**	0.07
#24	0.04	**#44**	0.07
#25	0.06	**#45**	0.11
#26	0.13	**#46**	0.11

Mesiodistal Crown Size of the Permanent Teeth of the Study

The sample consisted of 360 pretreatment models: Class I, Class II and Class III malocclusion, evenly distributed making the number of samples in each classification being 60 for males or females group (Table 6).

The mesiodistal crown sizes of individual tooth were measured from each model. The measurement data from all samples were analyzed for means, standard deviations, standard error of means, ranges and differences between maximums and minimums of the sizes of the individual teeth (Table 10). In the maxillary arch, means and standard deviations of the individual tooth sizes were 8.74 $\pm$ 0.49, 7.34 $\pm$ 0.53, 8.17 $\pm$ 0.41, 7.65 $\pm$ 0.41, 7.23 $\pm$ 0.42 and 10.66 $\pm$ 0.53 mm. for the central incisor, the lateral incisor, the canine, the first premolar, the second premolar and the first molar, respectively. In the mandibular arch, means and standard deviations of individual tooth sizes were 5.56 $\pm$ 0.33, 6.19 $\pm$ 0.35, 7.12 $\pm$ 0.41, 7.56 $\pm$ 0.39, 7.54 $\pm$ 0.43 and 11.56 $\pm$ 0.57 mm. for the central incisor, the lateral incisor, the canine, the first premolar, the second premolar and the first molar, respectively. The differences between maximums and minimums of the individual tooth sizes ranged between 1.85 mm. and 3.50 mm. These differences showed that mesiodistal width of the maxillary first molar and the maxillary lateral incisor had the widest range and the width of the mandibular central incisor had the narrowest range.

Table 10 Means, standard deviations (SD), standard error of means (SE), ranges and differences between minimums and maximums of the sizes of the individual teeth of the total sample

Tooth	Mean (mm)	SD (mm)	SE (mm)	Range (mm)	Max. – Min. (mm)
Maxillary					
Central incisor	8.74	0.49	0.03	7.61-10.63	3.02
Lateral incisor	7.34	0.53	0.03	5.84- 9.34	3.50
Canine	8.17	0.41	0.02	7.19- 9.38	2.19
First premolar	7.65	0.41	0.02	6.50- 8.77	2.27
Second premolar	7.23	0.42	0.02	6.28- 8.37	2.09
First molar	10.66	0.53	0.03	8.87-12.37	3.50
Mandibular					
Central incisor	5.56	0.33	0.02	4.65- 6.50	1.85
Lateral incisor	6.19	0.35	0.02	5.14- 7.17	2.03
Canine	7.12	0.41	0.02	6.12- 8.34	2.22
First premolar	7.56	0.39	0.02	6.56- 8.73	2.17
Second premolar	7.54	0.43	0.02	6.28- 8.87	2.59
First molar	11.56	0.57	0.03	10.10-13.38	3.28

Sample size = 360

The individual tooth sizes were compared between the right and left sides (Table 11). In the maxillary arch, means and standard deviations of the individual tooth sizes of the right and left sides were 8.74 $\pm$ 0.50 and 8.74 $\pm$ 0.49 mm. for the central incisors, 7.35 $\pm$ 0.56 and 7.32 $\pm$ 0.53 mm. for the lateral incisors, 8.19 $\pm$ 0.42 and 8.15 $\pm$ 0.43 mm. for the canines, 7.64 $\pm$ 0.41 and 7.67 $\pm$ 0.42 mm. for the first premolars, 7.23 $\pm$ 0.43 and 7.24 $\pm$ 0.45 mm. for the second premolars and 10.69 $\pm$ 0.55 and 10.64 $\pm$ 0.54 mm. for the first molars. In the mandibular arch, means and standard deviations of the individual tooth sizes of the right and left sides were 5.57 $\pm$ 0.33 and 5.55 $\pm$ 0.34 mm. for the central incisors, 6.19 $\pm$ 0.35 and 6.19 $\pm$ 0.36 mm. for the lateral

incisors, 7.12 ± 0.42 and 7.12 ± 0.43 mm. for the canines, 7.56 ± 0.40 and 7.56 ± 0.40 mm. for the first premolars, 7.53 ± 0.45 and 7.55 ± 0.45 mm. for the second premolars and 11.54 ± 0.58 and 11.57 ± 0.58 mm. for the first molars. The comparisons between the right and left sides of the individual tooth sizes showed that significant differences were detected in the upper lateral incisor, the upper first premolar, the lower central incisor and the lower first molar at $p<0.05$ and the upper canine and the upper first molar at $p<0.001$.

Table 11 Means and standard deviations of the sizes of the individual teeth of the right and left sides

Tooth	Right		Left		Sig.
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	
Maxillary					
Central incisor	8.74	0.50	8.74	0.49	NS
Lateral incisor	7.35	0.56	7.32	0.53	*
Canine	8.19	0.42	8.15	0.43	**
First premolar	7.64	0.41	7.67	0.42	*
Second premolar	7.23	0.43	7.24	0.45	NS
First molar	10.69	0.55	10.64	0.54	**
Mandibular					
Central incisor	5.57	0.33	5.55	0.34	*
Lateral incisor	6.19	0.35	6.19	0.36	NS
Canine	7.12	0.42	7.12	0.43	NS
First premolar	7.56	0.40	7.56	0.40	NS
Second premolar	7.53	0.45	7.55	0.45	NS
First molar	11.54	0.58	11.57	0.58	*

NS = No significant difference at $p<0.05$

* = Significant difference at $p<0.05$

** = Significant difference at $p<0.001$

Tooth Size Comparison between Males and Females

The tooth sizes were compared between males and females (Table 12). In the maxillary arch, means and standard deviations of the individual tooth sizes of males and females were 8.82 ± 0.52 and 8.66 ± 0.43 mm. for the central incisors, 7.40 ± 0.56 and 7.27 ± 0.48 mm. for the lateral incisors, 8.30 ± 0.43 and 8.04 ± 0.34 mm. for the canines, 7.71 ± 0.40 and 7.59 ± 0.40 mm. for the first premolars, 7.28 ± 0.42 and 7.20 ± 0.42 mm. for the second premolars and 10.81 ± 0.52 and 10.52 ± 0.50 mm. for the first molar. In the mandibular arch, means and standard deviations of the individual tooth sizes of males and females were 5.58 ± 0.35 and 5.54 ± 0.30 mm. for the central incisors, 6.22 ± 0.39 and 6.16 ± 0.30 mm. for the lateral incisors, 7.29 ± 0.42 and 6.95 ± 0.33 mm. for the canines, 7.62 ± 0.39 and 7.50 ± 0.37 mm. for the first premolars, 7.60 ± 0.41 and 7.48 ± 0.44 mm. for the second premolars and 11.73 ± 0.57 and 11.39 ± 0.52 mm. for the first molars. The results showed that the mean tooth sizes were larger in males than in females. There were significant differences in tooth sizes between gender for the upper central incisor, the upper lateral incisor, the lower first premolar and the lower second premolar at $p<0.05$ and the upper canine, the upper first premolar, the upper first molar, the lower canine and the lower first molar at $p<0.001$.

Table 12 Means and standard deviations of the sizes of the individual teeth of males and females

Tooth	Male (n=180)		Female (n=180)		Sig.
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	
Maxillary					
Central incisor	8.82	0.52	8.66	0.43	*
Lateral incisor	7.40	0.56	7.27	0.48	*
Canine	8.30	0.43	8.04	0.34	**
First premolar	7.71	0.40	7.59	0.40	**
Second premolar	7.28	0.42	7.20	0.42	NS
First molar	10.81	0.52	10.52	0.50	**
Mandibular					
Central incisor	5.58	0.35	5.54	0.30	NS
Lateral incisor	6.22	0.39	6.16	0.30	NS
Canine	7.29	0.42	6.95	0.33	**
First premolar	7.62	0.39	7.50	0.37	*
Second premolar	7.60	0.41	7.48	0.44	*
First molar	11.73	0.57	11.39	0.52	**

NS = No significant difference at $p<0.05$

* = Significant difference at $p<0.05$

** = Significant difference at $p<0.001$

Comparison of Tooth Size among Class I, Class II and Class III Malocclusion Groups

Means and standard deviations of the individual tooth sizes among three malocclusion groups were presented in Table 13. In the maxillary arch, means and standard deviations of the individual tooth sizes for Class I, Class II and Class III malocclusion groups were 8.79 ± 0.51, 8.82 ± 0.49 and 8.62 ± 0.43 mm. for the central incisors, 7.36 ± 0.58, 7.40 ± 0.48 and 7.25 ± 0.51 mm. for the lateral incisors, 8.24 ± 0.41, 8.21 ± 0.44 and 8.07 ± 0.36 mm. for the canines, 7.65 ± 0.45, 7.70 ± 0.39 and 7.60 ± 0.37 mm. for the first premolars, 7.20 ± 0.44, 7.31 ± 0.43 and 7.20 ± 0.39 mm. for the second premolars and 10.66 ± 0.49, 10.77 ± 0.58 and 10.57 ± 0.50 mm. for the first molars. In the mandibular arch, means and standard deviations of the individual tooth sizes for Class I, Class II and Class III malocclusion groups were 5.57 ± 0.35, 5.61 ± 0.32 and 5.51 ± 0.31 mm. for the central incisors, 6.22 ± 0.36, 6.22 ± 0.32 and 6.12 ± 0.35 mm. for the lateral incisors, 7.15 ± 0.39, 7.15 ± 0.45 and 7.06 ± 0.39 mm. for the canines, 7.56 ± 0.38, 7.60 ± 0.41 and 7.51 ± 0.37 mm. for the first premolars, 7.59 ± 0.44, 7.57 ± 0.46 and 7.48 ± 0.39 mm. for the second premolars and 11.57 ± 0.57, 11.56 ± 0.61 and 11.53 ± 0.54 mm. for the first molars. Comparisons among the individual tooth sizes of Class I, Class II and Class III malocclusion groups showed that Class II had prevalent tendency larger tooth sizes than the other classes. The one-way analysis of variance indicated that there were significant differences among the different malocclusion classes in the tooth size of the upper central incisors and the upper canines in which Class III < Class I & Class II and of the upper molars in which Class III < Class II ($p<0.05$). There were no significant differences among Class I, Class II and Class III in the tooth sizes of the lateral incisors, the first and the second premolars in the maxillary arch and all teeth from the central incisors to the first molars in the mandibular arch.

Table 13 Means and standard deviations of the sizes of the individual teeth of Class I, Class II and Class III

Classification	Class I (n=120)		Class II (n=120)		Class III (n=120)		Sig
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	
Maxillary							
Central incisor	8.79	0.51	8.82	0.49	8.62	0.43	*
Lateral incisor	7.36	0.58	7.40	0.48	7.25	0.51	NS
Canine	8.24	0.41	8.21	0.44	8.07	0.36	*
First premolar	7.65	0.45	7.70	0.39	7.60	0.37	NS
Second premolar	7.20	0.44	7.31	0.43	7.20	0.39	NS
First molar	10.66	0.49	10.77	0.58	10.57	0.50	*
Mandibular							
Central incisor	5.57	0.35	5.61	0.32	5.51	0.31	NS
Lateral incisor	6.22	0.36	6.22	0.32	6.12	0.35	NS
Canine	7.15	0.39	7.15	0.45	7.06	0.39	NS
First premolar	7.56	0.38	7.60	0.41	7.51	0.37	NS
Second premolar	7.59	0.44	7.57	0.46	7.48	0.39	NS
First molar	11.57	0.57	11.56	0.61	11.53	0.54	NS

NS = No significant difference at $p<0.05$

* = Significant difference at $p<0.05$

Comparison of tooth size in the present study to other studies in Thailand

Tooth sizes of the present study were compared to those of other Thai studies i.e. Srisopak (27), Bijaphala (28) and Dechkunakorn et al. (32) as shown in Table 14 Srisopak measured the tooth size from the skull of sampled Thai population about 40 teeth without classifying the occlusion type. Bijaphala measured the tooth size from the sample of Thai population. The samples were 950 extracted teeth with the proper shape. Dechkunakorn et al. studied in a group of Thai population (Bangkok) with normal occlusion. The samples were 100 dental models.

In the maxillary arch, means and standard deviations of the individual tooth sizes of the present study and the study of Srisopark, Bijaphala and Dechkunakorn et al. were 8.74 $\pm$ 0.49, 8.77 $\pm$ 0.49, 8.63 $\pm$ 0.51 and 8.57 $\pm$ 0.48 mm. for the central incisors, 7.34 $\pm$ 0.53, 7.23 $\pm$ 0.57, 7.05 $\pm$ 0.61 and 7.01 $\pm$ 0.50 mm. for the lateral incisors, 8.17 $\pm$ 0.41, 7.87 $\pm$ 0.51, 8.08 $\pm$ 0.46 and 8.01 $\pm$ 0.42 mm. for the canines, 7.65 $\pm$ 0.41, 7.10 $\pm$ 0.47, 7.72 $\pm$ 0.58 and 7.50 $\pm$ 0.36 mm. for the first premolars, 7.23 $\pm$ 0.42, 7.07 $\pm$ 0.40, 7.21 $\pm$ 0.49 and 6.88 $\pm$ 0.39 mm. for the second premolars and 10.66 $\pm$ 0.53, 10.53 $\pm$ 0.53, 10.77 $\pm$ 0.74 and 10.27 $\pm$ 0.43 mm. for the first molars. In the mandibular arch, means and standard deviations of the individual tooth sizes of the present study and the study of Srisopark, Bijaphala and Dechkunakorn et al. were 5.56 $\pm$ 0.33, 5.64 $\pm$ 0.42, 5.74 $\pm$ 0.31 and 5.46 $\pm$ 0.33 mm. for the central incisors, 6.19 $\pm$ 0.35, 6.20 $\pm$ 0.50, 5.94 $\pm$ 0.45 and 6.08 $\pm$ 0.32 mm. for the lateral incisors, 7.12 $\pm$ 0.41, 6.94 $\pm$ 0.41, 7.17 $\pm$ 0.48 and 6.97 $\pm$ 0.40 mm. for the canines, 7.56 $\pm$ 0.39, 7.43 $\pm$ 0.45, 7.27 $\pm$ 0.46 and 7.33 $\pm$ 0.34 mm. for the first premolars, 7.54 $\pm$ 0.43, 7.52 $\pm$ 0.41, 7.59 $\pm$ 0.45 and 7.16 $\pm$ 0.39 mm. for the second premolars and 11.56 $\pm$ 0.57, 11.46 $\pm$ 0.63, 11.50 $\pm$ 0.67 and 11.36 $\pm$ 0.52 mm. for the first molars. The results showed that means and standard deviations of the present study were larger than those of Dechkunakorn's study. But the means and standard deviations of this study were close to those of Srisopak's and Bijaphala's studies.

Table 14 Comparison of tooth size (mean ± SD) among the present study and other Thai studies (unit : mm)

Study	Srisopark	Bijaphala	Dechkunakorn et al.	Present study
Maxillary				
Central incisor	8.77±0.49	8.63±0.51	8.57±0.48	8.74±0.49
Lateral incisor	7.23±0.57	7.05±0.61	7.01±0.50	7.34±0.53
Canine	7.87±0.51	8.08±0.46	8.01±0.42	8.17±0.41
First premolar	7.10±0.47	7.72±0.58	7.50±0.36	7.65±0.41
Second premolar	7.07±0.40	7.21±0.49	6.88±0.39	7.23±0.42
First molar	10.53±0.53	10.77±0.74	10.27±0.43	10.66±0.53
Mandibular				
Central incisor	5.64±0.42	5.74±0.31	5.46±0.33	5.56±0.33
Lateral incisor	6.20±0.50	5.94±0.45	6.08±0.32	6.19±0.35
Canine	6.94±0.41	7.17±0.48	6.97±0.40	7.12±0.41
First premolar	7.43±0.45	7.27±0.46	7.33±0.34	7.56±0.39
Second premolar	7.52±0.41	7.59±0.45	7.16±0.39	7.54±0.43
First molar	11.46±0.63	11.50±0.67	11.36±0.52	11.56±0.57

Intermaxillary Tooth Size Ratios

The tooth size data were analyzed according to the Bolton analysis as follows:

$$\frac{\text{Sum mandibular 6-6}}{\text{Sum maxillary 6-6}} \times 100 = \text{Overall ratio}$$

$$\frac{\text{Sum mandibular 3-3}}{\text{Sum maxillary 3-3}} \times 100 = \text{Anterior ratio}$$

$$\frac{\text{Sum mandibular } P_1 + P_2 + M_1}{\text{Sum maxillary } P_1 + P_2 + M_1} \times 100 = \text{Posterior ratio}$$

Table 15 showed sample size, means, standard deviations, standard error of means and ranges for the anterior, posterior and overall ratios when both sexes and all groups were combined. The mean and standard deviation of the anterior ratio for all classes combined was 77.85 $\pm$ 2.24 , the posterior ratio being 104.35 $\pm$ 2.39 and the overall ratio being 91.44 $\pm$ 1.74.

Table 15 Sample size (n), means, standard deviations (SD), standard errors of mean (SE) and ranges for the anterior, the posterior and the overall ratios when both sexes and all groups were combined

Ratio	N	Mean	SD	SE	Range
Anterior ratio	360	77.85	2.24	0.12	71.12 – 83.41
Posterior ratio	360	104.35	2.39	0.13	96.74 – 110.64
Overall ratio	360	91.44	1.74	0.09	84.33 – 96.06

Tooth Size Ratios Comparison between Sexes among Class I, Class II and Class III malocclusion groups

Means and standard deviations of the anterior ratios between males and females were 77.90 ± 2.20 and 77.49 ± 2.54 for Class I, 77.57 ± 2.11 and 77.86 ± 2.08 for Class II and 78.22 ± 2.34 and 78.05 ± 2.14 for Class III. Means and standard deviations of the posterior ratios between males and females were 105.12 ± 2.13 and 104.44 ± 2.26 for Class I, 103.63 ± 2.34 and 103.74 ± 2.43 for Class II and 104.68 ± 2.51 and 104.52 ± 2.44 for Class III. Means and standard deviations of the overall ratios between males and females were 91.79 ± 1.54 and 91.25 ± 1.82 for Class I, 90.93 ± 1.66 and 91.16 ± 1.65 for Class II and 91.81 ± 1.81 and 91.67 ± 1.78 for Class III. The anterior, posterior and overall ratios were compared between males and females in each classification, no significant difference was detected between either sex (Table 16,17,18). As to the absolute value of tooth size ratios of different sexes, there was a prevalent trend. Tooth size ratios of males were larger than those of females in Class I and Class III patients, but the tooth size ratios of male patients were smaller than those of female patients in Class II (Fig 8,9,10).

Table 16 Sample size (n), means, standard deviations (SD), t-value and level of significance for the anterior ratio between males and females

Classification	Males			Females			t-value	Sig.
	n	Mean	SD	n	mean	SD		
Class I	60	77.90	2.20	60	77.49	2.54	0.950	NS
Class II	60	77.57	2.11	60	77.86	2.08	0.771	NS
Class III	60	78.22	2.34	60	78.05	2.14	0.420	NS

NS = No significant difference($p<0.05$)

Table 17 Sample size (n), means, standard deviations (SD), t-value and level of significance for the posterior ratio between males and females

Classification	Males			Females			t-value	Sig.
	n	Mean	SD	n	mean	SD		
Class I	60	105.12	2.13	60	104.44	2.26	1.714	NS
Class II	60	103.63	2.34	60	103.74	2.43	0.239	NS
Class III	60	104.68	2.51	60	104.52	2.44	0.347	NS

NS = No significant difference($p<0.05$)

Table 18 Sample size (n), means, standard deviations (SD), t-value and level of significance for the overall ratio between males and females

Classification	Males			Females			t-value	Sig.
	n	Mean	SD	n	mean	SD		
Class I	60	91.79	1.54	60	91.25	1.82	1.776	NS
Class II	60	90.93	1.66	60	91.16	1.65	0.742	NS
Class III	60	91.81	1.81	60	91.67	1.78	0.442	NS

NS = No significant difference($p<0.05$)

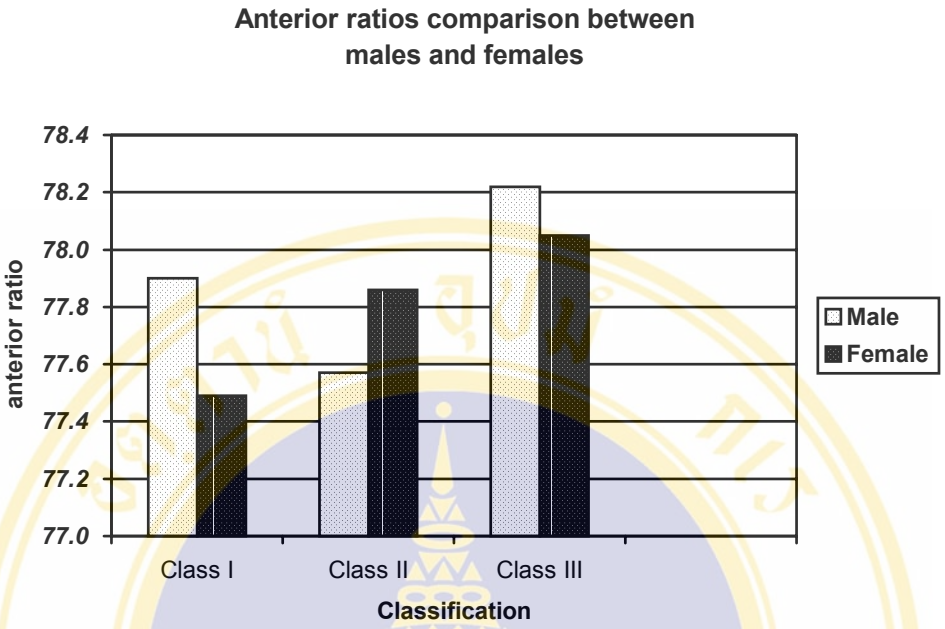

Figure 8. Sexual difference of the anterior ratios among Class I, Class II and Class III malocclusions.

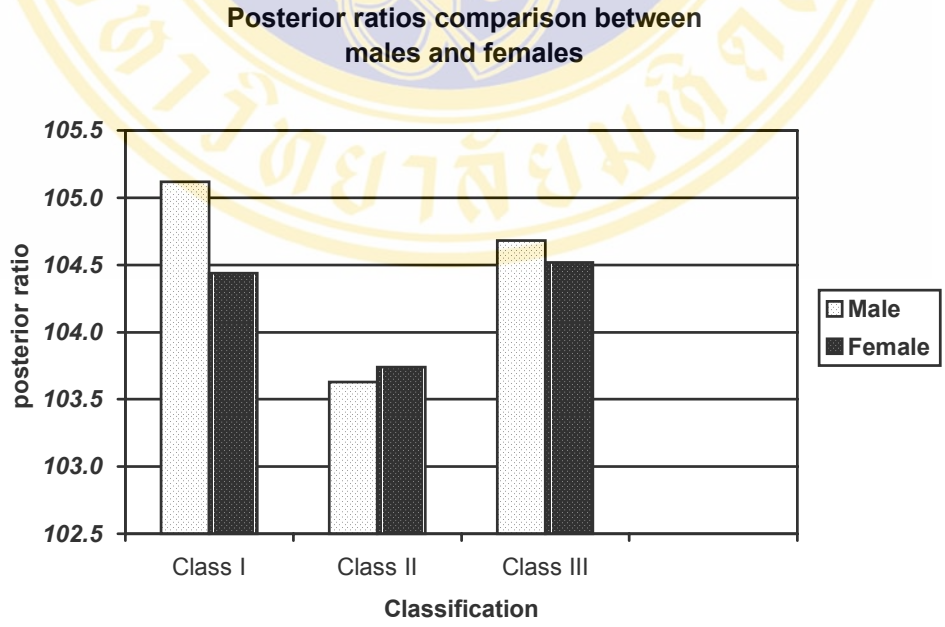

Figure 9. Sexual difference of the posterior ratios among Class I, Class II and Class III malocclusions.

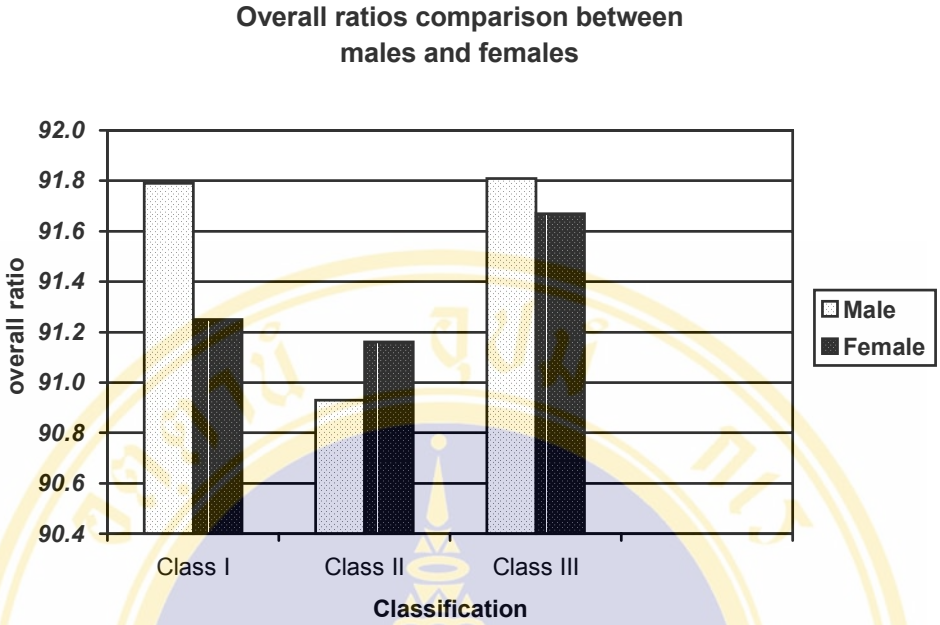

Figure 10. Sexual difference of the overall ratios among Class I, Class II and Class III malocclusions.

Comparison of Intermaxillary Tooth Size Ratios among Class I, Class II and Class III malocclusion classes

Because there was no significant sexual dimorphism for tooth size ratios, the gender-separated samples were combined for each class. Table 19,20 and 21 presented the sample size, means, standard deviations, standard error of means and ranges for the anterior, posterior and overall ratios among Class I, Class II and Class III malocclusion groups. Means and standard deviations of the anterior ratios were 77.69 $\pm$ 2.38, 77.72 $\pm$ 2.10 and 78.13 $\pm$ 2.23 for Class I, Class II and Class III malocclusion groups, respectively. Means and standard deviations of the posterior ratios were 104.78 $\pm$ 2.21, 103.69 $\pm$ 2.38 and 104.60 $\pm$ 2.46 for Class I, Class II and Class III malocclusion groups, respectively. Means and standard deviations of the overall ratios were 91.53 $\pm$ 1.70, 91.04 $\pm$ 1.65 and 91.74 $\pm$ 1.79 for Class I, Class II and Class III malocclusion groups, respectively. Figure 11,12 and 13 presented comparisons of the means of the anterior, posterior and overall ratios among Class I, Class II and Class III malocclusion groups. As to the mean values of tooth size ratios of different malocclusion classes, there was no prevalent trend. The trend for the anterior ratio was Class III > Class II > Class I, for the posterior ratio was Class I > Class III > Class II, and for the overall ratio was Class III > Class I > Class II.

Table 19 Sample size (n), means, standard deviations (SD), standard errors of mean (SE) and ranges for the anterior ratio in all malocclusion classes (both sexes were combined)

Angle classification	N	Mean	SD	SE	Range
Class I	120	77.69	2.38	0.22	71.97 – 82.95
Class II	120	77.72	2.10	0.19	71.42 – 82.49
Class III	120	78.13	2.23	0.20	71.12 – 83.41

Table 20 Sample size (n), means, standard deviations (SD), standard errors of mean (SE) and ranges for the posterior ratio in all malocclusion classes (both sexes were combined)

Angle classification	N	Mean	SD	SE	Range
Class I	120	104.78	2.21	0.20	99.75 – 109.98
Class II	120	103.69	2.38	0.22	96.74 – 110.64
Class III	120	104.60	2.46	0.22	99.17 – 110.42

Table 21 Sample size (n), means, standard deviations (SD), standard errors of mean (SE) and ranges for the overall ratio in all malocclusion classes (both sexes were combined)

Angle classification	N	Mean	SD	SE	Range
Class I	120	91.53	1.70	0.16	86.72 – 95.89
Class II	120	91.04	1.65	0.15	84.33 – 94.57
Class III	120	91.74	1.79	0.16	87.95 – 96.06

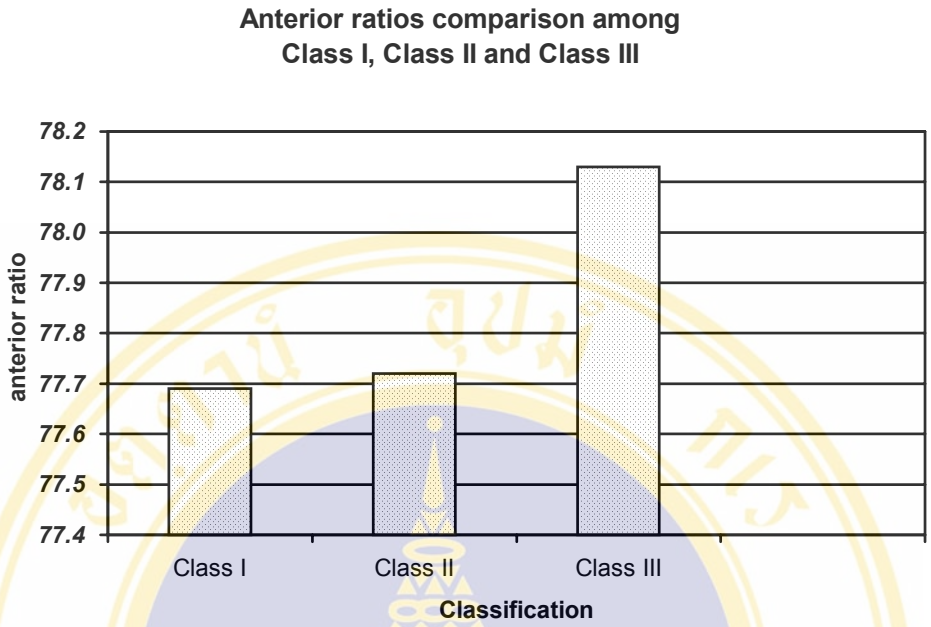

Figure 11. Comparison of anterior ratios among Class I, Class II and Class III malocclusions (both sexes were combined).

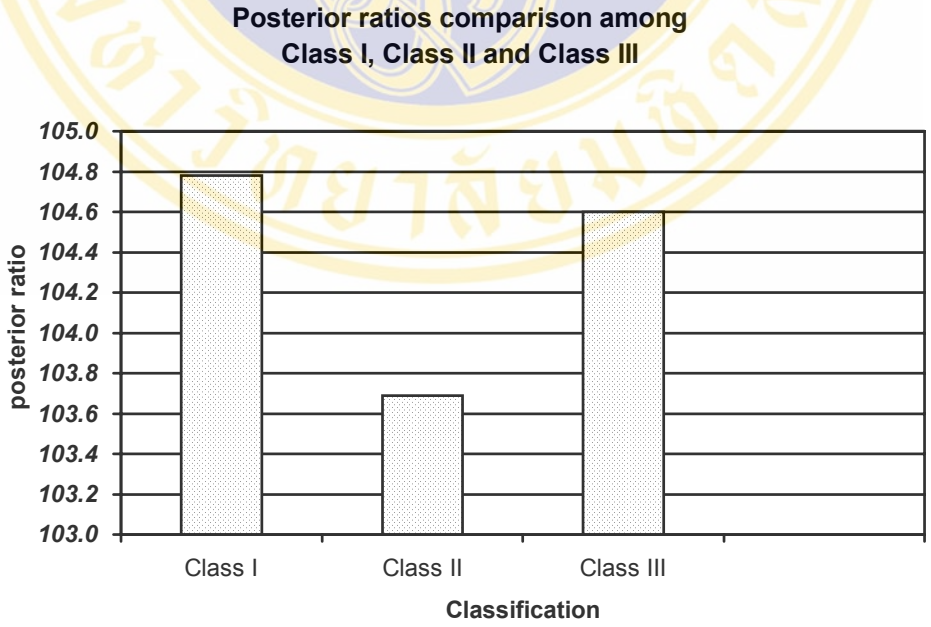

Figure 12. Comparison of posterior ratios among Class I, Class II and Class III malocclusions (both sexes were combined).

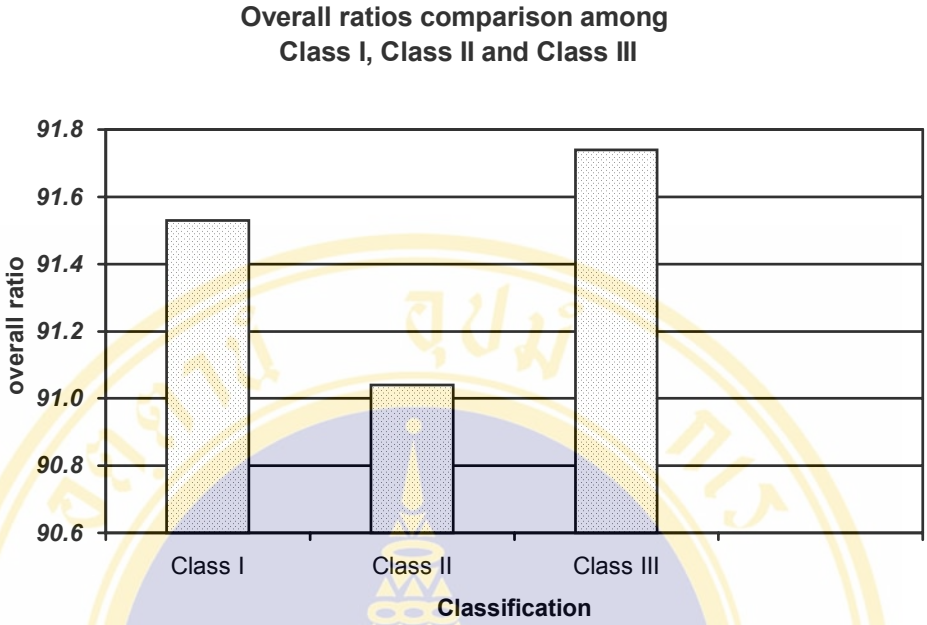

Figure 13. Comparison of overall ratios among Class I, Class II and Class III malocclusions (both sexes were combined).

The one-way analysis of variance (ANOVA) indicated that there were significant differences in the posterior and overall ratios among the different malocclusion classes (Table 22), thus Student-Newman-Keuls Multicomparison was performed to analyze the differences in those ratios (Table 23,24).

From Table 22, it was obvious that for the anterior ratio, there were no significant differences among the different malocclusion classes. But there were significant differences among the different malocclusion classes in the posterior and overall ratios ($p<0.05$).

From Table 23 and Table 24, the statistical results of multiple comparison showed that there was no significant difference between Class I and Class III in the posterior and overall ratios. But the mean - posterior and overall ratios of Class II were less than Class I and Class III. The differences between these groups were significant at the level of significance $p< 0.05$.

Table 22 ANOVA test for the anterior, posterior and overall ratios between the classes

Ratio		Sum of Squares	df	Mean Squares	F-value	Sig. Level
Anterior Ratio	Between Groups	14.597	2	7.298	1.456	0.235
	Within Groups	1790.032	357	5.014		
	Total	1804.629	359			
Posterior Ratio	Between Groups	82.213	2	41.107	7.425	*0.001
	Within Groups	1976.501	357	5.536		
	Total	2058.714	359			
Overall Ratio	Between Groups	30.638	2	15.319	5.207	*0.006
	Within Groups	1050.263	357	2.942		
	Total	1080.901	359			

*Significant difference at $p<0.05$

Table 23 Multiple comparisons of the posterior ratios among the malocclusion classes

Class	mean	SD	Class	II	I	III	Note
Class II	103.69	2.21	**II**		*	*	Class II<III<I
Class III	104.60	2.38	**III**	*			
Class I	104.78	2.46	**I**	*			

*Level of significance of multiple comparisons was $p < 0.05$

There was no significant difference between Class I and Class III.

Table 24 Multiple comparisons of the overall ratios among the malocclusion classes

Class	mean	SD	Class	II	I	III	Note
Class II	91.04	1.65	**II**		*	*	Class II<I<III
Class I	91.53	1.70	**I**	*			
Class III	91.74	1.79	**III**	*			

*Level of significance of multiple comparisons was $p < 0.05$

There was no significant difference between Class I and Class III.

Comparison of Class I, Class II and Class III Malocclusion Classes to Normal Occlusion

The results of the present study were compared to normal occlusion from the study of Dechkunakorn et al. (32) Comparisons of the anterior, posterior and overall ratios between normal occlusion and three malocclusion groups were presented in Table 25,26,27 and Fig. 14,15,16, respectively. Means and standard deviations of the anterior ratios were 78.53 $\pm$ 2.34, 77.69 $\pm$ 2.38, 77.72 $\pm$ 2.10 and 78.13 $\pm$ 2.23 for normal occlusion, Class I, Class II and Class III malocclusion groups, respectively. Means and standard deviations of the posterior ratios were 104.90 $\pm$ 2.17, 104.78 $\pm$

2.21, 103.69 ± 2.38 and 104.60 ± 2.46 for normal occlusion, Class I, Class II and Class III malocclusion groups, respectively. Means and standard deviations of the overall ratios were 92.00 ± 1.68, 91.53 ± 1.70, 91.04 ± 1.65 and 91.74 ± 1.79 for normal occlusion, Class I, Class II and Class III malocclusion groups, respectively. The results showed no statistically significant differences between normal occlusion and Class III malocclusion in the anterior, posterior and overall ratios. But there were significant differences between normal occlusion and Class I, II malocclusion (except posterior ratio of Class I) in the anterior, posterior and overall ratios.

Table 25 Comparison of the anterior ratio between the normal occlusion and malocclusion classes

Classification	n	Mean	SD	t-value compare to normal occlusion	Sig.
Normal (Dechkunakorn et al.)	100	78.53	2.34		
Class I (Present study)	120	77.69	2.38	2.63	*
Class II (Present study)	120	77.72	2.10	2.72	*
Class III (Present study)	120	78.13	2.23	1.31	NS

* = Significant difference at $p<0.05$

NS = Not significant ($p>0.05$)

Table 26 Comparison of the posterior ratio between the normal occlusion and malocclusion classes

Classification	n	Mean	SD	t-value compare to normal occlusion	Sig.
Normal (Dechkunakorn et al.)	100	104.90	2.17		
Class I (Present study)	120	104.78	2.21	0.40	NS
Class II (Present study)	120	103.69	2.38	3.87	**
Class III (Present study)	120	104.60	2.46	0.97	NS

** = Significant difference at $p<0.001$

NS = Not significant ($p>0.05$)

Table 27 Comparison of the overall ratio between the normal occlusion and malocclusion classes

Classification	n	Mean	SD	t-value compare to normal occlusion	Sig.
Normal (Dechkunakorn et al)	100	92.00	1.68		
Class I (Present study)	120	91.53	1.70	2.04	*
Class II (Present study)	120	91.04	1.65	4.17	**
Class III (Present study)	120	91.74	1.79	1.09	NS

* = Significant difference at $p<0.05$

** = Significant difference at $p<0.001$

NS = Not significant ($p>0.05$)

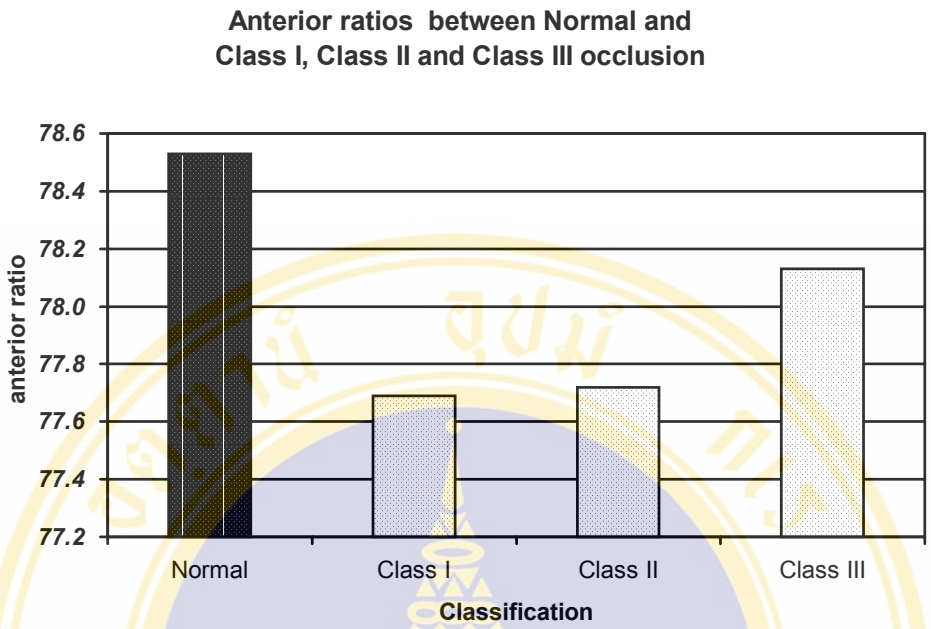

Figure 14. Comparison of the anterior ratios between the normal occlusion and Class I, Class II and Class III malocclusions.

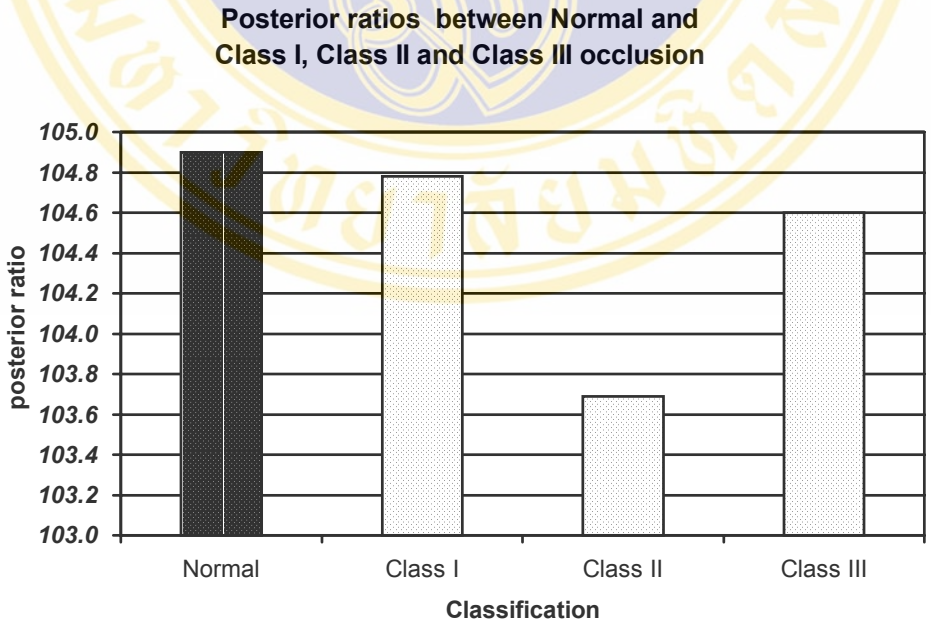

Figure 15. Comparison of the posterior ratios between the normal occlusion and Class I, Class II and Class III malocclusions.

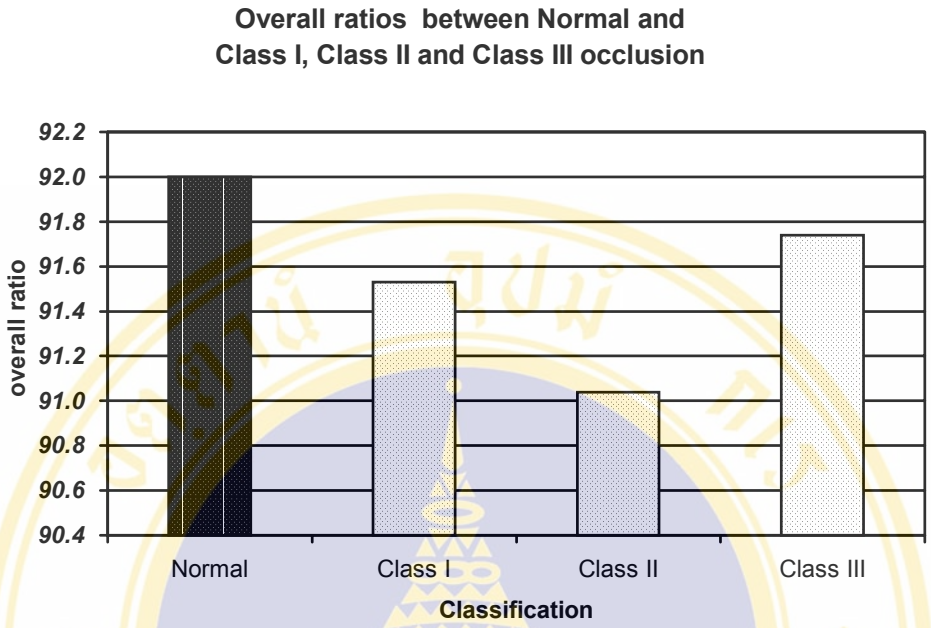

Figure 16. Comparison of the overall ratios between the normal occlusion and Class I, Class II and Class III malocclusions.

Comparison between Bolton's Ratios and the Ratios from the Present Study

Comparisons of the anterior and overall ratios between Bolton's and the present study were presented in Table 28,29 and Fig.17,18, respectively. Bolton's sample were normal occlusion group, while the samples of the present study were Class I, Class II and Class III malocclusion groups. Means and standard deviations of the anterior ratios of Bolton's study - normal occlusion group and the present study - Class I, Class II and Class III malocclusion groups were 77.20 $\pm$ 1.65, 77.69 $\pm$ 2.38, 77.72 $\pm$ 2.10 and 78.13 $\pm$ 2.23. Means and standard deviations of the overall ratios of Bolton's study - normal occlusion group and the present study -Class I, Class II and Class III malocclusion groups were 91.30 $\pm$ 1.91, 91.53 $\pm$ 1.70, 91.04 $\pm$ 1.65 and 91.74 $\pm$ 1.79. The comparisons showed no statistical significant difference was noted for both anterior and overall ratios in the malocclusion classes except anterior ratio in Class III malocclusion.

Table 28 Comparison of the anterior ratios between the present study and Bolton's study

Classification	n	Anterior ratio		t-value (compare to Bolton's)	Sig.
		mean	SD		
Normal (Bolton)	55	77.20	1.65		
Class I (Present study)	120	77.69	2.38	1.57	NS
Class II (Present study)	120	77.72	2.10	1.77	NS
Class III (Present study)	120	78.13	2.23	3.08	*

* = Significant difference at $p<0.05$

NS = Not significant ($p>0.05$)

Table 29 Comparison of the overall ratios between the present study and Bolton's study

Classification	n	Overall ratio		t-value (compare to Bolton's)	Sig.
		Mean	SD		
Normal (Bolton)	55	91.30	1.91		
Class I (Present study)	120	91.53	1.70	0.80	NS
Class II (Present study)	120	91.04	1.65	0.92	NS
Class III (Present study)	120	91.74	1.78	1.48	NS

NS = Not significant ($p>0.05$)

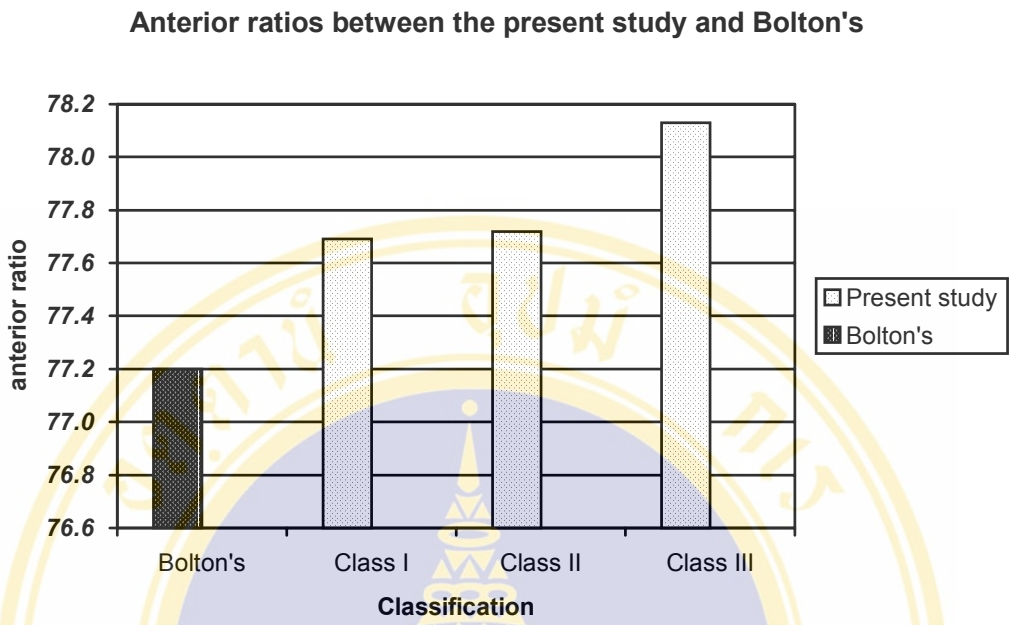

Figure 17. Comparison of the anterior ratios between the present study and Bolton's.

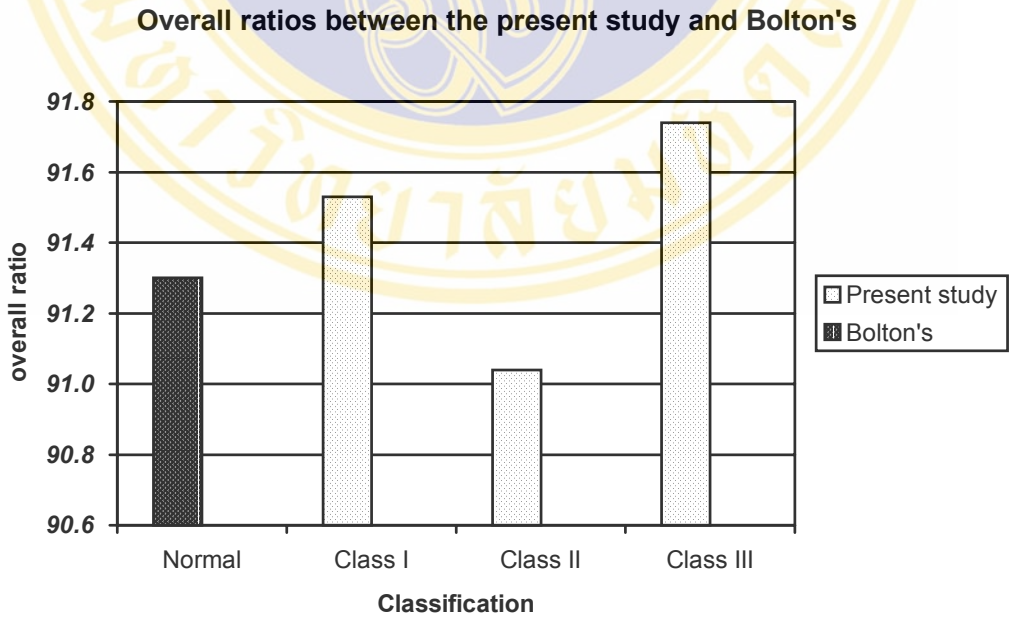

Figure 18. Comparison of the overall ratios between the present study and Bolton's.

Comparison of Tooth Size Ratios among Occlusal Categories of the Present Study to other Studies of other Groups of Population

The results of the present study were compared to the results of other studies (i.e. the studies of Crosby & Alexander (5), Nie & Lin (8) and Alkofide & Hashim (9)) that determined a prevalent tendency for intermaxillary tooth size discrepancies among different malocclusion groups in other groups of population (Table 30,31 and Fig. 19,20). Crosby & Alexander studied the anterior and overall ratios among Class I, Class II division 1, Class II division 2 and Class II surgery groups in USA. They did not include Class III patients in their study. Nie & Lin studied the anterior and overall ratios among Class I, Class II Class III groups in China. Alkofide & Hashim studied the anterior and overall ratios among Class I, Class II Class III groups in Saudi arabia. From Table 30 and Table 31, the results showed that there was no statistical significant difference for both anterior and overall ratios in each malocclusion groups between the present study and the study of Crosby & Alexander, but there were significant differences when the study results were compared to the studies of Nie & Lin and Alkofide & Hashim except the anterior ratio in Class III malocclusion of the studies of Alkofide & Hashim.

.

Table 30 Comparison of the anterior ratios of the present study to other groups of population

Classification	Study	Anterior ratio			Compare to Present study
		n	Mean	SD	Sig.
Class I	**Present study**	120	77.69	2.38	
	Crosby&Alexander (1989)-USA	30	77.2	2.7	NS
	Nie&Lin (1999)-China	120	81.54	2.75	**
	Alkofide&Hashim (2002)-Saudia Arabia	60	78.77	2.74	*
Class II	**Present study**	120	77.72	2.10	
Class II div.1	**Crosby&Alexander**	30	78.2	3.1	NS
Class II div.2		29	76.8	5.3	NS
Class II surgery		20	77.5	2.7	NS
	Nie&Lin	120	80.79	3.15	**
	Alkofide&Hashim	60	78.70	2.45	*
Class III	**Present study**	120	78.13	2.23	
	Nie&Lin	120	82.75	2.91	**
	Alkofide&Hashim	60	78.50	2.53	NS

* = Significant difference at $p<0.05$

** = Significant difference at $p<0.001$

NS = Not significant ($p>0.05$)

Table 31 Comparison of the overall ratios of the present study to other groups of population

Classification	Study	Overall ratio			Compare to Present study
		n	Mean	SD	Sig.
Class I	**Present study**	120	91.53	1.70	
	Crosby&Alexander (1989)-USA	30	91.3	2.4	NS
	Nie&Lin (1999)-China	120	93.39	2.46	**
	Alkofide&Hashim (2002)-Saudia Arabia	60	92.24	2.04	*
Class II	**Present study**	120	91.04	1.65	
Class II div.1	**Crosby&Alexander**	30	91.7	2.3	NS
Class II div.2		29	91.5	3.1	NS
Class II surgery		20	91.3	2.2	NS
	Nie&Lin	120	92.06	2.47	**
	Alkofide&Hashim	60	92.80	2.20	**
Class III	**Present study**	120	91.74	1.78	
	Nie&Lin	120	95.59	2.58	**
	Alkofide&Hashim	60	92.71	2.12	**

* = Significant difference at $p<0.05$

** = Significant difference at $p<0.001$

NS = Not significant ($p>0.05$)

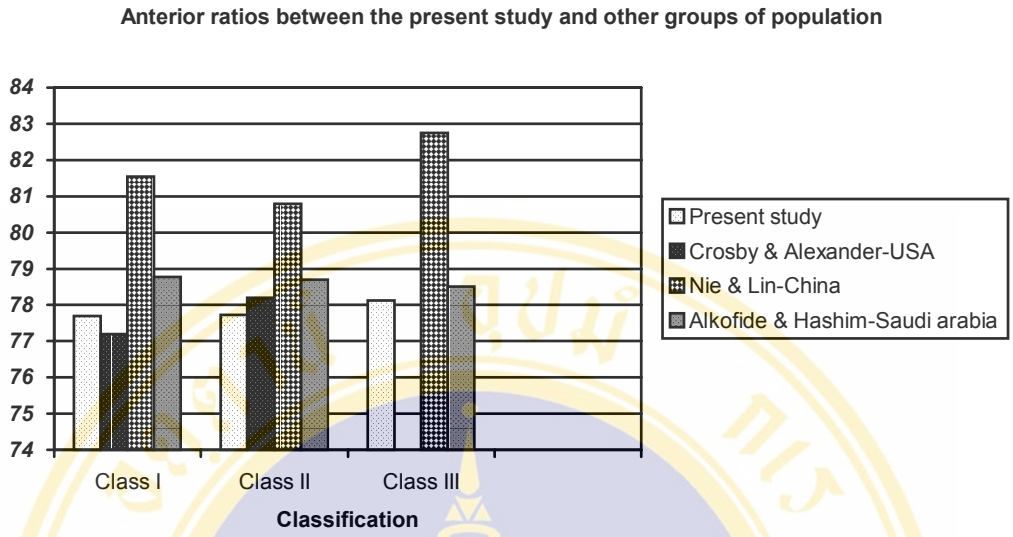

Figure 19. Comparison of the anterior ratios of the present study to other groups of population

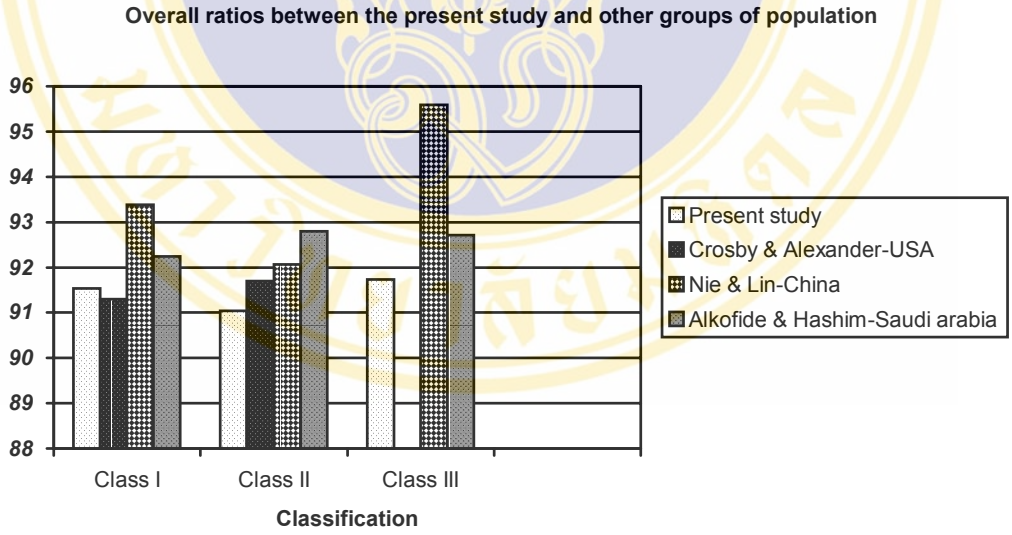

Figure 20. Comparison of the overall ratios of the present study to other groups of population

CHAPTER 5

DISCUSSION

The importance of harmony between the maxillary and mandibular teeth has drawn the attention of many investigators over the years. One of the causative factors leading to an inadequate relationship between both has been attributed to a tooth size discrepancy (39). There are 22.9 % and 30.6 % of orthodontic patients who have a significant anterior tooth size discrepancy found by Crosby and Alexander (5) and by Freeman et al.(19), respectively.

In the present study, the width of upper lateral incisor has the widest range. An anomaly in the size of upper lateral incisors may effect a tooth size discrepancy, and a variation in premolars or other teeth may effect a tooth size discrepancy (40). These anomalies are sometimes difficult to detect by inspection alone. Bolton tooth size analysis is a method that can help clinicians to check for this discrepancy. It would seem prudent for clinicians to routinely include a tooth size analysis in their initial case workup. Identifying such a discrepancy before final tooth alignment would prove beneficial in both treatment planning and final expectations of both the clinicians and the patients. Although such an analysis may appear to be time-consuming, the benefits would seem to outweigh this minor inconvenience by allowing more efficient diagnosis of problems, more specificity in treatment planning, and a higher success rate in achieving optimal occlusions, overbite and overjet (19). However, the Bolton's estimates of variation were underestimated because his samples were derived from the normal Class I occlusion. The population and the gender composition of the Bolton's samples were also not specified, which implied the potential selection bias. This study was designed as a cross-sectional retrospective study to determine whether there is a prevalent tendency for intermaxillary tooth size discrepancies among different malocclusion groups and different gender in Thai orthodontic patients. This study consisted of 360 models divided into 3 malocclusion groups (i.e., Class I, Class II, and Class III) with both sexes evenly distributed. The models were selected from private dental clinics in Bangkok and Orthodontic department, Faculty of Dentistry, Mahidol

University. The measurements included the maximum mesiodistal width of all the twelve maxillary and mandibular teeth from the right first permanent molar to the left first permanent molar.

Mesiodistal Crown Size of the Permanent Teeth

From 360 models, the means, standard deviations, minimums and maximums of mesiodistal crown sizes of individual teeth were shown in Table 10. The results showed that a mesiodistal width of the upper lateral incisor had a wide range. This agreed with many studies: e.g. Axelsson and Kirveskar (41), Srisopark (27), Bijaphala (28), Boondej and Sirinavin (31), and Dechkunakorn et al. (32). It indicated that an anomaly in the size of upper lateral incisor might effect a tooth size discrepancy. In contrast, a width of the lower central incisor had the narrowest range.

The mesiodistal dimensions of the maxillary teeth showed a higher variability than the mandibular teeth, with the first molar dimensions showing the greatest variability (greatest range). The sizes of the maxillary central and lateral incisors also presented high variability. This suggested that they could be responsible for incongruity in the anterior ratio and should, therefore, be examined clinically at the beginning of a treatment to detect any major size and shape variation.

When the means of individual teeth sizes were compared between the right side and the left side, significant differences were detected in many teeth: i.e. upper lateral incisor, upper canine, upper first premolar, upper first molar, lower central incisor and lower first molar. This agreed to Boondej and Sirinavin (31) that mesiodistal widths of same teeth were different between the right and left sides in each arch, but contradicted to Axelsson and Kirveskar (41) who concluded that there was no significant difference between the right and left sides in each arch.

Tooth Size Comparison between Males and Females

The tooth sizes were compared between males and females and the results were shown in Table 12. The means showed that the male teeth were larger than the female teeth. This agreed with many studies, for example, Arya et al. (42), Lavelle (16), Bishara et al. (43), Boondej and Sirinavin (31), and Dechkunakorn et al. (32)

Arya et al. (42) studied the relation between mesiodistal tooth size and both sex and occlusion. Their results showed that all teeth except the mandibular central incisor were significantly different between males and females. However, the present study showed that all teeth were significantly different except the maxillary second premolar, mandibular central and lateral incisors. This may be come from the fact that their study consisted only Class I and Class II while the samples of the present study consisted of all three classes, that were Class I, Class II and Class III malocclusion groups.

Comparison of Tooth Size among Different Malocclusion Groups

When the means of the individual tooth sizes were compared among Class I, Class II and Class III malocclusion groups, the results from Table 13 showed that Class II had larger values than other classes in many individual tooth sizes. But only in tooth size of maxillary central incisor, maxillary canine and maxillary molar that there were significant differences between the different malocclusion classes (Class III < Class I and Class II). The results disagreed to the study of Arya et al. (42). In their study, mean tooth sizes were compared only between the Class I and Class II occlusion groups. More than half of their observed means (twelve of twenty-two) were identical in the two groups, and there was no consistent pattern when compared between the Class I and Class II in individual tooth.

Lavelle (16) measured the mesiodistal crown diameters in a total of 120 sets of casts and showed that tooth sizes of Class III were the smallest among the three occlusion categories of maxillary teeth; but tooth sizes of Class III were the biggest in mandibular teeth. The present study showed that tooth sizes of Class III were the smallest among the 3 occlusion classes for both maxillary and mandibular teeth.

Comparison of Tooth Size between the Present Study to another Studies in Thailand

Tooth sizes of the present study were compared to those of another Thai studies, the results were shown in Table 14. The results showed that means and standard deviations of the present study were larger than the study of Dechkunakorn et al.(32). A cause of different results might be from the selection of samples. The samples of

Dechkunakorn et al. were normal occlusion but the samples of the present study were malocclusion. However, the means and standard deviations of the present study were close to the study of Srisopak(27) and Bijaphala(28). Srisopak measured the tooth sizes from dried skulls. Bijaphala measured the tooth sizes from 950 extracted teeth with the proper shape.

As such, tooth sizes may be one of the factors that causes malocclusion. Thus the tooth sizes must be in harmony with both arch sizes and interarches

Intermaxillary Tooth Size Ratios

The data of tooth size were analyzed according to Bolton's analysis as follows:

$$\frac{\text{Sum mandibular 6-6}}{\text{Sum maxillary 6-6}} \times 100 = \text{Overall ratio}$$

$$\frac{\text{Sum mandibular 3-3}}{\text{Sum maxillary 3-3}} \times 100 = \text{Anterior ratio}$$

$$\frac{\text{Sum mandibular } P_1 + P_2 + M_1}{\text{Sum maxillary } P_1 + P_2 + M_1} \times 100 = \text{Posterior ratio}$$

From the whole samples, the average anterior, posterior and overall ratios were 77.85, 104.35 and 91.44 respectively (Table 15).

Comparison of Tooth Size Ratios between Sexes

When the anterior, posterior and overall ratios were compared between males and females in each classification, no significant difference was detected between sexes (Table 16,17,18). Tooth size ratios of males were larger than those of females in Class I and Class III malocclusion groups. In Class II malocclusion group, tooth size ratios of males were smaller than those of females (Fig. 8,9,10).

These results agreed with Nie and Lin (8), who found no sexual dimorphism for these ratios in all malocclusion classes. The results partially agreed to the study of Alkofide and Hashim (9) who found no significant difference in overall ratio between

both sexes in all malocclusion classes but found a significant difference in the anterior ratio between males and females in Class III malocclusion.

Comparison of Intermaxillary Tooth Size Ratios among Class I, II and III Malocclusion Classes

Tooth size ratios were compared between the malocclusion groups (Table 19,20,21), the results of anterior ratio showed that there were no significant differences among the different malocclusion classes. But there were significant differences among the different malocclusion classes in the posterior and overall ratios. This is in partial agreement with Alkofide and Hashim (9) who found no significant difference in incidence of tooth size discrepancies among the different malocclusion classes for the anterior and overall ratios. This partially agreed with Crosby and Alexander (5) who found no significant difference among the different malocclusion classes for the overall and the anterior ratios, but they did not include Class III cases. Furthermore, this disagreed with Nie and Lin (8), who found significant differences among Class I, Class II and Class III malocclusion for both anterior and overall ratios, but no significant difference was found between subcategories of malocclusion which was not investigated in this study.

Prevalent trends of the present study were as follows: for the anterior ratio it was Class III > Class II > Class I, for the posterior ratio it was Class I > Class III > Class II, and for the overall ratio it was Class III > Class I > Class II. These differed to Nie and Lin (8) 's study that showed Class III >Class I > Class II for all the anterior, posterior and overall ratios.

Sperry et al. (18) concluded that the mandibular tooth-size excess were found in Class III group more than Class I and Class II groups. This conclusion was similar to a result of the present study. The similar result of the present study was that the overall ratio of Class III group was the highest among different malocclusion groups.

Lavelle (16) showed that the maxillary tooth sizes of Class III malocclusion were the smallest and the mandibular tooth sizes were the greatest among three malocclusion categories (Class I, Class II, and Class III). This possibly indicated that tooth size ratios of mandibular teeth divided by maxillary teeth in Class III may be the greatest among different malocclusion types. However, these ratios were not compared

in his study. His result was a kind of descriptive statistical result, which stated the mean size of each tooth in each malocclusion type and described a pattern of contrast. The present study compared these ratios and showed that anterior and overall ratios of Class III malocclusions were greater than another malocclusion groups.

Crosby and Alexander (5)compared the tooth size ratios among different malocclusion groups, as in this present study. But they did not include Class III patients in their study and selected only 20 to 30 cases for each group. They found that there were no significant differences among Class I, Class II Division 1, Class II Division 2, and Class II surgery groups. The present study did not divide Class II into Class II Division 1 and Class II Division 2.

Comparison of Class I, II and III Malocclusion Groups to Normal Occlusion

Table 25,26,27 presented the comparisons between the results of this present study and the study of Dechkunakorn et al.(32). The samples of the study of Dechkunakorn et al.were normal occlusion group. While the samples of this present study were Class I, Class II and Class III malocclusion groups. The comparisons showed no statistical significant differences between normal occlusion and Class III malocclusion in the anterior, posterior and overall ratios. But there were significant differences between normal occlusion and Class I, II malocclusion in anterior, posterior and overall ratios except posterior ratio of Class I malocclusion group. This disagreed with Nie and Lin (8) who showed there was no significant difference between normal occlusion and Class I malocclusion.

Comparison between Bolton's Ratios and the Ratios from the Present Study

When the anterior and overall ratios of this study were compared to those of Bolton's study, no statistical significant differences were noted for both the anterior and overall ratios in the malocclusion classes except for the anterior ratio in Class III malocclusion (Table 28,29). The anterior ratio of Class III malocclusion had a larger value (78.13 compared with Bolton's 77.20). Assuming that an ideal Class I canine is obtained during treatment, an anterior ratio of 78.13 ideally implies the necessity of removal of tooth structure for example interproximal recontouring in the mandibular

arch or addition of tooth structure for example veneers or composite buildups in the maxillary arch to achieve an acceptable overjet and overbite.

However, in clinical practice these procedures rarely represent the only solution to the problem. The excess of tooth material in the mandibular anterior segment in Class III malocclusion is usually compensated by the presence of a mandibular second premolar, which is approximately the same size of the mandibular first premolar (Table 12). A smaller maxillary second premolar usually compensates for the slightly oversized mandibular incisors and brings the overall ratio to normal values. A balanced overall ratio does not guarantee an optimal intercuspation. In the present study, the combination of mandibular premolar width differences and the higher Bolton anterior ratio led to the final occlusion —the tendency to a Class II canine in the presence of acceptable overjet and overbite and a Class I molar. The improvement of the canine relationship implied either an exaggeration of the Class I molar to a Class III or an interproximal recontouring of the maxillary premolars. To finally restore a balanced anterior ratio in Class III malocclusion, both solutions needed to be followed by the interproximal recontouring of the mandibular incisors or by prosthetic procedures to increase the widths of the maxillary incisors, usually the lateral incisor.

Alkofide and Hashim (9) found that a statistically significant difference was apparent when the anterior and overall ratios of their study were compared to those of Bolton's study. Their results disagreed with the results obtained by the present study.

Comparison of Tooth Size Ratios among Occlusal Categories of the Present Study to the Studies of another Groups of Population

The results of the present study were compared to the results of another studies that determined prevalent tendency for intermaxillary tooth size discrepancies among different malocclusion groups in another groups of population. Table 30 and Table 31 showed that there was no statistical significant differences for both anterior and overall ratios in each malocclusion groups between the present study and the study of Crosby & Alexander (5), but there were significant differences when the present study compared to the studies of Nie and Lin (8) as well as Alkofide and Hashim (9).

Crosby and Alexander (5) studied the tooth size ratios among different malocclusion groups in USA. They did not include Class III patients in their study.

They did not differentiate between sexes and did not mention the ratio of sexes in each group. In their study, it was not clear whether there was sexual dimorphism for tooth size ratios. The present study had separated sexes and demonstrated that there was no sexual dimorphism for tooth size ratios, thus the sexes were combined in the ratio of 1:1 for each groups.

Nie and Lin (8) studied the tooth size ratios among different malocclusion groups in China. Their study consisted of 60 subjects who served as the normal occlusion group and 300 patients divided into 5 malocclusion groups ; Class I with bimaxillary protrusion, Class II Division 1, Class II Division 2, Class III and Class III surgery. Occlusion categories of these were classified by the Angle's classification, coincided with skeletal categories. Their tooth size ratios were greater than another studies. A cause of this result may be from a method of their study, which was different to the others. In the method of their study, tooth size measurements were performed on the models by the YM-2115 Three Dimension Measuring Machine that might overestimate the results.

Alkofide & Hashim (9) studied the tooth size ratios among different malocclusion groups in Saudi patients. The study consisted of 240 pretreatment orthodontic casts; 60 cases in each malocclusion classes, in addition to normal occlusion. There were significant differences for tooth size ratios when the present study was compared to the study of Alkofide & Hashim (9).

In clinical practice, clinicians often note the discrepancy of tooth size and skeletal pattern but seldom pay attention to tooth size discrepancy between the maxillary and mandibular teeth. The present study showed the tendency of mandibular tooth size excess in Angle Class III malocclusion and the tendency of maxillary tooth size excess in Angle Class II malocclusion. This indicated that it might be reasonable for orthodontists to do interproximal stripping or tooth extraction in the mandibular dentition for Class III malocclusion and in the maxillary dentition for Class II malocclusion. These results suggested that the Bolton analysis is important and should be considered when diagnosing, planning, and predicting prognosis in clinical orthodontics.

CHAPTER 6

CONCLUSION

Samples were comprised of 360 good quality pretreatment models that permanent teeth erupt and present from right first molar to left first molar. Samples were comprised of both sexes; 180 males and 180 females. Samples evenly distributed in each class; 120 models in Class I, 120 models in Class II, and 120 models in Class III malocclusion. The results from the analysis of the sample revealed that

1. In general, male crown measurements were slightly larger and showed a higher variability than the female measurements.

2. Higher variability was found in the maxillary teeth as compared to the mandibular teeth. The maxillary first molars, the maxillary central incisors and lateral incisors presented higher variability and should be examined clinically as being the causative factors leading to a tooth size discrepancy.

3. Tooth size ratios were compared among three classifications, there were statistical significant differences between Class II and both Class I, III malocclusion in the posterior as well as overall ratios, whereas no significant difference was found among malocclusion classes in the anterior ratio.

4. There were no statistical significant differences between males and females in the anterior, posterior and overall ratios of all groups of malocclusion.

5. The means for the anterior and overall ratios for the malocclusion classes in the present study compared to those of Bolton's, a significant difference existed only for the anterior ratio in Class III malocclusion. The anterior ratios in Class III malocclusion of the present study was larger than the Bolton's anterior ratio.

6. Tooth size ratios were compared between normal occlusion and another malocclusion classes. There was no statistical significant difference between normal occlusion and Class III malocclusion for all ratios, whereas significant differences were found between normal occlusion and both Class I and Class II malocclusion excepting the posterior ratio in Class I malocclusion.

7. The means for the anterior and overall ratios in the present study (Thai patients) were statistically significant different when they were compared to those of Nie & Lin (Chinese patients.)and Alkofide & Hashim (Saudia patients). However, there was no significant difference between the results of the present study and those of Crosby & Alexander (American patients). But the study of Crosby & Alexander did not include Class III cases.

It demonstrated that intermaxillary tooth size discrepancy might be one of the important factors in the cause of malocclusions.

Clinical Implication

This study compared the anterior and overall ratios between normal occlusion and Class I, Class II and Class III malocclusions. The anterior and overall ratios in normal occlusion used to compare with the present study came from Bolton's work that studied in White American and the work of Dechkunakorn et al. (32) that studied in Thai population.

When comparing the anterior ratios in Class I, Class II and Class III malocclusions of the present study to those of Bolton in normal occlusion, there was a significant difference ($p<0.05$) only in Class III malocclusion (Table 28). The anterior ratios of this study were also compared to those of Dechkunakorn et al. It was found that there were significant differences in Class I and Class II malocclusions ($p<0.05$) (Table 25).

The results indicated that different orthodontic planning or treatment occurred according to value that was used as a standard. If the anterior ratios from Bolton's work are used as a standard for normal occlusion, a treatment method will be reduce the size of lower anterior teeth or increase the size of upper anterior teeth for correction of intermaxillary tooth size discrepancy in Class III malocclusion. If the anterior ratios from the work of Dechkunakorn et al. are used as a standard, no correction of intermaxillary tooth size discrepancy in Class III malocclusion will be use in treatment.

As well as an comparison in the overall ratios, if the Bolton's value was used as standard normal occlusion, there were no significant differences in Class I, Class II and Class III malocclusions (Table 29). When the overall ratios from the present study

was compared to those of Dechkunakorn et al., there were significant differences in Class I ($p<0.05$) and Class II ($p<0.001$) (Table 27). This indicated that if the Bolton's overall ratio was used as a standard, there would be no treatment in correction of intermaxillary tooth size discrepancy in Class I, Class II and Class III malocclusions. But if the overall ratio from the work of Dechkunakorn et al. are used as a standard, a treatment will be reduce the size of upper teeth or increase the size of lower teeth for correction of intermaxillary tooth size discrepancy in Class I and Class II malocclusion.

Since the difference in races of sample has resulted in different tooth sizes, the ratios from the study of Dechkunakorn et al., which studied in Thai sample, should be used as standard values of normal occlusion for an analysis of intermaxillary tooth size discrepancy in Thai patients. It should be more accurate and appropriate orthodontic treatment for Thai patients than using Bolton's values which were derived from White American.

Limitation of This Study

1. The study should use the criteria of sample selections such as divided classification as subcategories of malocclusion, for example: Class II Division 1 and Class II Division 2 in Class II categories.

2. This study used Angle's Classification for classifying the occlusal categories. Angle's classification took interest in interarch dental relationship. The criteria of sample selections should use skeletal pattern that coincided to Angle categories.

3. The study should select and divide the samples by using the severity of malocclusion in criteria, for example: Class I normal occlusion and Class I bimaxillary protrusion in Class I categories, Class II orthodontic treatment and Class II orthognathic surgery treatment in Class II categories as well as Class III orthodontic treatment and Class III orthognathic surgery treatment in Class III categories.

Suggestions from This Study

For the method of selection the samples

The present study focused an attention on the dental malocclusion regardless of the skeletal pattern that coincided with it . This may be an important impact on the

classification of samples. For example, some skeletal type II malocclusions can be converted to dental Class I malocclusions by forward movement of permanent first molar due to the premature loss of the deciduous second molar, so the Class I group may contain skeletal type I and type II patients.

Further research projects, therefore, should classify the samples by the criteria of Angle's classification and skeletal discrepancies. Furthermore, subcategories of malocclusion and the severity of malocclusion should use in classifying the occlusal groups.

For the method of measurement the samples

Over the years, the methods of measuring tooth size has been carried out with either of two basic instruments: (1) the sliding calipers with a vernier scale and (2) a pair of engineer dividers used in conjunction with a millimeter rule. With the latter, holes are punched on a card and the distances are then measured with the millimeter rule (44,45,46). Hunter and Priest (14) found the sliding calipers to be more accurate, while the dividers gave a consistently higher mean reading. The present study, therefore, used the sliding calipers with a vernier scale.

Today, many orthodontists are moving toward digitizing orthodontic records and using computers to assist with diagnosis and treatment planning. Proffit (2) stated that an advantage of digitizing tooth dimensions was that the computer could quickly provide a tooth size analysis. The available methods have been developed for measuring tooth sizes e.g. laser scanning (47), photocopies and computer-aided space analysis (48), sonic digitization (49), YM-2115 Three Dimension Measuring Machine (8,50), computerized methods: QuickCeph and Orthocad (51).

A direct measurement on three-dimensional objects has a high potential for error and variability. An advantage of the machine and computerized method is that a competent assistant can easily be trained to digitize the landmarks and print out the results, thus saving valuable time for an orthodontist. For example, YM-2115 Three Dimension Measuring Machine (8,50) is used extensively in the precision machine tool industry. The accuracy of the 3 orthogonal axes was all 0.01 mm. The frictionless air bearing and touch trigger probe is used to identify the measuring point, and to

record the corresponding X, Y, and Z coordinates automatically to a computer data file.

In further research projects, the machines and computerized methods are recommended to use.

REFERENCES

1. Dipaolo RJ and Boruchov MJ. Thoughts on stripping of anterior teeth. J Clin Orthod 1971; Sep: 510-511.
2. Proffit WR. Contemporary orthodontics. 3rd ed. Saint Louis: The C V Mosby Company, 2000.
3. Bolton WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthod 1958; 28: 113-130.
4. Bolton WA. The clinical application of a tooth-size analysis. Am J Orthod 1962; 48: 504-29.
5. Crosby DR and Alexander CG. The occurrence of tooth size discrepancies among different malocclusion groups. Am J Orthod Dentofacial Orthop 1989; 95: 457-61.
6. Fields HW. Orthodontic restorative treatment for relative mandibular anterior excess tooth size problems. Am J Orthod Dentofacial Orthop 1981; 79: 176-183.
7. Smith SS, Buschang PH and Watanabe E. Interarch tooth size relationships of 3 populations: "Does Bolton's analysis apply?" Am J Orthod Dentofacial Orthop 2000; 117: 169-174.
8. Nie Q and Lin J. Comparison of intermaxillary tooth size discrepancies among different malocclusion groups. Am J Orthod Dentofacial Orthop 1999; 116: 539-544.
9. Alkofide E and Hashim H. Intermaxillary tooth size discrepancies among different malocclusion classes: a comparative study. J Clin Pediatr Dent 2002; 26(4): 383-388.
10. Nance HN. Limitations of orthodontic treatment. Am J Orthod 1947; 33: 253-301.
11. Neff CW. The size relationship between the maxillary and mandibular anterior segments of the dental arch. Am J Orthod 1957; 27: 138-147.

12. Hixon EH and Oldfather RE. Estimation of the sizes of unerupted cuspid and bicuspid teeth. Angle Orthod 1958; 28: 236-240.
13. Barrett MJ, Brown T and MacDonald MR. Dental observations on the Australian Aborigines: Mesio-distal crown diameters of permanent teeth. Aust Dent J 1963; 8: 150-155.
14. Hunter WS and Priest WR. Errors and discrepancies in measurement of teeth size. J Dent Res 1960; 39(2): 405-414.
15. Moorrees CFA and Reed RB. Biometrics of crowding and spacing of the teeth in the mandible. Am J Phys Anthropol 1954; 12: 77-88.
16. Lavelle CLB. Maxillary and mandibular tooth size in different racial groups and in different occlusion categories. Am J Orthod 1972; 6: 29-37.
17. Santoro M, Ayoub ME, Pardi VA and Cangialosi TJ. Mesiodistal crown dimensions and tooth size discrepancy of the permanent dentition of Dominican Americans. Angle Orthod 2000; 70(4): 303-7.
18. Sperry TP, Worms FW, Isaacson RJ and Speidel TM. Tooth size discrepancy in mandibular prognathism. Am J Orthod Dentofacial Orthop 1977; 72: 183-90.
19. Freeman JE, Maskeroni AJ, and Lorton L. Frequency of Bolton tooth-size discrepancy among orthodontic patients. Am J Orthod Dentofacial Orthop 1996; Jul: 24-27.
20. Kesling HD. The philosophy of the tooth positioning appliance. Am J Orthod and Oral Surg 1945; 31: 297-304.
21. Stifter J. A study of Pont's, Howes', Rees', Neff's and Bolton analysis on Class I adult dentitions. Angle Orthod 1958; 28: 215-225.
22. Ho CTC and Freer TJ. The Graphical Analysis of tooth width discrepancy. Aust Orthod J 1994; 13: 64-70.
23. Tonn P. Uber die mesio-distalen Zahnbreitenrelationen der Zahne des Oberkiefers zu den entsprechenden des Unterkiefers bei normalen and anormalen Okklusion. Diss Berlin, 1937. Quoted in: Lundstrom A. Intermaxillary tooth width ratio and tooth alignment and occlusion. Acta Odontol Scand 1954; 12: 265-292.
24. Lundstrom A. Intermaxillary tooth width ratio and tooth alignment and occlusion. Acta Odontol Scand 1954; 12: 265-292.

25. Lundstrom A. Variation of tooth size in the aetiology of malocclusion. Am J Orthod 1955; 41: 872-876.
26. Richardson ER and Malhotra SK. Mesiodistal crown dimension of the permanent dentition of American Negroes. Am J Orthod 1975; 68(2): 157-164.
27. Srisopak SS. A study on the size of permanent teeth, shovel-shaped incisors and paramolar tubercle in Thai skulls. J Dent Assoc Thai 1972; 22: 199-205.
28. Bijaphala P. A study of the size of permanent teeth of Thai people. J Dent Assoc Thai 1974; 25: 37-51.
29. Kiatpongsan S. Mesio-distal width of teeth in normal occlusion of a group of Thai. Mahidol Dent J 1992; 12(1): 43-47.
30. Patanaporn V. Tooth size analysis. MS. Thesis in Orthodontics. Faculty of Graduate studies, Chulalongkorn University, 1982
31. Boondej A, Sirinavin I. Permanent tooth size in Northern Thai with normal occlusion and soft tissue function. CM Dent J 1990; 11: 78-86.
32. Dechkunakorn S, Chaiwat J, Sawaengkit P, Anuwongnukroh N and Nisalak P. Dental arch in normal occlusion : part 1 : size of teeth and percentage ratio between lower and upper teeth. J Dent Assoc Thai 1995; 45: 159-167.
33. Katz MI. Angle classification revisited 1: is current use reliable? Am J Orthod Dentofacial Orthop 1992; 102: 173-9.
34. Katz MI. Angle classification revisited 2: a modified Angle classification. Am J Orthod Dentofacial Orthop1992; 102: 277-84.
35. Pair JW, Luke L, White S, Atchinson K, Englehart R and Brennan R. Variability of study cast assessment among orthodontists. Am J Orthod Dentofacial Orthop 2001; 120: 629-38.
36. Halazonetis DJ. The Bolton ratio studied with the use of spreadsheets. Am J Orthod Dentofacial Orthop 1996; Feb: 215-219.
37. Dahlberg G. Statistical methods for medical and biological students. New York: Interscience Publications; 1940.
38. Houston WJB. The analysis of errors in orthodontic measurements. Am J Orthod 1983; 83: 382-90.

39. Heusdens M, Dermaut L and Verbeeck R. The effect of tooth size discrepancy on occlusion: An experimental study. Am J Orthod Dentofacial Orthop 2000; 77: 189-91.
40. Binder RE and Cohen SM. Clinical evaluation of tooth size discrepancy. J Clin Orthod 1998; 9: 544-546.
41. Axelsson G and Kirveskari P. Crown size of perment teeth in Icelanders. Acta Odontal Scand 1983; 41: 181-186.
42. Arya BS, Savara BS, Thomas D and Clarkson Q. Relation of sex and occlusion to mesiodistal tooth size. Am J Orthod 1974; 66: 479-86.
43. Bishara SE, Jakobsen JR, Abdallah EM, and Fernandoz GA. Comparisons of mesiodistal and buccolingual crown dimension of the permanent teeth in three populations from Egypt, Maxico and the United States. Am J Orthod Dentofacial Orthop 1989; 96(5): 416-422.
44. Doris JM, Bernard BW and Kuftinec MM. A biometric study of tooth size and dental crowding. Am J Orthod Dentofacial Orthop 1981; Mar: 326-336.
45. Richmond S. Recording the dental cast in three dimensions. Am J Orthod Dentofacial Orthop 1987; 92: 199-206.
46. Shellhart WC, Lange DW, Kluemper GT, Hicks EP and Kaplan AL. Reliability of the Bolton tooth-size analysis when applied to crowded dentitions. Angle Orthod 1995; 65: 327-334.
47. Kuroda T, Motohashi N, Tominaga R and Iwata K. Three-dimensional dental cast analyzing system using laser scanning. Am J Orthod Dentofacial Orthop 1996; 110: 365-9.
48. Schirmer UR and Wiltshire WA. Manual and computer-aided space analysis: A comparative study. Am J Orthod Dentofacial Orthop 1997; 112: 676-80.
49. Mok KHY and Cooke MS. Space analysis: a conparison between sonic digitization (DigiGraph^{TM} Workstation) and the digital caliper. Eur J Orthod 1998; 20: 653-661.
50. Braun S, Hnat WP and Fender DE. The form of the human dental arch. Angle Orthod 1998; 68: 29-36.

51. Tomassetti JJ, Taloumis LJ, Denny JM and Fischer JR. A comparison of 3 Computerized Bolton tooth-size analyses with a commonly used method. Angle Orthod 2001; 71(5): 351-357.

BIOGRAPHY

NAME	Miss Arunee Tiptawonnugul
DATE OF BIRTH	21 March 1973
PLACE OF BIRTH	Chanthaburi , Thailand
INSTITUTIONS ATTENDED	Mahidol University, 1991-1996: Doctor of Dental Surgery
	Mahidol University, 2002-2004: Master of Science (Orthodontics)
POSITION & OFFICE	Department of Orthodontics
	Faculty of Dentistry
	Mahidol University