# *CEPHALOMETRIC NORMS OF MALAYSIAN MALAYS COMPARED WITH GLASGOW CAUCASIANS*


**MOHD SHAFEEQ HASAN**

B.D.S.


This thesis was submitted in partial fulfilment of the requirements for the degree of

MSc (Med. Sc.) in Orthodontics.


University of Glasgow

Orthodontic Unit

Glasgow Dental School

Glasgow, Scotland

United Kingdom


April 1998

# CONTENTS

## Chapter 7. *Results*



## Chapter 8. *Discussion*



## Chapter 9. *Conclusion and Suggestions for Future Studies*

# *List of Figures*

## Chapter 5. *Methods*



## Chapter 7. *Results (Superimposition)*

# *List of Tables*

## Chapter 7. *Results*

## ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to Professor W.J.S. Kerr, project supervisor, for his help, inspiration, encouragement and masterful guidance. Also many thanks to Dr. J.H. McColl for his assistance in statistical analyses.

Deepest gratitude to Dr. Sarah Haniza Abdul Ghani, Dr. NorAzian Adnan and Dr. Rohanah Hussain for their help in the sample collection in Kuala Lumpur.

Not forgetting Dr. Shiu-Shiung Lin for his advice in the PCDIG computer programming. Many thanks to all the staff at Glasgow Dental Hospital and School and everybody who has helped with their time, effort and expertise, thank you very much.

I would also like to thank both my parents for their endless support and inspiration, and I have come to realise just how lucky I am to have them and thanks for always taking care of the loose ends that I always leave undone.

Last but not least, to my wife Azlina, for her patience, inspiration and enduring support. Not forgetting her professional advice, expertise and caring, and for showing me exactly what the word sacrifice really means. Thanks for being there from the start which has allowed me to live out a dream, and to her I dedicate this thesis.

## *Declaration*

This thesis is the work of MOHD SHAFEEQ HASAN. No part of the thesis has been previously submitted in support of an application for any degree or qualification of any university.

MOHD SHAFEEQ HASAN

## ABSTRACT

The aim of this study was to describe the lateral cephalometric norms for Malaysian Malays with normal occlusion and in addition, to document the differences between this sample and a Glasgow Caucasian sample. This is particularly to facilitate the description of dentofacial pattern/relationship, diagnosis and treatment planning, evaluation of treatment results, evaluation of stability and future relationships and as a baseline data for further research.

The sample consist of 54 Malays (24 males and 30 females) with a mean age of 23.1 years and 45 Caucasians (20 males and 25 females) with a mean age of 22.6 years. Cephalometric tracings were done and the landmarks were digitized using PCDIG computer software. Twenty subjects were randomly selected from each group for the error study.

The results indicated that:

1. The Malaysian Malays have a slightly more prognathic Maxilla and Mandible compared to the Caucasians. Otherwise, the skeletal pattern was almost similar.

2. The cranial base dimension suggested that the Malays have a smaller anterior and total cranial base length.

3. The Malays have a bimaxillary dental proclination. The upper incisor was $7^0$ more proclined than that of the Caucasians and the mandibular incisor was $5^0$ more proclined.

4. The Interincisal angle was $13^0$ smaller in the Malays.

5. The lower incisor was more prominent in relation to the A-Pog line (4mm more anterior compared to the Caucasian sample).

6. The soft tissue profile indicated that the Malays have a more prominent lower face and a flatter upper face. The lips are more procumbent and the nose are flatter compared to the Caucasian sample.

7. Similar differences were noted when the males and females were compared between the two populations, except that the Malay females have a larger lower facial height and mandibular corpus.

8. When comparing the Malays, the males have a slightly more prognathic maxilla and a smaller cranial base angle than the females. The male subjects also showed a larger dimension in all skeletal linear measurements. There were no differences in the dental variables.

9. As the Malays, the male Caucasians have a smaller cranial base angle and linear measurements were larger in the males compared to females. There were no significant differences in the dental parameters.

# *Chapter 1.* INTRODUCTION

The introduction of cephalometric radiography has brought about a change in orthodontic diagnosis and treatment planning. Cephalometric analyses are used to determine the relationship of the dentofacial skeleton and changes that are associated with growth and/or orthodontic treatment (Bishara and Fernandez, 1985).

Racial characteristics can lead to significant cephalometric variations. One set of cephalometric norms cannot be used for all populations (Bacon *et al.,* 1983). Many studies have shown significant differences in cephalometric standards between different racial groups and even between closely related ethnic group. Accurate diagnostic evaluation involves a comparison of individual's cephalometric findings with the norms for his or her ethnic group (Kapila, 1987). Therefore, cephalometric norms can be utilised to assist in diagnosing the region and severity of existing dentofacial discrepancies.

At present, there are no established cephalometric norms for the Malaysian Malays. For many years, diagnosis and treatment planning are based on norms of other racial groups which on the whole are different.

The purpose of this study is therefore to establish cephalometric norms for Malaysian Malays and in addition, to compare the differences with the Caucasian population in Glasgow. This study would act as a baseline for further research in this area.

# Chapter 2. LITERATURE REVIEW

## 2.1 FACIAL FORM and AESTHETICS

Facial aesthetics or beauty has been a topic for discussion for many centuries by artists , philosophers, orthodontists, plastic surgeons, critics and laymen. The question is what is aesthetics and what constitutes an excellent face? The perception of beauty from one person might differ from another and in different parts of the world. Stoner (1955) has suggested that each man's concept of facial beauty is a function of his own innermost sensibility and understanding. He also pointed out that there was a considerable agreement that certain faces fell well within the definition of harmony of form.

In the 18th-century, a German philosopher Alexander Baumgarten introduced the term aesthetics. It is derived from the Greek word for perception (aisthesis), to denote what he conceived as the realm of poetry, a realm of concrete knowledge in which content is communicated in sensory form. The term was subsequently applied to the philosophical study of all the arts and manifestations of natural beauty. In general, we can say that aesthetics is concerned with understanding beauty, particularly as it is manifest in art and human form.

Human form has been measured for many reasons. One has been to aid humanity's self-portrayal in sculpture, drawing and painting. Another has been to test the relation of physique, to health, temperament and behavioural traits (Jacobson, 1995).

Orthodontists, Maxillofacial and Plastic Surgeons have long pursued the study of human face and profile, in search of guidelines for the reconstruction of facial dysmorphology and correction of malocclusion.

The portrayal of human form began in ancient Egypt. They developed a quantitative system that defined the proportions of the human body using a grid system which was called canon (Iversen, 1975). Linear measurements of facial profile and frontal view were also seen in the head of a standing statue of the god Buddha. This was according to the highly detailed proportional system of 'Sariputra' dated 1200AD which closely reflected the natural relations of parts of the body to each other (Ruelius, 1974).

In the 15th century, names like Leonardo da Vinci (1459-1519) and Albrecht Durer (1471-1528) surfaced. Leonardo da Vinci's (1490) drawings included a study of facial proportions and projection of a coordinate system. Each face was posed in "natural head position". Albrecht Durer, on the other hand strictly uses geometric methods, providing a proportionate analysis of Leptoprosopic (long) and the Euryprosopic (short) face in a coordinate system. He developed a method for utilizing landmarks and defined the variations in facial morphology based on profile. In addition to the linear measurements and coordinate system, Durer also derived angular measurements. It was believed that his measurements were the key to the evolution of cephalometric analysis.

Petrus Camper (1722-1789) developed a horizontal line (Camper's horizontal) for angular measurements used to characterised evolutionary trends in studies of facial morphology and aging. He stressed that the facial angle is a standard measurement in craniology. Retsius introduced the term prognathic and orthognathic and these are associated to Camper's illustration of facial form (Martin, 1955).

The evolution of cephalometry in the twentieth century is associated with Edward Angle's publication of his classification of malocclusion (1899). In 1922, a method for standardized head radiography was introduced by Pacini. Broadbent (1931) in the United States and Hofrath (1931) in Germany simultaneously published methods to obtain a standardised head radiography. This advancement has enabled orthodontist to capture the field of cephalometry (measurements of living head) from the anatomist and anthropologist.

## 2.2 SEARCH FOR AN IDEAL

Lucien de Coster (1939) was the first to publish an analysis based on proportional relationship of the face. He used distortions of a Cartesian coordinate system to portray differences in location of landmarks in comparison to norms.

Study of harmonious facial profile has started since antiquity. From here, many researchers have gone into the search for an ideal. Angle devoted much effort to a search for an ideal facial form, in parallel with his search for the ideal dental occlusion. He consulted Professor Wuerpel, a famous artist at that time and was ridiculed. The artist suggested that the immense variety in human faces makes it impractical to specify any one facial form as ideal.

Angle then concluded that ideal facial aesthetics would result when the teeth were placed in an ideal occlusion and that is when the arches had been expanded so that all the teeth were in ideal occlusion. This concept did not go unchallenged. Calvin Case argued that expansion of arches will neither result in stability nor good aesthetics.

Cephalometric radiography helps in orthodontic diagnosis and treatment planning but it is important to recognised that it is only for descriptive purposes. The principle of cephalometric analysis is to compare the patient to a normal reference group, so that the differences between the patient's actual dentofacial relationship and those expected for his or her racial ethnic group are revealed.

Cephalometric norms have been part of orthodontics for more than half a century. The first cephalometric analysis was first popularised in the United States after the second World War in the form of Down's Analysis. This analysis was developed based on a reference group of 20 untreated adolescent whites selected because of their ideal dental occlusion (Downs, 1948). It was designed to illustrate the spread of all measurements of an individual by plotting these values on a chart at ±1 and ±2 standard deviations around a vertical representing the midpoint of the distribution of all variables. This was later known as a "wiggle".(Jacobson, 1995).

Since the correction of malocclusion or dysmorphology is based on normalising the dentition and face to achieve balance and harmony, Andresen (1930) stated that individual norms determine the actual treatment plan of a patient. The extent to which these norms should be followed is still a question and requires considerable interpretation and caution.

Jacobson (1995) stated that diagnosis and treatment planning was more than just looking at norms or standards. It involved the assessment of psychosocial impact on dentofacial disfigurement, physiologic impact of the malocclusion on lip function, jaw movement, breathing, growth and development, speech, mastication and oral health. In addition to that it also encompassed the anatomic aspects of tooth malalignment, occlusion, dental and basal arch relations, facial shape, soft tissue configuration, facial disharmony, and asymmetry of the face , dentition, and tooth morphology.

Hence, diagnosis and treatment planning should be based on a dynamic process rather than on numbers from cephalometric analysis. Generally, it should be determined on grounds in attaining an aesthetic and functional optimum for each individual patient rather than adherence to strict anatomic norms of occlusion and facial configuration.

Then the question arises as to why the orthodontist searches for an ideal? The answer is simply to have a guideline or a framework for diagnosis and treatment. Cephalometric norms can be an invaluable aid to the clinician in determining patient abnormalities. Norms define ideal cephalometric measurements for a patient based on factors like age, sex, size and race (Engel,1981).

Studies have shown that norms or ideal occlusion and divine proportion of hard and soft tissues can, at best determine a direction for treatment planning. It must do so within the confines of an individual norm derived from the specific characteristics of the actual patient (Jacobson, 1995).

Racial characteristics may lead to important cephalometric variations. Many studies have established that cephalometric measurements of different racial groups have measurable differences (Downs, 1948., Cotton *et al.,* 1951., Altemus, 1960., Drummond, 1968., Nanda and Nanda, 1969., Chan, 1972., Kowalski *et al.*, 1974,1975., Kerr and Ford, 1986., Cook and Wei, 1988.). One set of standards cannot be used in cephalometric analysis for all populations, therefore the insights of normal dentofacial pattern of various ethnic groups are vital for clinical and research purposes. Cephalometric standards should be available for different populations, sex, and age groups.

# 2.3 RACES OF MANKIND

## *2.3.1 RACE AND ETHNIC GROUP*

Richardson in 1980 looked into racial differences in dimensional traits of the human face and concluded that it was difficult to define race. Reference to groups was more accurately made on the basis of ethnic groups that were bound by some common bond, such as Swedish Whites, American Whites etc.

The assumption that there were but three primary races of mankind (Caucasoid, Negroid, and Mongoloid) became invalid during the European age of exploration, when new continents, new island chains, and new land masses were discovered along with new populations that did not fit into one of the three groupings mentioned above.

It is now thought that there are between six and ten major geographically delimited groupings. Nonetheless, there is a broad consensus among workers for designating nine historical geographic races (Britannica Encyclopedia, 1997).

1) the African geographic race, which consists of sub-Saharan Africa
2) the European geographic race, which includes Europe, North Africa, and the Middle East
3) the Asiatic geographic race, which includes Central, East, and Southeast Asia and the Aleutian Islands and western Alaska
4) the American Indian geographic race, which includes all of North and South America except western Alaska and the Aleutian Islands

5) the Indian geographic race, which includes the Indian subcontinent to Nepal and the Iranian border
6) the Australian geographic race, including Australia and (formerly) Tasmania
7) the Polynesian geographic race, including the island arch defined by Easter Island, the Hawaiian Islands, and New Zealand
8) the Micronesian geographic race, including the islands of Yap, Pohnpei, and Guam, with continuities with the Polynesian group
9) the Melanesian geographic race, which includes the island of New Guinea with continuities with the Australian group.

Even with a listing of nine geographic races, there still exist a number of isolated local populations in taxonomic limbo.

The human species is in the process of accelerated evolutionary change brought about by alterations in the relative size of different populations and by the breaching of geographic and social barriers to gene flow. When hundreds of thousands of individuals moved from South Korea and Vietnam to the United States, from Pakistan and India to England, or from Turkey to Germany and Denmark, gene frequencies in the host countries can scarcely stay static. It is evident that the human gene pool will be vastly different in a hundred years.

Based on this, it is logical to say that there are differences in facial characteristics between different races and ethnic groups. Many investigators have concluded that there are significant differences between the diverse ethnic and racial groups (Downs, 1948., Cotton *et al.,* 1951., Altemus, 1960., Drummond, 1968., Nanda and Nanda, 1969., Chan, 1972., Kowalski *et al.*, 1974,1975., Kerr and Ford, 1986., Cook and Wei, 1988.). This further stresses the importance of having a different cephalometric norms for different races.

Cephalometric norms based on lateral skull cephalometric values have been established for Caucasians, Indians, Iranians, Chinese, Japanese, African Americans, North Mexican, French, African, Hawaiian and Australian Aborigines (Table 1).

Malaysians are made up of three main ethnic groups namely the Malays, Chinese and Indians of which the Malays are the largest. Among the three, the Malays have yet to have their own standard cephalometric norms.

## 2.3.2 THE MALAYS

Malaysia is situated in the heart of South East Asia just north of the Equator. It is made up of two regions, consisting of Peninsular Malaysia (between Thailand and Singapore) on the Malay Peninsula, and East Malaysia (Sabah and Sarawak) which is situated across the South China Sea in the north part of the island of Borneo. Together, these two regions cover an area of about 330,434 square kilometres.

The astonishing characteristic of Malaysia's population today is its high variety of racial backgrounds. It is one of the archetype of a multi-racial society in the world. The Malaysian population consists mainly of the Malays, Chinese and Indians, whereby the majority resides on the peninsula. The Iban, Kadazan and Bidayuh are the main ethnic groups in Sabah and Sarawak. Bahasa Malaysia is the official national language but Chinese dialects and Tamil are still widely used in their respective communities, and most of the people are able to communicate in English.

The Malays in general are the ethnic people of the Malay Archipelago which stretches from the Malay Peninsular to the islands of the South Pacific. People residing in the Malay Archipelago are of fair to tanned skin with dark hair and dark coloured eyes. They are of average stature. By nature, Malays are basically mild mannered, very well cultured and industrious people with a flair for fine arts, trading, sailing and many varied interests.

The Malays forms about 62% of the ethnic group in Malaysia. Most of them resides in the West Malaysia and a substantial minority in Sarawak and a smaller group in Sabah. A distinction may be drawn between Malays long settled in the country, especially the Malays of the East Coast of the Peninsula, in Sarawak, Sabah, and those who crossed the Straits of Melaka from Sumatra and settled in considerable numbers during the latter part of the nineteenth and in the twentieth centuries.

Other ethnic groups regarded for practical purposes as Malays, and most of whom have settled in the country (mainly in the Malay Peninsula ) since 1850, include the Javanese, Banjarese, Boyanese, Bugis and Minangkabau.

The diversity within a racial group makes it difficult or impossible to actually define Malays. Furthermore, interracial marriages have likewise heightens the dilemma in categorising racial groups. Therefore, the term Malaysian Malays in general portrays a wide variety of ethnic composition.

# 2.4 CEPHALOMETRIC NORMS AND STANDARDS

## 2.4.1 Principles and Application

The term 'Norms' and 'Standards' have been used synonymously in many instances. Norms can be defined as average values representing a group or a population, which is a standard that is required , expected or designated as normal. Standards, on the other hand is an accepted or approved example of something against which others are judged or measured. Therefore, in order to have a standard, norms should be first derived for a certain group or population.

Cephalometric radiography has been in orthodontics practices for more than fifty years. The advantages of applying the cephalometric radiographic technique to craniofacial measurements are that it facilitates measurements on living subjects which would otherwise be impossible (Goldsman, 1959). It is no longer a tool or foundation for research but a necessary adjunct to a complete case analysis from which a diagnosis is made. Since then many different cephalometric variables and analysis have been established. (Tweed, 1946., Downs, 1948., Riedel, 1952., Steiner, 1953., Sassouni, 1955., Harvold, 1974., Jacobson., 1975., McNamara, 1984) .

Most of these analyses are based on established norms that have been statistically derived from a population samples. Studies in cephalometrics norms can be broadly divided into two groups based on sample selection:

*1. Unselected samples.*

This type of study does not specify criteria for sample selection. Samples were collected at random and those with severe malocclusion were excluded. This method was used by Coben (1955), Kowalski *et al.*(1974, 1975), Popovich and Thompson (1977), Engel and Spolter (1981) and Trenouth *et al.* (1985).

*2. Selected samples.*

Many studies have used samples according to a certain criteria (Downs, 1948., Riedel, 1952., Goldsman, 1959., Miura *et al.*, 1965., Drummond, 1968., Kerr and Ford, 1986., Altemus, 1960., Bishara and Fernandez, 1985). This type of research comprises more than eighty percent of studies on norms. Frequently, patients with ideal or normal occlusion with Class I incisors and molar relationship were selected. Those with pleasing facial profile were also included. Williams and Katz (1992), selected their samples based on facial beauty or aesthetics rather than dental occlusion alone. They also concluded that choosing a sample of Class I occlusion patients on the basis of aesthetics is a credible, valid and necessary variable to include when attempting to establish cephalometric norms.

Trenouth *et al.*(1985) and Cooke and Wei (1988) claimed that normative data based on selected sample, using ideal or normal occlusion is biased and not a true representative of a population. How much of this is true is still a subject for discussion. Do average values from random sampling accurately represent a norm or standard of a population? Or should a norm be set by a selected sample consisting of subjects with ideal characteristics to which others should be compared?

All this will direct us back to the definition of normal. What is normal and what is a normal occlusion? Normal can be defined as regular, common or typical and normal occlusion (British Standard Institution, BS 4492:1983) is an occlusion that satisfies the requirements of function and aesthetics but in which there may be minor irregularities of individual teeth. From here, it is fair to say that norms based strictly on normal occlusion cannot be rejected totally and are not necessarily biased when seen from a certain perspective.

A sample selected at random contains a mixture of malocclusions. Norms derived from these might not necessarily portray the true average of a population or groups, considering that an unbalanced sample predominated by subjects with malocclusion might occur. This indefinitely will shift the values and gives a false impression of the norms.

On the other hand, norms derived from an ideal or normal occlusion should also be regarded with caution since we are assuming that a normal occlusion is normal for every population. This is important when studying and comparing different ethnic groups. Normal is not easy to define and normal in one ethnic population might not be considered normal in others, the same as beauty or aesthetics.

However, based on previous studies it was shown that the distribution of malocclusion between different populations was reasonably similar. Foster and Day (1974), in their survey of malocclusion on 1,000 Shropshire school children aged 11-12 years showed that 44.3% had Class I occlusion, 27% had Class II division 1 malocclusion, 18% had Class II division 2 malocclusion and 3.5% with a true Class III malocclusion. Massler and Frankel(1951) examined 2,758 Caucasian North American children between

14-18 years of age and found that 50.1% had angle Class I , 16.7% had Angle Class II division 1, 2.7% with Class II division 2 and 9.4% with Class III. Altemus (1959) examined 3,289 North American Negro children between the ages of 12-16 years old. He found similar results with Angle Class I being dominant with 66.4%, 10.6% with Class II division 1, 1.6% had Class II division 2 and 5% had Class III.

In Malaysia, the study of malocclusion in three ethnic groups showed a similar trend (Woon, 1982). She found that 40% of the Malays had Class I occlusion, 35% had Class II and 24.9% had Class III malocclusion. The Chinese group, 42.1% had Class I, 29.2% had Class II and 29% had Class III. As for the Indian , 38.6% had Class I, 47% had Class II and 14.4% had Class III.

Based on these data, the distribution of malocclusion appears to vary between population but is predominated by Class I occlusion. Hence, we can assume that Class I occlusion is considered normal in the majority of population and therefore selection of sample based on ideal or normal occlusion is rational. Perhaps a study comparing the two methods of sample selection utilising the same ethnic group would be desirable in order to investigate any significant difference in the average values and range.

The argument should not be centred on sample selection alone when other factors also play and important role in the derivation of a population norms. Trenouth *et al.*(1985), gave five factors that can influence normative data:

*1. Age.*

Size and shape of the craniofacial region changes with age. Therefore, standards must be controlled for age. Changes in size tend to be more significant than changes in shape towards the end of the growth period.

*2. Sex.*

Different standards are often used for males and females because size is particularly influenced by sex after puberty.

*3. Ethnic group.*

Different ethnic groups showed measurable differences in craniofacial relationship. (Cotton *et al.*, 1951., Miura *et al*, 1965., Nanda and Nanda, 1972., Kowalski *et al.*, 1974,1975., Kerr and Ford, 1986., Shalhoub *et al.*, 1987). Therefore, norms for one ethnic group cannot be used for measuring a different population.

As our society becomes heterogenous, ethnic-specific cephalometric norms may become difficult to create and less appropriate for assessing specific population.

*4. Secular changes.*

Lavelle (1972a and b) described secular influences on stature, craniofacial size and dental arch and tooth dimensions, but it is not known if there is any influence on craniofacial shape.

*5. Social class.*

Social class is thought to have some control on craniofacial morphology but to date, no effect has been demonstrated.

In summary, cephalometric norms are used primarily to provide means of comparing an individual dentofacial characteristics with a population average. This is important to enable the clinician to recognise any significant dentoalveolar deviation or abnormalities. Apart from that, the relationship of skeletal, dental and soft tissue structures can be assessed.

Cephalometric norms should be utilised for the correct population or group in order to avoid errors in diagnosis and treatment. The patient examined should be compared with norms that have been derived from population that are similar to the subject with regard to race, age and sex.

## 2.4.2 RELEVANCE OF NORMS

For diagnostic purposes, cephalometric analyses are based upon comparing the values acquired from a certain individuals to an average values or norms for his or her own population, age group or sex. All cephalometric analyses are collection of measures, norms, and/or ideals which in combination provide information needed for treatment planning and assessment (Moyers, 1988). Today, cephalometric analyses have played a major part in the dentofacial diagnostic procedure. However, caution must be taken when using the norms or average since man is multiform and not uniform and variation exist among individuals. Furthermore, cephalometric analyses only give the anteroposterior and vertical dimension of the facial configuration and does not include the transverse dimension.

Moyers (1988) stressed the importance of using cephalometric norms correctly. We should know that normal means varies according to sex, ethnic groups, facial types and age. When using norms derived from a population, clinician should be aware of the variability of the measurements. As no patient is a member of a sample from which a mean was obtained, the mean is useful only if the sample which it summarizes is relevant to the clinical comparison. Furthermore, norms should be properly constructed as a range and not as a single value. In clinical practice, the extent of the range and its changes with facial type and age often are a more practical interest than the mean itself (Moyers, 1988).

Despite the problems and limitations of norms, it provides a quantitative way of comparing an individual to a certain standard. A clinician can assess how far a patient deviates from the normal. Those who fell outside the normal range can be said to have a dysplasia and one might even regard the means as a reasonable treatment objectives for this group of patients.

In summary, cephalometric norms are based on a two dimensional image and orthodontic diagnosis and treatment planning should not be based on this only. Other records like history taking, study models, clinical examination and other radiographic examination are needed for a complete diagnosis.

# 2.5 NORMS IN VARIOUS ETHNIC GROUPS

## *2.5.1 SAMPLE STUDIED (Table 1)*

Research on cephalometric norms have started about 50 years ago. Downs (1948), looked into 20 Caucasians with clinically excellent occlusion and good facial balance. He then develop what is now called the Downs analysis.

Since then many studies have evolved in many parts of the world (table 1). Researchers have studied facial configurations in various ethnic group. Most studies have looked into subjects with normal or excellent occlusion (Downs, 1948., Altemus, 1960., Nanda and Nanda, 1969., Bishara and Fernadez, 1985., Kerr and Ford, 1986., Faustini *et al*, 1997). However, as mentioned earlier (section 2.4.1), some workers have debated that selecting patients on the basis of normal occlusion are bias and not relevant (Trenouth *et al.*, 1985., Cooke and Wei, 1988).

The size of the samples studied ranges from 18 to as many as 381. From table 1, more than 50% of the sample studied consist of adults 18 years and over. The literature showed that the major ethnic group studied were those of European or American in origin. There were also a number of work done in the Middle East and the African continent. However, studies on norms in Asia were mainly centred around Hong Kong Chinese and Japanese and this only started in the late seventies and in the eighties. This is most probably due to the realisation that a single norm develop for a certain ethnic group is not applicable to others. There were no studies yet on the Malaysian Malays. The summary of the samples studied are laid out in table 1.

Table 1: Samples Studied in other populations

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Downs | 1948 | 12 - 17 | Mixed<br>10 M<br>10 F | 20 | Caucasian | 1. Clinically excellent occlusion.<br>2. Good facial balance. | 1. Downs analysis | 1. Mean ± S.D.<br>2. Range. |
| Cotton, Takano and Wong | 1951 | 11 - 34<br>*Cotton's group* | Mixed<br>10 M<br>10 F | 20 | San Francisco Bay Area Negro | 1. Sample did not in every instant represent perfect occlusal relationship.<br>2. No person with real malocclusion included. | 1. 10 values of Downs analysis.<br>2. Compare with values from Downs Analysis. | 1. Means<br>2. Range. |
| | | 21<br>*Takano's group* | 10 M<br>10 F | 20 | American-born Japanese (Seattle Nisei) | Similar to Downs:<br>1. Clinically excellent occlusion.<br>2. Good facial balance. | | |
| | | 11 - 16<br>*Wong's group* | 10 M<br>10 F | 20 | American-born Chinese (San Francisco) | 1. Normal arch relationship.<br>2. Good facial pattern. | | |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Craven | 1958 | 4 - 11 | Mixed<br>12 M<br>15 F | 27 | Australian Aborigines | - | 1. Wilders analysis to radiographic cephalometry. | - |
| | | 12 - 20 | 9 M<br>20 F | 29 | | | | |
| Altemus | 1960 | 12 - 16 | Mixed<br>40 M<br>40 F | 80 | North American Negro | 1. Normal occlusion.<br>2. All permanent teeth present except third molar. | 1. Downs analysis<br>2. Sassouni analysis. | - |
| Miura *et al.* | 1965 | 7.9-12.3 | Mixed<br>40 M<br>50 F | 90 | Japanese | 1. Normal Occlusion | | 1. Mean ± S.D.<br>2. Min & Max<br>3. t-test at 95%CI |
| Drummond | 1968 | 8 - 23 | - | 40 | American Negro | 1. Clinically acceptable occlusion.<br>2. Angle Class I molar.<br>3. Acceptable facial profile. | 1. Manual tracing. | 1. Students t-test<br>2. Mean ± S.D.<br>3. Standard error. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Wei | 1968 | <br>18.3 - 19<br>18.2 - 27 | Mixed<br>84 M<br>23 F | 107 | Chinese (South eastern part of China) | 1. Absence of obvious craniofacial deformity.<br>2. No orthodontic treatment done before.<br>3. Young adults of Chinese ethnic descent. | 1. Error study done. | 1. Mean ± S.D.<br>2. T-test<br>3. Correlation coefficient.<br>4. Dahlbergs statistics for error study. |
| Choy | 1969 | Skull age<br>32.77<br>26.56 | Mixed<br>18 M<br>25M | 43 | Hawaiian Skull | 1. Skulls of pure Hawaiian origin.<br>2. Class I and II occlusion. | 1. Cephalometrics from skull.<br>2. Analysis:<br>- Bjork<br>- Downs<br>- Steiner<br>- Tweed | - |
| Nanda and Nanda | 1969 | 17 - 25 | Mixed<br>25 M<br>25 F | 50 | North Indian Hindu (Uttar Pradesh, India) | 1. Excellent occlusions<br>2. Well balanced facial patterns.<br>3. Full complement of permanent teeth.<br>4. Proper intercuspation.<br>5. No rotation of incisors.<br>6. No crowding of incisors | 1. Downs analysis<br>2. Error analysis on 25 x-rays. | |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Bugg *et al.* | 1972 | 4-5 | - | 60 | Latin American | 1. Normal occlusion<br>2. Good facial profile | | |
| Chan | 1972 | 18 - 33 | M | 30 | Cantonese Chinese in Hong Kong (Kwangtung Province) | 1. Clinically excellent occlusion.<br>2. Class I molar relationship.<br>3. Pleasing and acceptable profile.<br>4. No previous orthodontic treatment. | 1. Downs analysis.<br>2. Alabama Analysis.<br>3. Soft tissue analysis. | 1. Mean ± S.D.<br>2. T-test. |
| Yen | 1973 | 11.8 | M | 50 | Taiwan Chinese | 1. Neutroclusion of permanent first molars.<br>2. Optimal labiolingual relationship of incisors.<br>3. Physiological balance of facial musculature. | 1. Tracings only.<br>2. Steiner analysis. | - |
| Kowalski *et al.* | 1974 | 20-60 | Male | 244<br><br>381 | Black<br><br>White | 1. Normal medical histories | 1. 13 Steiner variables used | 1. Mean ± S.D.<br>2. Linear discriminant analysis<br>3. Stepwise discriminant analyisis |

| Author | Year | Age | Sex | Size | Origin | Criteria for sample selection | Methods | Statistics |
|---|---|---|---|---|---|---|---|---|
| Velarde | 1974 | 12-25 | Mixed<br>31 M<br>9 F | 40 | North American from Chinhuanhua, Mexico | | 1. Compare with Ricketts, Steiner and Tweed samples | |
| Garcia | 1975 | 14.4-17.2 | Mixed<br>34 M<br>25 F | 59 | Mexican-American from Los Angeles | 1. Class I molar<br>2. Class I canines<br>3. Complete permanent dentition except for third molars<br>4. Overbite approximately 3.5 mm.<br>5. No increase in overjet<br>6. Minimal/no rotation<br>7. Minimal/no crowding or spacing. | 1. Compare with Downs, Steiner & Alabama analyses | 1. Means ± S.D.<br>2. Range<br>3. Frequency distribution.<br>4. T-test to compare analysis and sex. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Kowalski *et al.* | 1975 | 20 - 50 | M | 177 | Black American | - | 1. Steiner's analysis. | 1. Mean ± S.D.<br>2. Discriminant function analysis. |
| | | | M | 300 | White American | | | |
| | | | M | 65 | Sioux Indians (Hunkpapa) | | | |
| | | | M | 31 | Peruvian Cashinahua Indians | | | |
| Christie | 1977 | | Mixed<br>39 M<br>43 F | 82 | Caucasian | 1. Near ideal untreated occlusion. | | |
| Davoody & Sassouni | 1978 | <br>10.9-14.3<br>11 - 14.7 | Mixed<br>33 M<br>35 F | 68 | Iranians | 1. Normal occlusion<br>2. Normal molar and canine relation.<br>3. Minimum overjet and overbite.<br>4. Minimum crowding and spacing. | 1. Sassouni analysis. (archial & wigglegram)<br>2. Downs analysis.<br>3. Composite superimposition. | 1. Multivariate analysis of variance. |
| | | 10.1-14<br>11.6-13.4 | 29 M<br>28 F | 57 | American Caucasian | | | |

| Author | Year | Age | Sex | Size | Origin | Criteria for sample selection | Methods | Statistics |
|---|---|---|---|---|---|---|---|---|
| Jacobson | 1978 | | Mixed<br>27 M<br>27 F | 54 | South African Bantu-speaking Negroes (Skulls) | 1. Number of teeth present.<br>2. Excellence of occlusion. | 1. Lateral cephalometric radiograph taken on skulls.<br>2. Traced. | |
| | | | 23 M<br>23 F | 46 | Adult Caucasiods | | | |
| Engel and Spolter | 1981 | 5 - 26 | - | 72 | Japanese | 1. Unselected sample<br>2. subjects with severe malocclusion not included. | 1. Landmarks & measurements from Rocky Mountain data system used. | 1. Mean<br>2. Linear regression equation.<br>3. t-test |
| Bacon *et al.* | 1983 | 20-30 | Male | 40<br>40 | Cameroonian Bantu<br>Caucasian (French) | 1. Presence of all teeth<br>2. No obvious craniofacial anomalies<br>3. Class I molar<br>4. Class I canine<br>5. Normal profile | | 1. Students T-test to compare 2 groups<br>2. Factorial analysis to detect discriminant factors between 2 groups |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Foo & Woon | 1983 | 18 - 25 | Males | 41 | Malaysian Chinese | 1. Pleasing facial appearance.<br>2. Complete dentition except third molars.<br>3. Class I molars<br>4. No previous orthodontic treatment or orthognathic surgery. | 1. Traced twice and average of two tracings taken.<br>2. Tracing repeated if difference > $1^0$ or 1mm. | 1. Mean<br>2. No statistical analysis and S.D. |
| Foo & Woon | 1984 | 18 - 25 | F | 30 | Malaysian Chinese | 1. Complete dentition except third molars.<br>2. Class I molar<br>3. No crowding. | 1. Downs analysis<br>2. Bjorks analysis<br>3. Traced twice and average of two tracings taken.<br>4. Tracing repeated if difference > $1^0$ or 1mm. | 1. Mean ± S.D. |

| Author | Year | Age | Sex | Size | Origin | Criteria for sample selection | Methods | Statistics |
|---|---|---|---|---|---|---|---|---|
| Bishara & Fernandez | 1985 | 12.7-13 | Mixed<br>36 M<br>45 F<br><br>20 M<br>15 F | 81<br><br><br><br>35 | North Mexican<br><br><br><br>Iowa | 1. Normal Occlusion<br>2. Acceptable facial form<br>3. Class I molar<br>4. Class I canine<br>5. Little/no incisor crowding<br>6. No apparent dental/ skeletal discrepancies<br>7. No previous orthodontic treatment | 1. Combination of analysis:<br>-Bishara<br>-Jacobson<br>-Downs<br>-Reidel<br>-Steiner<br>-Tweed<br>-Wylie | 1. Mean ± S.D.<br>2. Min & Max<br>3. Analysis of Variance to compare 4 groups<br>4. F value for overall & intergroup comparison |
| Trenouth *et al.* | 1985 | 9 - 11 | Mixed<br>61 M<br>73 F | 134 | Manchester Caucasian | 1. No previous orthodontic treatment.<br>2. Unselected sample. | 1. Error analysis done on 30 of the originals.<br>2. Results were compared with: -<br>- Nymegen (Prahl-Anderson *et al.*,1979)<br>- Michigan studies. (Riolo *et al.*, 1974) | 1. Mean ± S.D.<br>2. T-test to compare the three groups. |

| Author | Year | Age | Sex | Size | Origin | Criteria for sample selection | Methods | Statistics |
|---|---|---|---|---|---|---|---|---|
| Kerr and Ford | 1986 | 10-15 | Male | 30<br>30<br>30 | Stockholm<br>Belfast<br>Glasgow | 1. Class I incisor | | 1. Unpaired t-test<br>2. Stepwise discriminant analysis |
| Shalhoub *et al.* | 1987 | 20-46 | Mixed<br>24 M<br>24 F | 48 | Saudi Arabians | 1. Class I malocclusion<br>2. No skeletal discrepancies in 3-planes of space<br>3. No previous orthodontic treatment before | | 1. Dahlbergs' method for error study<br>2. 2-tailed students t-test |
| Cooke and Wei | 1988 | 12 | Mixed<br>120 M<br>120 F | 240 | Southern Hong Kong Chinese | 1. Random sample | 1. Radiograph taken at 'orthoposition'.<br>2. Traced and digitized. | 1. Dahlber's formula for error study. |
| Cooke and Wei | 1988 | 12 | M | 120<br>40 | Hong Kong Chinese<br>Caucasian in Hong Kong | 1. Unselected samples. | 1. Error study done. | 1. Dahlbergs statistics for error study.<br>2. Mean ± S.D. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Kapila | 1988 | 9 - 15 | Mixed<br>28 M<br>28 F | 56 | Kenyan children of Kikuyu descent (Bantu origin) | 1. Pleasing facial profile<br>2. Mild crowding of < 5mm.<br>3. Class I molars and canines. | 1. Radiographs traced twice & mean taken if difference ≤ $1^0$.<br>2. Repeated tracings done if error beyond acceptable range | 1. Mean ± S.D.<br>2. Min. & Max.<br>3. T-test to compare with white & black American children. |
| Argyropoulos and Sassouni. | 1989 | <br>11.5<br><br><br>11.9<br>11.7 | Mixed<br>24 M<br>30 F<br><br>29 M<br>28 F | <br>54<br><br><br>57 | <br>Greek<br><br><br>American Caucasian | 1. Ethnic background.<br>2. Good health.<br>3. Same age range.<br>4. Acceptable facial relationship with normal lip seal.<br>5. Angle Class I molar & canine.<br>6. Incisor contact & well aligned teeth.<br>7. No history of previous orthodontic treatment.<br>8. Minor rotation, slight overjet & overbite acceptable. | 1. Sassouni analysis. (archial & Wigglegram).<br>2. Downs<br>3. Composite superimposition.<br>4. Error analysis done on 20 random sample. | 1. Multivariate analysis of variance. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Ben-Bassat *et al.* | 1992 | 11-13 | Mixed<br>7 M<br>11 F | 18 | Jewish East European | 1. Early permanent dentition<br>2. No previous orthodontic treatment<br>3. Minor rotations<br>4. Mild anterior crowding<br>5. Overjet ≤ 4mm<br>6. Overbite ≤ 5mm | 1. Traced twice<br>2. Superimposition done<br>3. Digitised | 1. Mean ± S.D.<br>2. T-test to compare between sexes & between total sample & Downs' Analysis |
| Lew *et al.* | 1992 | 18 - 24 | Mixed<br>36 M<br>36 F | 72 | Chinese | 1. Harmonious facial profiles<br>2. Presence of intact dentition. | 1. To determine Soft Tissue cephalometric norms.<br>2. Radiograph traced & photograph & judge by panels.<br>3. Error analysis done on 10 radiographs. | 1. Mean ± S.D.<br>2. Student's t-test<br>3. Dahlberg's analysis |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Criteria for sample selection* | *Methods* | *Statistics* |
|---|---|---|---|---|---|---|---|---|
| Bishara *et al.* | 1997 | 12 .5 | Mixed<br>39 M<br>51 G | 90 | Egyptian | 1. Class I molar & canine.<br>2. Little or no incisor crowding.<br>3. No apparent dental or skeletal discrepancies.<br>4. No history of orthodontic treatment. | 1. Two investigators involved in landmark identification.<br>2. Error analysis done. | 1. Descriptive statistics.<br>2. Analysis of Variance.<br>3. F-value |
| | | 13.0 | 33 M<br>22 F | 55 | Iowa Whites | 1. Acceptable occlusion.<br>2. Well orientated dentition with respect to the face. | | |
| Faustini *et al.* | 1997 | 15.0<br>13.8 | Mixed<br>18 M<br>25 F | 43 | Black Americans of African descent | 1. No orthodontic treatment before.<br>2. Late mixed or permanent dentition.<br>3. Class I dental occlusion.<br>4. Minimal crowding of ≤ 4mm. | 1. MESH diagram analysis.<br>2. Compare with caucasian norms. | 1. Error study<br>- one way ANOVA<br>- I.C.C.<br>2. two tailed single sample t-test |

## 2.5.2 FINDINGS (Table 2)

Enlow (1982), has pointed out that there were age, sex and population differences in the pattern of facial structures. Population norms from a given sample are not necessarily valid for other groups particularly if ethnic variations are involved. Studies comparing various ethnic groups have revealed significant difference in facial morphology and configuration (table 2).

The demarcation exist when the whites were compared to non-whites. Significant differences were found in the dental and skeletal morphology between this two groups. It was shown in most studies that the non-whites have a more protrusive denture compared to the whites. These protrusions were mainly clear in the black population in many parts of the world (Altemus, 1960., Drummond, 1968., Kowalski *et al.*, 1974, 1975., Fonseca and Klein, 1978., Jacobson, 1978., Bacon *et al.*, 1983., Kapila, 1988). Prominent maxilla and mandible were also found to be common in this ethnic group.

In Asia, the Chinese showed a more flat profile compared to other population (Wei, 1968). However, the incisors and alveolar bone were found to be slightly prominent (Wei, 1968., Yen. 1973). They also showed a tendency for a more vertical growth (Cooke and Wei, 1988).

The differences in facial morphology is not only seen in different ethnic groups but even within a similar population. Kerr and Ford (1986) showed differences in facial form between Caucasians. Studies on the Orientals also showed differences in facial pattern when comparing Chinese from different parts of the world. Foo and Woon

(1983), stated that there are differences in cephalometric norms within the same racial group but it is not as marked as between races.

The summary of the findings found in the literature are presented in table 2.

Table 2 : Findings in other populations

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Findings* |
|---|---|---|---|---|---|---|
| Downs | 1948 | 12 - 17 | Mixed<br>10 M<br>10 F | 20 | Caucasian | 1. There is a facial pattern that represents mean or average form for individuals possesing excelent occlusion.<br>2. Excessive deviation from mean suggest abnormalities.<br>3. The manner in which all the variables fit together and their correlation with type, function and aesthetics are more important than single reading. |
| Craven | 1958 | 4 - 11<br><br>12 - 20 | Mixed<br>12 M<br>15 F<br><br>9 M<br>20 F | 27<br><br>29 | Australian Aborigines | 1. No significant differences in cranial and facial analysis.<br>2. Aborigines have more midfacial prognathism compared to the Swede and Bantu.<br>3. Individual variation among Aborigines similar to the Swede and Bantu.<br>4. Growth changes in facial profile of the Aborigines similar to the Swede and Bantu.<br>5. Alveolar prognathism in Aborigines increase with age in contrast to the Swede and Bantu. |

| Author | Year | Age | Sex | Size | Origin | Findings |
|---|---|---|---|---|---|---|
| Altemus | 1960 | 12 - 16 | Mixed<br>40 M<br>40 F | 80 | North American Negro | 1. There are measurable differences in the configurations of facial patterns between North American Negro and Caucasians.<br>2. North American Negro showed dental prognathism.<br>3. Lower facial height is larger than the upper in North American Negro.<br>4. The skeletal pattern (in profile) of the Negro and Caucasian seem to be similar. |
| Miura *et al.* | 1965 | 7.9-12.3 | Mixed<br>40 M<br>50 F | 90 | Japanese | 1. Variations occur within ethnic groups and to a greater extent between ethnic groups.<br>2. Retroposition of the mandible and labial inclination of the upper and lower incisors were typical of the Japanese face. |
| Drummond | 1968 | 8 - 23 | - | 40 | American Negro | 1. The Negro's mandibular plane is steeper than caucasian.<br>2. The maxilla is more anteriorly placed in the Negro.<br>3. The upper and lower incisors are more procumbent in the Negro. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Findings* |
|---|---|---|---|---|---|---|
| Wei | 1968 | <br>18.3 - 19<br>18.2 - 27 | Mixed<br>84 M<br>23 F | 107 | Chinese (South eastern part of China) | 1. Chinese facial profile retrognathic compared with other populations.<br>2. The maxillary alveolar is more prognathic in the Chinese.<br>3. Chinese had low facial convexity and flat facial profile.<br>4. Increased prognathism was associated with increased cranial base angulation. |
| Choy | 1969 | Skull age<br>32.77<br>26.56 | Mixed<br>18 M<br>25M | 43 | Hawaiian Skull | 1. The Hawaiian has a craniofacial structure similar to the White groups.<br>2. Hawaiians showed greater alveolar prognathism compared to the Whites.<br>3. The Hawaiian showed flat mandible and occlusal plane.<br>4. The maxillary incisors of the Hawaiian are very erect while the mandibular incisors are more labially inclined. |

| Author | Year | Age | Sex | Size | Origin | Findings |
|---|---|---|---|---|---|---|
| Nanda and Nanda | 1969 | 17 - 25 | Mixed<br>25 M<br>25 F | 50 | North Indian Hindu (Uttar Pradesh, India) | 1. The skeletal norms for the Hindus were almost similar to the American White, but were retrusive when compared with the Chinese, Negro and Japanese.<br>2. The dental pattern of the Hindus were more protrussive than the American Whites.<br>3. The males have a more protrusive skeleto-dental pattern compared to the females. |
| Chan | 1972 | 18 - 33 | M | 30 | Cantonese Chinese in Hong Kong (Kwangtung Province) | 1. Facial pattern of Chinese different from that of other ethnic group.<br>2. Chinese have more protrusive upper and lower incisors.<br>3. Chinese have a much more protrusive lips. |
| Yen | 1973 | 11.8 | M | 50 | Taiwan Chinese | 1. Flattening of the upper face due to vertical inclination of the nasal bone and flat contour of the frontal bone.<br>2. Slight lack of chin prominent.<br>3. Procumbent incisors and alveolar and bone. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Findings* |
|---|---|---|---|---|---|---|
| Kowalski *et al.* | 1974 | 20-60 | Male | 244<br><br>381 | Black<br><br>White | 1. Study showed substantial differences between the two ethnic groups.<br>2. Lower incisors are more proclined in the Blacks.<br>3. The maxilla is more prominent in the Blacks.<br>4. The interincisal angle is higher in Whites. |
| Garcia | 1975 | 14.4-17.2 | Mixed<br>34 M<br>25 F | 59 | Mexican-American from Los Angeles | 1. Skeletally the Mexican American sample was more protrusive than the Caucasian sample.<br>2. The lower incisor of the Mexican American sample was more labially inclined.<br>3. Upper incisor of the Mexican American sample was more procumbent than the Caucasian sample.<br>4. The interincisal angle was more acute in the Mexican American sample. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Findings* |
|---|---|---|---|---|---|---|
| Kowalski *et al.* | 1975 | 20 - 50 | M | 177 | Black American | 1. There are substantial differences in dentofacial morphology in all four groups. |
| | | | M | 300 | White American | 2. Proclination of lower incisor to the NB line is much higher in the non-White sample. |
| | | | M | 65 | Sioux Indians (Hunkpapa) | 3. The Black group showed the highest degree of prognathism and the Cashinahua the lowest. |
| | | | M | 31 | Peruvian Cashinahua Indians | 4. The results support the need for modification of these norms according to race. |
| Christie | 1977 | | Mixed<br>39 M<br>43 F | 82 | Caucasian | 1. People with normal occlusion tend to have more brachyfacial than dolicofacial pattern.<br>2. Many of the norms vary significantly with different facial patterns. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Findings* |
|---|---|---|---|---|---|---|
| Davoody & Sassouni | 1978 | <br>10.9-14.3<br>11 - 14.7 | Mixed<br>33 M<br>35 F | 68 | Iranians | 1. Skeletally, Iranian showed flat skeletal profile due to retruded maxilla and protruded chin. They also showed larger vertical dimensions anteriorly and posteriorly.<br>2. Dentally, Iranians demonstrates more lip convexity due to bidental protrusion with a smaller interincisal angle.<br>3. Iranians have smaller overbite. |
| | | 10.1-14<br>11.6-13.4 | 29 M<br>28 F | 57 | American Caucasian | |
| Fonseca and Klein | 1978 | 20-30 | F | 40 | American Negro woman | 1. Maxilla & mandible more protrusive in Negros.<br>2. More proclined upper & lower incisors.<br>3. Shorter middle facial height & longer LFH in Negros.<br>4. Protrusive upper & lower lip. |
| | | 18-25 | F | 20 | Caucasian Female | |
| Jacobson | 1978 | | Mixed<br>27 M<br>27 F | 54 | South African Bantu-speaking Negroes (Skulls) | 1. The South African Negro showed forward position of maxilla.<br>2. The labial inclination of upper incisors of South African Negro is not as pronounced as those of American Negro but similar to the inclination found in Caucasians.<br>3. The lower incisors in South African Negro are severely proclined due to large ANB angle. |
| | | | 23 M<br>23 F | 46 | Adult Caucasiods | |

| Author | Year | Age | Sex | Size | Origin | Findings |
|---|---|---|---|---|---|---|
| Scheideman *et al.* | 1980 | <br>21-35<br>20-32 | Mixed<br>32 M<br>24 F | <br>56 | Caucasian | 1. Data provides measurements that are useful in diagnosis & treatment.<br>2. Horizontal soft-tissue chin prominence was nearly equal for males and females relative to subnasale, soft tissue nasion and glabella. |
| Engel and Spolter | 1981 | 5 - 26 | - | 72 | Japanese | 1. The Japanese have a more protrusive denture compared to the Caucasian counterpart.<br>2. The Japanese have a more vertical growth pattern than Caucasian.<br>3. From the frontal view, the Caucasian is narrower in width. |
| Bacon *et al.* | 1983 | 20-30 | Male | 40<br><br>40 | Cameroonian Bantu<br><br>Caucasian (French) | 1. The position and angulation of the incisors appeared to be the strongest discriminant factors.<br>2. Higher values for convexity, ANB angle, SNA angle and lower facial height were representative racial characteristics in the Bantu.<br>3. Upper face height and facial taper were dominant traits in whites. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Findings* |
|---|---|---|---|---|---|---|
| Foo & Woon | 1983 | 18 - 25 | Males | 41 | Malaysian Chinese | 1. There are differences in cephalometric norms within the same racial group but not as marked as between races. |
| Foo & Woon | 1984 | 18 - 25 | F | 30 | Malaysian Chinese | 1. Facial pattern of Chinese female similar to those established by Hong (1960) and Wei (1966).<br>2. Dental prognathism found compared to the Caucasian.<br>3. The mandible is more prognathic compared to other studies of Chinese origin. |
| Bishara & Fernandez | 1985 | 12.7-13 | Mixed<br>36 M<br>45 F<br><br>20 M<br>15 F | 81<br><br><br><br>35 | North Mexican<br><br><br><br>Iowa | 1. Significant differences between boys and girls within each population were found in the skeletal and linear parameters.<br>2. North Mexican boys have a more convex soft tissue profiles than the girls.<br>3. Between population, there is absence of significant differences.<br>4. North Mexican female have a relatively more protrusive mandible than the Iowa female |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Findings* |
|---|---|---|---|---|---|---|
| Trenouth *et al.* | 1985 | 9 - 11 | Mixed<br>61 M<br>73 F | 134 | Manchester<br>Caucasian | 1. The greatest differences were observed between the Manchester and Nymegen group (Holland).<br>2. The Nymegen group was skeletal II relative to the Manchester group and had higher lower incisor angle.<br>3. The Manchester and Michigan group (North America) were closer to each other than either were to the Nymegen group. |
| Kerr and Ford | 1986 | 10-15 | Male | 30<br>30<br>30 | Stockholm<br>Belfast<br>Glasgow | 1. Celtic groups show greatest similarity but exhibit differences in shape and size from the Swedish group at 10 & 15 years.<br>2. The Swedes show more prognathism of the jaws and teeth and a larger horizontal linear dimension.<br>3. Study showed differences in facial form between the three groups. |
| Shalhoub *et al.* | 1987 | 20-46 | Mixed<br>24 M<br>24 F | 48 | Saudi<br>Arabians | 1. The Saudi female showed a protrusive maxilla compared to the Saudi male and North American white female.<br>2. The Saudi male has a more protrusive midface and lesser amount of overbite compared to their North American counterpart. |

| Author | Year | Age | Sex | Size | Origin | Findings |
|---|---|---|---|---|---|---|
| Cooke and Wei | 1988 | 12 | Mixed<br>120 M<br>120 F | 240 | Southern Hong Kong Chinese | 1. No highly significant sex differences in the angular measurements were found.<br>2. Chinese males were 1-2% larger in overall linear measurements.<br>3. Upper and lower lip were more protrusive relative to the E-plane, in the Chinese males.<br>4. Overbite greater in males.<br>5. The Chinese was found to have sagittal Class I with bimaxillary dental and alveolar prognathism.<br>6. Significant differences found between the Chinese males and a comparative Caucasian male. |
| Cooke and Wei | 1988 | 12 | M | 120<br><br>40 | Hong Kong Chinese<br><br>Caucasian in Hong Kong | 1. The Chinese has a shorter cranial base, a shorter maxilla and a more obtuse angle between the mandibular ramus and posterior skull base.<br>2. Proclined maxillary and mandibular incisors in the Chinese.<br>3. Mandibular incisors tip more anteriorly to A/Po line in the Chinese.<br>4. The Y-axis is greater in the Chinese suggesting a more vertical growth.<br>5. The Chinese soft tissue profile showed a less prominent, and more obtuse, nose and chin but a more protrusive upper and lower lips. |

| Author | Year | Age | Sex | Size | Origin | Findings |
|---|---|---|---|---|---|---|
| Kapila | 1988 | 9 - 15 | Mixed<br>28 M<br>28 F | 56 | Kenyan children of Kikuyu descent (Bantu origin) | 1. Statistically significant differences were found between Kikuyu children with Black and White American children.<br>2. Kikuyu children showed greater mandibular inclination relative to the Frankfort horizontal plane and a less proclined mandibular incisors in comparison with Black American children.<br>3. Kikuyu children have a more prognathic maxilla, a greater mandibular incisor inclination and a more acute interincisal angle. |
| Argyropoulos and Sassouni. | 1989 | 11.5<br><br>11.9<br>11.7 | Mixed<br>24 M<br>30 F<br><br>29 M<br>28 F | 54<br><br>57 | Greek<br><br>American Caucasian | 1. Ethnic differences in facial traits exist.<br>2. The Greek showed prognathic profile. The entire degree of prognathism is located in the mandible.<br>3. More mandibular alveolar prognathism in Greek compared to Americans.<br>4. The upper posterior facial height is larger and the lower posterior facial height is smaller in the Greeks.<br>5. Cranial base angle is smaller in Greeks resulting in a more protrusive mandible.<br>6. The position of lower incisor is more lingual in Greeks than American Caucasian. |

| *Author* | *Year* | *Age* | *Sex* | *Size* | *Origin* | *Findings* |
|---|---|---|---|---|---|---|
| Park *et al.* | 1989 | 18 | Mixed<br>35 M<br>45 F | 80 | Korean | 1. Skeletal pattern generally simialr to caucasians.<br>2. Facial convexity larger in Koreans.<br>3. Upper & Lower incisors more protrussive and labially inclined.<br>4. Upper & lower lips more protrusive in Koreans. |
| Ben-Bassat *et al.* | 1992 | 11-13 | Mixed<br>7 M<br>11 F | 18 | Jewish East European | 1. The cephalometric pattern of Jewish East European adolescents differs significantly, mainly regarding convex profile.<br>2. They concluded that the clinical objective of orthodontic treatment for the ethnic group studied, is not necessary a straight profile. |
| Lew *et al.* | 1992 | 18 - 24 | Mixed<br>36 M<br>36 F | 72 | Chinese | 1. The Chinese nose was less prominent and the nasolabial angle was less obtuse copared to White norms.<br>2. Both upper and lower lips were more protrussive in the Chinese.<br>3. The upper lip curvature was greater and the soft-tissue chin thickness was less in the Chinese. |

| Author | Year | Age | Sex | Size | Origin | Findings |
|---|---|---|---|---|---|---|
| Bishara *et al.* | 1997 | 12 .5<br><br><br>13.0 | Mixed<br>39 M<br>51 G<br>33 M<br>22 F | 90<br><br><br>55 | Egyptian<br><br><br>Iowa Whites | 1. Egyptian boys have a tendency toward bimaxillary dental protrusion and a decreased overbite as compared with the Iowa boys.<br>2. Egyptian girls have a relatively more convex profile and a tendency toward mandibular dental protrusion.<br>3. Generally, there is a great similarity in the overall facial morphology between the Egyptian and Iowa population. |

# 2.6 CEPHALOMETRY

## 2.6.1 HISTORY

Cephalometry is the study of skull radiographs, which includes the lateral, postero-anterior and oblique projections. It is a technique for abstracting the complexities of live human head into a geometric scheme (Moyers, 1988). The lateral view is the most frequently used in Orthodontics than any other cephalometrics because the facial variations of greatest orthodontics importance are in the sagittal plane and other views are difficult to interpret and measure.

Contemporary practice utilises the *cephalogram*, a two-dimensional radiographic image on film. The input to cephalometrics is biology but the output is geometry. From the cephalogram, a *cephalometric analysis* is derived whereby anatomic structures are reduced to landmark points, curves and lines. It is primarily a collection of numbers to compress information from the cephalogram for clinical and research purposes. The analysis provides information on size and growth, skeletal pattern, morphology, deformation and displacement of craniofacial structures.

The objective of cephalometrics is to interpret this geometric expression of cranial anatomy (Moyers, 1988). Conventionally it proceeds in two stages:

1. The geometric abstraction is "measured" using distances and angles.
2. These measurements are compared with population standards, ideals, or their own earlier values.

From the comparisons emerge "analysis", "prediction" or "forecast", "facial types", and assessment of "growth" and "the effects of treatment" (Moyers, 1988).

Broadbent (1937) emphasised the three dimensional nature of facial relationship and recommended that postero-anterior and lateral cephalometric radiographs should be acquired.

Craniostat was invented by Antropologists for orientating dry skulls, making it easier for comparison. These led to modification of the technique which is the standardized radiographic procedure, in order to study the living human head.

The first attempt to establish standards for exact measurement of the skull was done by Pacini in 1922. The skull was orientated in cephalometric planes and measurements were made based on radiographs. About a decade later advances were made by Broadbent (1931) in the United States of America and Hoftrath (1931) in Germany independently introduced standardised lateral head films. At the same time Simon's (1922) system of gnathostatics , a method for orientating orthodontic cast was in use. All these formed a new technology known as the radiographic cephalometry.

Since the introduction by Broadbent, the lateral cephalometric radiograph has become an essential tool in orthodontic analysis. Downs (1952) reported a method which demonstrated the use of cephalometric measurements in diagnosis and treatment planning. Many analyses have evolved since and about 50 different methods of assessing skeletal pattern have been documented (Brown, 1981). The assessments encompassed dental and skeletal structures and some methods also included a growth prediction. All cephalometric analysis were a collection of measures, norms, and/or ideals which in combination, provides information needed for treatment planning and assessment. The total analysis is dependent on the value of the individual measures and on the adequacy of their combination (Moyers, 1988). Different problems require different solutions and no one cephalometric analysis is appropriate for all clinical needs.

## 2.6.2 CEPHALOMETRIC TECHNIQUE

The method of radiographic cephalometry was derived from anthropologic craniometric studies and the use of the Broadbent-Bolton cephalometer invented in 1931. Measurements of dry skull from osteologic landmarks, called craniometry, was applied to living subjects through palpation of bony landmarks. This is called cephalometry, but it is not accurate since measurements were taken through skin and soft tissue coverage. The discovery of X-rays by Roentgen in 1895 and the measurements of the head from a radiographic image and later standardization of cephalometric technique using high powered X-ray machine and a head holder (Broadbent, 1931., Hofrath, 1931) have revolutionised the dental profession.

A cephalometric apparatus comprises a cephalostat or a head holder, an X-ray source, collimators, filters and a cassette holder. The X-ray source must produce sufficiently high voltage to penetrate the hard tissue and to provide the delineation of both hard and soft tissue structures. The X-ray film is held in the cassette holder and usually contains intensifying screens to reduce the exposure. In addition to that, a fixed or a moving grid may be used to produce sharper images. A grid absorbs the secondary radiation produced by deflections from bones and allows only those rays coming directly from the source to progress to the film.

The distance between the X-ray source to the midsagittal plane and between midsagittal plane to the film are variable depending on the system used. The cephalostat or the head holder is based on the same principle as described by Broadbent (1931). The patient's head is fixed by the two ear-rods inserted into the ear holes. The central beam of the X-rays coincides with the transmeatal axis, with the ear-rods of the cephalostat. The head which is centred in the cephalostat, is orientated with the Frankfort plane parallel to the floor and the midsagittal plane vertical and parallel to the film. The projection is taken when the teeth are in centric occlusion and the lips repose unless other specifications are requested. If it is necessary to produce the cephalogram in natural head position which represents the true horizontal plane, the patient should be standing up and should look directly into the reflection of his or her own eyes in a mirror directly ahead in the middle of the cephalostat (Solow and Tallgren, 1971).

## 2.6.3 USES AND APPLICATION

Use of cephalometric radiographs:

1. General Diagnosis
    a. Pathology
    b. Assessment of crowding
    c. Soft tissue outline
    d. Unerupted teeth
    e. Angulation of teeth, overjet or overbite
2. Specific aid to Orthodontic diagnosis and treatment planning.
    a. Skeletal pattern
    b. Dental arch length
    c. Soft tissues
    d. Dental factors
3. Prognosis determination.
4. Growth prediction.
5. Assessment of treatment progress
   (Hernandez-Orsini *et al.* 1989, Forssell *et al.*, 1992)
6. Assessment of treatment changes.
7. Assessment of growth changes.
9. Research.

Longitudinal growth studies provide population Norms for the purpose of comparison and provide the insight into normal and abnormal growth trends.

Cephalometry is not without its limitations and the problems encountered include conventions and assumptions, fallacies, and blatant misuses of the method. Mills (1970), stated that cephalometry is only one tool in the armamentarium and one that needs to be used with rational, in other words, "It is a good servant but a poor master".

Conventional cephalometric is however prone to error, therefor attention to detail is necessary in all aspects of planning, execution, and the presentation of a cephalometric study as in all other scientific work.

# 2.6.4 CEPHALOMETRIC ANALYSIS

## 2.6.4.1 Classification of Analysis (Rakosi, 1982)

### *A. Methodological Classification*

This can be divided into angular and linear analysis. The angular measurements are measured in degrees while the linear assessment in millimetres. Angular analysis is not without its drawback. The lines are constructed based on a constant reference plane and if deviation exist in the reference plane, the result or readings would be unreliable.

Angular and linear analysis can further be subdivided.

**a). Angular analysis.**

i. Dimensional analysis.

ii. Proportional analysis.

iii. Positional analysis.

**b). Linear analysis.**

i. Orthogonal analysis.

ii. Dimensional linear analysis.

iii. Proportional linear analysis.

### *B. Normative Classification*

Analysis which is classified according to the concepts on which normal values are based. This can be divided into:

**a). Mononormative Analyses.**

Averages acts as norms and may be in the form of arithmetic or geometric.

The arithmetical norms are average figures based on angular, linear or proportional measurements. Geometrical norms are average tracings in a graphic form and it gives a rapid orientation when comparison is made with the case under analysis.

**b). Multinormative Analyses.**

A complete series of norms are used in this case, taking into account the age and sex.

**c). Correlative Analyses.**

This is used to determine individual variations of facial structure in order to establish their common relationship and is appropriate for diagnostic purposes.

### *C. Classification According to Area of Analysis*

A more specific analysis involving limited areas or the whole of the facial skeleton. This can be divided into:

**a). Dentoskeletal Analyses.**

This involves the analysis of dental and skeletal structures and can be obtained from norma lateralis, norma frontalis or three dimensionally.

**b). Soft Tissue Analyses.**

Soft tissue analysis may involve the whole profile or isolated to a certain structure only like the lips.

**c). Functional Analysis.**

This analysis take into consideration the functional relations such as the occlusion to the interocclusal space relationship in norma lateralis and norma frontalis.

## 2.6.4.2 Standard Analysis

Cephalometric radiography have been about in orthodontics for more than 60 years but it was not until two decades ago that it gained a wider recognition and acceptance for clinical application.

Since the advent of standardised cephalometric radiography (Broadbent, 1931., Hoftrath, 1931), researchers around the globe have combined cephalometric variables in order to form an analysis of dentofacial and craniofacial morphology. These analyses were based on norms that have been established from a population sample. As previously stated, Rakosi (1982) has classified cephalometric analysis in detail. However, a more practical an acceptable method of cephalometric investigation are those of the standard or traditional analysis.

These analysis are as below.

1. Bjork Analysis. (Bjork, 1947).
2. Tweed Analysis. (Tweed, 1946, 1953).
3. Wylie Analysis. (Wylie, 1947).
4. Downs Analysis. (Downs, 1948).
5. Riedel Analysis. (Riedel, 1952).
6. Steiner Analysis. (Steiner, 1953, 1959).
7. Sassouni Analysis. (Sassouni, 1955, 1958, 1969).

8. Coben Craniofacial and Dentition Analysis (Basion Horizontal). (Coben, 1955, 1979).
9. Ricketts Analysis. (Ricketts, 1957).
10. Schwartz Analysis (Schwarz, 1961).
11. Di Paolo's Quadrilateral Analysis. (Di Paolo, 1969).
12. Jarabak Analysis. (Jarabak, 1972).
13. Harvold Analysis. (Harvold, 1974).
14. Wits Appraissal. (Jacobson, 1975, 1976).
15. Worms and Coworkers' Analysis. (Worms *et al.,* 1976).
16. Burstone and Coworkers Analysis for Orthognathic Surgery. (Burstone *et al.*, 1979).
17. Bell, Proffit and White Norms. (Bell *et al.*, 1980)
18. Legan and Burstone Soft Tissue Analysis for Orthognathic Surgery. (Legan and Burstone, 1980).
19. Holdaway Analysis. (Holdaway, 1983, 1984).
20. McNamara Analysis. (McNamara, 1984).

The details and application of these analysis can be found in the respective papers. Most of this analysis were derived from a Caucasian samples. To obtain appropriate application of the various cephalometric analysis, it should be compared with norms derived from groups that is identical or similar to patients examined with regard to race , age and sex.

In the present study, variables from a combination of analysis were taken into account. These includes those of Downs'(Downs, 1948), Steiners'(Steiner, 1953, 1959)., Ricketts' (Ricketts, 1957), Wits' (Jacobson, 1975, 1976) and McNamaras' (McNamara, 1984),

# 2.6.5 TRACING TECHNIQUE AND IDENTIFICATION OF LANDMARKS

## 2.6.5.1 Tracing Technique

Cephalometric tracings are one of the earliest methods of transferring a radiographic image into a meaningful illustration or picture. Hard and soft tissue landmarks were distinguished and identified and this may be unilateral (median structures) or bilateral. These points may be anatomical, anthropological or radiological depending on their origin. In depth knowledge of the gross anatomy of the head, especially the bony components of the cranium and face are important in order to relate the two-dimensional cephalogram with a three dimensional skull.

It is important to visualize that a two-dimensional cephalogram represents a three dimensional object and that bilateral structures will be projected onto the film (Jacobson, 1995). These bilateral images are not superimposed in most occasions due to facial asymmetry, difference in magnification between two sides of the face and imperfect positioning of the patient in the cephalostat. By convention, bilateral structures are first traced independently and an average is then drawn by visual equal, which is represented by a broken line (Jacobson, 1995).

The type of tracing equipment used is important in producing accurate and consistent tracings. The equipment and apparatus used in this study (section 5.2.2.1) is that recommended by most researchers.

There are many ways in tracing cephalograms. Jacobson (1995), suggested a stepwise tracing technique which comprises of four steps:

1. Soft tissue profile, external cranium and vertebra.
2. Cranial base, internal borders of cranium, frontal sinus and ear lobs.
3. Maxilla and related structures including nasal bone and pterygomaxillary fissures.
4. The mandible.

### 2.6.5.2 *Identification of Landmarks*

The next step after tracing is identification of landmarks. Exact landmark definition is important in order to prevent error in identification. Landmarks which by definition are on the lowest, most anterior or innermost (e.g. Menton, Pogonion, A point) depends on the orientation of the head. For example, if the head is tipped downwards, the lowest point (e.g. Menton) would be more anteriorly positioned. Therefore, it is recommended that the cephalogram be orientated to the Frankfort horizontal plane. Once this plane is determined, landmarks that are affected by changes in head positioning can be identified by using either a line perpendicular or parallel to the Frankfort horizontal.

A stepwise method of landmark identification can also be used:

1. Locate porion and orbitale to establish the Frankfort Horizontal plane.
2. Locate landmarks on the cranial base and adjacent areas.
3. Locate landmarks on maxilla
4. Locate landmarks on mandible

Generally, after all the landmarks have been located and marked, lines are drawn on the tracing paper to mark the reference planes. Linear measurements are made by linking two points and angular measurements between three points. Linear and angular variables are based on one particular line representing a reference plane. Usually, it is either the Frankfort horizontal plane or the sella-nasion line (Rakosi, 1979). Sella-nasion line is preferred over Frankfort horizontal, because the former was based on median structures as compared to the later where porion and orbitale are bilateral in nature. Furthermore, bilateral points are usually subjected to error.

Following that, the conventional analysis mentioned previously can be used to analyse the data. A combination of cephalometric analysis (section 2.6.4.2) can be utilised instead of strictly adhering to one since certain variables needed might not exist in a single form of analysis.

## 2.6.6 Cephalometric Errors

### 2.6.6.1 Guidance in Cephalometric Studies

In cephalometric studies, attention to details is important in all aspects of planning, execution and presentation of cephalometric studies. The guidelines presented by Stirrups (1993) on cephalometric base research were adopted as a foundation.

The paper presented advice on planning and presentation of cephalometric investigation in order to raise the quality of presentation and made it more informative. It covered sample selection, radiological consideration, cephalometric measurements and statistical presentation.

In addition, he gave a checklist for cephalometric study and emphasised on the topics that should be addressed adequately.

**A. Sample Selection**

1. Population definition
2. Sample Size
3. Case Mix Description
4. Case selection
5. Exclusion
6. Controls
7. Treatment allocations

**B. Radiology**

1. Technique
2. Magnification

**C. Cephalometrics**

1. Landmark choice
2. Landmark definition
3. Measurement method

4. Standardisation
5. Measurement order randomisation
6. Error Analysis

**D. Statistical Presentation**

1. Hypothesis tests
2. Confidence intervals
3. Multiple comparisons

Cephalometric measurements involved (Lin, 1995);

1. Landmark choice and identification
2. Measurement technique
3. Maintenance of standardisation of landmark identification for multiple observers or if the measurements are to be carried out over a delayed period.
4. Randomisation of measuring radiographs if more than one group of subjects is being studied.
5. Error analysis.

## 2.6.6.2 Errors in Cephalometric Measurements

There are numerous sources of error in cephalometry. Many studies have been carried out to evaluate the potential errors in measurements from cephalometric radiographs. These errors are essentially due to the numerous stages that are required before a definite analysis is achieved. These stages include the taking of radiographs, film processing, tracing or digitising, landmark identification, measurements and interpretation. All these stages can produce errors which will influence the analysis substantially. Therefore, a cephalometric based study should be analysed with caution bearing in mind the possible errors which might be encountered. The guidelines suggested by Stirrups (1993) is a good foundation in evaluating cephalometric studies.

Different classification of cephalometric errors are shown below:

1. Gravely and Benzies (1974)
    a. Projection errors
    b. Tracing errors
2. Bjork (1947)
    a. Errors in different method in taking radiographs, causing the radiographic image to vary (projection error)
    b. Errors due to variation in marking the reference points.
    c. Errors in reading linear and angular measurements.

3. Baumrind and Frantz (1971).
    a. Errors in projection
    b. Errors in landmark location
    c. Mechanical errors

From the studies above, potential errors in cephalometric studies can be collectively divided into:

1. Errors of projection
2. Errors of Identification

***Errors of Projection***

***Errors of projection*** occurs when a three-dimensional object is converted into a two-dimensional radiography, whereby the head film is a two-dimensional shadow of a three-dimensional object. The rays which produce the shadow are nonparallel and originates from a very small source. This produces an enlarge and possibly distorted radiographic image. The enlargement factor varies with the plane at which the estimated point lies. Further distortion occurs by foreshortening of distances between points lying in different planes and by radial displacements of all points and structures not on the central ray.

Brooke (1949), Hixon (1960), Bjork (1962) and Salzmann (1964) commented on these errors and several attempts have been made to introduce correction factors for some of these errors. However the difficulty of computations has mitigated against the general use of these adjustments (Adams, 1940., Vogel, 1967).

***Enlargement errors***

Projection errors can be divided into enlargement errors and distortion errors. *Enlargement* is a result of the inherent property of x-rays to proceed in straight line, diverging from a point source or anode.

$$\text{Enlargement} \propto \frac{\text{Distance of film to object}}{\text{Distance of object to x-ray source}}$$

From the equation above, enlargement is proportionate to the distance of film to the object and inversely proportionate to the distance of object to the x-ray source. Therefore, enlargement can be reduced in two ways:

1. Reducing the distance between the film and the object.
2. Increasing the distance between the object and the x-ray source.

However, this is impractical because by increasing the distance between the object and the x-ray source, the time needed for exposure have to be amplified to achieve a reasonable quality radiographs. Hence, it is unrealistic to increase the distance of the object and x-ray by 5 feet (152.4 centimetres) since the concentration of the penetrating x-rays decline inversely as the square of the distance from the anode to object.

Broadbent (1930), constructed his cephalostats to incorporate a 5 feet distance and a vernier scale to facilitate enlargement compensation for linear measurements. Enlargement of linear measurements must be compensated, and this must be done if radiographs taken in different systems are to be compared.

Enlargement compensation is obtained by the following method.

$$\text{Size of object} = \frac{\text{target to object distance}}{\text{target to film distance X size of image}}$$

## *Magnification Factor*

In this study, two different groups of X-rays were investigated and the enlargement factors were calculated and compensated in order to compare both the X-rays. Instead of measuring the actual magnification for each radiograph, a specific enlargement factor was set and all the radiographs were corrected to that value.

This is done in order to reduce further error which could surface as a result of measurement error on the veneer scale of the radiographs. . With this method, only mathematical calculations were done. Therefore it was decided that all radiographs were compensated to a specific value that is equivalent to 183cm from the X-ray source to the midsagittal plane and 14cm from the midsagitatl plane to the film

For the Malay sample, all magnification were corrected to 0.697. As for the Caucasian, seven radiographs were corrected to 0.697, one was corrected to 0.950 and another to 0.850.

***Distortion***

*Distortion* on the other hand is an inaccurate duplication of a structure or area. This is different from enlargement where an accurate proportional extension of a structure is achieved. Distortions can be due to several reasons:

1. Size differences between structures closer to anode as opposed to those closer to the film.
2. Rotation of the head in the cephalostat.
3. Divergent X-rays form tangents to rounded surfaces that fall on the tangent side of the midsaggital plane.

Broadbent (1975), recommended that skeletal landmarks in the lateral headfilm should be coordinated with the posteroanterior headfilm to correct for projective distortion. An Orientator was introduced to reconstruct landmarks determined from the lateral and posteroanterior radiographs into a three-dimensional points in space. However, its used was not widely accepted by the orthodontic community.

## *Errors of Identification*

***Errors of Identification*** is an error encountered during the identifying and localisation of specific anatomic landmarks. This may be caused by lack of clarity of cephalometric landmarks due to superimposition of structures, blurring of the image brought about by movement during exposure, lack of film contrast and emulsion grain. Other than that, measurements error due to thickness of pencil line and perceptive limits of human eye can bring about tracing errors.

Jacobson (1990), showed that Porion, Condylion, Orbitale and Basion are less readily identified than other landmarks and that Gnathion was more readily recognised than Condylion. Baumrind and Frantz (1971) assessed errors in landmark identification using five operators and twenty cephalometric radiographs. They found that certain landmarks such as sella and nasion were more reproducible than others and gonion and lower incisor apex were the least reliable landmarks. Landmarks lying on vertical edges were more accurately located in the horizontal dimension than the vertical dimension and vice versa. Richardson (1966) also found that most landmarks have a margin of error of plus or minus one millimetre.

The effect of digitising and manual tracing of radiographs was studied by Richardson (1981) who found that the digitiser was slightly more accurate than manual tracing. Sandler (1986, 1988) found no significant difference between manual tracing and digitiser but the digitiser was more quicker and more convenient to use.

Houston (1983) reviewed on the analysis of errors in cephalometric measurements, whereby he discussed the validity, reproducibility and sources of error in cephalometric measurements and analysis.

Validity is the extent to which, in the absence of measurement errors, the value obtained represent the object of interest. This is also termed " accuracy". Reproducibility or precision is the closeness of successive measurements of the same object. This is also referred to as "reliability" but the term reliability also could include validity. Therefore, reproducibility is a preferred terminology.

Many cephalometric landmarks have been defined for the convenience of identification and reproducibility, rather than on the grounds of anatomic validity. This is often unavoidable, and no better alternative may be available. Rather than to reject such variables as invalid, it is preferred to use them with caution and to recognise that in certain circumstances, they may be misleading.

## 2.6.6.3 Types of Errors

Houston (1983), divided errors of measurements into:

1. Systematic error (bias)
2. Random error

### *2.6.6.3.1 Systematic error (bias)*

This error occurs if a particular measurement is persistently over or underrecorded. Systematic error can arise in the following situation:

1. *Magnification* :

    When measurements from two different sources are compared and it is presumed that the magnification are equal then the comparison is said to be bias. This occurs when the geometry of the system varies during the process of obtaining radiographs.

2. *Multiple observer :*

   When two series of cephalograms are measured by different person with different concept of landmark definition, systematic error will occur.

3. *Single observer :*

   Bias can develop if a single observer changes his landmark concept over a period of time or when a practice of a single operator changes with experience. Therefore, one series of measurements may differ systematically from a series made at a different time.

4. *Subconsciously weighting results :*

   This can be introduced when two series of measurement are compared.

## 2.6.6.3.2 Random error

Random error can arise from:

1. Variations in positioning of patients in the cephalostats. Soft tissue points especially is affected by the way the patient is positioned. (Hillesund *et al.,* 1978)
2. Variation of film density and sharpness.
3. Difficulty in identifying a particular landmark or imprecision in its definition is the greatest source of random errors. Many landmarks are difficult to identify and ones opinion on exact location of a point may vary at random. This is partly due to imprecision of many anatomic definitions.

## 2.6.6.4 Methods of Controlling Errors

Errors in cephalometric studies can be contained by the following methods:

1. Taking radiographs
2. Standardisation and Landmark identification
3. Calibration and Cephalometric course attendance
4. Experimental design

### *2.6.6.4.1 Taking Radiographs*

The relationship of x-ray target, head holder and film must be fixed. The metal markers in the ear rods must be aligned. A metal scale can be incorporated to allow for enlargement compensation.

The equipment used in Glasgow and Kuala Lumpur was quite similar with some minor differences. In this study, the taking and quality of radiographs are beyond the control of the operator. However, in both systems, all the necessary precautions were made to ensure that radiographs of high quality is produced.

Both systems used a 2 millimetres thick aluminium filter wedge to improve the definition of the soft tissues and anterior bony structures. Fast speed films were used in both occasions to reduce radiation exposure but this might compromise the quality of film and hence the definition of landmarks. Halse and Hedin (1978), however stated that poorer quality of image makes little difference to the accuracy with which landmarks can be identified. The quality of both sets of films in this study are acceptable and only those with clear landmarks were included.

## 2.6.6.4.2 Standardisation & Landmark Identification

The tracings were carried out over a period of time and methods of maintaining standardisation of tracing and landmark identification were taken into account. Guidelines for identification of landmarks and tracing techniques are laid down to maintain standardisation.

Precise definition of landmarks were selected before commencing the study and these values were referred to throughout the study; from the start of data collection, tracings, digitisation and until the process of analysis.

Radiographs were traced using a clear acetate ultra-fine drafting paper. Tracing papers were not used since they tended to obscure the structures and produce a misleading picture. Sharp 7H drawing pencil were utilised to produce fine lines similar to the cross-hair cursor of the digitiser.
All tracings were done in similar surroundings in a darkened room with a light source behind the area of interest only. Sheets of black cardboard and a hollow cardboard tube were used to increase the contrast of films and isolate specific landmarks

## 2.6.6.4.3 Calibration and Cephalometric course attendance

The most important contributions to improvement of landmark identification are experience and calibration (Houston, 1983). The operator has undergone a Cephalometric course by Professor Lysle Johnston whereby hands on experience with landmark localisation, tracing and measurements were covered. From the course, the operator had passed the landmark identification test and is capable in the subject below:

1. Definition, location and interpretation of conventional cephalometric landmarks in the face of normal anatomical variation.
2. Execution of anatomically accurate and artistically pleasing cephalometric tracings.
3. Performing and interpretation of a variety of conventional cephalometric analysis.
4. Execution of descriptive analysis by way of plastic templates
5. Application of regional superimposition techniques to forecast and evaluate changes due to growth, treatment and relapse.

Therefore, the tracing techniques employed will be based on the teachings of Professor Lysle Johnston in combination with the guidelines set by British Orthodontics Society.

## *2.6.6.4.4 Experimental Design*

Identical conditions for tracing, digitisation and measurements were maintained throughout the study. The same digitiser and computer software were used to prevent conflicts and discrepancies between systems.

The function of double determination in the PCDIG software was utilised to increase the accuracy of digitisation. The difference in the first and second digitisation were set at a level of 0.3mm. Repeated digitisation was required if this set level was not met. There was no noticeable discrepancies between the first and second digitisation throughout the study.

## 2.6.6.5 Methods of Error Assessment

Houston (1983) described the methods of assessing systematic and random errors. They can be divided into:

1. Duplicating radiographs
2. Replicating measurements
3. Detecting systematic errors
4. Estimating random errors

### *2.6.6.5.1 Duplicate radiographs*

Houston (1983), stated that the largest error occurred in landmark identification. Therefore duplicating tracings or measurements of radiographs should be done if possible.

However duplicating radiographs is not possible due to ethical reasons. This is due to reasons whereby it is unwise to call for unnecessary radiation to subjects. Therefore, samples in this study consisted of subjects with normal occlusion and very low treatment need, where it is not justified to obtained a duplicate radiographs.

### *2.6.6.5.2 Replicating measurements*

Measurement replication was used to estimate error in this study. Twenty radiographs from each group were selected at random for error study. The error study was carried out at least 4 weeks after the first tracings to prevent memory bias. Tracings, digitisation and measurements were done under standard conditions as in the initial study.

## 2.6.6.5.3 Systematic errors

Systematic errors were measured using a one-sample t-test for each pair of replicates. A number of factors must be taken into account:

i). *A sufficient number of cases must be replicated:* otherwise a large systematic errors will result.

ii). *The standard deviation of the differences:* If the standard deviation of the differences is large due to reflection of large random errors, systematic errors will tend to be obscure. In this case, the standard error is large and p-value will be small.

iii). *The level of significance chosen:* Statistical test of significance are based on the null hypothesis that there are no difference between groups. The null hypothesis is rejected only if the difference detected is obvious and unlikely due to chance. The level of significance for this study was set at 95%.

There is no systematic bias if P is greater than 0.1, which is the level where Houston (1983) suggested as a level for concern.

## 2.6.6.5.4 Random errors

Random errors in this study were estimated by assessing the correlation between repeated measurements (Houston, 1983). The intra-class correlation coefficient (I.C.C.) or index of reliability, would be equal to one when there is lack of random error

Index of reliability is classified into four groups:

| ***Index of reliability*** | |
|---|---|
| 1. *Poor* | Index of reliability ≤ 0.600 |
| 2. *Acceptable* | 0.600 < Index of reliability ≤ 0.700 |
| 3. *Good* | 0.700 < Index of reliability ≤ 0.900 |
| 4. *Excellent* | 0.900 < Index of reliability |

Stirrups (1993), stated that values above 0.95 are usually acceptable for most cephalometric studies.

# 2.6.7 LIMITATIONS OF CEPHALOMETRY

Cephalometry is a useful tool in orthodontic diagnosis, however it is not without its limitations. Moyers (1988) classified this limitations into assumptions and fallacies.

## *2.6.7.1 Assumptions*

*a). Symmetry*

Human faces in general, have minor asymmetries which is clinically unimportant, but serious imbalance may exist and usually the lateral projection is based on a presumed skeletal symmetry.

*b). Occlusal Position*

It is normal to position the mandible in the usual occlusal position, however in cases with malocclusion with an important functional component, this convention may be misleading.

*c). Orientation on the Transmeatal Axis*

Ear rods are used to orient the patient's head. The central ray is supposed to pass along the transmeatal axis but the problem of asymmetry surface again. The external auditory meatus are prone to asymmetry as other cephalic structures.

*d). Adequacy of one or two Planar Projections*

Lateral cephalometric radiograph is a two-dimensional image of a three-dimensional object. The use of additional views like the posteroanterior, oblique and basalar views could give a more three-dimensional cephalometric method.

### 2.6.7.2 Fallacies

***a). The Fallacy of False Precision***

A standard error of 1.5 degrees will be encountered if 2 series of separate radiograph of the same head were traced (Houston, 1983). Therefore, there is a gray area of approximately ± 1.5 degrees in measurements. This is important especially when comparing to standards of film traced by a different tracer.

***b). The Fallacy of Ignoring the Patient***

Means are population averages which have nothing to do with specific characteristics of a particular patient. It is not prudent to treat a malocclusion base on a fixed cephalometric goal, rather, it should be combined with other records like dental cast, case history and clinical examination of the patient.

***c). The Fallacy of superimposition***

Superimposition of tracings is usually done to assess treatment outcome and growth changes. However, this is prone to errors since the amount of changes seen depends on the point or plane of reference for superimposition.

***d). The Fallacy of Using Chronologic Age***

Chronological age is usually used for comparisons and reference. However, developmental age is thought to be better since it reduces the variance of size, angles and proportions within age classes.

## 2.6.8 ADVANCES IN CEPHALOMETRY

Cephalometric analysis has been a major tool in orthodontic diagnosis and treatment planning. Until now, the process of hand-tracing and analysing radiographs is still clinically useful but it has distinct drawbacks. It is time consuming and the product is difficult to present to a lay patient.

At present, technology advances in computers have made a breakthrough in the dental profession. Computers have been used in many aspects of orthodontics from data management to aiding in diagnosis and treatment planning. Now, it is possible to use computers in cephalometry. The method is called digitisation, whereby graphical information within the cephalogram can be transformed into numbers. Generally, there are two methods, one is by using a digitizing tablet and the other is through direct digitization from the monitor. The first method requires the clinician to place the radiograph on the tablet and locate the landmarks using a stylus. In contrast to that, on-screen digitization necessitates the image of the radiograph to be fed directly into the computer. This can be done by using a video source or a back-lit scanning. The advantage of this method is that the image can be enhanced according to the clinicians need by changing the exposure, brightness, contrast, gamma correction, hue or saturation.

Even with computer digitization, it is still hard to explain patients facial configuration based on numbers and plots. This could be overcome if a patient's photograph could be laid on top of the cephalometric plots. Technique like video imaging have made this possible (Jacobson, 1995). This allows the patient's projected facial image to be related and calibrated with her actual facial configuration from the traced/digitized cephalograms (Sarver and Johnston, 1990).

The method helps in visualization of the underlying skeletal and dental hard tissues in relation to the profile. This is particularly useful in surgical planning and in communicating with surgical patients and in addition to normal everyday use in treatment planning. Therefore, it is useful as a diagnostic tool and as a tool for communication.

Advances in cephalometric analysis have reached the era where a three-dimensional analysis is made possible. This allows a clinician to examine the facial dimension in a more detailed and accurate level whereby size, shape, position and proportions of the face can be analysed. This manner of analysis will overcome many problems that is related to the conventional cephalometry. These include image enlargement and distortions (Broadbent, 1937), exposure to radiation and chemical hazards. Errors in projection can occur when a three-dimensional object is converted into a two-dimensional image (Franklin, 1952).

The three-dimensional analysis involves the use of laser and ultrasonic scanners which are used to scan the head and face. Hard and soft tissues landmarks are then topographically recorded in the computer and screen. With the advent of videoimaging and non-invasive magnetic capabilities (e.g. magnetic resonance imaging) , it is possible to produce a three-dimensional analysis that combines many features of manual craniometric techniques and radiographic cephalometric techniques (Jacobson, 1995).

# Chapter 3. AIMS OF STUDY

The aim of this study is to describe the lateral cephalometric norms for Malaysian Malays and in addition to document the differences between:

1. Malays and Glaswegian Caucasians.
2. Malay males and Glaswegian males.
3. Malay females and Glaswegian females.
4. Malay males and females.
5. Glaswegian males and females.

This is particularly to facilitate:

1. description of dentofacial pattern/relationship
2. diagnosis and treatment planning
3. evaluation of results of treatment
4. act as a baseline data for further research

# Chapter 4. MATERIALS

## 4.1 INTRODUCTION

This is a retrospective study involving the collection and analysis of lateral cephalometric radiographs of patients. The sample collection of lateral cephalometric radiographs was obtained from the Dental Faculty, University of Malaya, Kuala Lumpur and from Glasgow Dental Hospital and School, Glasgow.

The samples studied were patients with ***normal occlusion*** based on the ***British Standards***, that is an occlusion that satisfies the requirements of function and aesthetics with a class I incisor relationship with or without minor irregularities of the individual teeth.

## 4.2 THE SAMPLE

The sample collection were based on the criteria below:

1. All those selected were in good health, based on previous records.
2. The age group consist of adults age 18 years and above.
3. Those with normal occlusion as defined above with a Class I incisor relationship based on British Standard Incisor Classification of Malocclusion (BS4492, 1982), that is the lower incisal edges occlude with or lie immediately below the cingulum plateau (middle part of the palatal surface) of upper central incisors.

4. Class I molar relationship based on Angle's Classification of molar relationship, whereby the mesiobuccal cusp of the upper first permanent molar occludes with the buccal groove of the lower first molar.
5. Subjects had no previous orthodontic treatment.
6. Full dentition from second molars.
7. No apparent dental or skeletal discrepancies and asymmetries.
8. Little or no incisor crowding.

### 4.2.1 The Malay Sample

The subjects for the Malay sample were selected from third year students studying in the Dental Faculty, University of Malaya, Kuala Lumpur. Selection was based on study models and cephalometric radiographs. These records were taken on an annual basis of every new third year dental student for the purpose of education.

Students who fell into the Malay ethnic group were isolated. In addition, the family lineage of each subject had to indicate that at least 3 generations of the family had resided in Malaysia. These were accomplished by going through the records of each student. Those who were in doubt were excluded from the selection.

All together, there were approximately 500 study models and cephalometric radiographs from the year 1984 to 1995. Preliminary examination on the records were done using the criteria stated above. Ninety five subjects met the criteria in the preliminary examination.

Of these 95 subjects, 24 were eliminated due to different type of malocclusion or abnormal skeletal features. Another 6 were excluded because they were not long-term resident in Malaysia and the exact ethnic composition was not clear. A closer examination of the radiographs forced another 11 to be excluded due to poor quality or exposure. Thus, a total of 54 subjects (24 males and 30 females) were included in the present study (Table 3).

The mean age for males was 23.1 years, with a range from 22.4 to 23.8 years. The mean age for females was also 23.1 years, with a range from 22.4 to 23.9 years. (Table 4).

The socioeconomic background of the subjects' parents varied from commercial, skilled to non-skilled and professional fields.

### 4.2.2 The Caucasian Sample

The Caucasian sample represented the control group. The subjects were obtained from 3 sources:

1. Records of lateral cephalometric radiographs of approximately 1000 patients taken in the past 10 years.
2. Records of approximately 500 patients who attended the Glasgow Dental Hospital and School for the past 2 years.
3. Dental students who met the inclusion criteria.

Ethical approval was obtained from the Area Dental Ethics Committee. Consent form and patient information sheet containing simple information of the dosage used were provided.

The selection of the sample was based on cephalometric radiographs, classification by consultants and partly based on patients and study models where available.

Forty five subjects met the criteria whereby 20 of them were males and 25 were females (Table 3). The age for males ranged from 21.6 to 23.7 years with a mean of 22.5 years. For females, the mean age was 22.6 years with a range from 21.5 to 23.6 years (Table 4). These closely matched the age range of the Malaysian sample.

## 4.3 PROBLEMS ENCOUNTERED

The limitation in the number of subjects and the age bracket studied in both samples was due to:

1. Ethical considerations, whereby it is not justified to take radiographs on normal individuals. Therefore, the sample consists of only adults age 18 years and above. The subjects selected on this study were clearly outside the range of ages of the typical orthodontic patient, but there is some evidence that craniofacial shape remains fairly stable with increasing age (Walker and Kowalski, 1972). However caution must be exercised, especially for male mandibular morphology (Kowalski *et al.*, 1974). It would have been desirable if subjects between the ages of 9 to 15 could have been included in this study.
2. Problems in identifying the true ethnic composition of subjects. A reasonable number of Malaysian Malays come from interracial marriages and the selection was based only on available records.
3. In retrospective studies, the limitation of availability of material seldom allows random sampling and therefore it is difficult to meet the prerequisite for statistical testing of a random choice of subjects.

4. There was a problem with the quality of the cephalometric radiographs whereby reasonable number of radiographs with poor exposure, deficient magnification factor and missing landmarks were observed.

**Table 3 :** Summary of Materials used.

| | *Malays* | *Caucasians* |
|---|---|---|
| 1. *Subjects* | 54 | 45 |
| 2. *Male* | 24 | 20 |
| 3. *Females* | 30 | 25 |
| 4. *Mean age* | 23.12 | 22.59 |

**Table 4 :** Descriptive information on the age of subjects evaluated in the study.

| | Mean | SEMean | StDev | Minimun value | Maximum value | n |
|---|---|---|---|---|---|---|
| ***Malays*** | | | | | | |
| Males | 23.12 | 0.083 | 0.405 | 22.4 | 23.8 | 24 |
| Females | 23.11 | 0.084 | 0.458 | 22.4 | 23.9 | 30 |
| Pooled | 23.12 | 0.059 | 0.431 | 22.4 | 23.9 | 54 |
| ***Caucasians*** | | | | | | |
| Males | 22.53 | 0.119 | 0.532 | 21.6 | 23.7 | 20 |
| Females | 22.63 | 0.127 | 0.634 | 21.6 | 23.6 | 25 |
| Pooled | 22.59 | 0.087 | 0.586 | 21.6 | 23.7 | 45 |

# Chapter 5. METHODS

## 5.1 RADIOGRAPHIC EQUIPMENT AND TECHNIQUES

Two cephalostats with different magnifications were involved in this study. Enlargement and linear measurements were compensated because two different systems were compared.

All radiographs were taken with the teeth in centric occlusion and Frankfort horizontal plane parallel to the floor.

### 5.1.1 EQUIPMENT IN KUALA LUMPUR & GLASGOW

Summary of equipment used in both settings are shown in table 5.

## 5.2 TRACING AND DIGITIZATION

### 5.2.2 EQUIPMENT AND APPARATUS

The following items were used:

#### *5.2.2.1 Tracing*

a). Tracing paper : Acetate ultrafine drafting paper

(0.003 inches thick and 8 X 10 inches in dimension)

b). Pencil : Sharp 7H Staedtler drawing pencil

c). Masking tape

d). Tracing template: Protractor tracing template (3M Unitek)

e). Viewbox : by H. A. West (X-Ray) Ltd.

f). Lighting : Darkened room with light behind the area of interest only.

g). Sheets of black cardboard 30 X 24 cm and a hollow cardboard tube.

h). Pencil sharpener to sharpen the pencil lead into a very fine tip similar in diameter to the cross-hair cursor of the digitiser.

i). Soft Staedtler eraser.

#### 5.2.2.2 Digitization

a). Software : PCDIG (version 5.0), Mc William, 1989. (see section 5.3)

b). Tracing Tablet

c). Plotter: Hewlett Packard compatible plotter

d). Printer: Epson compatible dot matrix printer

e). Computer: IBM 286SX compatible

f). Digitiser : cross-hair cursor

#### 5.2.2.3 Computer Software

a). Statistical software: Minitab version 10.1 for Windows

b). Word processing software: Microsoft Word for Windows 95 version 7.0

c). Database software: Microsoft Excell for Windows 95 version 7.0a

### 5.2.3 METHODS OF TRACING AND DIGITIZATION

The radiographs were selected at random using a random number table. The cephalograms were then traced on acetates under a similar environment (see section 5.2.2 for equipment and apparatus). Direct digitisation was not done because there were intermediate landmarks on the soft tissue profile which can only be identified by bisecting two known landmarks. These landmarks are important in assisting in the mean plot of the profile and for comparison between groups.

After all the X-rays were traced, the landmarks were then digitised using a backlit GTCO 15 digitiser interface to an IBM P.C. AT computer. PCDIG software (Mc William, 1989) was used whereby landmarks and analysis can be pre-programmed according to personal requirements. The results were stored in an ASCII file which enable the transfer of data into a statistical packages like the Minitab and Microsoft Excell.

## 5.3 PCDIG COMPUTER SOFTWARE

PCDIG computer software is a DOS based programme developed by John McWilliam (1989), Associate Professor of Jaw Orthopaedics at the Karolinska Institute in Stockholm. The programme enables us to digitisation of a two dimensional image, saving X, Y coordinates, and producing results in the form of geometrically calculated distances, angles and projections.

The unique feature of the programme is that it allows the user to define his/her own analysis protocol, by designing beforehand the desired landmarks, angular parameters and linear parameters. A maximum of one hundred operator defined landmarks can be selected and in addition, two hundred parameters of various form can be programmed using the analytical command file.

The type of measurements that can be pre-set are as below:

1. Angle between three points.
2. Slope between two lines.
3. Slope between two points.
4. Distance between two points.

5. Distance from a point to a line.
6. Distance between two projected points.
7. Distance from a point to a perpendicular.
8. X-axis projection.
9. Y-axis projection.
10. Ratio of two distance on intercepted line.
11. Area of polygon (maximum 6 points).

The digitised landmarks can be plotted according to the requirement of the user. The programme offers a high degree of flexibility and an image can be constructed using lines and best fit curves. The image can then be printed on an Epson compatible dot matrix printer or a Hewlett Packard compatible plotter.

Superimposition of plots or mean plots can be achieve by selecting a reference plane defined by two landmarks. The result can then be viewed raw on the screen or printed as a hard copy.

**Table 5:** Summary of equipment used in Kuala Lumpur and Glasgow.

| | ***Kuala Lumpur*** | ***Glasgow*** |
|---|---|---|
| 1. *Distance from tube to midsaggital plane* | 152.4cm | 152.4cm |
| 2. *Distance from midsaggital plane to film* | 20cm | 14 cm - 20 cm |
| 3. *Centering device* - shadow of cross-beam when ear plugs and nose at rest position | yes | yes |
| 4. *Craniostat* | Siemen X-Ray Teleradiography | Wehmer Cephalostat |
| 5. *Filter used* | 2mm thick Aluminium filter | 2mm thick Aluminium filter |
| 6. *Collimator* fixed to the front of the X-ray tube head | yes | yes |
| 7. *X-rays coned down* using light beam diaphragm | yes | yes |
| 8. *X-ray tube* - focal spot | 0.5 X 0.5 mm | 0.5 X 0.5 mm |
| 9. *Film size* | 20.3 X 25.4 cm fast speed Quirx film | 18 X 24 cm fast speed Kodak film |
| 10. *Exposure factors* - *Milliamperage* | 12.8maS | 4-5 maS |
| *Kilovoltage* | 75 kV | 73 kV |
| *Time* | 0.64 msec | 21.1-26.6 msec |

## 5.4 LANDMARKS , REFERENCE LINES AND MEASUREMENTS

The landmarks selected for this study were a combination of landmarks from the chosen analysis. These were derived and modified from Steiner (1953) Downs(1956), Rakosi (1982) and McNamara (1984). All together there were forty-nine Landmarks, twenty-three dentoskeletal, twenty-four soft tissue landmarks, two constructed and eighteen reference plane. In addition there were twenty-six Angular and twenty-seven linear measurements.

The methods of analysis taken into account were as follows:

1. Steiner (1953)
2. Wits Appraisal (University of Witwatersrand, School of Dentistry, Johannesburg, South Africa)
3. McNamara (1984)
4. Downs' (1956)
5. Ricketts (1957)

**Table 6:** Total number of landmarks, reference planes, angular and linear measurements.

| | *Total* | *Dentoskeletal* | *Soft-tissue* | *Constructed* |
|---|---|---|---|---|
| ***Landmarks*** | 49 | 23 | 24 | 2 |
| ***Reference planes*** | 18 | | | |
| ***Angular measurements*** | 26 | | | |
| ***Linear measurements*** | 27 | | | |

## 5.4.1 LANDMARKS

### 5.4.1.1 Dentoskeletal Landmarks (figure 1)

1. ***Sella Turcica (S) :*** The centre point of hypophysial or pituitary fossa of the sphenoid bone lodging the pituitary body.
2. ***Nasion (N) :*** The craniometric point where the midsagittal plane intersects the most anterior point of the nasofrontal suture.
3. ***Orbitale (Or) :*** The lowest point on the inferior margin of the orbit. The average of right and left orbital margins were taken.
4. ***Anatomic Porion (Po) :*** The point on the upper margin of the porus acustus externus. The most superior point on the average of the bony external acoustic meatus taken.
5. ***Condylion (Cd) :*** Posterosuperior point on the average of the right and left outlines of condylar heads.
6. ***Anterior Nasal Spine (ANS) :*** The tip of the bony anterior nasal in the median plane.
7. ***Posterior Nasal Spine (PNS) :*** The point of intersection of a continuation of the anterior wall of the pterygopalatine fossa and the floor of the nose. This point marks the dorsal limit of the maxilla.
8. ***Subspinale (Point A) :*** The deepest midline point in the curved bony outline from the base to the alveolar process of maxilla.
9. ***Incisor Superiors (U1E) :*** The tip of the crown of the most anterior maxillary central incisor. Average point taken when there is incisor overlap.
10. ***Apex of Upper Incisor (U1A) :*** The root apex of the most anterior maxillary central incisor.
11. ***Incisor Inferiors (L1E) :*** The tip of the crown of the most anterior mandibular central incisor. Average point taken when there is overlapping.

12. ***Apex of Lower Incisors (L1A) :*** The root apex of the most anterior mandibular central incisor. Average point taken when there is overlapping.

13. ***Supramentale (Point B) :*** The most posterior point in the outer contour of the mandibular process in the median plane.

14. ***Pogonion (Pog) :*** The most anterior point of the symphisis of the mandible in the median plane.

15. ***Gnathion (Gn) :*** The mid-point between the most anterior and the most inferior point of the symphisis of the mandible. The point taken as the intersection between the facial and mandibular plane.

16. ***Menton (Me) :*** The most inferior point on the symphisis of the mandible in the median plane.

17. ***Gonion (Go) :*** The external angle of the mandible. Located by bisecting the angle formed by tangents to the posterior border of the ramus and the inferior border of the mandible.

18. ***Articulare (Ar) :*** The point of intersectionn of the posterior margin of the ascending ramus and the outer margin of the cranial base.

19. ***Basion (Ba) :*** The point where the median sagittal plane of the skull intersects the lowest point on the anterior margin of the foramen magnum.

20. ***PT Point (PT) :*** The junction of the pterygomaxillary fissure and foramen rotundum: The outline of foramen rotundum can be approximated at the 10:30(face of a clock) position on the circular outline of the superior border of pterygomaxilary fissure. The pterygomaxillary fissure are taken as the average when there is overlapping. (Point located at the most postero-superior aspect of pterygomaxillary fissure).

21. ***Points from planes at pterygoid (CF) :*** The point of intersection of the pterygoid root vertical to the Frankfort horizontal plane.

22. ***Upper Molar (A6) :*** A point on the occlusal plane located perpendicular to the distal surface of the crown of the upper first molar.

23. ***Lower Molar (B6) :*** A point on the occlusal plane located perpendicular to the distal surface of the crown of the lower first molar.

### *5.4.1.2 Constructed Landmarks*

24. ***Reference Nasion (RN) :*** The point of intersection of the horizontal reference line and the perpendicular line drawn through Nasion.

25. ***Reference Sella (RS) :*** The point on the horizontal reference line and located at 50 mm posterior to Sella.

### *5.4.1.3 Soft Tissue Landmarks (figure 2)*

26. ***Glabella (GS) :*** The most anterior point of the soft tissue forehead.

27. ***Point 2 :*** The mid-point between Glabella and Nasion.

28. ***Nasion (NS) :*** The most concave point of the soft tissue outline of the bridge of the nose.

29. ***High-nose point (H) :*** The intersection point of upper nose outline and the vertical line drawn through Glabella.

30. ***Point 5 :*** The intermediate point between H-nose and Mid-nose.

31. ***Mid-nose (MNS) :*** The mid point between H-nose and Pronasale.

32. ***Point 6 :*** The intermediate point of bisected distance from Mid-Nose to Pronasale.

33. ***Pronasale (PRN) :*** The most anterior, inferior point on the nose tip at which intersects by tangent line connecting with chin profile.

34. ***En :*** A point on soft tissue nose tangent to the aesthetic plane or E-line

35. ***Point 10 :*** The mid-point on the columella from Subnasale to Pronasale.

36. ***Subnasale (SBN) :*** The point at which the columella merges with the upper cutaneous lip.

37. ***Superior Labial Sulcus (SLS) :*** The most posterior point on the concavity between the upper lip and nose.

38. ***Point 13 :*** The mid-point on the concavity between Superior Labial Sulcus and Labrale Superius.

39. ***Labrale Superius (LS) :*** The most anterior point on the convexity of the upper lip.

40. ***Point 15 :*** The mid-point on the convexity of the upper lip between Labrale Superius and Upper Stomion.

41. ***Upper Stomion (UST) :*** The most inferior point of the anterior portion of the upper lip when the patients presents incompetent lips, or the point of the upper lip at which it merges with the lower lip when the patient presents competent lips.

42. ***Lower Stomion (LST) :*** The most superior point of the anterior portion of the lower lip when the patient presents incompetent lips, or the point of the lower lip at which it merges with the upper lip when the patient presents competent lips.

43. ***Labrale Inferius (LI) :*** The most anterior point on the convexity of the lower lip.

44. ***Point 19 :*** The mid-point on the curvature between Labrale Inferius and Inferior Labial sulcus.

45. ***Inferior Labial Sulcus (ILS) :*** The most posterior point on the concavity between the lower lip and chin.

46. ***Soft Tissue Pogonion (PGS) :*** The most anterior point on the convexity of the soft tissue chin.
47. ***DT :*** The point on the anterior curve of the soft tissue chin tangent to the aesthetic plane or E - Line
48. ***Soft Tissue Gnathion (GNS) :*** The most everted point of the soft tissue chin; this is obtained by locating the mid-point on the curvature between Soft Tissue Pogonion and Menton.
49. ***Soft Tissue Menton (MES) :*** The most inferior point of the soft tissue outline of chin.

## 5.4.2 REFERENCE LINES

1. ***Frankfort Plane (FH) :*** Line extending from Porion to Orbitale.
2. ***Sella-Nasion (SN) :*** Line connecting Sella and nasion. The anterior cranial base.
3. ***Mandibular Plane (MdP) :*** Line connecting Menton and Gonion.
4. ***Maxillary Plane (MxP) :*** Line extending from Posterior Nasal Spine to Anterior Nasal Spine
5. ***Nasion Perpendicular (Nper) :*** A vertical line drawn through Nasion and perpendicular to Frankfort Horizontal Plane.
6. ***Point-A Perpendicular (Aper) :*** A vertical line extending from Point-A and perpendicular to Frankfort Horizontal Plane.
7. ***Nasion to Point-A (NA) :*** Line joining Nasion and Point-A.
8. ***Nasion to Point-B (NB) :*** Line connecting Nasion and Point-B.
9. ***Point-A to Pogonion (Apog) :*** A line from Point-A to Pogonion is often referred as the dental plane.

10. ***Basion to Nasion (BaN) :*** Line joining Basion and Nasion, the cranial base. It divides the face and cranium.
11. ***Posterosuperior PTM to Gnathion (PTMS-Gn) :*** Line from a point at posterosuperior aspect of pterygomaxillary fissure to Gnathion.
12. ***Incisor Superiors to Apex of upper incisor (U1A-U1E) :*** Line connecting tip of upper incisor to apex of upper incisor.
13. ***Incisor Inferiors to Apex of loweer incisor (L1A-L1E) :*** Line connecting the tip and apex of lower incisor.
14. ***E-Line :*** The aesthetic line or plane extending from the soft tissue tip of nose to the soft tissue chinpoint.
15. ***Facial Plane (NaPog) :*** Extends from Nasion to Pogonion.
16. ***Pterygoid Vertical (PtV) :*** A vertical line drawn through the distal radiographic outline of the pterygomaxillary fissure and perpendicular to the Frankfort Horizontal.
17. ***Occlusal Plane (Op) :*** The functional occlusal plane is represented by a line extending through the first molars and premolars.
18. ***Facial Axis :*** A line extending from the foramen rotundum (PT to Gn).

### 5.4.3 Constructed Referrence Lines

1. ***Horizontal reference line (HRL) :*** Line constructed at $7^0$ to Sella-Nasion (Burstone *et al.*, 1978)
2. ***Vertical reference line (VRL) :*** A line drawn through reference Sella perpendicular to the horizontal reference line. All the landmarks are positioned at the right side of this line to provide positive parameters.

# 5.5 MEASUREMENTS

## 5.5.1 HARD TISSUES

### 5.5.1.1 ANGULAR

**A. *Maxilla to Cranial Base***

1. SNA

**B. *Mandible to Cranial Base***

*a). Horizontal*

1. SNB
2. SN to Pogonion

*b). Vertical*

1. SN to Mandibular plane
2. Facial Depth angle (N-Pog to Po-Or)
3. SN to Maxillary plane

**C. *Maxilla to Mandible***

*a). Antero-posterior*

1. ANB

*b). Vertical relation*

1. Maxillo-mandibular plane angle (MMPA)
2. Frankfort-mandibular plane angle (FMPA)
3. Facial axis angle
4. Occlusal plane to SN

### *D. Cranial Base*

1. Ba-S-N

### *E. Dental*

1. Upper incisor to Frankfort Horizontal plane
2. Upper incisor to Maxillary plane
3. Lower incisor to Mandibular plane
4. Interincisal angle
5. Upper incisor to SN
6. Maxillary Incisor position (UI-NA)
7. Lower incisor to NB angle

### *F. Mandibular Dimension*

1. Ar-Go-Me

### *G. Others*

1. Y-Axis/Growth axis (FH to S-Gn)
2. Facial Angle (Po-Or to N-Pog)
3. A-B Plane (N-Pog to A-B)

## *5.5.1.2 LINEAR*

### *A. Maxilla to Cranial Base*

*a). Vertical*

1. Upper facial Height (UFH)

*b). Horizontal*

1. A to N-perpendicular
2. A to Sella-Vertical

## *B. Mandible to Cranial Base*

*a). Vertical*

1. Total facial height (TFH)
2. Anterior facial height (AFH) : N-Me
3. Posterior facial height (PFH) : S-Go
4. Ratio LFH:TFH

*b). Horizontal*

1. Pogonion - Nperpendicular

## *C. Maxilla to Mandible*

*a). Vertical*

1. Lower facial height (LFH)
2. Lower anterior facial height (LAFH) : ANS-Me

*b). Horizontal*

1. Effective Maxillary length (Co-A)
2. Effective Mandibular length (Co-Gn)
3. Maxillo-mandibular differential
4. Wits

## D. Cranial Base

1. Ba - S
2. S - N
3. Ba - N

## E. Dentition

*a). Maxilla*

1. Upper incisor to A-perpendicular
2. Upper incisor to NA

*b). Mandible*

1. Lower incisor to A-pogonion
2. Lower Incisor to NB

*c). Maxilla and Mandible*

1. Overjet (OJ)
2. Overbite (OB)

## E. Mandibular Dimension

1. Go-Gn
2. Ar-Go

## 5.5.2 SOFT TISSUES

1. Lower lip to E-plane

# 5.6 SUMMARY OF LANDMARKS, REFERENCE LINES & MEASUREMENTS

## *Dentoskeletal Landmarks*

1. Sella (S)
2. Nasion (N)
3. Orbitale (Or)
4. Porion (Po)
5. Condylion (Cd)
6. Anterior Nasal Spine (ANS)
7. Posterior Nasal Spine (PNS)
8. Subspinale (point A)
9. Incisor Superius (U1E)
10. Apex of Upper Incisor (U1A)
11. Incisor Inferiors (L1E)
12. Apex of Lower Incisors (L1A)
13. Supramentale (point B)
14. Pogonion (Pog)
15. Gnathion (Gn)
16. Menton (Me)
17. Gonion (Go)
18. Articulare (Ar)
19. Basion (Ba)
20. PT point (PT)
21. Points from planes at pterygoid (CF)
22. Upper Molar (A6)
23. Lower Molar (B6)

## *Constructed Landmarks*

24. Reference Nasion (RN)
25. Reference Sella (RS)

## *Soft Tissue Landmarks*

26. Glabella (GS)
27. Point 2
28. Nasion (NS)
29. High-Nose Point (H)
30. Point 5
31. Mid-nose (MNS)
32. Point 6
33. Pronasale (PRN)
34. En
35. Point 10
36. Subnasale (SBN)

37. Superior labial sulcus (SLS)
38. Point 13
39. Labrale Superius (LS)
40. Point 15
41. Upper Stomion (UST)
42. Lower Stomion (LST)
43. Labrale Inferius (LI)
44. Point 19
45. Inferior labial sulcus (ILS)
46. Soft tissue pogonion (PGS)
47. DT
48. Soft tissue Gnathion (GNS)
49. Soft Tissue Menton (MES)

## *Reference Lines*

1. Frankfort Plane
2. Sella-Nasion
3. Mandibular Plane
4. Maxillary Plane
5. N-Perpendicular
6. A-Perpendicular
7. N-A
8. N-B
9. A-Pog
10. Ba-N
11. Posterosuperior PTM-Gn
12. U1A-U1E
13. L1A-L1E
14. E-line
15. Facial Plane (N-Pog)
16. Pterygoid vertical (PtV)
17. Occlusal plane (Op)
18. Facial Axis

## *Constructed Reference Lines*

1. Horizontal reference line (HRL)
2. Vertical reference line (VRL)

## *Angles*

1. SNA
2. SNB
3. S-N-Pog
4. S-N-Mdplane
5. Facial Depth (N-Pog to FH)
6. MMPA

7. FMPA
8. Facial axis angle
9. Ba-S-N
10. Upper incisor - FH
11. Upper incisor - Mxplane
12. Lower incisor - Mdplane
13. Interincisal angle
14. Upper incisor - SN
15. ANB
16. Ar-Go-Me
17. SN - Mx Plane
18. Go - Gn - SN
19. Occlusal plane - SN
20. A - B plane angle
21. Y - (Growth) Axis
22. Mx. Incisor position
23. Md. Incisor position

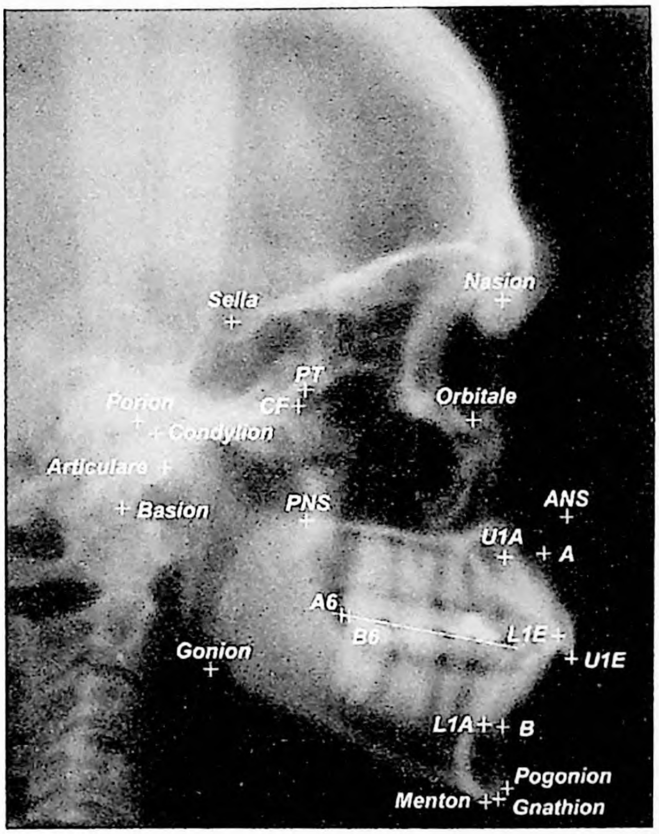
## *Linear*

1. UFH
2. A-Nper
3. A-Sella vertical
4. TFH
5. N-Me (AFH)
6. S-Go (PFH)
7. Pog-Nper
8. LFH
9. ANS-Me (LAFH)
10. Co-A (Effective maxillary length)
11. Co-Gn (Effective mandibular length)
12. Mx-Md differential
13. Ba-S
14. S-N
15. Ba-N
16. Upper incisor - Aper
17. Lower Incisor edge - Apog
20. Wits (BO-AO)
21. TFH:LFH
22. Go-Gn
23. Ar-Go
24. OJ
25. OB
26. U1 - NA
27. L1 - NB

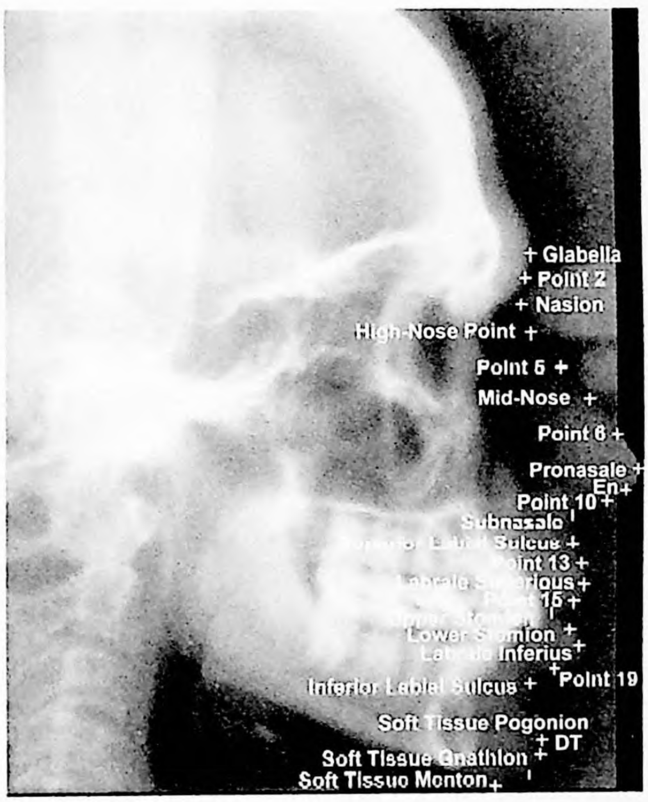
## *Soft Tissue*

1. lower lip to E-plane

# *Figure 1.* Dento-skeletal landmarks



## *Figure 2.* Soft tissue landmarks



# 5.7 STATISTICAL ANALYSIS

## 5.7.1 Two-sample t-statistic

Statistical analysis was carried out to determine whether there were any significant differences in the variables measured between the two groups. This is achieved by executing a "two-sample t-test" using a Minitab statistical software package.

Three level of significance were set:

a. 0.1% level ($p \leq 0.001$)

b. 1 % level ($p \leq 0.01$)

c. 5 % level ($p \leq 0.05$)

The groups that were compared were:

a. Malays and Caucasians (pool)

b. Malays and Caucasians (males)

c. Malays and Caucasians (females)

d. Malay males and females

e. Caucasian males and females

The results are laid out in table 10 to table 15.

# *Chapter 6.* ERROR OF METHODS

## 6.1 Malay sample (table 8)

### *a). Systematic error*

**p-Value :**

There is no systematic bias when p > 0.1 (Houston, 1983). No evidence of bias was found in the Malay sample (table 8). All p-Values were more than 0.1 except:

| | |
|---|---|
| A-N Perpendicular | 0.080 |
| Overjet | 0.096 |
| Lower Incisor-NB angle | 0.068 |
| Go-Gn to SN | 0.067 |

**95.0% Confidence interval:**

Null hypothesis showed that there was no difference between the first and second measurements. The confidence intervals all contained the value zero, therefore no evidence of bias was found.

### *b). Random error*

**Intra-class Correlation Coefficient (I.C.C.):**

Random error was estimated by assessing correlation between repeated measurements. The intra-class correlation coefficient which is termed as index of reliability, would be equal to one when there is lack of random error. The closer the I.C.C. is to one, the nearer the intra-class measurements (table 7).

The I.C.C. for all variables was found to be greater than 0.900 (excellent), with the exception of the following:

| | | |
|---|---|---|
| NS-Horizontal Ref. Line | 0.761 | (Good) |
| S-RS | 0.740 | (Good) |

## 6.2 Caucasian sample (Table 9)

### *a). Systematic error*

**p-Value :**

No evidence of bias was found since all p-Values were more than 0.1

**95.0% Confidence interval:**

Null hypothesis showed that there was no difference between the first and second measurements. The confidence intervals all contained the value zero, therefore no evidence of bias was found.

### *b). Random error*

The I.C.C. for all variables were found to be greater than 0.900 (excellent), with the exception of the following:

| | | |
|---|---|---|
| NS-Horizontal Ref. Line | 0.719 | (Good) |
| S-RS | 0.698 | (Acceptable) |
| LI-NB | 0.763 | (Good) |

On the whole, the error study for both the Malay and Caucasian samples was excellent with the exception of a few parameters. Therefore, caution should be taken when using these variables. However, the errors found were within acceptable limits.

| ***Table 7:*** Index of reliability | |
|---|---|
| *1. Poor* | Index of reliability ≤ 0.600 |
| *2. Acceptable* | 0.600 < Index of reliability ≤ 0.700 |
| *3. Good* | 0.700 < Index of reliability ≤ 0.900 |
| *4. Excellent* | 0.900 < Index of reliability |

Table 6: Error of study (Malay sample)

| Variable | Mean | StDev | P-Value | 95.0% C.I | I.C.C. |
|---|---|---|---|---|---|
| NS - Horizontal Ref. Line | -0.005 | 0.076 | 0.770 | ( -0.041, 0.031 ) | 0.761 |
| S - RS = 50mm | 0.010 | 0.141 | 0.750 | ( -0.056, 0.076 ) | 0.740 |
| NRN - Hori. Ref. Line = 90 | 0.000 | 0.159 | 1.000 | ( -0.074, 0.074 ) | 0.926 |
| SNA | 0.090 | 0.331 | 0.240 | ( -0.065, 0.245 ) | 0.994 |
| SNB | 0.000 | 0.243 | 1.000 | ( -0.114, 0.114 ) | 0.997 |
| ANB | -0.020 | 0.275 | 0.750 | ( -0.149, 0.109 ) | 0.984 |
| S - N - Pog | 0.000 | 0.175 | 1.000 | ( -0.082, 0.082 ) | 0.999 |
| SN - Maxillary Plane | 0.035 | 0.376 | 0.680 | ( -0.141, 0.211 ) | 0.995 |
| SN - Mandibular Plane | 0.110 | 0.395 | 0.230 | ( -0.075, 0.295 ) | 0.997 |
| N - Pog to FH (Facial Depth) | 0.085 | 0.230 | 0.110 | ( -0.023, 0.193 ) | 0.997 |
| FMPA | 0.045 | 0.419 | 0.640 | ( -0.151, 0.241 ) | 0.996 |
| MMPA | 0.080 | 0.337 | 0.300 | ( -0.078, 0.238 ) | 0.997 |
| Facial Axis Angle | 0.035 | 0.248 | 0.530 | ( -0.081, 0.151 ) | 0.998 |
| BA - S - N | 0.030 | 0.417 | 0.750 | ( -0.165, 0.225 ) | 0.997 |
| Upper Incisor - FH Plane | -0.070 | 0.220 | 0.170 | ( -0.173, 0.033 ) | 1.000 |
| Upper Incisor - Mx. Plane | 0.040 | 0.216 | 0.420 | ( -0.061, 0.141 ) | 0.999 |
| Lower Incisor - Md. Plane | 0.025 | 0.428 | 0.800 | ( -0.175, 0.225 ) | 0.997 |
| Interincisal Angle | 0.035 | 0.223 | 0.490 | ( -0.069, 0.139 ) | 1.000 |
| Upper Incisor - SN | 0.210 | 0.622 | 0.150 | ( -0.081, 0.501 ) | 0.997 |
| Ar - Go - Me (Md Dimension) | -0.052 | 0.246 | 0.360 | ( -0.167, 0.064 ) | 0.999 |
| UFH | -0.005 | 0.375 | 0.950 | ( -0.180, 0.171 ) | 0.994 |
| A - N Perpendicular | -0.090 | 0.217 | 0.080 | ( -0.192, 0.012 ) | 0.997 |
| A - Sella Vertical | -0.015 | 0.333 | 0.840 | ( -0.171, 0.141 ) | 0.997 |
| TFH | 0.130 | 0.511 | 0.270 | ( -0.109, 0.369 ) | 0.996 |
| AFH (N - Me) | 0.115 | 0.530 | 0.340 | ( -0.133, 0.363 ) | 0.996 |
| PFH (S - Go) | 0.045 | 0.490 | 0.690 | ( -0.185, 0.275 ) | 0.997 |
| Pog - N Perpendicular | 0.135 | 0.432 | 0.180 | ( -0.067, 0.337 ) | 0.997 |
| LFH | 0.130 | 0.356 | 0.120 | ( -0.036, 0.296 ) | 0.994 |
| Anterior LFH (ANS - Me) | -0.020 | 0.217 | 0.680 | ( -0.121, 0.081 ) | 0.998 |
| Effective Mx. Length (Cd - A) | 0.060 | 0.537 | 0.620 | ( -0.192, 0.312 ) | 0.990 |
| Effective Md. Length (Cd - Gn) | 0.195 | 0.562 | 0.140 | ( -0.068, 0.458 ) | 0.990 |

| Variable | Mean | StDev | P-Value | 95.0% C.I | I.C.C. |
|---|---|---|---|---|---|
| Wits | -0.105 | 0.284 | 0.110 | ( -0.238, 0.028 ) | 0.995 |
| Ba - S | 0.100 | 0.387 | 0.260 | ( -0.081, 0.281 ) | 0.991 |
| S - N | -0.145 | 0.427 | 0.150 | ( -0.345, 0.055 ) | 0.986 |
| Ba - N | -0.030 | 0.616 | 0.830 | ( -0.318, 0.258 ) | 0.989 |
| Upper Incisor - A Perpendicular | 0.095 | 0.278 | 0.140 | ( -0.035, 0.225 ) | 0.995 |
| Lower Incisor - Apog | 0.020 | 0.214 | 0.680 | ( -0.080, 0.120 ) | 0.996 |
| OJ | 0.075 | 0.192 | 0.096 | ( -0.015, 0.165 ) | 0.961 |
| OB | 0.035 | 0.157 | 0.330 | ( -0.038, 0.108 ) | 0.992 |
| Mandibular Dimension (Go - Gn) | -0.070 | 0.444 | 0.490 | ( -0.278, 0.138 ) | 0.993 |
| Mandibular Dimension (Ar - Go) | -0.050 | 0.420 | 0.600 | ( -0.247, 0.147 ) | 0.996 |
| Nasolabial Angle | -0.105 | 3.109 | 0.880 | ( -1.56, 1.350 ) | 0.977 |
| Lower Lip - E plane | 0.015 | 0.228 | 0.770 | ( -0.092, 0.122 ) | 0.994 |
| LFH : TFH | 0.035 | 0.176 | 0.380 | ( -0.047, 0.117 ) | 0.993 |
| Facial Angle (Po-Or to N-Pog) | 0.085 | 0.230 | 0.110 | ( -0.023, 0.193 ) | 0.997 |
| A - B Plane (N-Pog to A - B) | 0.070 | 0.208 | 0.150 | ( -0.027, 0.167 ) | 0.995 |
| Y - Axis (Growth Axis)-FH to S-Gn | 0.050 | 0.269 | 0.420 | ( -0.076, 0.176 ) | 0.996 |
| Mx. Incisor Position (UI - NA) | 0.145 | 0.504 | 0.210 | ( -0.091, 0.381 ) | 0.998 |
| Upper Incisor - NA | 0.015 | 0.223 | 0.770 | ( -0.089, 0.119 ) | 0.997 |
| Lower Incisor - NB Angle | 0.160 | 0.369 | 0.068 | ( -0.013, 0.333 ) | 0.998 |
| LI - NB | 0.040 | 0.150 | 0.250 | ( -0.030, 0.110 ) | 0.997 |
| Occlusal - SN | -0.065 | 0.230 | 0.220 | ( -0.173, 0.043 ) | 0.998 |
| Go - Gn to SN | 0.140 | 0.322 | 0.067 | ( -0.011, 0.291 ) | 0.998 |

## Table 8 : Error of study (Caucasian sample)

| *Variable* | *Mean* | *StDev* | *p-Value* | *95.0% C.I.* | *I.C.C.* |
|---|---|---|---|---|---|
| *NS - Horizontal Ref. Line* | 0.010 | 0.072 | 0.540 | ( -0.024, 0.044 ) | 0.719 |
| *S - RS = 50mm* | -0.010 | 0.202 | 0.830 | ( -0.105, 0.085 ) | 0.698 |
| *NRN - Hori. Ref. Line = 90* | -0.065 | 0.216 | 0.190 | ( -0.166, 0.036 ) | 0.913 |
| *SNA* | 0.005 | 0.132 | 0.870 | ( -0.057, 0.067 ) | 0.999 |
| *SNB* | 0.030 | 0.337 | 0.700 | ( -0.128, 0.188 ) | 0.995 |
| *ANB* | -0.025 | 0.385 | 0.770 | ( -0.205, 0.155 ) | 0.985 |
| *S - N - Pog* | 0.015 | 0.088 | 0.450 | ( -0.026, 0.056 ) | 1.000 |
| *SN - Maxillary Plane* | 0.005 | 0.119 | 0.850 | ( -0.051, 0.061 ) | 0.999 |
| *SN - Mandibular Plane* | 0.035 | 0.248 | 0.530 | ( -0.081, 0.151 ) | 0.999 |
| *N - Pog to FH (Facial Depth)* | 0.095 | 0.269 | 0.130 | ( -0.031, 0.221 ) | 0.994 |
| *FMPA* | 0.035 | 0.293 | 0.600 | ( -0.102, 0.172 ) | 0.998 |
| *MMPA* | 0.010 | 0.143 | 0.760 | ( -0.058, 0.078 ) | 0.999 |
| *Facial Axis Angle* | -0.005 | 0.263 | 0.930 | ( -0.128, 0.118 ) | 0.997 |
| *BA - S - N* | 0.025 | 0.102 | 0.290 | ( -0.023, 0.073 ) | 1.000 |
| *Upper Incisor - FH Plane* | 0.020 | 0.136 | 0.520 | ( -0.044, 0.084 ) | 1.000 |
| *Upper Incisor - Mx. Plane* | 0.155 | 0.523 | 0.200 | ( -0.090, 0.400 ) | 0.996 |
| *Lower Incisor - Md. Plane* | -0.095 | 0.454 | 0.360 | ( -0.307, 0.117 ) | 0.998 |
| *Interincisal Angle* | -0.205 | 0.574 | 0.130 | ( -0.474, 0.064 ) | 0.999 |
| *Upper Incisor - SN* | 0.040 | 0.119 | 0.150 | ( -0.016, 0.096 ) | 1.000 |
| *Ar - Go - Me (Md Dimension)* | -0.100 | 0.531 | 0.410 | ( -0.349, 0.149 ) | 0.996 |
| *UFH* | 0.010 | 0.148 | 0.770 | ( -0.059, 0.079 ) | 0.998 |
| *A - N Perpendicular* | 0.065 | 0.250 | 0.260 | ( -0.052, 0.182 ) | 0.996 |
| *A - Sella Vertical* | -0.005 | 0.140 | 0.870 | ( -0.070, 0.060 ) | 0.999 |
| *TFH* | 0.020 | 0.147 | 0.550 | ( -0.049, 0.089 ) | 1.000 |
| *AFH (N - Me)* | 0.310 | 1.426 | 0.340 | ( -0.358, 0.978 ) | 0.976 |
| *PFH (S - Go)* | 0.020 | 0.191 | 0.640 | ( -0.069, 0.109 ) | 1.000 |
| *Pog - N Perpendicular* | 0.015 | 0.135 | 0.620 | ( -0.048, 0.078 ) | 1.000 |
| *LFH* | 0.025 | 0.183 | 0.550 | ( -0.061, 0.111 ) | 0.999 |
| *Anterior LFH (ANS - Me)* | 0.045 | 0.179 | 0.280 | ( -0.039, 0.129 ) | 0.999 |
| *Effective Mx. Length (Cd - A)* | 0.050 | 0.140 | 0.130 | ( -0.015, 0.115 ) | 1.000 |
| *Effective Md. Length (Cd - Gn)* | 0.020 | 0.147 | 0.550 | ( -0.049, 0.089 ) | 1.000 |

| Variable | Mean | StDev | p-Value | 95.0% C.I. | I.C.C. |
|---|---|---|---|---|---|
| Wits | -0.020 | 0.191 | 0.640 | ( -0.109, 0.069 ) | 0.998 |
| Ba - S | 0.095 | 0.391 | 0.290 | ( -0.088, 0.278 ) | 0.992 |
| S - N | 0.020 | 0.180 | 0.620 | ( -0.064, 0.104 ) | 0.999 |
| Ba - N | 0.000 | 0.178 | 1.000 | ( -0.083, 0.083 ) | 1.000 |
| Upper Incisor - A Perpendicular | -0.055 | 0.206 | 0.250 | ( -0.152, 0.042 ) | 0.996 |
| Lower Incisor - Apog | 0.010 | 0.180 | 0.810 | ( -0.074, 0.094 ) | 0.997 |
| OJ | -0.040 | 0.167 | 0.300 | ( -0.118, 0.038 ) | 0.957 |
| OB | 0.070 | 0.223 | 0.180 | ( -0.034, 0.174 ) | 0.991 |
| Mandibular Dimension (Go - Gn) | -0.045 | 0.147 | 0.190 | ( -0.114, 0.024 ) | 1.000 |
| Mandibular Dimension (Ar - Go) | 0.004 | 0.166 | 0.930 | ( -0.074, 0.081 ) | 0.999 |
| Nasolabial Angle | -0.050 | 0.386 | 0.570 | ( -0.231, 0.131 ) | 1.000 |
| Lower Lip - E plane | -0.020 | 0.188 | 0.640 | ( -0.108, 0.068 ) | 0.996 |
| LFH : TFH | 0.035 | 0.173 | 0.380 | ( -0.046, 0.116 ) | 0.995 |
| Facial Angle (Po-Or to N-Pog) | 0.095 | 0.269 | 0.130 | ( -0.031, 0.221 ) | 0.994 |
| A - B Plane (N-Pog to A - B) | 0.000 | 0.245 | 1.000 | ( -0.115, 0.115 ) | 0.997 |
| Y - Axis (Growth Axis)-FH to S-Gn | 0.030 | 0.329 | 0.690 | ( -0.124, 0.184 ) | 0.994 |
| Mx. Incisor Position (UI - NA) | -0.060 | 0.190 | 0.170 | ( -0.149, 0.029 ) | 0.999 |
| Upper Incisor - NA | -0.060 | 0.179 | 0.150 | ( -0.144, 0.024 ) | 0.996 |
| Lower Incisor - NB Angle | 0.010 | 0.460 | 0.920 | ( -0.205, 0.225 ) | 0.998 |
| LI - NB | 0.495 | 1.709 | 0.210 | ( -0.305, 1.295 ) | 0.763 |
| Occlusal - SN | -0.060 | 0.246 | 0.290 | ( -0.175, 0.055 ) | 0.999 |
| Go - Gn to SN | 0.040 | 0.262 | 0.500 | ( -0828, 0.163 ) | 0.999 |

# Chapter 7. RESULTS

## 7.1 INTER-GROUP COMPARISON

### 7.1.1 POOL (tables 10 and 15)

#### *7.1.1.1 SKELETAL PARAMETERS*

***Angular Measurements***

Significant differences were found in the angles ***SNA, SNB*** at 0.1% level ($p \leq 0.001$). The Malays have a larger SNA and SNB angles compared to the Caucasians. The differences in the ***S-N-Pog*** and ***S-N-Maxillary plane*** angles were statistically significant at 1% level ($p \leq 0.01$). The Caucasians exhibited a smaller S-N-Pog angle but a larger S-N-Maxillary plane angle. ***Mandibular Dimension*** (Ar-Go-Me) was found to be significantly larger in the Caucasians at 5% level ($p \leq 0.05$).

***Linear Measurements***

Significant differences were observed between the 2 groups studied. These were ***A-N perpendicular*** ($p \leq 0.01$), ***Wits*** ($p \leq 0.001$), ***S-N*** ($p \leq 0.001$) and ***Ba-N*** ($p \leq 0.01$). The Malays have a larger A-N perpendicular but smaller Wits, S-N and Ba-N measurements.

#### *7.1.1.2 DENTAL PARAMETERS*

***Angular Measurements***

All the parameters measured were significantly different at 0.1% level ($p \leq 0.001$). The ***upper incisor-FH plane, upper incisor-Maxillary plane, lower incisor-Mandibular plane, upper incisor-SN, Maxillary incisor position*** and ***lower incisor-***

***NB angle*** (table 10) were significantly larger in the Malays. However, the ***interincisal angle*** was significantly larger in the Caucasians.

#### *Linear Measurements*

As with the angular analysis, all variables were significantly different ($p \leq 0.001$) except the overbite and overjet, which were the selection criteria. The ***upper incisor-A perpendicular, upper incisor-NA, lower incisor-A Pogonion*** and ***lower incisor-NB*** were significantly larger in the Malays.

### *7.1.1.3 SOFT TISSUE PARAMETERS*

The ***lower lip - E plane*** was significantly different between the 2 groups at 0.1% level ($p \leq 0.001$). The Malays have a larger value indicating more prominent lips.

## 7.1.2 MALES (tables 11 and 15)

### *7.1.2.1 SKELETAL PARAMETERS*

#### *Angular Measurements*

Four measurements were found to be statistically significant. These were ***SNA*** ($p \leq 0.001$), ***SNB*** ($p \leq 0.01$), ***S-N-Pog*** ($p \leq 0.05$) and ***Ar-Go-Me*** ($p \leq 0.001$). The Malays have a larger SNA, SNB and S-N-Pog but a smaller Ar-Go-Me.

#### *Linear Measurements*

The only linear difference was found in the cranial base dimensions. The distance between ***S-N*** (anterior cranial base) was found to be significantly larger in the Caucasians at 0.1% level ($p \leq 0.001$) and the ***Ba-N*** (total cranial base) was found to be significantly larger in the Caucasians at 5% level ($p \leq 0.05$).

### 7.1.2.2 DENTAL PARAMETERS

#### Angular Measurements

All the measurements showed significant differences except the Maxillary incisor position(UI-NA). The upper incisor angulation in relation to Frankfort plane (*UI-FH*), Maxillary plane (***UI-Mx plane***) and Sella-Nasion (*UI-SN*) was found to be significant at 1% level ($p \leq 0.01$). On the other hand, the lower incisor angulation (***LI-Md plane*** and ***LI-NB***) was statistically significant at 0.1% level ($p \leq 0.001$). These values were found to be larger in the Malays. On the other hand, the interincisal angle was found to be significantly smaller in the Malays.

#### Linear Measurements

Analysis of the linear measurements also showed significant differences between groups. The ***UI-A perpendicular***, ***LI-A Pogonion*** and ***LI-NB*** were significantly larger in the Malays at 0.1% level ($p \leq 0.001$). Other than that, the ***UI-NA*** ($p \leq 0.01$) and ***Overjet*** ($p \leq 0.05$) were found to be significantly larger in the Malays. However the difference in Overjet was only 0.56mm, which is too small to be clinically significant.

### 7.1.2.3 SOFT TISSUE PARAMETERS

The relationship of ***lower lip to E-plane*** was found to be significant at 0.1% level ($p \leq 0.001$). The Malays have more protrusive lips.

# 7.1.3 FEMALES (tables 12 and 15)

## 7.1.3.1 SKELETAL PARAMETERS

### Angular Measurements

When the female subjects were compared, 5 angular measurements were found to be statistically significant. These were the ***SNA*** and ***SNB*** ($p \leq 0.01$). Both these variables were larger in the Malay females. Three other measurements, ***S-N-Pog***, ***S-N-Maxillary plane*** and ***MMPA*** were significant at 5% level ($p \leq 0.05$). The Malay females have a larger S-N-Pog and MMPA and a smaller S-N-Maxillary plane angle.

### Linear Measurements

The linear measurements that were statistically significant were the ***LFH*** ($p \leq 0.05$), ***A-N Perpendicular*** ($p \leq 0.01$), ***Wits appraisal*** ($p \leq 0.001$), ***S-N*** ($p \leq 0.01$), ***Ba-N*** ($p \leq 0.01$) and ***Go-Gn*** ($p \leq 0.05$). The Malay females have a significantly larger LFH, A-N Perpendicular and Go-Gn but a smaller cranial base length, S-N and B-N.

## 7.1.3.2 DENTAL PARAMETERS

### Angular Measurements

All parameters showed significant differences at 0.1% level ($p \leq 0.001$) except the lower incisor to mandibular plane angle. These variables were upper incisor angulation in relation to Frankfort plane (***UI-FH***), Maxillary plane (***UI-Mx plane***), Sella-Nasion (***UI-SN***) and likewise, the lower incisor angulation (***LI-NB***) and interincisal angle. These angles were smaller in the Caucasian females with the exception of interincisal angle.

***Linear Measurements***

The linear measurements were in agreement with those of the angular measurements. ***Upper incisor to A perpendicular, upper incisor - NA, lower incisor - A Pog and lower incisor - NB*** were all significantly larger in the Malays at 0.1% level ($p \leq 0.001$). In addition, there was a significant difference in the ***overbite*** ($p \leq 0.01$) in the female subjects between the two samples with the Caucasians having a larger overbite.

#### *7.1.3.3 SOFT TISSUE PARAMETERS*

The lower lip to Ricketts E-plane was significantly larger in the Malay females at 1% level ($p \leq 0.001$).

# 7.2 WITHIN-GROUP COMPARISON

## 7.2.1 MALAYS (tables 13 and 15)

#### *7.2.1.1 SKELETAL PARAMETERS*

***Angular Measurements***

When the male and female subjects were compared in the Malay sample, 7 angular measurements were found to be statistically significant. These were the ***SNA*** ($p \leq 0.05$), ***S-N-Mandibular plane*** ($p \leq 0.01$), ***FMPA*** ($p \leq 0.05$), ***MMPA*** ($p \leq 0.05$). ***Ba-S-N*** ($p \leq 0.01$), ***occlusal-SN*** ($p \leq 0.01$) and ***Go-Gn to SN*** ($p \leq 0.01$). The male subjects have a larger SNA value but have smaller values for the rest of the variables.

***Linear Measurements***

Unlike the angular measurements, the linear analysis showed significant differences in most of the variables with the males having larger values. These were the ***UFH, LFH, TFH, AFH, PFH, anterior LFH, A-Sella vertical, effective maxillary*** and ***mandibular length, Ba-S, S-N, Ba-N*** and ***the mandibular dimension (Go-Gn and Ar-Go).***

#### *7.2.1.2 DENTAL PARAMETERS*

***Angular and Linear Measurements***

There was no significant difference in the dental parameters when the males were compared to the females.

#### *7.2.1.3 SOFT TISSUE PARAMETERS*

There was no significant difference found between both sexes.

### 7.2.2 CAUCASIANS (table 14 and 15)

#### *7.2.2.1 SKELETAL PARAMETERS*

***Angular Measurements***

Only one parameter showed a significant difference between the sexes. This was the ***cranial base angle*** (Ba-S-N), which was significantly larger in the female subjects at 5% level ($p \leq 0.05$).

***Linear Measurements***

As with the Malay males, the linear measurements were significantly larger in most of the variables. These include ***UFH, LFH, LFH:TFH, TFH, AFH, PFH, anterior LFH, A-Sella vertical, effective maxillary*** and ***mandibular length, Ba-S, S-N, Ba-N*** and ***the mandibular dimensions (Go-Gn and Ar-Go).***

### *7.2.2.2 DENTAL PARAMETERS*

#### *Angular and Linear Measurements*

There was no significant difference when the dental variables were measured.

### *7.2.2.3 SOFT TISSUES PARAMETERS*

There was no significant difference when the lower lip was measured in relation to the aesthetic plane.

## *Table 10: Descriptive Statistics and 95.0% Confidence Interval for Malays and Caucasian(pool)*

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| *Age* *** | 23.12 | 0.43 | ( 23.00, 23.24 ) | 22.59 | 0.59 | ( 22.41, 22.76 ) |
| **REFERENCE PARAMETERS** | | | | | | |
| *NS - Horizontal Ref. Line* | 6.97 | 0.09 | ( 6.95, 6.99 ) | 6.95 | 0.09 | ( 6.93, 6.98 ) |
| *S - RS = 50mm* | 50.00 | 0.19 | ( 49.95, 50.05 ) | 49.99 | 0.16 | ( 49.95, 50.04 ) |
| *NRN - Hori. Ref. Line = 90* | 89.92 | 0.68 | ( 89.72, 90.09 ) | 89.81 | 0.36 | ( 89.70, 89.91 ) |
| **SKELETAL PARAMETERS** | | | | | | |
| ***1. Angular Measurements*** | | | | | | |
| *SNA* *** | 84.22 | 3.46 | ( 83.28, 85.16 ) | 80.79 | 4.04 | ( 79.58, 82.00 ) |
| *SNB* *** | 80.77 | 3.68 | ( 79.77, 81.78 ) | 77.65 | 3.91 | ( 76.48, 78.85 ) |
| *ANB* | 3.45 | 1.98 | ( 2.91, 3.99 ) | 3.14 | 2.42 | ( 2.41, 3.87 ) |
| *S - N - Pog* ** | 81.48 | 3.78 | ( 80.45, 82.51 ) | 79.15 | 3.91 | ( 77.97, 80.32 ) |
| *SN - Maxillary Plane* ** | 7.70 | 3.28 | ( 6.81, 8.60 ) | 9.56 | 2.81 | ( 8.715, 10.41 ) |
| *SN - Mandibular Plane* | 33.46 | 5.30 | ( 32.02, 34.91 ) | 34.16 | 5.38 | ( 32.54, 35.78 ) |

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | **Mean** | **StDev** | **95.0 % C.I.** | **Mean** | **StDev** | **95.0 % C.I.** |
| *N - Pog to FH (Facial Depth)* | 89.73 | 3.59 | ( 88.75, 90.71 ) | 88.66 | 3.16 | ( 87.71, 89.61 ) |
| *FMPA* | 25.21 | 4.77 | ( 23.91, 26.51 ) | 24.67 | 4.48 | ( 23.32, 26.01 ) |
| *MMPA* | 25.75 | 4.60 | ( 24.50, 27.01 ) | 24.61 | 4.87 | ( 23.15, 26.07 ) |
| *Facial Axis Angle* | 87.65 | 3.57 | ( 86.68, 88.63 ) | 88.88 | 4.19 | ( 87.62, 90.13 ) |
| *BA - S - N* | 129.42 | 6.23 | ( 127.72, 131.13 ) | 131.09 | 5.85 | ( 129.33, 132.85 ) |
| *Ar - Go - Me (Md Dimension)* * | 124.19 | 6.09 | ( 122.52, 125.85 ) | 126.58 | 4.92 | ( 125.10, 128.05 ) |
| *Occlusal - SN* | 16.51 | 4.48 | ( 15.29, 17.73 ) | 16.67 | 4.89 | ( 15.20, 18.14 ) |
| *Go - Gn to SN* | 30.92 | 5.18 | ( 29.51, 32.33 ) | 31.84 | 5.36 | ( 30.23, 33.46 ) |
| *Y - Axis (Growth Axis)-FH to S-Gn* | 59.37 | 3.42 | ( 58.42, 60.29 ) | 58.52 | 3.46 | ( 57.48, 59.56 ) |
| *Facial Angle (Po-Or to N-Pog)* | 89.73 | 3.59 | ( 88.75, 90.71 ) | 88.66 | 3.16 | ( 87.71, 89.61 ) |
| ***2. Linear Measurements*** | | | | | | |
| *UFH* | 50.89 | 3.47 | ( 49.94, 51.83 ) | 50.99 | 3.07 | ( 50.06, 51.91 ) |
| *LFH* | 62.98 | 4.08 | ( 61.87, 64.10 ) | 62.12 | 5.18 | ( 60.57, 63.68 ) |
| *LFH : TFH* | 55.46 | 1.69 | ( 55.00, 55.92 ) | 55.29 | 1.58 | ( 54.82, 55.76 ) |
| *TFH* | 113.87 | 6.11 | ( 112.20, 115.54 ) | 113.10 | 7.20 | ( 110.93, 115.26 ) |
| *AFH (N - Me)* | 114.49 | 6.25 | ( 112.78, 116.19 ) | 114.10 | 7.20 | ( 111.93, 116.26 ) |

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | **Mean** | **StDev** | **95.0 % C.I.** | **Mean** | **StDev** | **95.0 % C.I.** |
| *PFH (S - Go)* | 75.28 | 6.86 | ( 73.41, 77.16 ) | 73.85 | 5.95 | ( 72.07, 75.64 ) |
| *Pog - N Perpendicular* | -0.52 | 6.67 | ( -2.34, 1.30 ) | -2.54 | 6.03 | ( -4.35, -0.73 ) |
| *Anterior LFH (ANS - Me)* | 64.77 | 4.19 | ( 63.63, 65.92 ) | 64.50 | 5.21 | ( 62.94, 66.07 ) |
| *A - N Perpendicular* ** | 2.38 | 3.60 | ( 1.40, 3.36 ) | 0.31 | 3.41 | ( -0.71, 1.34 ) |
| *A - Sella Vertical* | 66.05 | 4.37 | ( 64.85, 67.24 ) | 66.53 | 5.05 | ( 65.01, 68.05 ) |
| *Effective Mx. Length (Cd - A)* | 84.72 | 4.28 | ( 83.56, 85.89 ) | 85.99 | 5.54 | ( 84.32, 87.65 ) |
| *Effective Md. Length (Cd - Gn)* | 112.43 | 5.57 | ( 110.91, 113.95 ) | 112.71 | 7.60 | ( 110.43, 114.99 ) |
| *Wits* *** | -1.89 | 2.85 | ( -2.67, -1.11 ) | 0.18 | 3.11 | ( -0.75, 1.12 ) |
| *Ba - S* | 43.31 | 3.23 | ( 42.43, 44.19 ) | 42.72 | 2.80 | ( 41.87, 43.56 ) |
| *S - N* *** | 64.44 | 3.15 | ( 63.59, 65.30 ) | 67.21 | 3.71 | ( 66.10, 68.33 ) |
| *Ba - N* ** | 97.68 | 4.49 | ( 96.46, 98.91 ) | 100.40 | 4.25 | ( 99.12, 101.68 ) |
| *A - B Plane (N-Pog to A - B)* | 5.35 | 2.52 | ( 4.67, 6.04 ) | 6.10 | 3.47 | ( 5.05, 7.14 ) |
| *Mandibular Dimension (Go - Gn)* | 73.93 | 4.40 | ( 72.73, 75.14 ) | 72.45 | 5.24 | ( 70.88, 74.02 ) |
| *Mandibular Dimension (Ar - Go)* | 46.23 | 4.45 | ( 45.02, 47.45 ) | 45.37 | 4.02 | ( 44.16, 46.57 ) |

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| **DENTAL PARAMETERS** | | | | | | |
| **1. Angular Measurements** | | | | | | |
| Upper Incisor - FH Plane *** | 114.42 | 7.18 | ( 112.46, 116.38 ) | 106.44 | 7.98 | ( 104.05, 108.84 ) |
| Upper Incisor - Mx. Plane *** | 113.87 | 6.27 | ( 112.16, 115.58 ) | 106.50 | 7.95 | ( 104.11, 108.89 ) |
| Lower Incisor - Md. Plane *** | 96.74 | 5.80 | ( 95.16, 98.33 ) | 91.62 | 7.61 | ( 89.33, 93.91 ) |
| Interincisal Angle *** | 123.64 | 8.92 | ( 121.21,126.08 ) | 137.27 | 12.77 | ( 133.43, 141.10 ) |
| Upper Incisor - SN *** | 106.16 | 7.64 | ( 104.08, 108.25 ) | 96.95 | 8.69 | ( 94.34, 99.56 ) |
| Mx. Incisor Position (UI - NA) *** | 21.95 | 7.11 | ( 20.01, 23.89 ) | 16.16 | 8.34 | ( 13.65, 18.67 ) |
| Lower Incisor - NB Angle *** | 30.97 | 5.58 | ( 29.45, 32.49 ) | 23.42 | 7.51 | ( 21.16, 25.68 ) |
| **2. Linear Measurements** | | | | | | |
| Upper Incisor - A Perpendicular *** | 6.51 | 2.83 | ( 5.74, 7.28 ) | 2.55 | 2.78 | ( 1.72, 3.39 ) |
| Upper Incisor - NA *** | 5.47 | 2.73 | ( 4.72, 6.22 ) | 2.46 | 3.00 | ( 1.56, 3.36 ) |
| Lower Incisor - Apog *** | 4.71 | 2.04 | ( 4.15, 5.27 ) | 0.99 | 2.41 | ( 0.27, 1.72 ) |
| LI - NB *** | 7.26 | 1.96 | ( 6.73, 7.80 ) | 3.96 | 2.52 | ( 3.20, 4.72 ) |
| OJ | 2.95 | 0.77 | ( 2.74, 3.16 ) | 2.67 | 0.78 | ( 2.44, 2.91 ) |
| OB | 2.42 | 2.75 | ( 1.67, 3.17 ) | 3.37 | 2.09 | ( 2.73, 3.98 ) |

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | **Mean** | **StDev** | **95.0 % C.I.** | **Mean** | **StDev** | **95.0 % C.I.** |
| **SOFT TISSUE PARAMETERS** | | | | | | |
| *Lower Lip - E plane* *** | 1.58 | 2.06 | ( 1.02, 2.14 ) | -3.75 | 2.33 | ( -4.45, -3.05 ) |

****** Significant at 0.1 % level ($p \leq 0.001$)***
***** Significant at 1 % level ($p \leq 0.01$)***
**** Significant at 5 % level ($p \leq 0.05$)***

**Table 11: Descriptive Statistics and 95.0% Confidence Interval for Malay and Caucasian Males**

| Variables | MALAYS | | | CAUCASIAN | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| Age *** | 23.13 | 0.41 | ( 22.96, 23.30 ) | 22.53 | 0.53 | ( 22.28, 22.78 ) |
| **REFERENCE PARAMETERS** | | | | | | |
| NS - Horizontal Ref. Line | 6.98 | 0.07 | ( 6.95, 7.01) | 6.94 | 0.10 | ( 6.89, 6.98 ) |
| S - RS = 50mm | 50.02 | 0.17 | ( 49.95, 50.09 ) | 49.96 | 0.16 | ( 49.88, 50.03 ) |
| NRN - Hori. Ref. Line = 90 | 89.80 | 0.67 | ( 89.51, 90.08 ) | 89.88 | 0.36 | ( 89.71, 90.04 ) |
| **SKELETAL PARAMETERS** | | | | | | |
| **1.Angular Measurements** | | | | | | |
| SNA *** | 85.29 | 3.48 | ( 83.82, 86.76 ) | 81.26 | 3.89 | ( 79.44, 83.08 ) |
| SNB ** | 81.77 | 3.60 | ( 80.25, 83.29 ) | 78.62 | 2.86 | ( 77.28, 79.95 ) |
| ANB | 3.53 | 1.64 | ( 2.84, 4.22 ) | 2.65 | 2.48 | ( 1.48, 3.81 ) |
| S - N - Pog * | 82.53 | 3.56 | ( 81.03, 84.03 ) | 80.42 | 2.58 | ( 79.22, 81.63 ) |
| SN - Maxillary Plane | 7.42 | 3.85 | ( 5.79, 9.05 ) | 9.08 | 2.35 | ( 7.98, 10.18 ) |
| SN - Mandibular Plane | 31.16 | 5.32 | ( 28.91, 33.41 ) | 33.45 | 4.00 | ( 31.58, 35.32 ) |

| Variables | MALAYS | | | CAUCASIAN | | |
|---|---|---|---|---|---|---|
| | ***Mean*** | ***StDev*** | ***95.0 % C.I.*** | **Mean** | **StDev** | **95.0 % C.I.** |
| *N - Pog to FH (Facial Depth)* | 90.20 | 3.61 | ( 88.68, 91.73) | 89.65 | 2.90 | ( 88.29, 91.00 ) |
| *FMPA* | 23.48 | 4.92 | ( 21.40, 25.56 ) | 24.25 | 3.58 | ( 22.58, 25.93 ) |
| *MMPA* | 23.73 | 4.64 | ( 21.77, 25.69 ) | 24.41 | 3.99 | ( 22.54, 26.28 ) |
| *Facial Axis Angle* | 87.38 | 3.46 | ( 85.92, 88.84 ) | 89.18 | 3.32 | ( 87.63, 90.73 ) |
| *BA - S - N* | 126.97 | 5.13 | ( 124.80, 129.14 ) | 128.97 | 6.29 | ( 126.02, 131.92 ) |
| *Ar - Go - Me (Md Dimension)* ** | 122.65 | 6.79 | ( 119.78, 125.52 ) | 127.25 | 3.46 | ( 125.64,128.87 ) |
| *Occlusal - SN* | 14.57 | 4.27 | ( 12.77, 16.37 ) | 15.17 | 4.30 | ( 13.16, 17.18 ) |
| *Go - Gn to SN* | 28.68 | 5.19 | ( 26.49, 30.87 ) | 31.19 | 3.97 | ( 29.33, 33.05 ) |
| *Y - Axis (Growth Axis)- FH to S-Gn* | 59.27 | 3.26 | ( 57.89, 60.64 ) | 58.01 | 3.19 | ( 56.51, 59.50 ) |
| *Facial Angle (Po-Or to N-Pog)* | 90.20 | 3.61 | ( 88.68, 91.73 ) | 89.65 | 2.90 | ( 88.29, 91.00 ) |
| ***2. Linear Measurements*** | | | | | | |
| *UFH* | 52.78 | 3.14 | ( 51.46, 54.11 ) | 52.59 | 3.23 | ( 51.07, 54.10 ) |
| *LFH* | 64.83 | 3.42 | ( 63.38, 66.27 ) | 65.84 | 4.25 | ( 63.84, 67.83 ) |
| *LFH : TFH* | 55.27 | 1.81 | ( 54.50, 56.03 ) | 55.90 | 1.41 | ( 55.23, 56.56 ) |
| *TFH* | 117.61 | 4.26 | ( 115.81, 119.41 ) | 118.41 | 6.45 | ( 115.39, 121.43 ) |
| *AFH (N - Me)* | 118.09 | 4.56 | ( 116.16, 120.01 ) | 118.97 | 6.37 | ( 115.99, 121.95 ) |
| *PFH (S - Go)* | 80.53 | 4.89 | ( 78.46, 82.59 ) | 77.69 | 5.31 | ( 75.21, 80.18 ) |

| Variables | MALAYS | | | CAUCASIAN | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| Pog - N Perpendicular | 0.37 | 6.86 | ( -2.53, 3.27 ) | -0.73 | 5.60 | ( -3.35, 1.89 ) |
| Anterior LFH (ANS - Me) | 66.26 | 3.73 | ( 64.69, 67.84 ) | 67.60 | 4.33 | ( 65.57, 69.62 ) |
| A - N Perpendicular | 2.93 | 3.70 | ( 1.37, 4.50 ) | 0.63 | 4.13 | ( -1.31, 2.56 ) |
| A - Sella Vertical | 68.33 | 3.78 | ( 66.73, 69.92 ) | 69.05 | 5.24 | ( 66.60, 71.50 ) |
| Effective Mx. Length (Cd - A) | 87.60 | 3.51 | ( 86.12, 89.08 ) | 89.56 | 5.41 | ( 87.03, 92.09 ) |
| Effective Md. Length (Cd - Gn) | 116.19 | 3.71 | ( 114.63, 117.76 ) | 118.83 | 6.55 | ( 115.77, 121.90 ) |
| Wits | -1.19 | 2.88 | ( -2.40, 0.03 ) | 0.20 | 3.59 | ( -1.483, 1.883 ) |
| Ba - S | 45.55 | 2.65 | ( 44.43, 46.67 ) | 44.42 | 2.73 | ( 43.14, 45.70 ) |
| S - N *** | 66.09 | 2.47 | ( 65.05, 67.13 ) | 69.40 | 3.68 | ( 67.67, 71.12 ) |
| Ba - N * | 100.26 | 3.75 | ( 98.68, 101.85 ) | 103.08 | 4.05 | ( 101.19, 104.97 ) |
| A - B Plane (N-Pog to A - B) | 5.59 | 2.29 | ( 4.63, 6.56 ) | 5.91 | 3.84 | ( 4.11, 7.71 ) |
| Mandibular Dimension (Go - Gn) | 75.84 | 3.80 | ( 74.24, 77.45 ) | 75.83 | 5.10 | ( 73.44, 78.22 ) |
| Mandibular Dimension (Ar - Go) | 49.37 | 3.87 | ( 47.73, 51.00 ) | 46.97 | 4.40 | ( 44.91, 49.03 ) |

| Variables | MALAYS | | | CAUCASIAN | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| **DENTAL PARAMETERS** | | | | | | |
| **1. Angular Measurements** | | | | | | |
| Upper Incisor - FH Plane ** | 113.52 | 7.08 | ( 110.53, 116.51 ) | 107.40 | 6.18 | ( 104.51, 110.29 ) |
| Upper Incisor - Mx. Plane ** | 113.29 | 5.98 | ( 110.76, 115.81) | 107.24 | 7.33 | ( 103.81, 110.67 ) |
| Lower Incisor - Md. Plane *** | 96.82 | 5.33 | ( 94.57, 99.07 ) | 89.72 | 5.67 | ( 87.06, 92.38 ) |
| Interincisal Angle *** | 126.18 | 9.84 | ( 122.03, 130.34 ) | 138.63 | 10.75 | ( 133.59, 143.66 ) |
| Upper Incisor - SN ** | 105.85 | 8.22 | ( 102.38, 109.33 ) | 98.18 | 7.29 | ( 94.77, 101.60 ) |
| Mx. Incisor Position (UI - NA) | 20.56 | 7.36 | ( 17.45, 23.67 ) | 16.92 | 7.40 | ( 13.46, 20.38 ) |
| Lower Incisor - NB Angle *** | 29.73 | 5.35 | ( 27.47, 31.99 ) | 21.80 | 6.11 | ( 18.94, 24.65 ) |
| **2. Linear Measurements** | | | | | | |
| Upper Incisor - A Perpendicular *** | 6.39 | 2.98 | ( 5.13, 7.65 ) | 2.79 | 2.11 | ( 1.80, 3.77 ) |
| Upper Incisor - NA ** | 5.11 | 3.01 | ( 3.84, 6.39 ) | 2.66 | 2.96 | ( 1.27, 4.04 ) |
| Lower Incisor - Apog *** | 4.20 | 2.39 | ( 3.20, 5.21 ) | 0.69 | 1.96 | ( -0.23, 1.60 ) |
| LI - NB *** | 6.98 | 2.07 | ( 6.10, 7.85 ) | 3.79 | 2.06 | ( 2.82, 4.75 ) |
| OJ * | 3.13 | 0.81 | ( 2.79, 3.48 ) | 2.57 | 0.81 | ( 2.19, 2.95 ) |
| OB | 3.02 | 2.80 | ( 1.83, 4.20 ) | 2.95 | 2.52 | ( 1.77, 4.13 ) |

| *Variables* | *MALAYS* | | | *CAUCASIAN* | | |
|---|---|---|---|---|---|---|
| | ***Mean*** | ***StDev*** | ***95.0 % C.I.*** | **Mean** | **StDev** | **95.0 % C.I.** |
| ***SOFT TISSUE PARAMETERS*** | | | | | | |
| *Lower Lip - E plane **** | 1.89 | 2.15 | ( 0.98, 2.80 ) | -3.96 | 2.27 | ( -5.02, -2.89 ) |

****** Significant at 0.1 % level ($p \leq 0.001$)***
***** Significant at 1 % level ($p \leq 0.01$)***
**** Significant at 5 % level ($p \leq 0.05$)***

### Table 12 : Descriptive Statistics and 95.0% Confidence Interval of Malay and Caucasian Females

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| Age * | 23.11 | 0.46 | ( 22.94, 23.28 ) | 22.63 | 0.63 | ( 2.37, 22.89 ) |
| **REFERENCE PARAMETERS** | | | | | | |
| NS - Horizontal Ref. Line | 6.96 | 0.10 | ( 6.92, 7.00 ) | 6.97 | 0.07 | ( 6.94, 7.00 ) |
| S - RS = 50mm | 49.98 | 0.20 | ( 49.90, 50.05 ) | 50.02 | 0.15 | ( 49.96, 50.09 ) |
| NRN - Hori. Ref. Line = 90 | 90.00 | 0.68 | ( 89.74, 90.25 ) | 89.75 | 0.36 | ( 89.60, 89.90) |
| **SKELETAL PARAMETERS** | | | | | | |
| **1. Angular Measurements** | | | | | | |
| SNA ** | 83.36 | 3.24 | ( 82.15, 84.57 ) | 80.41 | 4.20 | ( 78.68, 82.15 ) |
| SNB ** | 79.98 | 3.60 | ( 78.64, 81.32 ) | 76.88 | 4.50 | ( 75.02, 78.74) |
| ANB | 3.39 | 2.24 | ( 2.55, 4.22 ) | 3.54 | 2.34 | ( 2.57, 4.50) |
| S - N - Pog * | 80.63 | 3.79 | ( 79.22, 82.05 ) | 78.13 | 4.51 | ( 76.27, 80.00) |
| SN - Maxillary Plane * | 7.92 | 2.79 | ( 6.88, 8.96 ) | 9.94 | 3.13 | ( 8.65, 11.24 ) |
| SN - Mandibular Plane | 35.32 | 4.58 | ( 33.60, 37.02 ) | 34.72 | 6.30 | ( 32.12, 37.33 ) |
| N - Pog to FH (Facial Depth) | 89.35 | 3.59 | ( 88.01, 90.69 ) | 87.86 | 3.20 | ( 86.54, 89.18 ) |

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | **Mean** | **StDev** | **95.0 % C.I.** | **Mean** | **StDev** | **95.0 % C.I.** |
| *FMPA* | 26.59 | 4.23 | ( 25.01, 28.18 ) | 25.00 | 5.13 | ( 22.89, 27.12 ) |
| *MMPA* * | 27.37 | 3.93 | ( 25.91, 28.84 ) | 24.77 | 5.55 | ( 22.48, 27.06 ) |
| *Facial Axis Angle* | 87.87 | 3.69 | ( 86.49, 89.25 ) | 88.63 | 4.83 | ( 86.64, 90.63 ) |
| *BA - S - N* | 131.39 | 6.41 | ( 128.99, 133.78 ) | 132.78 | 4.98 | ( 130.73, 134.84 ) |
| *Ar - Go - Me (Md Dimension)* | 125.41 | 5.26 | ( 123.45, 127.38 ) | 126.03 | 5.84 | ( 123.62, 128.44 ) |
| *Occlusal - SN* | 18.06 | 4.07 | ( 16.54, 19.59 ) | 17.87 | 5.09 | ( 15.77, 19.97 ) |
| *Go - Gn to SN* | 32.71 | 4.49 | ( 31.03, 34.39 ) | 32.37 | 6.29 | ( 29.78, 34.97 ) |
| *Y - Axis (Growth Axis)-FH to S-Gn* | 59.43 | 3.59 | ( 58.08, 60.77 ) | 58.93 | 3.68 | ( 57.42, 60.45 ) |
| *Facial Angle (Po-Or to N-Pog)* | 89.35 | 3.59 | ( 88.01, 90.69 ) | 87.86 | 3.20 | ( 86.54, 89.18 ) |
| ***2. Linear Measurements*** | | | | | | |
| *UFH* | 49.37 | 2.96 | ( 48.26, 50.47 ) | 49.71 | 2.28 | ( 48.77, 50.65 ) |
| *LFH* * | 61.51 | 4.01 | ( 60.01, 63.00 ) | 59.15 | 3.77 | ( 57.60, 60.71 ) |
| *LFH : TFH* | 55.62 | 1.59 | ( 55.02, 56.22 ) | 54.80 | 1.56 | ( 54.16, 55.45 ) |
| *TFH* | 110.87 | 5.74 | ( 108.73, 113.02 ) | 108.85 | 4.46 | ( 107.01, 110.69 ) |
| *AFH (N - Me)* | 111.61 | 5.96 | ( 109.38, 113.84 ) | 110.20 | 5.22 | ( 108.04, 112.36 ) |
| *PFH (S - Go)* | 71.09 | 5.12 | ( 69.18, 73.00 ) | 70.78 | 4.50 | ( 68.917, 72.64 ) |
| *Pog - N Perpendicular* | -1.23 | 6.54 | ( -3.68, 1.21 ) | -3.98 | 6.09 | ( -6.50, -1.47 ) |

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | **Mean** | **StDev** | **95.0 % C.I.** | **Mean** | **StDev** | **95.0 % C.I.** |
| *Anterior LFH (ANS - Me)* | 63.58 | 4.23 | ( 62.01, 65.16 ) | 62.03 | 4.55 | ( 60.15, 63.90 ) |
| *A - N Perpendicular* ** | 1.93 | 3.52 | ( 0.62, 3.25 ) | 0.06 | 2.76 | ( -1.08, 1.21 ) |
| *A - Sella Vertical* | 64.22 | 3.98 | ( 62.74, 65.71 ) | 64.51 | 3.95 | ( 62.88, 66.14 ) |
| *Effective Mx. Length (Cd - A)* | 82.42 | 3.36 | ( 81.16, 83.68 ) | 83.13 | 3.74 | ( 81.59, 84.68 ) |
| *Effective Md. Length (Cd - Gn)* | 109.42 | 4.98 | ( 107.56, 111.29 ) | 107.81 | 3.94 | ( 106.18, 109.44 ) |
| *Wits* *** | -2.45 | 2.75 | ( -3.48, -1.43 ) | 0.17 | 2.74 | ( -0.96, 1.30 ) |
| *Ba - S* | 41.52 | 2.45 | ( 40.60, 42.43 ) | 41.35 | 2.03 | ( 40.51, 42.19 ) |
| *S - N* ** | 63.13 | 3.04 | ( 61.99, 64.27 ) | 65.46 | 2.72 | ( 64.34, 66.59 ) |
| *Ba - N* ** | 95.62 | 3.97 | ( 94.14, 97.10 ) | 98.26 | 3.06 | ( 96.99, 99.52 ) |
| *A - B Plane (N-Pog to A - B)* | 5.16 | 2.72 | ( 4.15, 6.18 ) | 6.25 | 3.22 | ( 4.92, 7.58 ) |
| *Mandibular Dimension (Go - Gn)* * | 72.41 | 4.31 | ( 70.80, 74.02 ) | 69.74 | 3.55 | ( 68.28, 71.21 ) |
| *Mandibular Dimension (Ar - Go)* | 43.73 | 3.11 | ( 42.57, 44.89 ) | 44.08 | 3.22 | ( 42.75, 45.42 ) |
| ***DENTAL PARAMETERS*** | | | | | | |
| ***1. Angular Measurements*** | | | | | | |
| *Upper Incisor - FH Plane* *** | 115.14 | 7.31 | ( 112.41, 117.87 ) | 105.68 | 9.23 | ( 101.87, 109.49 ) |
| *Upper Incisor - Mx. Plane* *** | 114.34 | 6.55 | ( 111.89, 116.78 ) | 105.91 | 8.52 | ( 102.39, 109.42 ) |
| *Lower Incisor - Md. Plane* | 96.68 | 6.24 | ( 94.35, 99.01 ) | 93.14 | 8.67 | ( 89.56, 96.72 ) |

| Variables | MALAYS | | | CAUCASIANS | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| *Interincisal Angle* *** | 121.61 | 7.67 | ( 118.74, 124.48 ) | 136.18 | 14.30 | ( 130.28, 142.08 ) |
| *Upper Incisor - SN* *** | 106.41 | 7.28 | ( 103.69, 109.13 ) | 95.96 | 9.70 | ( 91.96, 99.96 ) |
| *Mx. Incisor Position (Ul - NA)* *** | 23.06 | 6.84 | ( 20.50, 25.61 ) | 15.55 | 9.12 | ( 11.79, 19.32 ) |
| *Lower Incisor - NB Angle* *** | 31.97 | 5.63 | ( 29.86, 34.07 ) | 24.72 | 8.36 | ( 21.27, 28.18 ) |
| **2. Linear Measurements** | | | | | | |
| *Upper Incisor - A Perpendicular* *** | 6.61 | 2.74 | ( 5.58, 7.63 ) | 2.37 | 3.25 | ( 1.03, 3.71 ) |
| *Upper Incisor - NA* *** | 5.76 | 2.50 | ( 4.82, 6.69 ) | 2.30 | 3.08 | ( 1.03, 3.58 ) |
| *Lower Incisor - Apog* *** | 5.11 | 1.64 | ( 4.50, 5.73 ) | 1.24 | 2.73 | ( 0.11, 2.36 ) |
| *LI - NB* *** | 7.49 | 1.88 | ( 6.79, 8.19 ) | 4.10 | 2.88 | ( 2.91, 5.29 ) |
| *OJ* | 2.80 | 0.71 | ( 2.54, 3.07 ) | 2.76 | 0.76 | ( 2.44, 3.07 ) |
| *OB* ** | 1.94 | 2.66 | ( 0.94, 2.93 ) | 3.68 | 1.65 | ( 3.0, 4.36 ) |
| ***SOFT TISSUE PARAMETERS*** | | | | | | |
| *Lower Lip - E plane* *** | 1.33 | 1.98 | ( 0.59, 2.07 ) | -3.58 | 2.41 | ( -4.57, -2.59 ) |

***** Significant at 0.1 % level ($p \leq 0.001$)**

**** Significant at 1 % level ($p \leq 0.01$)**

*** Significant at 5 % level ($p \leq 0.05$)**

## *Table 13: Descriptive Statistics and 95.0% Confidence Interval for Malay Males and Females*

| Variables | MALAYS | | | | | |
|---|---|---|---|---|---|---|
| | MALES | | | FEMALES | | |
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| *Age* | 23.13 | 0.41 | ( 22.96, 23.30) | 23.11 | 0.458 | ( 22.94, 23.28 ) |
| ***REFERENCE PARAMETERS*** | | | | | | |
| *NS - Horizontal Ref. Line* | 6.98 | 0.07 | ( 6.95, 7.01) | 6.96 | 0.0968 | ( 6.92, 7.00 ) |
| *S - RS = 50mm* | 50.02 | 0.17 | ( 49.95, 50.09 ) | 49.98 | 0.199 | ( 49.90, 50.05 ) |
| *NRN - Hori. Ref. Line = 90* | 89.80 | 0.67 | ( 89.51, 90.08 ) | 90.00 | 0.683 | ( 89.74, 90.25 ) |
| ***REFERENCE PARAMETERS*** | | | | | | |
| ***1. Angular Parameters*** | | | | | | |
| *SNA* * | 85.29 | 3.48 | ( 83.82, 86.76 ) | 83.36 | 3.242 | ( 82.15, 84.57 ) |
| *SNB* | 81.77 | 3.60 | ( 80.25, 83.29 ) | 79.98 | 3.596 | ( 78.64, 81.32 ) |
| *ANB* | 3.53 | 1.64 | ( 2.84, 4.22 ) | 3.39 | 2.239 | ( 2.55, 4.22 ) |
| *S - N - Pog* | 82.53 | 3.56 | ( 81.03, 84.03 ) | 80.63 | 3.789 | ( 79.22, 82.05 ) |
| *SN - Maxillary Plane* | 7.42 | 3.85 | ( 5.79, 9.05) | 7.92 | 2.787 | ( 6.88, 8.96 ) |

| *Variables* | *MALES* | | | *FEMALES* | | |
|---|---|---|---|---|---|---|
| | ***Mean*** | ***StDev*** | ***95.0 % C.I.*** | ***Mean*** | ***StDev*** | ***95.0 % C.I.*** |
| *SN - Mandibular Plane* ** | 31.16 | 5.32 | ( 28.91, 33.41 ) | 35.31 | 4.581 | ( 33.60, 37.02 ) |
| *N - Pog to FH (Facial Depth)* | 90.20 | 3.61 | ( 88.68, 91.73 ) | 89.35 | 3.589 | ( 88.01, 90.69 ) |
| *FMPA* * | 23.48 | 4.92 | ( 21.40, 25.56 ) | 26.59 | 4.235 | ( 25.01, 28.18 ) |
| *MMPA* * | 23.73 | 4.64 | ( 21.77, 25.69 ) | 27.37 | 3.928 | ( 25.91, 28.84 ) |
| *Facial Axis Angle* | 87.38 | 3.46 | ( 85.92, 88.84 ) | 87.87 | 3.693 | ( 86.49, 89.25 ) |
| *BA - S - N* ** | 126.97 | 5.13 | ( 124.80, 129.14 ) | 131.39 | 6.41 | ( 128.99, 133.78 ) |
| *Ar - Go - Me (Md Dimension)* | 122.65 | 6.79 | ( 119.78, 125.52 ) | 125.41 | 5.26 | ( 123.45, 127.38 ) |
| *Occlusal - SN* ** | 14.57 | 4.27 | ( 12.77, 16.37 ) | 18.06 | 4.074 | ( 16.54, 19.59 ) |
| *Go - Gn to SN* ** | 28.68 | 5.19 | ( 26.49, 30.87 ) | 32.71 | 4.493 | ( 31.03, 34.39 ) |
| *Y - Axis (Growth Axis)- FH to S-Gn* | 59.27 | 3.26 | ( 57.89, 60.64 ) | 59.43 | 3.594 | ( 58.08, 60.77 ) |
| *Facial Angle (Po-Or to N-Pog)* | 90.20 | 3.61 | ( 88.68, 91.73 ) | 89.35 | 3.589 | ( 88.01, 90.69 ) |
| ***2. Linear Measurements*** | | | | | | |
| *UFH* *** | 52.78 | 3.14 | ( 51.46, 54.11 ) | 49.37 | 2.961 | ( 48.26, 50.47 ) |
| *LFH* ** | 64.83 | 3.42 | ( 63.38, 66.27 ) | 61.51 | 4.006 | ( 60.01, 63.00 ) |
| *LFH : TFH* | 55.27 | 1.81 | ( 54.50, 56.03 ) | 55.62 | 1.594 | ( 55.02, 56.22 ) |
| *TFH* *** | 117.61 | 4.26 | ( 115.81, 119.41 ) | 110.87 | 5.74 | ( 108.73, 113.02 ) |
| *AFH (N - Me)* *** | 118.09 | 4.56 | ( 116.16, 120.01 ) | 111.61 | 5.96 | ( 109.38, 113.84 ) |

| *Variables* | *MALES* | | | *FEMALES* | | |
|---|---|---|---|---|---|---|
| | ***Mean*** | ***StDev*** | ***95.0 % C.I.*** | ***Mean*** | ***StDev*** | ***95.0 % C.I.*** |
| *PFH (S - Go)* *** | 80.53 | 4.89 | ( 78.461, 82.59 ) | 71.09 | 5.116 | ( 69.18, 73.00 ) |
| *Pog - N Perpendicular* | 0.37 | 6.86 | ( -2.53, 3.27 ) | -1.23 | 6.54 | ( -3.68, 1.21 ) |
| *Anterior LFH (ANS - Me)* * | 66.26 | 3.72 | ( 64.69, 67.84 ) | 63.58 | 4.225 | ( 62.01, 65.16 ) |
| *A - N Perpendicular* | 2.93 | 3.70 | ( 1.37, 4.50 ) | 1.93 | 3.516 | ( 0.62, 3.25 ) |
| *A - Sella Vertical* *** | 68.33 | 3.78 | ( 66.73, 69.92 ) | 64.22 | 3.983 | ( 62.74, 65.71 ) |
| *Effective Mx. Length (Cd - A)* *** | 87.60 | 3.51 | ( 86.12, 89.08 ) | 82.42 | 3.363 | ( 81.16, 83.68 ) |
| *Effective Md. Length (Cd - Gn)* *** | 116.19 | 3.71 | ( 114.63, 117.76 ) | 109.42 | 4.98 | ( 107.56, 111.29 ) |
| *Wits* | -1.19 | 2.88 | ( -2.40, 0.03 ) | -2.45 | 2.751 | ( -3.48, -1.43 ) |
| *Ba - S* *** | 45.55 | 2.65 | ( 44.43, 46.67 ) | 41.52 | 2.447 | ( 40.60, 42.43 ) |
| *S - N* *** | 66.09 | 2.47 | ( 65.05, 67.13 ) | 63.13 | 3.043 | ( 61.99, 64.27 ) |
| *Ba - N* *** | 100.26 | 3.75 | ( 98.68, 101.85 ) | 95.62 | 3.974 | ( 94.14, 97.10 ) |
| *A - B Plane (N-Pog to A - B)* | 5.59 | 2.29 | ( 4.63, 6.56 ) | 5.163 | 2.721 | ( 4.15, 6.18 ) |
| *Mandibular Dimension (Go - Gn)* ** | 75.84 | 3.80 | ( 74.24, 77.45 ) | 72.41 | 4.306 | ( 70.80, 74.02 ) |
| *Mandibular Dimension (Ar - Go)* *** | 49.37 | 3.87 | ( 47.73, 51.00 ) | 43.73 | 3.107 | ( 42.57, 44.89 ) |

| Variables | MALES | | | FEMALES | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| **DENTAL PARAMETERS** | | | | | | |
| **1. Angular Measurements** | | | | | | |
| *Upper Incisor - FH Plane* | 113.52 | 7.08 | ( 110.53, 116.51 ) | 115.14 | 7.31 | ( 112.41, 117.87 ) |
| *Upper Incisor - Mx. Plane* | 113.29 | 5.98 | ( 110.76, 115.81 ) | 114.34 | 6.55 | ( 111.89, 116.78 ) |
| *Lower Incisor - Md. Plane* | 96.82 | 5.33 | ( 94.57, 99.07 ) | 96.68 | 6.24 | ( 94.35, 99.01 ) |
| *Interincisal Angle* | 126.18 | 9.84 | ( 122.03, 130.34 ) | 121.61 | 7.67 | ( 118.74, 124.48 ) |
| *Upper Incisor - SN* | 105.85 | 8.22 | ( 102.38, 109.33 ) | 106.41 | 7.28 | ( 103.69, 109.13 ) |
| *Mx. Incisor Position (UI - NA)* | 20.56 | 7.36 | ( 17.45, 23.67 ) | 23.06 | 6.84 | ( 20.50, 25.61 ) |
| *Lower Incisor - NB Angle* | 29.73 | 5.35 | ( 27.47, 31.99 ) | 31.97 | 5.63 | ( 29.86, 34.07 ) |
| **2. Linear Measurements** | | | | | | |
| *Upper Incisor - A Perpendicular* | 6.39 | 2.98 | ( 5.13, 7.65 ) | 6.61 | 2.739 | ( 5.58, 7.63 ) |
| *Upper Incisor - NA* | 5.11 | 3.01 | ( 3.84, 6.39 ) | 5.76 | 2.5 | ( 4.82, 6.69 ) |
| *Lower Incisor - Apog* | 4.20 | 2.39 | ( 3.20, 5.21 ) | 5.11 | 1.64 | ( 4.50, 5.73 ) |
| *LI - NB* | 6.98 | 2.07 | ( 6.10, 7.85 ) | 7.49 | 1.882 | ( 6.79, 8.19 ) |

| Variables | MALES | | | FEMALES | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| OJ | 3.13 | 0.81 | ( 2.79, 3.48 ) | 2.80 | 0.706 | ( 2.54, 3.07 ) |
| OB | 3.02 | 2.80 | ( 1.83, 4.20 ) | 1.94 | 2.661 | ( 0.94, 2.93) |
| **SOFT TISSUE PARAMETERS** | | | | | | |
| Lower Lip - E plane | 1.89 | 2.15 | ( 0.98, 2.80 ) | 1.33 | 1.978 | ( 0.59, 2.07 ) |

*** Significant at 0.1 % level ($p \leq 0.001$)
** Significant at 1 % level ($p \leq 0.01$)
* Significant at 5 % level ($p \leq 0.05$)

## *Table 14 : Descriptive Statistics and 95.0% Confidence Interval for Caucasian Males and Females*

| Variable | CAUCASIAN | | | | | |
|---|---|---|---|---|---|---|
| | MALES | | | FEMALES | | |
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| Age | 22.53 | 0.53 | ( 22.28, 22.78 ) | 22.63 | 0.63 | ( 22.37, 22.89 ) |
| **REFERENCE PARAMETERS** | | | | | | |
| NS - Horizontal Ref. Line | 6.94 | 0.10 | ( 6.89, 6.98) | 6.97 | 0.07 | ( 6.94, 7.00 ) |
| S - RS = 50mm | 49.96 | 0.16 | ( 49.88, 50.03 ) | 50.02 | 0.15 | ( 49.96, 50.08 ) |
| NRN - Hori. Ref. Line = 90 | 89.88 | 0.36 | ( 89.71, 90.04 ) | 89.75 | 0.36 | ( 89.60, 89.90 ) |
| **SKELETAL PARAMETERS** | | | | | | |
| **1. Angular Measurements** | | | | | | |
| SNA | 81.26 | 3.89 | ( 79.44, 83.08 ) | 80.41 | 4.20 | ( 78.68, 82.15 ) |
| SNB | 78.62 | 2.86 | ( 77.28, 79.95 ) | 76.88 | 4.50 | ( 75.02, 78.74) |
| ANB | 2.65 | 2.48 | ( 1.48, 3.81) | 3.54 | 2.34 | ( 2.57, 4.50 ) |
| S - N - Pog | 80.42 | 2.58 | ( 79.22, 81.63 ) | 78.13 | 4.51 | ( 76.27, 80.00 ) |
| SN - Maxillary Plane | 9.08 | 2.35 | ( 7.98, 10.18 ) | 9.94 | 3.13 | ( 8.65, 11.24) |

| Variable | MALES | | | FEMALES | | |
|---|---|---|---|---|---|---|
| | **Mean** | **StDev** | **95.0 % C.I.** | ***Mean*** | ***StDev*** | ***95.0 % C.I.*** |
| *SN - Mandibular Plane* | 33.45 | 4.00 | ( 31.58, 35.32 ) | 34.72 | 6.30 | ( 32.12, 37.33 ) |
| *N - Pog to FH (Facial Depth)* | 89.65 | 2.90 | ( 88.29, 91.00 ) | 87.86 | 3.20 | ( 86.54, 89.18 ) |
| *FMPA* | 24.25 | 3.58 | ( 22.58, 25.93 ) | 25.00 | 5.13 | ( 22.89, 27.12 ) |
| *MMPA* | 24.41 | 3.99 | ( 22.54, 26.28 ) | 24.77 | 5.55 | ( 22.48, 27.06 ) |
| *Facial Axis Angle* | 89.18 | 3.32 | ( 87.63, 90.73 ) | 88.63 | 4.83 | ( 86.64, 90.63 ) |
| *BA - S - N* * | 128.97 | 6.29 | ( 126.02, 131.92 ) | 132.78 | 4.98 | ( 130.73, 134.84 ) |
| *Ar - Go - Me (Md Dimension)* | 127.25 | 3.46 | ( 125.64, 128.87 ) | 126.03 | 5.84 | ( 123.62, 128.44 ) |
| *Occlusal - SN* | 15.17 | 4.30 | ( 13.16, 17.18 ) | 17.87 | 5.09 | ( 15.77, 19.97 ) |
| *Go - Gn to SN* | 31.19 | 3.97 | ( 29.33, 33.05 ) | 32.37 | 6.29 | ( 29.78, 34.97 ) |
| *Y - Axis (Growth Axis)-FH to S-Gn* | 58.01 | 3.19 | ( 56.51, 59.50 ) | 58.93 | 3.68 | ( 57.42, 60.45 ) |
| *Facial Angle (Po-Or to N-Pog)* | 89.65 | 2.90 | ( 88.29, 91.00 ) | 87.86 | 3.20 | ( 86.54, 89.18 ) |
| ***2. Linear Parameters*** | | | | | | |
| *UFH* ** | 52.59 | 3.23 | ( 51.07, 54.10 ) | 49.71 | 2.28 | ( 48.77, 50.65 ) |
| *LFH* *** | 65.85 | 4.25 | ( 63.84, 67.83 ) | 59.15 | 3.77 | ( 57.60, 60.71 ) |
| *LFH : TFH* * | 55.90 | 1.41 | ( 55.23, 56.56 ) | 54.80 | 1.56 | ( 54.16, 55.45 ) |
| *TFH* *** | 118.41 | 6.45 | ( 115.39, 121.43 ) | 108.85 | 4.46 | ( 107.01, 110.69 ) |
| *AFH (N - Me)* *** | 118.97 | 6.37 | ( 115.99, 121.95 ) | 110.20 | 5.22 | ( 108.04, 112.36 ) |

| Variable | MALES | | | FEMALES | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | Mean | StDev | 95.0 % C.I. |
| PFH (S - Go) *** | 77.69 | 5.31 | ( 75.21, 80.18 ) | 70.78 | 4.50 | ( 68.92, 72.64 ) |
| Pog - N Perpendicular | -0.73 | 5.60 | ( -3.35, 1.89 ) | -3.98 | 6.09 | ( -6.50, -1.47 ) |
| Anterior LFH (ANS - Me) *** | 67.60 | 4.33 | ( 65.57, 69.62 ) | 62.03 | 4.55 | ( 60.15, 63.90 ) |
| A - N Perpendicular | 0.63 | 4.13 | ( -1.31, 2.56 ) | 0.06 | 2.76 | ( -1.08, 1.21 ) |
| A - Sella Vertical ** | 69.05 | 5.24 | ( 66.60, 71.50 ) | 64.51 | 3.95 | ( 62.88, 66.14 ) |
| Effective Mx. Length (Cd - A) *** | 89.56 | 5.41 | ( 87.03, 92.09 ) | 83.13 | 3.74 | ( 81.59, 84.68 ) |
| Effective Md. Length (Cd - Gn) *** | 118.83 | 6.55 | ( 115.77, 121.90 ) | 107.81 | 3.94 | ( 106.18, 109.44 ) |
| Wits | 0.20 | 3.59 | ( -1.483, 1.883 ) | 0.17 | 2.74 | ( -0.96, 1.30 ) |
| Ba - S *** | 44.42 | 2.73 | ( 43.14, 45.70 ) | 41.35 | 2.03 | ( 40.51, 42.19 ) |
| S - N *** | 69.40 | 3.68 | ( 67.67, 71.12 ) | 65.46 | 2.72 | ( 64.34, 66.59 ) |
| Ba - N *** | 103.08 | 4.05 | ( 101.19, 104.97 ) | 98.26 | 3.06 | ( 96.99, 99.52 ) |
| A - B Plane (N-Pog to A - B) | 5.91 | 3.84 | ( 4.11, 7.71 ) | 6.25 | 3.22 | ( 4.92, 7.58 ) |
| Mandibular Dimension (Go - Gn) *** | 75.83 | 5.10 | ( 73.44, 78.22 ) | 69.74 | 3.55 | ( 68.28, 71.22) |
| Mandibular Dimension (Ar - Go) * | 46.97 | 4.40 | ( 44.91, 49.03 ) | 44.08 | 3.22 | ( 42.75, 45.42 ) |

| Variable | MALES | | | FEMALES | | |
|---|---|---|---|---|---|---|
| | Mean | StDev | 95.0 % C.I. | *Mean* | *StDev* | *95.0 % C.I.* |
| ***DENTAL PARAMETERS*** | | | | | | |
| ***1. Angular Measurements*** | | | | | | |
| *Upper Incisor - FH Plane* | 107.40 | 6.18 | ( 104.51, 110.29 ) | 105.68 | 9.23 | ( 101.87, 109.49 ) |
| *Upper Incisor - Mx. Plane* | 107.24 | 7.33 | ( 103.81, 110.67 ) | 105.91 | 8.52 | ( 102.39, 109.42 ) |
| *Lower Incisor - Md. Plane* | 89.72 | 5.67 | ( 87.06, 92.38 ) | 93.14 | 8.67 | ( 89.56, 96.72 ) |
| *Interincisal Angle* | 138.63 | 10.75 | ( 133.59, 143.66 ) | 136.18 | 14.30 | ( 130.28, 142.08 ) |
| *Upper Incisor - SN* | 98.18 | 7.29 | ( 94.77, 101.60 ) | 95.96 | 9.70 | ( 91.96, 99.96 ) |
| *Mx. Incisor Position (UI - NA)* | 16.92 | 7.40 | ( 13.46, 20.38 ) | 15.55 | 9.12 | ( 11.79, 19.32 ) |
| *Lower Incisor - NB Angle* | 21.80 | 6.11 | ( 18.94, 24.65 ) | 24.72 | 8.36 | ( 21.27, 28.18 ) |
| | | | | | | |
| ***2. Linear Measurements*** | | | | | | |
| *Upper Incisor - A Perpendicular* | 2.79 | 2.11 | ( 1.80, 3.77 ) | 2.37 | 3.25 | ( 1.03, 3.71 ) |
| *Upper Incisor - NA* | 2.66 | 2.96 | ( 1.27, 4.04 ) | 2.30 | 3.08 | ( 1.03, 3.58 ) |
| *Lower Incisor - Apog* | 0.69 | 1.96 | ( -0.23, 1.60 ) | 1.24 | 2.73 | ( 0.11, 2.36 ) |
| *LI - NB* | 3.79 | 2.06 | ( 2.82, 4.75 ) | 4.10 | 2.88 | ( 2.91, 5.29 ) |

| Variable | *MALES* | | | *FEMALES* | | |
|---|---|---|---|---|---|---|
| | **Mean** | **StDev** | **95.0 % C.I.** | ***Mean*** | ***StDev*** | ***95.0 % C.I.*** |
| *OJ* | 2.57 | 0.81 | ( 2.19, 2.95 ) | 2.76 | 0.76 | ( 2.44, 3.07) |
| *OB* | 2.95 | 2.52 | ( 1.77, 4.13 ) | 3.68 | 1.65 | ( 3.00, 4.36 ) |
| ***SOFT TISSUE PARAMETERS*** | | | | | | |
| *Lower Lip - E plane* | -3.96 | 2.27 | ( -5.02, -2.89 ) | -3.58 | 2.41 | ( -4.57, -2.59 ) |

****** Significant at 0.1 % level ($p \leq 0.001$)***
***** Significant at 1 % level ($p \leq 0.01$)***
**** Significant at 5 % level ($p \leq 0.05$)***

## *Table 15: P-Value for inter- and intra- group comparison.*

| Variables | INTER-GROUP | | | INTRA-GROUP | |
|---|---|---|---|---|---|
| | Pooled | Males | Females | Malays | Caucasian |
| Age | 0.0001*** | 0.0001*** | 0.021* | 0.89 | 0.89 |
| **REFERENCE PARAMETERS** | | | | | |
| NS - Horizontal Ref. Line | 0.39 | 0.10 | 0.73 | 0.42 | 0.21 |
| S - RS = 50mm | 0.93 | 0.20 | 0.33 | 0.39 | 0.15 |
| NRN - Hori. Ref. Line = 90 | 0.37 | 0.64 | 0.11 | 0.28 | 0.26 |
| **SKELETAL PARAMETERS** | | | | | |
| **1. Angular Measurements** | | | | | |
| SNA | 0.0001*** | 0.0008*** | 0.0049** | 0.041* | 0.49 |
| SNB | 0.0001*** | 0.0029** | 0.0064** | 0.076 | 0.14 |
| ANB | 0.48 | 0.16 | 0.81 | 0.80 | 0.22 |
| S - N - Pog | 0.0034** | 0.033* | 0.030* | 0.066 | 0.050 |
| SN - Maxillary Plane | 0.0035** | 0.10 | 0.014* | 0.58 | 0.31 |
| SN - Mandibular Plane | 0.52 | 0.12 | 0.69 | 0.0033** | 0.44 |
| N - Pog to FH (Facial Depth) | 0.12 | 0.58 | 0.12 | 0.39 | 0.060 |
| FMPA | 0.57 | 0.56 | 0.21 | 0.016* | 0.58 |
| MMPA | 0.23 | 0.61 | 0.047* | 0.029* | 0.81 |
| Facial Axis Angle | 0.12 | 0.087 | 0.51 | 0.62 | 0.67 |
| BA - S - N | 0.18 | 0.25 | 0.38 | 0.007** | 0.028* |
| Ar - Go - Me (Md Dimension) | 0.037* | 0.0088** | 0.68 | 0.098 | 0.41 |
| Occlusal - SN | 0.87 | 0.65 | 0.87 | 0.0034** | 0.065 |
| Go - Gn to SN | 0.39 | 0.085 | 0.82 | 0.0036** | 0.47 |
| Y - Axis (Growth Axis)-FH to S-Gn | 0.23 | 0.20 | 0.62 | 0.87 | 0.38 |
| Facial Angle (Po-Or to N-Pog) | 0.12 | 0.58 | 0.12 | 0.39 | 0.060 |

*** *Significant at 0.1 % level ($p \leq 0.001$)*
** *Significant at 1 % level ($p \leq 0.01$)*
* *Significant at 5 % level ($p \leq 0.05$)*

| Variables | INTRA-GROUP | | | INTER-GROUP | |
|---|---|---|---|---|---|
| | Pooled | Males | Females | Malays | Caucasian |
| **2. Linear Measurements** | | | | | |
| UFH | 0.88 | 0.84 | 0.64 | 0.0001*** | 0.0011** |
| LFH | 0.36 | 0.39 | 0.030* | 0.0022** | 0.0001*** |
| LFH : TFH | 0.60 | 0.21 | 0.062 | 0.45 | 0.019* |
| TFH | 0.57 | 0.63 | 0.16 | 0.0001*** | 0.0001*** |
| AFH (N - Me) | 0.77 | 0.60 | 0.36 | 0.0001*** | 0.0001*** |
| PFH (S - Go) | 0.27 | 0.073 | 0.81 | 0.0001*** | 0.0001*** |
| Pog - N Perpendicular | 0.12 | 0.57 | 0.11 | 0.38 | 0.072 |
| Anterior LFH (ANS - Me) | 0.77 | 0.28 | 0.19 | 0.018* | 0.0001*** |
| A - N Perpendicular | 0.0045** | 0.057 | 0.035** | 0.32 | 0.59 |
| A - Sella Vertical | 0.61 | 0.60 | 0.79 | 0.0003*** | 0.0019** |
| Effective Mx. Length (Cd - A) | 0.20 | 0.15 | 0.46 | 0.0001*** | 0.0001*** |
| Effective Md. Length (Cd - Gn) | 0.83 | 0.10 | 0.20 | 0.0001*** | 0.0001*** |
| Wits | 0.0008*** | 0.16 | 0.0009*** | 0.11 | 0.97 |
| Ba - S | 0.34 | 0.17 | 0.79 | 0.0001*** | 0.0001*** |
| S - N | 0.0001*** | 0.001*** | 0.0044** | 0.0003*** | 0.0002*** |
| Ba - N | 0.0028** | 0.021* | 0.009** | 0.0001*** | 0.0001*** |
| A - B Plane (N-Pog to A - B) | 0.22 | 0.74 | 0.18 | 0.54 | 0.75 |
| Mandibular Dimension (Go - Gn) | 0.13 | 0.99 | 0.017* | 0.0034** | 0.0001*** |
| Mandibular Dimension (Ar - Go) | 0.32 | 0.061 | 0.68 | 0.0001*** | 0.015* |
| **DENTAL PARAMETERS** | | | | | |
| **1. Angular Measurements** | | | | | |
| Upper Incisor - FH Plane | 0.0001*** | 0.0043** | 0.0001*** | 0.42 | 0.48 |
| Upper Incisor - Mx. Plane | 0.0001*** | 0.0043** | 0.0001*** | 0.55 | 0.58 |
| Lower Incisor - Md. Plane | 0.0003*** | 0.0001*** | 0.085 | 0.93 | 0.14 |
| Interincisal Angle | 0.0001*** | 0.0002*** | 0.0001*** | 0.060 | 0.53 |
| Upper Incisor - SN | 0.0001*** | 0.0023** | 0.0001*** | 0.79 | 0.40 |
| Mx. Incisor Position (UI - NA) | 0.0003*** | 0.11 | 0.001*** | 0.20 | 0.59 |
| Lower Incisor - NB Angle | 0.0001*** | 0.0001*** | 0.0004*** | 0.14 | 0.20 |

****** Significant at 0.1 % level ($p \leq 0.001$)***
***** Significant at 1 % level ($p \leq 0.01$)***
**** Significant at 5 % level ($p \leq 0.05$)***

| Variables | INTRA-GROUP | | | INTER-GROUP | |
|---|---|---|---|---|---|
| | Pooled | Males | Females | Malays | Caucasian |
| **2. Linear Measurements** | | | | | |
| Upper Incisor - A Perpendicular | 0.0001*** | 0.0001*** | 0.0001*** | 0.78 | 0.62 |
| Upper Incisor - NA | 0.0001*** | 0.0096** | 0.0001*** | 0.39 | 0.70 |
| Lower Incisor - Apog | 0.0001*** | 0.0001*** | 0.0001*** | 0.10 | 0.45 |
| LI - NB | 0.0001*** | 0.0001*** | 0.0001*** | 0.34 | 0.68 |
| OJ | 0.079 | 0.027* | 0.81 | 0.12 | 0.43 |
| OB | 0.063 | 0.93 | 0.0062** | 0.15 | 0.25 |
| **SOFT TISSUE PARAMETERS** | | | | | |
| Lower Lip - E plane | 0.0001*** | 0.0001*** | 0.0001*** | 0.32 | 0.60 |

*** Significant at 0.1 % level ($p \leq 0.001$)
** Significant at 1 % level ($p \leq 0.01$)
* Significant at 5 % level ($p \leq 0.05$)

# 7.3 SUPERIMPOSITION

Superimposition is a method whereby two cephalometric radiographs are compared graphically. It gives a better idea on the differences or similarities between two radiographs.

### 7.3.1 S-N Plane Superimposition

**A. Inter-Group Comparison (Figure 3)**

Figure 3A showed the superimposition of the Malay and Caucasian samples. Differences were seen mainly in the dentoalveolar area. The Malays showed a bimaxillary dental proclination and a more prognathic maxilla and mandible. The soft tissue profile indicates that the Malays have a prominent lower face and a flatter upper face compared to the Caucasians. The upper and lower lips are more procumbent in the Malays and this is mainly due to the prominent denture and its bases.

When the Malay and Caucasian males were compared, similar picture can be seen (Figure 3B). The females however showed similar findings with the exception of the lower face height (Figure 3C). The Malay females have a slight increase in lower facial height compared to the Caucasians.

**B. Within-Group Comparison (Figure 4)**

Within-group comparison showed that the facial pattern were similar in the females and the males. In both samples, the males showed a larger dimension horizontally and vertically (Figure 4A and 4B). This confirms the findings whereby the males in both groups showed a larger linear measurements in almost all the variables measured.

### 7.3.2 Maxillary Plane Superimposition

#### A. Inter-Group Comparison (Figure 5)

When the Maxillary plane was used as a reference plane for superimposition, similar findings were seen , whereby the Malays showed a bimaxillary dental proclination (Figure 5A, 5B and 5C). The position of the teeth are more anterior in relation to their bases. Soft tissue profile also suggest a bimaxillary lip protrusion in the Malays compared to the Caucasians.

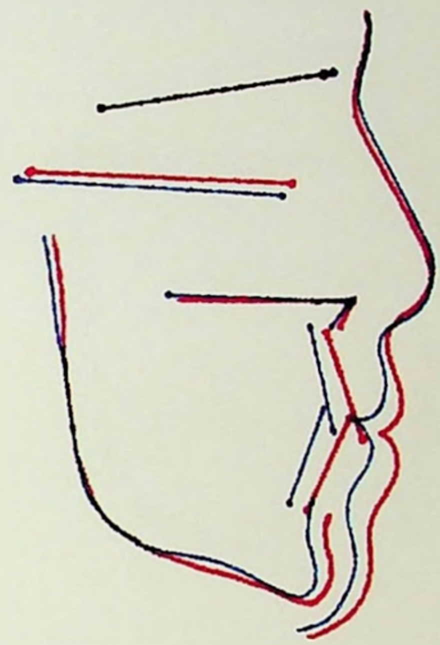
#### A. Within-Group Comparison (Figure 6)

The facial configuration of the males and females were similar in both groups and the males in general showed a larger facial dimension (Figure 6A and 6B).

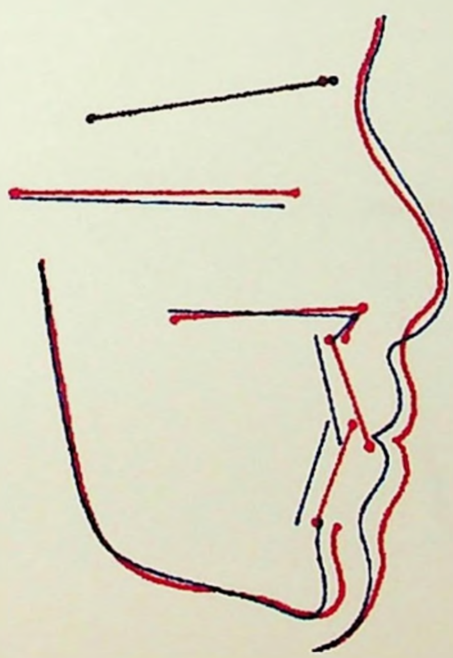
## <u>FIGURE 3</u> : *INTER-GROUP COMPARISON MALAY VS CAUCASIAN*

*(Sella-Nasion Plane)*

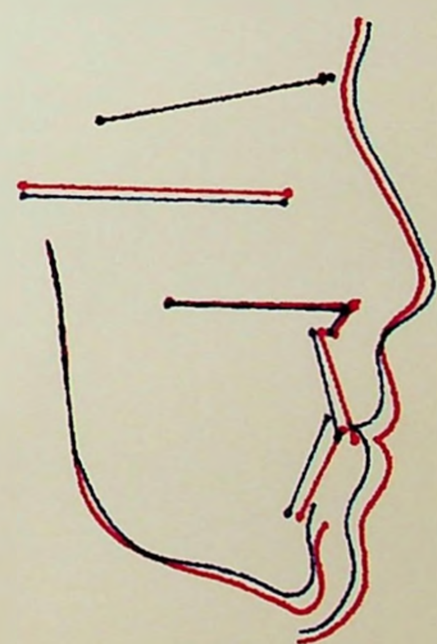
*A. POOL*



*B. MALES*



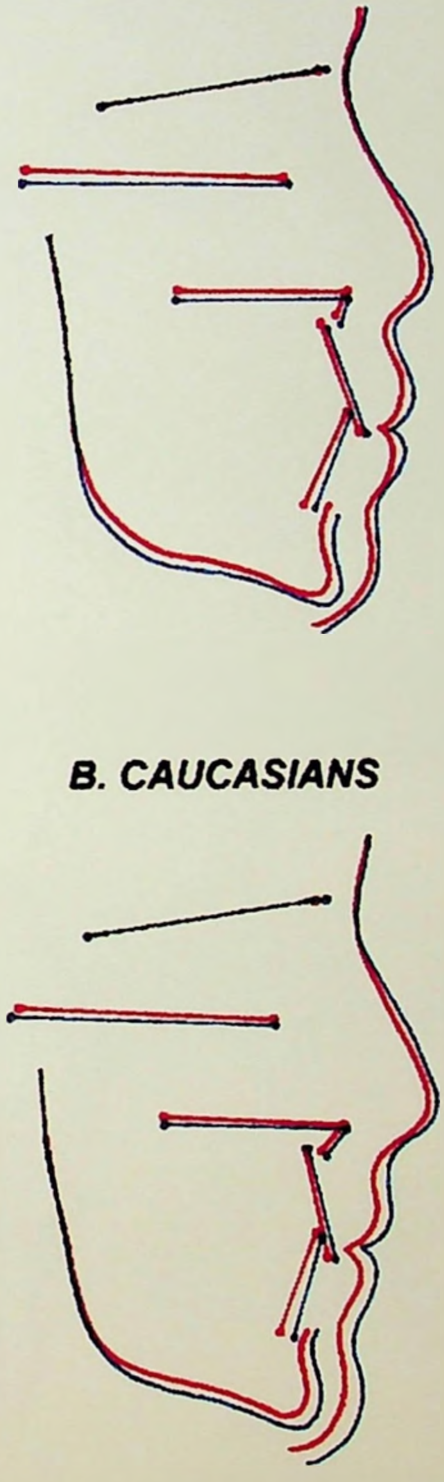
*C. FEMALES*



**MALAYS**
**CAUCASIANS**

# FIGURE 4 : WITHIN GROUP COMPARISON
## (Sella-Nasion Plane)

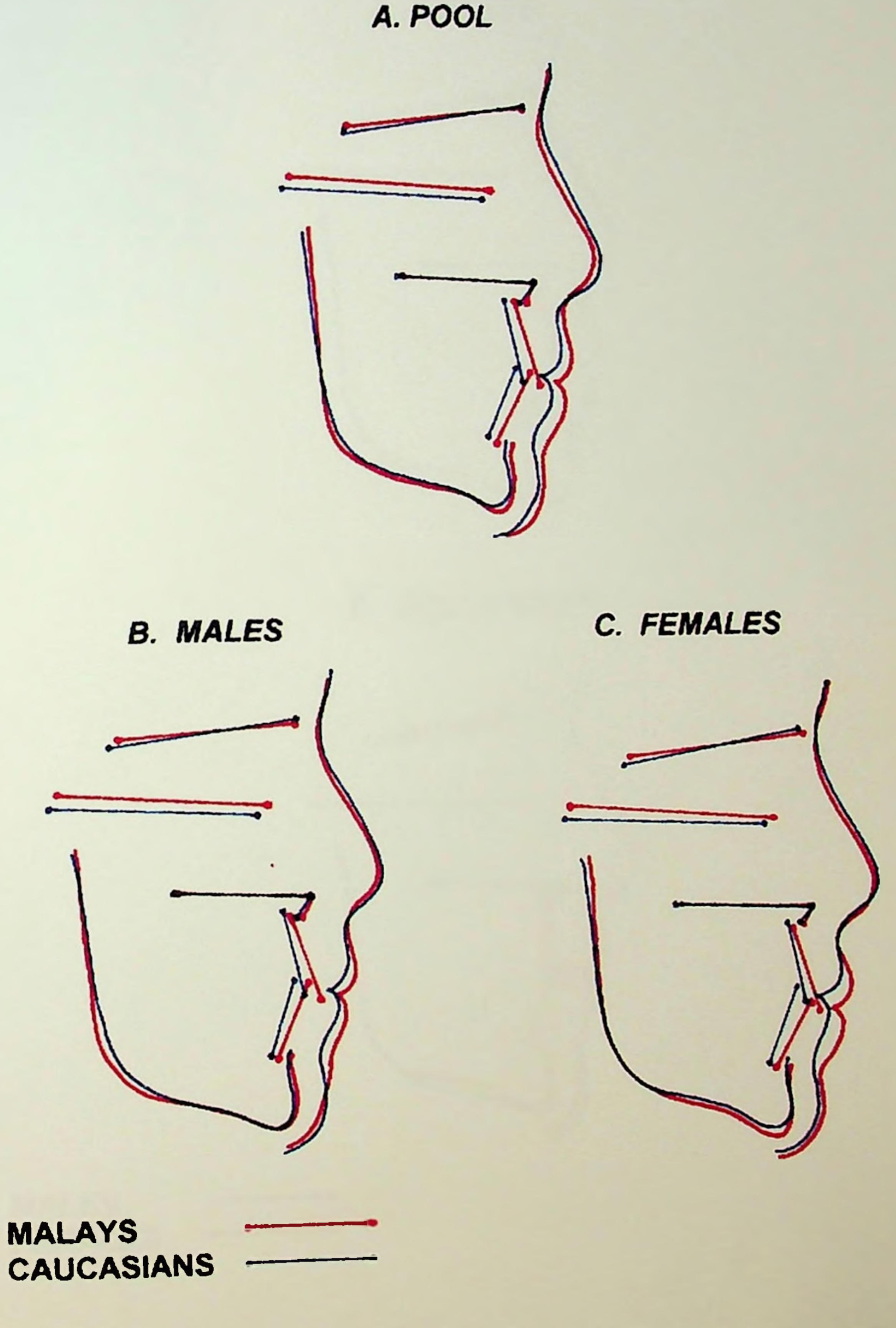
A. MALAYS



B. CAUCASIANS

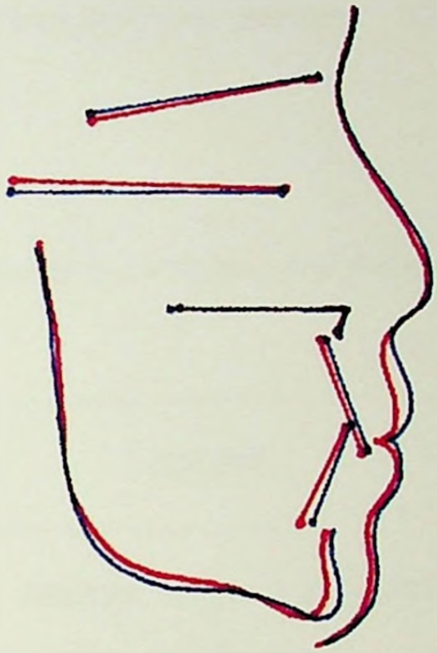
MALES
FEMALES

**FIGURE 5 :** ***INTER-GROUP COMPARISON MALAY VS CAUCASIAN (Maxillary Plane)***

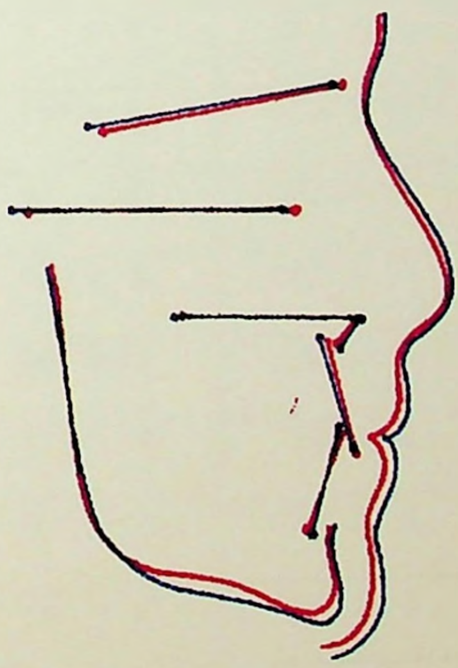


# FIGURE 6 : *WITHIN GROUP COMPARISON*
## *(Maxillary Plane)*

*A. MALAYS*



*B. CAUCASIANS*



**MALES**
**FEMALES**

## 7.4 DIAGRAMATIC REPRESENTATION OF RESULTS

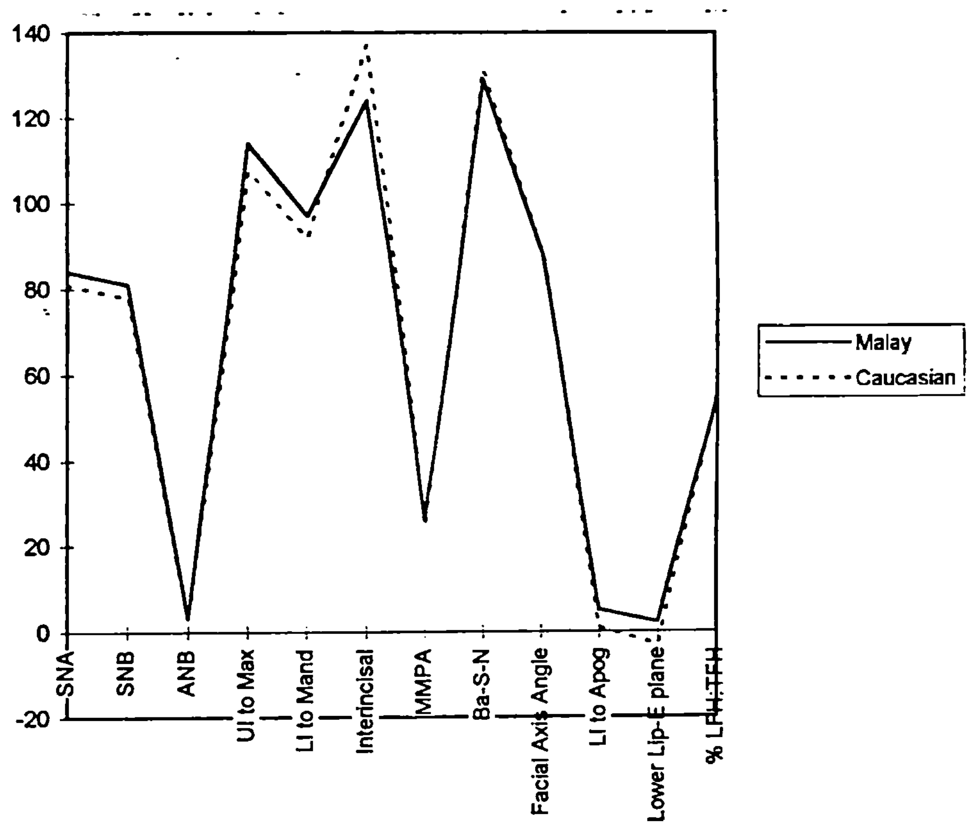
Many variables were analysed in the present study. However, not all of them are routinely used in everyday clinics. The table below shows the common parameters that are useful in diagnosis and treatment planning. The values are compared to those of Houston (1986).

***Table 16.*** Comparison of common parameters used in diagnosis and treatment planning.

| | *STUDY* | | *HOUSTON (1986)* |
|---|---|---|---|
| | ***Malays*** | ***Caucasian*** | ***Caucasian*** |
| *SNA* | 84 ± 3 | 81 ± 4 | 81 ± 3 |
| *SNB* | 81 ± 4 | 78 ± 4 | 78 ± 3 |
| *ANB* | 3 ± 2 | 3 ± 2 | 3 ± 2 |
| *UI to Max. plane* | 114 ± 6 | 107 ± 8 | 109 ± 6 |
| *LI to Mand. plane* | 97 ± 6 | 92 ± 7 | 92 ± 5 |
| *Interincisal angle* | 124 ± 8 | 137 ± 5 | 132 ± 5 |
| *MMPA* | 26 ± 5 | 25 ± 5 | 27 ± 3 |
| *Ba - S - N* | 129 ± 6 | 131 ± 6 | 130 ± 14 |
| *Facial Axis Angle* | 88 ± 4 | 89 ± 4 | 90 ± 3 |
| *LI to Apog* | +5 ± 2 | +1 ± 2 | +1 ± 2 |
| *Lower Lip - E plane* | +2 ± 2 | -3 ± 2 | -2 ± 2 |
| *% LFH:TFH* | 55 % | 55 % | 55 % |

Figure 7 showed the differences in commonly used variables between the Malays and Caucasians. A clear separation can be seen in the angles SNA, SNB, upper incisor to maxillary plane, lower incisor to mandibular plane and the interincisal angle. Linear measurements also exhibit two differences, that is the lower incisor to Apog and the lower lip to E-plane.

***Figure 7.*** Graphical comparison on common variables between the Malay and Caucasian samples.



# Chapter 8. DISCUSSION

## 8.1 DISCUSSION OF RESULTS

### 8.1.1 INTER-GROUP COMPARISON

#### *8.1.1.1 POOL*

The differences between groups were tested using a 2-sample t-test. The level of significance were set at 5% ($p \leq 0.05$), 1% ($p \leq 0.01$) and 0.1% ($p \leq 0.001$). Significant differences were found between the Malays and Caucasian especially in relation to the dental parameters.

*A. SKELETAL PARAMETERS*

*i) Angular Measurements*

Significant differences were found in 5 angular measurements between the two groups. These were the ***SNA, SNB, S-N-Pog, S-N-Maxillary plane*** and ***Ar-Go-Me***.

*Anteroposterior (Maxillary and Mandibular Skeletal Relationship)*

The anteroposterior spatial relationship of the jaws relative to Nasion was measured using the angle SNA and SNB. The SNA angle for the Malay is $84.2 \pm 3.5^0$ and $80.8 \pm 4.0^0$ for the Caucasian. There was also a significant difference in the SNB angle between the Malay and Caucasian with the value of $80.8 \pm 3.7^0$ and $77.7 \pm 3.9^0$ respectively.

These values indicate that the Malays have a more prominent maxilla and mandible than the Caucasians, with the difference being in a range of $3.0\text{-}4.0^0$. This is in agreement with the study by Johnson, Soetamat and Winoto (1978) on the occlusion of Indonesian Malays whereby they found higher SNA and SNB angle in the Indonesian Malays compared to the Caucasian sample. The SNA angle was 84.0 ± 3.8$^0$, which is almost identical to the Malaysian Malays value . However, the SNB angle was 78.0 ± 3.5$^0$, which is about 2$^0$ less than that found in the present study. The higher SNA and SNB angles in the Indonesian sample contributed to the increase in the ANB angle (6.0 ± 2.0$^0$), which gave the illusion of a Class II dental base relationship.

In contrast to the Indonesian Malays, there was no significant difference in the ANB angle in the Malaysian Malays even when there was an increase in the SNA and SNB angles. This observation suggests a bimaxillary skeletal protrusion.

However, it should be borne in mind that the sample for the Indonesian study was randomly selected irrespective of malocclusion. In addition, there was a large age difference (7 - 13 years) and the size of the sample was also large (184 children). These differences could therefore influence the results.

The SNA and SNB angle are dependant on the spatial position of Nasion. Nasion by definition is the most anterior point on the frontonasal suture in the midsagittal plane. It is used as the anterior limit of the cranial base and forms part of the frontal bone which increases in thickness during life due to surface deposition (Romanes, 1986). This is accompanied by an increase in pneumatization of the frontal sinus especially during adolescent (Ursi *et al.,* 1993). In addition, the size of the frontal sinus could be variable depending on growth. These factors could influence the position of Nasion.

The increase in SNA and SNB angle in the Malays may be due to a posterior position of Nasion. There is a possibility that growth in the anterior cranial base ceased early in the Malays compared with Caucasians. As we shall see later, the length of the anterior cranial base (S - N) was significantly different at 0.1% level ($p \leq 0.001$). The Malays have a shorter anterior cranial base (64.4 ± .3.2 mm) compared to the Caucasians (67.2 ± 3.7 mm), which could be related to the early cessation of growth in this area or may be due to a small frontal sinus. Further studies are needed in this area especially concerning growth of the craniofacial region in the Malays.

In contrast to the horizontal positioning of the Nasion, the rotational effect of the S-N line has virtually no anteroposterior positioning effect on the Nasion point (Jacobson, 1995). Therefore, the SNA, SNB and ANB angles are minimally affected by angular deviations of S-N from the horizontal.

The protrusive skeletal pattern found was also similar to those found in the Chinese (Chan, 1972, Cooke and Wei, 1988), Saudi Arabians (Shalhoub *et al.*, 1987), Mexican American (Garcia, 1975) and American Negros (Cotton *et al.*, 1951., Altemus, 1960., Drummond, 1968., Kowalski *et al.*, 1974).

The mandibular basal prognathic angle (S-N-Pog) confirms the procumbency of the mandible. This angle was significantly greater in the Malays (81.5 ± 3.8$^0$) compared to the Caucasians (79.2 ± 3.9$^0$). Other studies have shown that the angle exhibit small differences in various ethnic groups. It ranges from 79.0$^0$ in the Chinese (Wei, 1968) and Japanese (Miura, 1965) to 83.0$^0$ in Australian Aborigines (Craven, 1958). Barrett *et al.* (1963), concluded that S-N-Pog appeared to be relatively constant in all population groups. However, this angle is again dependant on the position of Nasion.

When comparing the Malays to the Malaysian Chinese, the latter have a tendency towards a Class III skeletal pattern due to a more forward position of the mandible. This is also shown in other studies on Chinese (Wong, 1951., Chan, 1972). Argyropoulos and Sassouni (1989) also found a similar mandibular alveolar prognathism in Greek population.

***Vertical Relationships***

Vertically, there were no significant differences between the two groups as indicated by the Maxillo mandibular plane angle and the Frankfort mandibular plane angle (see table 10). The only significant difference is in the S-N-Maxillary plane angle. It was larger in the Caucasian ($9.6 \pm 2.8^0$) compared to the Malay sample ($7.7 \pm 3.3^0$). This indicates that the upper facial height is larger in the Caucasian. However, when linear distances were measured, there was no significant difference between the two groups. In fact, the values for the upper facial height were identical. The contrasting results between the angular and linear measurements could be due to the differences in the inclination of the S-N plane or the Maxillary plane.

Growth axis (Y-axis), defined as the angle between the Frankfort horizontal plane and the plane connecting Sella and Gnathion. No significant differences were observed in the 2 groups and the values were within the normal limits and similar to those of Downs (1948) and the North Indians (Nanda and Nanda, 1969). The Y-axis is larger in the Chinese (Cooke and Wei, 1988) and Japanese (Cotton, Takano and Wong, 1951). The increase in this axis is suggestive of a retrusive mandible in relation to the cranium and also a more vertical component of growth.

The Growth axis values were in agreement with the Facial angle, which was within the normal range. This suggests normal growth in both the populations studied.

***Mandibular Dimension***

The gonial angle was measured by the angle Ar-Go-Me. Results obtained showed a higher value in the Caucasian ($126.6 \pm 5.0^0$) with a difference of $2.4^0$. This may suggest that the Caucasians have a more downward rotation of the Mandible during the growth period as compared to the Malays.

***Cranial Base Relationships***

The cranial base angle (Ba-S-N) was slightly larger in the Caucasians but this was not statistically significant. This angle determines the anteroposterior relationship of the mandible in relation to cranial base. A smaller angle denotes a protrusive mandible and vice versa. As stated previously, the mandibular prognathism in the Greeks was related to a small cranial base angle (Argyropoulos and Sassouni, 1989).

***ii). Linear Measurements***

Various linear comparisons were made to determine the anteroposterior and vertical relationship of the skeletal components. Out of the 18 analyses, 4 measurements were found to be significantly different between the two groups. These measurements were ***A-N perpendicular, Wits analysis, S-N and Ba-N.***

***Anteroposterior (Maxillary and Mandibular Skeletal Relationships)***

As with the angular measurements, anterior positioning of the maxilla was confirmed when the horizontal distance between point A to a line drawn perpendicular to the point Nasion was measured (McNamara, 1984). The relationship of point A to Nasion perpendicular provided some indication of the anteroposterior position of the maxilla. It was found that in the Malays, the A point was 2.4 ± 3.6 mm. anterior to N-perpendicular. For the Caucasian, the value was found to be 0.31 ± 3.4 mm. The normal range given by McNamara (1984) was 0-1mm.

The linear relationship between the length of the midface and the mandible was measured using effective maxillary length (Co-A) and effective mandibular length (Co-Gn). Any given effective midfacial length corresponds to an effective mandibular length within a given range. It must be stressed that the effective lengths of the midface and the mandible are not age or sex dependent but are related only to the size of component parts. Therefore the terms "small," "medium," and "large" are used instead of "mixed dentition" or "adult" (Jacobson, 1995). To determine the maxillomandibular differential, the effective maxillary length is subtracted from that of the effective mandibular length. The ideal maxillomandibular differentials given by McNamara(1984) are: small, 20 - 23 mm; medium, 25 - 27 mm; and large, 30 -33 mm. From the present study, the maxillomandibular differential for the Malays was 28 mm and 27 mm for the Caucasians. These values placed the Malays and Caucasians in the medium size group. However there was no significant difference between the two samples studied.

The relationship of the maxilla to the mandible was further tested using the Wits appraisal (Jacobson, 1975). The purpose of this assessment was to identify instances in which the ANB reading (Riedel, 1952) did not accurately reflect the extent of anteroposterior jaw relationship. A few factors can influence the ANB reading such as the position of Nasion and the rotational effect of the jaws relative to the anterior cranial base.

The results showed that in the Malay sample, the mandible is 1.9 ± 2.8 mm anterior to the maxilla, while in the Caucasian, the value is 0.2 ± 3.1 mm. These values were within the normal limits ( - 1.0 mm in males and 0 mm in females). However, the relationship between the maxilla and mandible was different between the 2 groups. The Caucasian group appeared to have a slight anterior positioning of the maxilla to the mandible, whereas, the opposite was observed in the Malays. We have to bear in mind that this analysis is based on the functional occlusal plane. The values are dependant upon the inclination of the plane and might not clearly represent the true relationship of the Maxilla to the Mandible.

***Vertical Relationships***

There was no significant difference in the vertical dimension between the Malay and the Caucasian Sample. Results showed that all the vertical measurements (Total facial height, upper facial height, lower facial height, anterior facial height and the ratio between lower and total facial height ) were very similar (see table 10). Herzberg and Holic (1943), mentioned that the proportion of upper facial height to total facial height was similar in many racial groups and our results supported this.

The linear distance for the upper facial height does not fit in with the angular measurement (SN-Maxillary plane). The Malays have a significantly smaller angle and as stated earlier, this could be due to the inclination of Sella-Nasion and the Maxillary plane.

However, the values for Maxillo-mandibular plane angle (MMPA) were in contrast with those found in the Indonesian Malays (Johnson *et al.*, 1978). The Indonesian Malays had a larger angle (31 ± 4.4$^{0}$).

### *Mandibular Dimensions*

There was no significant difference in mandibular dimensions measured by the distances between Ar - Go and Go - Gn.

### *Cranial Base Relationships*

The cranial base length was determined by measuring the distance between Basion and Nasion (Ba-N). It was discovered that there was a significant difference between the two samples. The Malays have a smaller total cranial base length (97.7 ± 4.5 mm) compared with Caucasians (100.4 ± 4.5 mm). As a general rule, the tendency for increased prognathism is related to a shorter cranial base length (Bjork, 1955). This was evident in the Malay sample.

The anterior cranial base length was also significantly larger in the Caucasians with a value of 67.2 ± 3.7 mm compared to 64.4 ± 3.2 mm in the Malays.

## *B. DENTAL PARAMETERS*

### *i) Angular Measurements*

From this study, significant differences were observed in **all** the angular measurements ($p \leq 0.001$). The Malays have a bimaxillary dental protrusion in comparison to the Caucasians. This is in agreement with other studies involving non White populations, for example the Nubian people of Egypt (Shehata, 1982), Kikuyu children of Kenya (Kapila, 1988), Negro (Cotton *et al*,, 1951., Altemus, 1960), Hong Kong Chinese (Chan, 1972), Taiwan Chinese (Yen, 1973) and Koreans (Park *et al.*, 1989). (see table 2)

The upper incisors were found to be 7.4$^0$ more proclined in the Malays compared with the Caucasians.

| | Malays | Caucasian |
|---|---|---|
| Upper Incisor to Frankfort Horizontal plane | 114.2 ± 7.2$^0$ | 106.4 ± 7.9$^0$ |
| Upper Incisor to Maxillary plane | 113.9 ± 6.3 | 106.5 ± 7.9$^0$ |
| Upper Incisor to Sella-Nasion | 106.2 ± 7.6$^0$ | 97.0 ± 8.7$^0$ |
| Maxillary Incisor Position (Upper incisor to Nasion-A) | 22.0± 7.1$^0$ | 16.2 ± 8.3$^0$ |

In addition to the upper teeth, the lower incisors of the Malays were also proclined in relation to the dental bases.

| | Malays | Caucasian |
|---|---|---|
| Lower Incisor to Mandibular plane | 96.7 ± 5.8$^0$ | 91.6 ± 7.6$^0$ |
| Upper Incisor to NB angle | 31.0 ± 5.6$^0$ | 23.4 ± 7.5$^0$ |

The interincisal angle was significantly less in the Malay sample (123.6 ± 8.9$^0$) compared to the Caucasian (137.3 ± 12.8$^0$). This contributes to the bimaxillary dental protrusion. In addition, it also causes the profile to be convex (Figure 3A). A study of Indonesian Malays (Johnson, Soetamat and Winoto, 1978) also showed a smaller interincisal angle (122 ± 9.9$^0$) similar to the Malaysian Malays.

The bimaxillary proclination of incisors in the Malays found was similar to the Indonesian Malays (Johnson *et al*,, 1978). Furthermore, they found the upper incisors to maxillary plane to be 113 ± 7.1$^0$, while the lower incisor angulation was 94 ± 7.1$^0$, which was about 2$^0$ less than the Malaysian Malays.

The bimaxillary dental proclination in the Malays could be due to several factors:

***Altered muscle balance.***

The more upright position of the incisors and alveolar process in the Caucasian could be due to refinement of neuromuscular control of the labial musculature (Craven, 1958). The muscles act as a restraining influence to forward movement of the teeth.

Proffit (1978) in his equilibrium theory, showed that there were 2 factors involved in dental equilibrium, one being the resting posture of lip or cheek and tongue, the other being the forces produced by metabolic activity within periodontal ligament. He further stated that the resting posture of tongue and lips are not in equilibrium, therefore other factors must be involved in equilibrium, such as the stabilising effect exerted by the periodontal ligament. Extrinsic forces may also play a part provided they are maintained for a sufficient time. It is possible that the balance between the intrinsic forces and the stabilising effect of the periodontal ligament were different in the Malays. Tongue forces in the Malays could be larger resulting in a more proclined dentures or the lip pressure and strength is less that that of the Caucasians. Further studies on the relationship and behaviour of the tongue, cheek and lips and their effect on the dentures are needed. To date, no such studies have been done on Malays.

### *Size of Teeth and Arch Dimension*

At present, there are no studies comparing the size of teeth or arch dimension between the Malays and the Caucasians. Teeth with a large mesiodistal width occupy more space and this could lead to proclination (Carter and Slattery, 1988). On the other hand, a smaller arch dimensions could also result in proclination of the dentures.

### *Angulation and Inclination of Teeth*

Increase in angulation and inclination of teeth could result in a more protrusive denture. A tooth with increased mesiodistal tip occupies more space. A study which is similar to Andrews (1972) "Six Keys to Normal Occlusion" could be repeated in the Malay sample to see the differences in angulation, inclination and other features which are consistent in the Malay population.

### *Tooth Morphology*

This is highly unlikely but differences in cuspal morphology could favour some mesial migration of teeth and hence bimaxillary protrusion.

### *Growth*

Variation in growth between the two samples could result in differences in dental configurations. If the maxilla or the mandible moves forward during growth, therefore, some bimaxillary proclination can be expected. Other than that, growth in the maxillary and mandibular complex in a non-Caucasian might ceased later in life, producing a more procumbent incisors. Longitudinal growth studies are needed to determine the differences in growth between ethnic groups in order to understand the variations in craniofacial morphology.

### *Genetics and Environment*

The dental and skeletal morphology of an ethnic group could be genetically or environmentally determined. When dealing with normal occlusion, the genes possibly provide the framework or structure while the environment plays a part in producing the final result. An unfavourable environment might lead to malocclusion, but we have to bear in mind that abnormal genes can lead to dyplasia.

In addition to that, the genetic and environmental factors could act upon one another to multiply the effects. The genes can drive towards a certain environmental experience away from the others. This is evident when there are differences even within the same ethnic group living in different parts of the world (Foo and Woon, 1983). Kerr and Ford (1986) also showed measurable differences in facial form when comparing 3 groups of Caucasians from different geographical areas.

### ***ii). Linear Measurements***

Angular measurements were insufficient in determining the actual position of the incisors. Proclination of the incisors does not give an indication of the actual anteroposterior positioning. Teeth can be proclined but still be within the normal anteroposterior limits. Therefore, linear measurements are needed to verify the exact relationship of the incisors to the cranial base.

Linear measurements proved that the dentition in the Malays is not only proclined but is more prominent than the Caucasian sample ($p \leq 0.001$) . The distance between **upper incisor to A perpendicular** was larger in the Malays (6.5 ± 2.8 mm) by 4.0 mm (see table 10). However, when compared to the norms given by McNamara (1984), the value for the Malays were closed to his ideal limits (4-6 mm). This placed the Caucasians with a slightly retropositioned incisors (2.6 ± 2.8 mm). This could be due to a mildly retrusive maxillary base as compared to the norms given by Riedel (1952). The SNA for Caucasians in the present study was 80.8 ± 4.0$^0$ compared to 82.0 ± 3.9$^0$ in Riedels' study. Another reason could be due to a slight retroclination of the upper incisors to maxillary plane. The upper incisors were 2$^0$ less than the norms given by Houston (1986).

The upper incisor is also more anterior in relation to the **NA line**. (Malays: 5.5 ± 2.7 mm, Caucasians:2.5 ± 3.0 mm). The norms for the upper incisor to NA line is 4 mm (Steiner, 1953). The results confirmed that the Malays have slightly prominent upper incisors while the Caucasians have more retrusive incisors.

The linear relationship of the lower incisors to the dental bases was assessed by measuring the tip of the **lower incisors to A-Pog** line and to **NB line**. Both analyses indicated that the Malays have a more prominent lower incisors.

The **Lower incisor to A-Pog** was 4.7 ± 2.0 mm in the Malays compared to 1.0 ± 2.4 mm in the Caucasian. This analysis assessed the position of mandibular incisor and a range of -2 mm to +3 mm is considered a satisfactory incisor position whereas +0.5mm is said to be ideal (Downs, 1956). Ricketts (1957) on the other hand gave a value of 1 ± 2 mm to be the normal and stable position.

As with the lower incisor angulation, there are 2 main reasons in the importance of the lower incisor to A-Po line. One concerns stability and another in regard to space estimation in the lower arch. As a general rule, the position of the lower incisor should not be altered because it will be unstable. Mills (1968), stressed that proclination of lower incisor would result in relapse due to lip pressure and muscular imbalance. However certain condition permit the labiolingual movement of lower incisors, 3 examples include: retraction of lower incisors in Class III case if a sufficient overbite is established, proclination of lower incisor in Class II cases in patients with digit sucking habits and patient with a Class II Div. 2 cases where proclination to a true soft tissue balance will be stable (Mills 1968).

The proclination of lower incisors and the acute interincisal angle in the Malays bears an important clinical implication. Uprighting of these teeth during orthodontic treatment maybe unstable due to imbalance between the dentition and the muscular soft tissue environment. However, there is yet no evidence in relation to this. Investigation of lip strength and pressure on the teeth using a dynamometer and electromyography would be beneficial. Questions will arise if Malays are treated to the norms in the present study? Further studies are needed in this area comparing the stability of treatment using the new norms and with the Malays that have been treated using the Caucasian norms.

The amount of space required in the mandibular arch can be assessed using the A-Po line. Mandibular dental arch crowding or spacing can be determine in concord with measurements in mesiodistal width of mandibular teeth and lower arch circumference (Jacobson, 1995). The reason for using the lower incisor to A-Po measurement is because advancing or retracting the mandibular incisor by 1 mm will result in either a 2 mm gain or a 2 mm reduction in the mandibular dental arch (Jacobson, 1995). When using the lower incisor angulation, tipping the lower incisor forward by $3^0$ will result in an increase of 2.5 mm in total arch length and vice versa

(Tweed, 1954). From here, a clinician can plan whether an extraction or a non-extraction approach should be followed.

The **lower incisor to NB line** was 7.3 ± 2.0 mm in the Malays and 4.0 ± 2.5 mm in the Caucasians (Normal: 4 mm., Steiner, 1953). This indicates more prominent lower incisors in the Malays in relation to their bony base. There were no significant differences found in the overjet and overbite, as these were the selection criteria.

### C. *SOFT TISSUE PARAMETERS*

Assessment of soft tissues using Ricketts' lower lip to E-plane analysis, showed a significant difference at 0.1% ($p \leq 0.001$) level. Based on the results of the dental parameters, it was not surprising to find that the lower lip was more prominent in Malays than Caucasians. The lower lip was 1.6 ± 2.1 mm ahead of the E-plane, while in the Caucasian, the value was negative (-3.7 ± 2.3 mm), implying that the lower lip is behind the E-plane.

From the radiographic superimposition (figure 3A & 5A), it is evident that the lips are more prominent in the Malays compared to the Caucasians. This is mainly due to the prominent denture and its bases. The nose in the Malays is flatter in comparison to the Caucasians.

## 8.1.1. MALES

### A. SKELETAL PARAMETERS

*i) Angular Measurements*

When comparing the male subjects, the results were quite similar whereby there were significant differences in the anteroposterior spatial relationship of the skeletal bases. These angles were the SNA, SNB and SN-Pog.

***Anteroposterior** (Maxillary and Mandibular Skeletal Relationships)*

The SNA angle was was $85.3 \pm 3.5^0$ in the Malays and $81.3 \pm 3.9^0$ in the Caucasian. SNB angle was $3.2^0$ larger in the Malays($81.8 \pm 3.6^0$) compared to the Caucasian ($78.6 \pm 2.9^0$). Results showed that the Malay males have a more prominent maxilla and mandible compared to the Caucasians males. The ANB angle however was within the normal range.

The position of Pogonion in relation to Nasion was also significantly different. The mandibular basal prognathic angle suggested that the Malay males have a more prominent Pogonion in relation to the Caucasian males. The values were $82.5 \pm 3.6^0$ and $80.4 \pm 2.6^0$ in the Malay males and Caucasian males respectively.

***Vertical Relationships***

There were no significant differences in the vertical dimension between the 2 groups (see table 11). The FMPA and MMPA angles found in this study were smaller than that of Houston (1995) whose normal value was $27 \pm 5^0$. However, when compared to those of McNamara (1984), the FMPA angle given by him was similar to the present study ($22 \pm 4^0$).

### *Mandibular Dimensions*

The gonial angle in the Malay male was 122.7 ± 6.8$^0$ in contrast to caucasian male. The latter had the value of 127.5 ± 3.5$^0$ which is significantly larger than that of the Malays. This could be due to the downward and backward rotation of mandible during growth.

### *Cranial Base Relationships*

There was no significant difference in the cranial base angle between Malay and Caucasian males.

### *ii). Linear Measurements*

When linear measurements were done, only two variables were statistically significant. It was established that there was a significant difference in the cranial base length between the Malay and Caucasian males. Caucasian males have a larger total cranial base length (Ba-N) and anterior cranial base length (S-N).

## B. DENTAL PARAMETERS

### *i). Angular Measurements*

As with the pool results, the dental parameters were significantly different between the two groups except the angle between the upper incisor and Nasion-A line. Results obtained suggested that the Malay males have a bimaxillary proclination with proclined upper and lower incisors.

### *ii). Linear Measurements*

Linear measurements corresponds to the angular. The Malay males have a procumbent upper and lower incisors. In contrast to the pool results, the overjet between the Malay males and Caucasian males was statistically significant ($p \leq 0.05$). The overjet for the Malay males was larger (3.1 ± 0.8 mm) compared to the Caucasian (2.6 ± 0.8 mm). However these values might not be significant clinically.

### C. SOFT TISSUE PARAMETERS

Due to bimaxilalry proclination, the Malay males have a more convex soft tissue profile compared to the Caucasians. The relationship of lower lip to E-plane was found to be statistically significant ($p \leq 0.001$). Malay males have a more prominent lips compared to the Caucasians. This is evident when looking at the mean superimposition between the two groups.

## 8.1.1.3 FEMALES

### A. SKELETAL PARAMETERS

***i) Angular Measurements***

***Anteroposterior (Maxillary and Mandibular Skeletal Relationships)***

A significant difference was observed when Malay females were compared to Caucasian females. Anteroposteriorly, both the SNA and SNB angle were larger in the Malay females (see table 12), again showing the tendency for bimaxillary skeletal relationship.

*Vertical Dimension*

In the vertical dimension, two analysis showed significant differences. These were the **SN - Maxillary plane angle and the maxillo mandibular plane angle.** The SN - Maxillary plane angle was larger in the Caucasian females indicating that the Malay females have a smaller upper facial height. This was not observed in the males.

However, the linear measurements showed no significant difference in upper facial height. This could be due to a steeper inclination of the S-N plane and/or Maxillary plane in the Caucasian females.

In addition to that, the Malay females showed a larger lower facial height compared to the Caucasian. This was measured by looking at the maxillo mandibular plane angle. However, there was no significant difference when Frankfort plane was used instead.

***Mandibular Dimensions***

In contrast to the male subjects, there was no significant difference in the gonial angle measured by the angle Ar-Go-Me.

***Cranial Base Relationships***

There was no significant difference in the cranial base angle when both groups are compared.

***ii). Linear Measurements***

***Anteroposterior (Maxillary and Mandibular Skeletal Relationships)***

Antero-posteriorly, unlike the males, a significant difference was found when point-A was measured in relation to Nasion perpendicular. Malay females have a more prominent A point compared to the Caucasian, confirming the skeletal protusion.

Wits analysis also showed differences ($p \leq 0.001$). Results showed that the Malay females have a slightly prominent point B in relation to A. This indicates a Class III tendency. However, this should be interpreted with caution since it may be dependent on the functional occlusal plane. A slight change in inclination of this plane could affect the linear measurements.

*Vertical Relationships*

The only significant difference in the vertical dimension was the lower facial height. The Malay females have a larger lower facial height by 2.4mm. However, the ratio between lower and total facial height was similar. The total facial height was also larger in the Malays but this was not significant.

*Mandibular Dimensions*

When mandibular length was measured between Gonion and Gnathion, it was found that the Malay females have a longer mandible (72.4 ± 4.3 mm) compared to Caucasian (69.7 ± 3.6 mm). Again there is a Class III tendency in the Malay females.

*Cranial Base Relationships*

The Caucasian females have a larger anterior and total cranial base length by 2.3 mm and 2.6 mm respectively.

## B. DENTAL PARAMETERS

*__i) Angular Measurements__*

In the angular analysis, the Malay females showed a more prominent upper incisors. However, the lower incisor angle was not significantly different. This was quite surprising since the result was in contrast to what was found in males and also the pool sample.

These findings could be related to the larger mandibular dimension measured between Gonion and Gnathion. The longer dimension might cause the lower incisor to be inhibited by the upper and thus compensation of alveolar prognathism occurs. Therefore the lower incisors become less proclined.

*ii). Linear Measurements*

The linear measurements verified that the incisors were more prominent in the Malays. In comparison to the males, there was a significant difference in the overbite measurements with the Caucasian having a slightly larger figure.

### C. SOFT TISSUE PARAMETERS

Like the previous results, the Malay females have a more prominent soft tissue profile compared to the Caucasians (see figure 3C). For the female Caucasians, the lower lip is about 3.6 mm behind the aesthetic plane. This is slightly less than the norms given by Ricketts (1957) which is -2 mm ± 2 mm. However, this value was obtained for a 9 year old individual and according to him, the lower lip tend to be less protrusive with growth and it decreased by approximately 0.2 mm per year. This might explain the reason for the values to be smaller than that of the norms.

## 8.1.4 WITHIN-GROUP COMPARISON

## 8.1.4.1 MALAYS

### A. SKELETAL PARAMETERS

*i) Angular Measurements*

There were significant differences when the Malay males and females were compared. The angular measurements did not reveal any marked differences between the sexes. This was in agreement with previous study (Wei, 1968., Bishara and Femandez, 1985). The most obvious distinction was in the vertical dimension.

*Anteroposteriorly (Maxillary and Mandibular Skeletal Relationships)*

Anterior posteriorly, the SNA angle showed differences at 5% level ($p \leq 0.05$). The males have a slightly prominent maxilla compared to the females. However there were no differences in the ANB angle.

The results in the present study were in contrast to studies by Abbie (1947), Wei (1968), and Shalhoub *et al.,* (1987). They found that female subjects of the same ethnic group tend to be more prognathic than the males. The pronounce prognathism was described as a secondary sex character. However, the values in males are more variable due to large standard deviations and ranges (Wei, 1968).

*Vertical Relationships*

Vertically, SN - **Mandibular plane angle, Frankfort Mandibular plane angle, maxillo mandibular plane angle, occlusal to SN angle** and **Go-Gn to SN** were statistically significant. Results indicated that the females have a larger total facial height as indicated by the angle SN -Mandibular plane and Go -Gn to SN. The differences were $4.2^0$ and $4.0^0$ respectively. In addition, the lower facial height is also larger in the females. This is manifested by the larger maxillo mandibular plane angle and Frankfort mandibular plane angle.

*Mandibular Dimensions*

There was no significant difference found in the angle Ar-Go-Me between the males and females.

*Cranial Base Relationships*

The cranial base angle was larger in the females compared to the males. Wider cranial base angle in the females were also reported in other studies (Wei, 1968., Craven, 1958., Sarnas, 1957). It was also suggested to be related to secondary sex characteristics similar to a prognathic tendency mentioned earlier (Abbie, 1947).

***ii). Linear Measurements***

Table 13 showed that most linear measurements were significantly larger in males compared to females. This was in concord with many studies and in agreement with the notion that male subjects have a longer period of active growth compared to the females (Wei, 1968). However, even with sexual dimorphism in the linear dimensions, the facial configuration and proportions of male and females subjects within an ethnic group were highly similar. When linear distances were measured, there were significant differences in 14 out of 19 variables measured. These included the vertical dimension, the cranial base length, the anteroposterior position of the maxilla and the mandible and the length of the maxilla and the mandible.

***Anteroposterior (Maxillary and Mandibular Skeletal Relationships)***

Anteroposteriorly, the males have a more prominent maxilla. This confirmed the finding when the SNA angle was measured. The distance between **A point to Sella vertical** was larger in males.

Likewise, the females have a smaller mandible and maxilla compared to the males. These were verified by the effective maxillary length (Cd - A) and the effective mandibular length (Cd - Gn). However, there was no significant difference in the maxillo-mandibular differences.

### *Vertical Relationships*

The results for the vertical dimension was not in agreement with the angular measurements. As stated earlier, the females have a larger angle indicating larger vertical dimension. However, when linear distances were measured, the males were significantly larger in all aspects. The males have a larger upper, lower and total facial height. Furthermore, the anterior and posterior facial height were also larger in the males ($p \leq 0.001$).

These contradicting results could be due to the differences in the angulation or slant of the planes used to measure the angles. The planes used could be steeper in the females, hence producing a larger angle. However, the ratio between lower and total facial height showed no significant differences.

### *Mandibular Dimension*

The mandibular dimension was also smaller in females compared to the males. The distances between Gonion and Gnathion and also Articulare to Gonion were found to be larger in the males.

### *Cranial Base Relationships*

The linear measurements of the cranial base was significantly greater in males than females . These include the anterior, posterior and total cranial base lengths. This was in agreement with a study by Wei (1968).

These differences are possibly due to sexual dimorphism. " Sexual dimorphism is in the main an expression of secondary sexual characteristics that occur after puberty and during adolescent years" (Broadbent *et.al.*,1975). According to Forsberg (1979) on the average, the craniofacial complex is 5% to 9% larger in the males than females, depending upon the measurements taken.

Different patterns of sexual dimorphism exist in the anterior (S-N) and posterior cranial base sizes (Ba-S) (Ursi *et al.*, 1993). They found that in the females, the value for anterior cranial based plateaued at the age of 12 while in males in continues into young adulthood. On the other hand, the dimorphism in the posterior cranial base was not evident until the age of 16, when males showed a larger value. However, there was no significant difference in the cranial base angle although both showed a slight decrease with growth. These explained the significant difference found in the male and female subjects in relation to the cranial base length. It would be interesting in future to look into the growth changes and sexual dimorphism in the Malays.

### B. DENTAL PARAMETERS

The upper and lower incisors were more proclined in the females. This was true when both angular and linear measurements were taken into account. However, these differences were not statistically significant. Craven (1958) found that the females have a more bidental protrusion than the males but Davoody and Sassouni (1978) found otherwise.

## 8.1.4.2 CAUCASIANS

### B. SKELETAL PARAMETERS

***i) Angular Measurements***

Unlike the Malays, the only difference found in the angular measurement was the **cranial base angle (Ba - S - N)**. The Caucasian females have a larger cranial base angle compared to the males. These angles were $132.8 \pm 5.0^0$ and $129.0 \pm 6.3^0$ in the females and males respectively. These were in agreement with those found by Wei (1968), Craven, (1958) and Sarnas (1957) which was thought to be related to secondary sex characteristics.

## *ii). Linear Measurements*

There were differences between the males and the females. These differences were mainly due to the fact that the males have a larger overall dimension of the facial skeleton.

### *Anteroposterior (Maxillary and Mandibular Skeletal Relationships)*

The Caucasian males have a slightly prominent maxilla compared to the females when the distance between A point to Sella vertical was measured ($p \leq 0.01$).

As with the Malays ,the effective mandibular and maxillary length were also larger in the males.

### *Vertical Relationships*

In the vertical dimension, the males showed a significantly larger upper, lower and total facial height. However, in comparison with the Malays, there was a significant difference ($p \leq 0.05$) in the ratio between the lower facial height and the total facial height. The males have a slightly higher ratio. The anterior and posterior facial height were also larger in the males.

### *Mandibular Dimension*

When the mandibular dimension was measured, there was a significant difference with the females having a smaller value. The mandibular length (Go-Gn) was 6.1 mm longer in the males. However, the standard deviation is greater indicating a large variation.

### *Cranial Base Relationships*

The cranial base length was also significantly larger in the males compared to the females . This was observed in all the measurements: anterior, posterior and total. This was possibly due to continuation of growth in the anterior and posterior cranial base until young adulthood (Ursi, 1993)

## C. DENTAL PARAMETERS

The upper incisors were more proclined in the males but the lower was the opposite. However, like the Malays, these were not statistically significant.

## D. SOFT TISSUES PARAMETERS

There was no difference found when the lower lip to E-plane was measured.

# 8.3 CLINICAL IMPLICATIONS

Aesthetics, facial harmony and stability have been the issue of discussion among orthodontists for many decades. For the past years, orthodontists in Malaysia have been treating patients based on Caucasian norms. This is essentially due to the lack of our own standards. Many studies have shown that there are measurable differences in human facial pattern and form among various ethnic group (Cotton *et.al.,* 1951., Kowalski, 1974., Kerr and Ford, 1986).

The present study supports the need for modification of norms according to ethnic group. Malay norms for everyday use are given in table 16. A more detail account of the values are given in table 10-12. The mean values for measurement of one racial group cannot be considered normal for others. Steiner (1953) and Downs (1948) indicated that their norms or mean were to be used as guides and not as an absolute values for every patients. This variety of facial patterns not only exist in different ethnic groups but even within racial groups.

Cox and Van der Linden (1971), stated that persons with poor facial aesthetics in general have a relatively more convex profile due to a more anterior position of dental, skeletal and soft tissue structures in the mid face region. However, this is debatable since aesthetics is very subjective and people within and between an ethnic group has different perception on aesthetics. A convex profile or face might be aesthetically pleasing in Asian people or in those of Afro-Caribbean origin.

Further studies are needed in determining the aesthetic perception of Malaysian Malays. A selection of randomly selected judges from various professions and backgrounds could possibly be used to determine what is aesthetically pleasing from a profile photograph or silhouette.

The present study showed that the Malaysian Malays have a bimaxillary dental and skeletal protrusion. Based on this, it is sensible to say that the Malays should be treated or compared to a standard different from that of the Caucasians. The question arise as to whether treatment using the new norms would be stable. It would be interesting to recall patients that have been treated based on the Caucasian norms and assess their stability. In future, this could then be compared to patients that will be treated according to the new norms.

However, we have to bear in mind that orthodontic treatment is not only based on the numerical values from cephalometric measurements. It involves a multitude of factors like patient's chief complaint, social and behavioural characteristics, growth, facial aesthetics, oral health, jaw and occlusal function, soft tissue relationships and others. Therefore, cephalometric norms are just a guideline to characterise a patient's dental and skeletal relationships, so that the differences between the patient's actual dentofacial relationship and those expected for his or her racial ethnic group are revealed.

# Chapter 9. CONCLUSION AND SUGGESTIONS FOR FUTURE STUDIES

## 9.1 CONCLUSION

The present study showed that there were significant differences in facial configuration when the Malaysian Malays were compared to Glasgow Caucasians, both with normal (Class I) occlusions. Differences were found in skeletal, dental and soft tissue parameters. The most notable differences were observed in the dental measurements.

The conclusion that can be drawn from this study are:

1. The Malaysian Malays have a slightly more prognathic Maxilla and Mandible compared to the Caucasians. Otherwise, the skeletal pattern was almost similar.

2. The anterior and total cranial base length was smaller in the Malays.

3. The Malays have a more prominent dentures and a bimaxillary detail proclination. The upper incisor was $7^0$ more proclined than the Caucasians and the mandibular incisor was $5^0$ more proclined.

4. The Interincisal angle was $13^0$ smaller in the Malays.

5. The lower incisor was more prominent in relation to the A-Pog line (4 mm more anterior compared to the Caucasian sample).

6. The soft tissue profile indicated that the Malays have a more procumbent lip and a flatter nose. This will give a more prominent lower face and a flatter upper face.

7. Similar differences were noted when the males and females were compared between the two populations, except that the Malay females have a larger lower facial height and mandibular corpus.

8. When comparing the Malays, the males have a slightly more prognathic maxilla and a smaller cranial base angle. The male subjects also showed a larger dimension in all skeletal linear measurements. There were no differences in the dental variables.

9. As in the Malay samples, the male Caucasians have a smaller cranial base angle and linear measurements were larger in the males compared to females. There were no significant differences in the dental parameters.

10. A table of Malay norms has been developed for diagnostic purposes.

This study indicated that normal measurements of one group cannot be considered normal for other racial groups. Therefore, different racial groups will have to be treated according to their own individual characteristics.

## 9.2 APPLICATION OF FINDINGS

Findings from this study are useful in:

1. Providing information on the standard norms of dentofacial pattern of the Malaysian Malays which is evidently different from other races.

2. Providing better understanding of the facial structure and soft tissue pattern to facilitate diagnosis, treatment planning and teaching.

3. Formulating base line data for future study and research.

To date, there is a paucity of dental research on the Malaysian Malays. Orthodontically, further studies on the occlusion, growth and malocclusion would be beneficial in order to help in treatment planning and management. A growth study would be advantageous to see the changes in craniofacial structures with age. This would also give an idea of the differences or similarities between the males and females.

# Chapter 10. References

**Abbie, A.A. (1947)**
Headform and Human Evolution.
*Journal of Anatomy(London)*, **81**, 233-258.

**Adams, J.W. (1940)**
Correction of error in cephalometric roentgenograms.
*Angle Orthodontist*, **10**, 3-13.

**Alexander T, Hitchock H. T. (1978)**
Cephalometrics Standards for American Negro Children,
*American Journal of Orthodontics,* **74**, 298-304.

**Andrews, L.F. (1975)**
The Six Keys to Normal Occlusion.
*American Journal of Orthodontics,* **62**, 296-309.

**Altemus, L.A. (1959)**
Frequency of the Incidence of Malocclusion in American Negro Children
Aged 12 to 16.
*Angle Orthodontist,* **29**, 189.

**Altemus, L.A. (1960)**
A comparison of cephalofacial relationships.
*Angle Orthodontist,***30**,223-240.

**Argyropoulos, E., Sassouni, V. (1989)**
Comparison of the Dentofacial Patterns for Native Greek and American-Caucasian Adolescents.
*American Journal of Orthodontics and Dentofacial Orthopaedics,* **95**, 238-49.

**Bacon W, Girardin P, Turlot J C. (1983)**
A Comparison of Cephalometric Norms for the African Bantu and a Caucasian Population,
*European Journal of Orthodontics,* **5**, 233-240.

**Bacon, W., Girardin, P., and Turlot, J.C. (1983)**
A comparison of cephalometric norms for the African Bantu and a Caucasoid population.
*European Journal of Orthodontics*, **5**, 233-240.

**Baumrind, S., and Frantz, R.C. (1971)**
The reliability of head film measurements.
Part 1: landmark identification
*American Journal of Orthodontics*, **60**, 111.
Part 2: conventional angular and linear measures.
*American Journal of Orthodontics*, **60**, 505.

**Bibby, R.E. (1979)**
A Cephalometric Study of Sexual Dimorphism.
*American Journal of Orthodontics,* **76**, 256-259.

**Bishara S. E. (1981)**
Longitudinal Cephalometric Standards from 5 years of Age to Adulthood,
*American Journal of Orthodontics,* **79**, 35-44.

**Bishara, S.E., Abdalla, E.M., Hoppens, B.J. (1990)**
Cephalometric Comparisons of Dentofacial Parameters between Egyptian and North American Adolescents.
*American Journal of Orthodontics, 97*, 413-421.

**Bishara, S.E., and Fernandez, A.G. (1985)**
Cephalometric comparison of the dentofacial relationships of two adolescent population from Iowa and Northern Mexico.
*American Journal of Orthodontics*, **88**, 312-322.

**Bishara, S.E., Jakobsen, J.R. (1985)**
Longitudinal Changes in Three Normal Facial Types.
*American Journal of Orthodontics, 88*,466-502.

**Bjork A. (1947)**
The face in profile.
*Svensk. Tandlak.,-T*, **40**, No.5b

**Barrett, M.J., Brown, T., MacDonald, M.R. (1963)**
Dental Observations on Australian Aborigines. A Roentgenographic study of prognathism.
*Australian Dental Journal*, **8**, 418-427.

**Bell, W.H., Proffit, W.R., White, R.P. (1980)**
Surgical Correction of Dentofacial Deformities, Volume I.
*WB Saunders: Philadelphia*, 137-150.

**Bjork, A. and Solow, B. (1962)**
Measurements on radiographs.
*Journal of Dental Research*, **41**, 672-683.

**Broadbent B. H. (1931)**
A new X-ray technique and its application to orthodontia,
*Angle Orthodontist*, **1**, 45-66

**Broadbent, B.H. (1937)**
Bolton standards and technique in orthodontic practice.
*Angle Orthodontist*, **7**, 209-233.

**Broadbent, B.H. (1937)**
Bolton Standards and Technique in Orthodontic Practice.
*Angle Orthodontist*, **7**, 209-233.

**Broadbent, B.H.Sr., Broadbent, B.H.Jr., and Golden, W. (1975)**
Bolton standards of dentofacial developmental growth
*CV Mosby Co: St Louis*

**Brodie, A.G. (1949)**
Cephalometric roentgenology: History, technique and uses.
*Journal of Oral Surgery*, **7**, 185-195.

**Brodie, A.G. (1940)**
Some Recent Observation on the Growth of the Mandible.
*Angle Orthodontist*, **10**, 63-77.

**Brown M. (1981)**
Eight methods of analysing a cephalogram to establish antero-posterior skeletal discrpancy.
*British Journal of Orthodontics*, **8**, 139-146

**Bugg, J., Canavati, P., and Jennings, R. (1973)**
A cephalometric study for pre-school children.
*J Dent Child* ,**40**,103-104.

**Burstone, C.J., James, R.B., Legan, H., Murphy, G.A., Norton, L.A. (1979)**
Cephalometrics for Orthognathic Surgery.
*Journal of Oral Surgery,* **36**, 269-277.

**Bushra, A.G. (1948)**
Variations in Human Facial Pattern in Normal Israelis.
*Angle Orthodontist, **18***, 100-102.

**Carter, N.E. and Slattery, D.A. (1988)**
Bimaxillary Proclination in Patients of Afro-Caribbean Origin.
*British Journal of Orthodontics,* **15**, 175-184.

**Chan, G. (1972)**
A cephalometric appraisal of the Chinese (Cantonese).
*American Journal of Orthodontics*, **61**, 279-285.

**Choy, C. (1969)**
A cephalometric study of the Hawaiiain.
*Angle Orthodontist*,39,93-108.

**Coben, S.E. (1955)**
The integration of facial skeletal variants.
*American Journal of Orthodontics*, **41**, 407-434.

**Cooke M.S., Wei H.Y. (1988)**
Cephalometric Standards for the Southern Chinese,
*European Journal of Orthodontics*, **10**, 264-272.

**Coben, S.E. (1955)**
The Integration of Facial Skeletal Variants.
*American Journal of Orthodontics, **41***, 407-434.

**Coben, S.E. (1955)**
The Intergration od Facial Skeletal Variants.
*American Journal of Orthodontics,* **41**, 407-434.

**Coben, S.E. (1979)**
Basion Horizontal Coordinate Tracing Film.
*Journal of Clinical Orthodontics,* **31**, 598-605.

**Connor, A.M., Moshiri, F. (1985)**
Orthognathic Surgery Norms for American Black Patients.
*American Journal of Orthodontics, 87*, 119-34.

**Cooke, M.S., Wei, S.H.Y. (1988)**
Cephalometric "Standards" for the Southern Chinese.
*European Journal of Orthodontics*, **10**, 264-272.

**Cooke, M.S., Wei, S.H.Y. (1988)**
An improved Method for assessment of the Sagittal Skeletal Pattern and its Correlation to Previous Methods.
*European Journal of Orthodontics*, **10**, 122-127.

**Cotton, W., Takano, W,. and Wong, W. (1951)**
The Downs analysis applied to three other ethnic group.
*Angle Orthodontics*,**28**,12-35.

**Cox, N.H. and Van der Linden, F.G.M. (1971)**
Facial Harmony
*American Journal of Orthodontics* ,**60**,175-183.

**Davoody, P.R., Sassouni, V. (1978)**
Dentofacial Pattern Differences Between Iranians and American Caucasians.
*American Journal of Orthodontics,73*, 667-675.

**Di Paolo, R.J. (1969)**
The Quadrilateral Analysis, Cephalometric Analysis of the Lower Face.
*Journal of Clinical Orthodontics,* **3**, 523-530.

**Downs W. B. (1952)**
The role of cephalometrics in orthodontic case analysis and diagnosis.
*American Journal of Orthodontics*, **38**, 162-182.

**Downs, W.B. (1948)**
Variation in facial relationship-Their significance in treatment and prognosis.
*American Journal of Orthodontics*, **34**, 182.

**Downs, W.B. (1956)**
Analysis of the dento-facial profile.
*Angle Orthodontics*, **26**, 191-212.

**Drummond, R.A. (1968)**
A determination of Cephalometric Norms for Negro Race
*American Journal of Orthodontics*, **54**, 305-320.

**El-Batouti A, Ogaard B, Bishara S. E. (1994)**
Longitudinal Cephalometric Standards for Norwegians Between 6 and 18 Years of Age,
*European Journal of Orthodontics,* 16, 501-509.

**Elisha R. Richardson. (1980)**
Racial Differences in dimensional Traits of the Human Face,
*Angle Orthodontics*, **50**, 301-311.

**Engel G, Spotler B. (1981)**
Cephalometric and Visual Norms for a Japanese Population,
*American Journal of Orthodontics,* **80**, 48-60.

**Finlay, L.M. (1980)**
Craniometry and Cephalometry: A History Prior to the Advent of Radiography.
*Angle Orthodontics*,50,312-321.

**Flynn, T.R. (1989)**
Cephalometric Norms for Orthognathic Surgery in Black American Adults.
*American Journal of Orthodontics, 47*, 30-38.

**Fonseca, R.J., Klein, W.D. (1978)**
A Cephalometric Evaluation of American Negro Women.
*American Journal of Orthodontics, 73*, 152-160.

**Foo G.C. (1986)**
A Cephalometric Study of the Chinese in Profile,
*Australian Orthodontic Journal*, 9, 285-288.

**Foo G.C., Woon K.C. (1984)**
Some Cephalometric Norms in Young Adult Malaysian Chinese Female with Harmonious Facial Appearances,
*Dental Journal Malaysia*, 7, 33-39.

**Forsberg, C.M. (1979)**
Facial Morphology and Ageing: Longitudinal Investigation of Young Adults.
*European Journal of Orthodontics*, **1**, 15-23.

**Forsell, K., Turvey, T.A., Phillips, C. and Proffit, W.R. (1992)**
Superior repositioning of the maxilla combined with mandibular advancement: Mandibular RIF improves stability.
*American Journal of Orthodontics and Dentofacial Orthopedics*, **102**, 342-350.

**Forster, T.D., Day (1974)**
A Survey of Malocclusion and the Need for Orthodontic Treatment in a Shropshire School Population.
*British Journal of Orthodontics, 1*, 73.

**Franklin, J.B. (1952)**
Certain Factors of Aberration to be Considered in Clinical Roentgenographic Cephalometrics.
*American Journal of Orthodontics*, 38, 351-368.

**Fuji Miura, Naohiko Inoue, Kazuo Suzuki. (1965)**
Cephalometric Standards for Japanese According to the Steiner Analysis,
*American Journal of Orthodontics,* 51, 288-295.

**Garcia, C. (1975)**
Cephalometric evaluation of Mexican Americans using Downs and Steiner analysis.
*American Journal of Orthodontics,* 68, 67-74.

**Ghafari, J. (1987)**
Modified use of the Moorrees Mesh Diagram Analysis.
*American Journal of Orthodontics and* , 91, 475-482.

**Goldsman, S. (1959)**
The variation in skeletal and denture patterns in excellent adult facial types.
*Angle Orthodontist,* 29,63-92.

**Gravely J.F., and Benzies P.M. (1974)**
The clinical significance of tracing error in cephalometry.
*British Journal of Orthodontics,* 1, 95-101

**Graven, A.H. (1958)**
A Radiographic Cephalometric Study of Central Australian Aborigines.
*Angle Orthodontist, 28,* 12-35.

**Halse, A., and Hedin, M. (1978)**
May fast film-screen combinations be used for cephalometry.
*British Journal of Orthodontics,* 5,189-192.

**Haralabakis, H. (1954)**
Familial resemblances in Craniofacial Greek Families.
*Abstract in American Journal of Orthodontics.*

**Harris, J.E., Johnston, L., Moyers R.E. (1963)**
A Cephalometric Template: Its constructions and Clinical Significance.
*American Journal of Orthodontics*, **49**, 249.

**Harvold, E.P. (1974)**
The Activator in Orthodontics.
*CV Mosby: St.-Louis, 37-56.*

**Hernandez-Orsini, R., Jacobson, A., Sarver, D.M. and Bartolucci, A. (1989)**
Short-term and long-term soft tissue profile changes after mandibular advancements using rigid fixation techniques.
*International Journal of Adult Orthodontics and Orthognathic Surgery*, **4**, 209-218.

**Herzberg, F. and Holic, R. (1943)**
An Anthropologic Study of Face Height.
*American Journal of Orthodontics and Oral Surgery*, **29**, 90-100.

**Higley, L. (1954)**
Standards for children from 4-8 years of age.
*American Journal of Orthodontics*, **40**, 51-59.

**Higley, L.B. (1954)**
Cephalometric Standards for Children 4 to 8 years of Age.
*American Journal of Orthodontics, 40*, 51-59.

**Hillesund, E., Fjeld, D., and Zachrisson, B.U. (1978)**
Reliability of soft-tissue profile in cephlalometrics.
*American Journal of Orthodontics*, **74**,537-550.

**Hixon, E.H. (1960)**
Cephalometrics and longitudinal research.
*American Journal of Orthodontics*, **46**, 36-42.

**Hoftrath H. (1931)**

Die Bedeutung der Röntgenfem- und Abstansaufnahmefur die Diagnostik der Kieferanomalien,

*Fortschr Orthod,* **1**, 232

**Houston, W.J.B. (1983)**

The analysis of errors in orthodontic measurements.

*American Journal of Orthodontics*, **83**, 382-390.

**Houston, W.J.B. (1986)**

Sources of error in measurements for cephalometric radiography.

*European Journal of Orthodontics*, **8**, 148-151.

**Houston, W.J.B. (1995)**

Cephalometric Analysis

*A Textbook of Orthodontics,* **2nd Edition,** 80-118.

**Holdaway, R.A. (1983)**

A Soft-Tissue Cephalometric Analysis and its Use in Orthodontic Treatment Planning. Part 1.

*American Journal of Orthodontics,* **84**, 1-28.

**Holdaway, R.A. (1984)**

A Soft-Tissue Cephalometric Analysis and its Use in Orthodontic Treatment Planning. Part II.

*American Journal of Orthodontics,* **85**, 279-293.

**Jacobson, A. (1975)**

The 'Wits' Appraisal of Jaw Disharmony.

*American Journal of Orthodontics,* ***67***, 125-138.

**Jacobson, A. (1978)**
The Craniofacial Skeletal Pattern of the South African Negro.
*American Journal of Orthodontics,* ***73,*** 681-691.

**Jacobson, A. (1975)**
The "Wits" appraisal of jaw disharmony.
*American Journal of Orthodontics*, **67**, 155-138.

**Jacobson, A. (1976)**
Application of the 'Wits' Appraisal.
*American Journal of Orthodontics*, 70, 179-189.

**Jacobson, A. (1979)**
The Proportionate Template as a Diagnostic Aid.
*American Journal of Orthodontics*, **75**, 156-277.

**Jacobson, A. (1988)**
Update on the "Wits" appraisal.
*Angle Orthodontics*, **58**, 205-219.

**Jacobson, A., Sadowsky, P.L. (1977)**
A Visualized treatment objective.
*Journal of Clinical Orthodontist*, **14**, 554.

**Jarabak, J.R., Fizzell, J.A. (1972)**
Technique and Treatment with Lightwire Edgewise Appliance.
*CV Mosby: St Louis*

**Johnson, J.S., Soetamat, A., Winoto, N.S. (1978)**
A Comparison of some Features of the Indonesian Occlusion with those of two other Ethnic Groups.
*British Journal of Orthodontics,* **5**, 183-188.

**Johnston, L.E.Jr. (1987)**
Template Analysis.
*Journal of Clinical Orthodontics*, **21**, 585-590.

**Jones, O.G. (1989)**
A Cephalometric Study of 32 North American Black patients with Anterior Open Bite.
*American Journal of Orthodontics, 95*, 289-296.

**Kerr, W.J.S., Ford, I. (1986)**
A Comparison of Facial Form in Three Western European Male Groups,
*European Journal of Orthodontics*, **8**, 106-111.

**Kerr, W.J.S. (1979)**
A Longitudinal Cephalometric Study of Dento-facial Growth from 5-15 Years,
*British Journal of Orthodontics*, **6**, 115-121.

**Kowalski, C.J., Nasjlti, C.E., Walker, G.F. (1974)**
Differential Diagnosis of Adult Male Black and White Populations,
*Angle Orthodontics*, **44**, 346-350.

**Kowalski, C.J., Nasjleti, C.E., and Walker, G.F. (1975)**
Dentofacial variations within and between four groups of adult American males.
*Angle Orthodontics*,**2**,146-151.

**Lavelle C L B. (1974)**
Craniofacial Profile Angles in Caucasians and Negros,
*Journal of Dentistry*, **2**, 160-166.

**Lavelle, C.L.B. (1972a)**
Secular Trends in Different Racial Groups.
*Angle Orthodontist, 42*, 19-25.

**Lavelle, C.L.B. (1972b)**
Secular Trends of the Face and Stature.
*Angle Orthodontist, **42***, 221-226.

**Legan, H., Burstone, C.J. (1980)**
Soft Tissue Cephalometric Analysis for Orthognathic Surgery.
*Journal of Oral Surgery,* 38, 744-751.

**Margolis, H.I. (1939)**
A Plastic and Graphic Technique for Recording Dental Changes and Facial Growth.
*American Journal of Orthodontics,* **25**, 1027-1036.

**Margolis, H.I. (1940)**
Standardizing X-ray Cephalometrics.
*American Journal of Orthodontics,* **26**, 725.

**Margolis, H.I. (1947)**
A basic facial pattern and its application in clinical orthodontics.
*American Journal of Orthodontics*,33, 631-641.

**Massler, M., Frankel, J.M. (1951)**
Prevalence of Malocclusion in Children Aged 14 to 18 years.
*American Journal of Orthodontics, **37***, 751.

**McNamara, J.A.Jr. (1984)**
A method of cephalometric evaluation.
*American Journal of Orthodontics*, 86, 449-469.

**McNamara, J.A.Jr. (1984)**
A Method of Cephalometric Evaluation.
*American Journal of Orthodontics, **86***, 449-469.

**Millet, D.T., Gravely, J.F. (1991)**
The Assessment of Antero-Posterior Dental Base Relationships,
*British Journal of Orthodontics,* **18**, 285-297.

**Mills J.R.E. (1966)**
The Long Term Results of the Proclination of Lower Incisors.
*British Dental Journal*, **120**, 355-364.

**Mills J.R.E. (1968)**
The Stability of the Lower Labial Segment
*Dental Practitioner*, **18**, 293-305.

**Mills J.R.E. (1970)**
The application and importance of cephalometry in orthodontic treatment.
*The Orthodontist*, 32-47

**Miura, F., Inoue, N., and Suzuki, K. (1965)**
Cephalometric standards for Japanese according to Steiner Analysis
*American Journal of Orthodontics*, **51**, 288-295.

**Moorrees, C.F.A., Van Venrooij, M.E., Lebret, L.M.L., Glatky, C.B., Kent, R.L.Jr., Reed, R.B. (1976)**
New Norms for the Mesh Diagram Analysis.
*American Journal of Orthodontics*, **69**, 57-71.

**Moorress, C.F.A, (1953)**
Normal Variation and its bearing on the use of Cephalometric Radiography in Orthodontic Radiography.
*American Journal of Orthodontics*, **39**, 942-950.

**Moyers R. E. (1988)**
Analysis of the Craniofacial Skeleton: Cephalometrics.
*Handbook of Orthodontics*, **4th Edition**, 247-302

**Moyers, R.E., Bookstein, F.L. (1979)**
Inappropriateness of Conventional Cephalometriy.
*American Journal of Orthodontics*, **75**, 599-617.

**Nanda, R., and Nanda, R. (1969)**
Cephalometric study of dentofacial complex of North Indians.
*Angle Orthodontics*,39,22-28.

**Nanda, R.S., Meng, H., Kapila, S., Goorhuis, J. (1990)**
Growth Change in Soft Tissue Facial Profile.
*Angle Orthodontist, 60*, 177-190.
**P.N. Hirschmann, D.J. Lovelock, J.F. Gravely, W.B. Senior. (1985)**
The Reduction of the Dose to Patients During Lateral Cephalometrc Radiography,
*British Journal of Orthodontics*, **12**, 176-178.

**Pacini A. J. (1922)**
Roentgen ray anthropometry of the skull,
*Journal of Radiology*, **5**, 230-238, 322-331, 418-426.

**Park, I.C., Bowman, D., Klapper, L. (1989)**
A Cephalometric Study of Korean Adults.
*American Journal of Orthodontics, 96*, 54-59.

**Popovich, F., Thompson, G.W. (1977)**
Craniofacial Templates for Orthodontic Case Analysis.
*American Journal of Orthodontics, 71*, 406-420.

**Proffit, W.R. (1978)**
The Equilibrium Theory Revisited: Factors Influencing the Position of the Teeth.
*Angle Orthodontist*, **48**, 175-186.

**Rakosi, T. (1982)**
Classification of Cephalometric Analysis.
*An Atlas and Manual of Cephalometric Radiography*, 8-19.

**Richard G. Oliver. (1991)**
Cephalometric Analysis Comparing Five Different Methods,
*British Journal of Orthodontics,* **18**, 277-283.

**Ricketts R.M. (1972)**
Value of Cephalometrics and Computerized Tech.
*Angle Orthodontists,* **42**, 179-199.

**Ricketts, M et al (1976)**
Orientation-Sella-Nasion or Frankfort horizontal.
*American Journal of Orthodontics*, **69**, 648-654.

**Ricketts, R.M. (1957)**
Planning treatment on the basis of the facial pattern and an estimate of its growth.
*Angle Orthodontist*, **27**, 14-37.

**Ricketts, R.M. (1957)**
Planning Treatment on the Basis of the Facial Pattern and an Estimate of its Growth.
*American Journal of Orthodontics, 27*, 14-37.

**Ricketts, R.M. (1968)**
Esthetics, Environment, and the Law of Lip Relations.
*American Journal of Orthodontics*, **54**, 272-289.

**Ricketts, R.M. (1969)**
The evolution of diagnosis to computerized cephalometrics.
*American Journal of Orthodontics*, **55**, 795.

**Ricketts, R.M. (1972)**
An Overview of Computerized Cephalometrics.
*American Journal of Orthodontics*, **61**, 1-28.

**Ricketts, R.M. (1972)**
The Value of Cephalometrics and Computerized Technology.
*American Journal of Orthodontics, 42*, 179-199.

**Ricketts, R.M. (1981)**
Perspective in clinical application of cephalometrics.
*Angle Orthodontist*, **51**, 115.

**Ricketts, R.M., Bench, R.W., Higlers, J.J., Schulhof, R. (1972)**
An Overview of Computerized Cephalometrics.
*American Journal of Orthodontics, 61*, 1-28.

**Riedel, R.R. (1952)**
The Relation of Maxillary Structures to Cranium in Malocclusion and in Normal Occlusion.
*Angle Orthodontist, 22*, 142-145.

**Robert E. Moyers, Fred L. Bookstein, W. Stuart Hunter**
Analysis of the Craniofacial Skeleton:Cephalometrics,
*Handbook of Orthodontics,* **Chapter 12**, 247-301.

**Romanes, G.J. (1986)**
Cunningham's Manual of Practical Anatomy.
Volume 3: Head and Neck and Brain (15th Edition).

**Roth, R. (1982)**
The "Wits" appraisal-its skeletal and dentoalveolar background.
*European Journal of Orthodontics*, **4**, 21-28.

**Shalhoub, S.Y., Sarhan, O.A., Shaikh, H.S. (1987)**
Adult Cephalometric Norms for Saudi Arabians with a Comparison of Values for Saudi and North American Caucasians,
*British Journal of Orthodontics*, **14**, 273-279.

**Salzmann, J.A. (1964)**
Limitations of roentgenographic cephalometrics.
*American Journal of Orthodontics*, **50**, 169-188.

**Sarnas, K.V. (1957)**
Growth changes in Skulls of Ancient Man in North America.
*Acta Odontologica Scandinavica*, **15**, 213-271.

**Sarver, D.M. and Johnston, M.W. (1990)**
Video Imaging: Techniques for Superimposition of Cephalometric Radiography and Profile Images.
*International Journal of Adult Orthodontic and Orthognathic Surgery*, **5**, 241-248.

**Sassouni, V. (1955)**
A roentgenographic cephalometric analysis of cephalo-faciodental relationships.
*American Journal of Orthodontics*, **41**, 735-764.

**Sassouni, V. (1955)**
A Roentgenographic Cephalometric Analysis of Cephalo-facio-dental Relationship.
*American Journal of Orthodontics, **41***, 735-764.

**Sassouni, V. (1958)**
Diagnosis and Treatment Planning via Roentgenographic Cephalometry.
*American Journal of Orthodontics,* **44**, 433-63.

**Sassouni, V. (1969)**
A Classification of Skeletal Facial Types.
*American Journal of Orthodontics,* **55**, 109-123.

**Savage, M. (1963)**
Dental investigation of Bantu children.
*Angle Orthodontist*, **33**,105-109.

**Scheidemann, G.B., Bell, W.H., Legan, H.L., Finn, R.A., Reisch, J.S. (1980)**
Cephalometric Analysis of Dentofacial Normals.
*American Journal of Orthodontics, 78*, 404-420.

**Schwarz, A.M. (1961)**
Roentgenostatics. A practical Evaluation of the X-ray Headplate.
*American Journal of Orthodontics,* **47**, 561-585.

**Shalhoub, S.Y., Sarhan, O.A., and Shaikh, H.S. (1987)**
Adult cephalometric norms for Saudi Arabians with comparison of values for Saudi and North American Caucasians
*British Journal of Orthodontics*, **14**, 273-279.

**Shehata, F.I. (1982)**
Bimaxillary Prognathism in the Nubian People of Egypt.
*Angle Orthodontist*, **52**,19-25.

**Simon P. W. (1922)**
Grundzuge einer systemische Diagnostic der Gegiss-Anomalien,
*Berlin, Meusser.*

**Solow, B. and Tallgren, A (1971)**
Natural Head Position in Standing Subjects.
*Acta Odontologica Scandinavica*, **29**, 591-607.

**Steiner, C.C. (1953)**
Cephalometrics for you and me.
*American Journal of Orthodontics*, **39**, 729.

**Steiner, C.C. (1959)**
Cephalometrics in clinical practice.
*Angle Orthodontist*, **29**, **8**.

**Steiner, C.C. (1960)**
The use of cephalometric as an aid to planning and assessing orthodontic treatment.
*American Journal of Orthodontics*, **46**, 721.

**Stirrups, D.R. (1993)**
Guidance on presentation of cephalometry-based research studies: a personal perspective.
*British Journal of Orthodontics*, **20**, 359-365.

**Stoner, M.M. (1955)**
A Photometric Analysis of the Facial Profile.
*American Journal of Orthodontics*, **41**, 453-469.

**Taylor, W. and Hitchcock, H. (1966)**
The Alabama analysis
*American Journal of Orthodontics*, **52**, 245-265.

**Tedesco, L.A., Algino, J.E., Cunat, J.J., Slakter, M.J., Waltz, M.S. (1983)**
A Dentofacial Attractiveness Scale. Part II: Consistency of Perception.
*American Journal of Orthodontics*, **83**, 44-46.

**Tweed, C.H. (1946)**
The Frankfort Mandibular Plane Angle in Orthodontic Diagnosis, Classification, Treatment Planning and Prognosis.
*American Journal of Orthodontics, **32**,* 175-230.

**Tweed, C.H. (1953)**
Evolutionary Trends in Orthodontics, Past, Present, and Future.
*American Journal of Orthodontics* ,**39**,81-94.

**Tweed, C.H. (1954)**
The Frankfort-Mandibular Incisor Angle (FMIA) in Orthodóntic Diagnosis, Treatment Planning and Prognosis.
*Angle Orthodontist*, **24**,121-169.

**Ursi, W.J., Trotman, C.A., McNamara, J.A.Jr., Behrents, R.G. (1993)**
Sexual Dimorphism in Normal Craniofacial Growth.
*Angle Orthodontist, 63*, 47-56.

**Velarde, E.A. (1974) - from Bisharas' paper 1985**
Cephalometric norms for Mexican population using the Ricketts, Steiner and Tweed analyses.
*Master's thesis, Loma Linda University Graduate School.*

**Vogel, C.J. (1967)**
Correction of frontal dimensions from head x-rays.
*Angle Orthodontist*, **37**, 1-8.

**Walker, G.F. (1972)**
A New Approach to the Analysis of Craniofacial Morphology and Growth.
*American Journal of Orthodontics*, **61**, 221-245.

**Walker, G.F. and Kowalski, C.J. (1972)**
Use of Angular Measurements in Cephalometric Analyses.
*Journal of Dental Research*, **51**, 1015-1021.

**Wei, S. (1969)**
Craniofacial variations, sex differences and nature of prognathism in Chinese subjects.
*Angle Orthodontist*, **39**,303-315.

**Wei, S.H.Y. (1968)**
A roentgenographic cephalometric study of prognathism in Chinese males and females.
*Angle Orthodontist*, **38**,305-320.

**Wei, S.H.Y. (1968)**
A Roentgenographic cephalometric study of Prognathism in Chinese Males and Females.
*Angle Orthodontist*, **38**, 405-320.

**William, L., Katz, M. (1994)**
Are Cephalometric Standards Based on Esthetics Valid?
*American Journal of Orthodontics*, **105**, 104.

**Woon, K.C. (1982)**
The Distribution of Malocclusion in Malaysians.
*Jurnal Pergigian Universiti Malaya* , 31-35.

**Worms, F.W., Isaacson, R.J., Speidel, T.M. (1976)**
Surgical Orthodontic Treatment Planning: Profile Analysis and Mandibular Surgery.
*Angle Orthodontist,* **46**, 1-25.

**Wylie, W.L. (1947)**
The assessment of Anteroposterior Dysplasia.
*Angle Orthodontist,* **17**, 97-109.

**Yen, P. (1973)**
The facial configuration in a sample of Chinese boys.
*Angle Orthodontist*, **43**,301-304.