CRANIOFACIAL MORPHOMETRY IN SAUDI POPULATION

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TABLES OF CONTENTS

LISTS OF TABLES

LISTS OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

+	Plus
±	Plus Minus
×	Multiplication
=	Equal
°	Degree
%	Percent
/	Or
>	Greater than
<	Less than
II	Two
III	Three
2D	Two dimensional
3D	Three dimensional
AAPA	American Association of Physical Anthropologists
ABO	American Board of Orthodontics
BC	Before Christ
CBCT	Cone beam computed tomography
CT	Computerised tomography
CASSOS	Computer-Assisted Simulation System for Orthognathic Surgery
CI	Confidence Interval
COGS	Cephalometric for orthognathic surgery
Cl	Confidence Interval
F	Female

HREC	Human Research Ethics Committee
ID	Identity
i.e	In other words
IBM	International Business Machines Corporation
JEPeM	Jawatankuasa Etika Penyelidikan Manusia
JPEG	A format for compressing image files
KVp	Kilovolt power
M	Male
m	Meter
MRI	Magnetic resonance imaging
MSCT	Multi-slice computer tomography
n	Sample
P	Level of Significance
SD	Standard Deviation
SE	Standard Error
SPSS	Statistical Package for Social Sciences
TMJ	Temporomandibular joint
USM	Universiti Sains Malaysia

MORFOMETRI KRANIOFASIAL DALAM KALANGAN POPULASI SAUDI

ABSTRAK

Kajian ini bertujuan untuk memahami dengan lebih mendalam struktur morfometri kraniofasial dan perbandingan dimorfisme seksual dalam kalangan populasi Saudi. Etnisiti, tisu keras, tisu lembut dan ciri-ciri gigi perlu dipertimbangkan semasa rawatan, khususnya dalam pembedahan ortodontik dan ortognatik. Radiograf sefalometrik lateral untuk analisis sefalometrik menyediakan perincian berkenaan hubungkait struktur rangka, hubungkait antara struktur rangka dengan gigi dan struktur tisu lembut muka. Radiograf sefalometrik lateral membantu pakar ortodontik untuk menumpukan perhatian terhadap struktur muka semasa dan juga meramal pertumbuhan muka pada masa hadapan semasa membuat perancangan rawatan pesakit. Kajian keratan lintang 500 radiograf sefalometrik lateral ini melibatkan 250 lelaki dan 250 perempuan. Sampel direkrut dari Pusat Pergigian, Hospital Besar King Khalid, Hafer al Batin, Kerajaan Arab Saudi yang berumur antara 18 hingga 30 tahun. Kesemua radiograf telah disurih menggunakan perisian CASSOS dan dianalisa menggunakan Burstone, Down, Eastman, Holdaway, Jarabak, McNamara, Ricketts, Steiner, Tweed, dan analisis Wits. Dalam kajian ini terdapat perbezaan secara statistik pada beberapa pengukuran berbanding data morfometrik dari kajian lain yang terdahulu. Oleh itu, populasi Saudi memerlukan analisis sefalometriknya yang tersendiri sebagai rujukan. Analisis sefalometrik berganda amat penting dalam menyediakan maklumat morfometrik kraniofasial yang melibatkan tisu keras, tisu lembut dan struktur gigi kumpulan rasnya sendiri.

CRANIOFACIAL MORPHOMETRY IN SAUDI POPULATION

ABSTRACT

The purpose of this research is to have a better understanding of the craniofacial morphometric structures and comparison of the sexual dimorphism of the Saudi population. The ethnicity, hard tissue,soft tissue and dental features should be considered during treatment, especially in orthodontics and orthognathic surgery. Lateral cephalometric radiograph for cephalometric analysis provides details about skeletal structure relationships, relationships between skeletal structures with the teeth and facial soft tissue structures. The lateral cephalometric radiographs help the orthodontists to pay attention to the current facial structures as well as predict future facial growth when planning a treatment plan for the patient. It is a cross sectional study of 500 lateral cephalometric radioghraphs which contain 250 males and 250 females. These samples were recruited from the Dental Center, King Khalid General Hospital, Hafer al Batin, Kingdom of Saudi Arabia with age group 18 to 30 years old. All the radiographs were traced by using CASSOS software. All the radiographs were analyzed by using Burstone, Down, Eastman, Holdaway, Jarabak, McNamara, Ricketts, Steiner, Tweed, Wits analysis. In this study there were some statistically differences in some of the measurements as compared to other established morphometric data, therefore Saudi population requires its own cephalometric analysis as a reference. Multi cephalometric analysis are essential for providing complete craniofacial morphometric information whereby it's included hard tissue, soft tissue and dental structures of its own racial group.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Orthodontics originates from two Greek words: 'Orthos' means straight or proper or perfect and 'Odous' means Tooth. Orthodontics is one of the specialized and essential branches of dentistry. Bishara et al (1998) stated that facial esthetical harmony and an effective functional occlusion are the most important target for orthodontic treatment. For this reason, knowledge of normal dentofacial structural patterns in different ethnic, racial, and age groups are significant for clinical orthodontic treatment planning and research purposes. Cephalometric radiograph is an important diagnostic tool for orthodontists and maxillofacial surgeons (Athanasiou 1997) since its introduction by Broadbent in 1931(Broadbent 1931). Lateral cephalometric radiograph has been used in orthodontics for the prognosis of growth, analysis of craniofacial structures, diagnosis purpose, and treatment design for many years.

The face is the most important, first appearance, and changeable part of the human body which is influenced by human sex, ethnicity, geographical location, race, and age. Nowadays, the urban areas of the earth have different types of patient population and these multiple racial and ethnic backgrounds patients are not satisfied with a specific facial esthetic standard when diagnostic and treatment planning are making for patients. Earlier on, most of the patients for orthodontic treatment usually were from few racial or ethnic groups such as Americans- European, Japanese, and Afro-Americans. Due to the increased global communication via social media in this multicultural society, facial esthetic standards of different racial and ethnic groups are starting to change. For example, in Saudi Arabia due to the influence of American - European social media and Hollywood movies, nowadays increasing the number of Saudi people are seeking facial esthetic treatment from orthodontists, orthognathic surgeons, and plastic surgeons. To determine the treatment plan for different types of malocclusions, skeletal and dentoalveolar structure craniofacial characteristic differences play an important role. Orthodontists and maxillofacial surgeons need to emphasize the normal and variations in craniofacial structures of patients in detail during the diagnosis and treatment of craniofacial and dentoalveolar structures. Morphological assessment of the craniofacial structure is an essential part of clinical practice and in research work. The standard values of human facial measurements are used for assessment of the craniofacial structure, assessment of facial deformities and to check the postoperative improvements.

Cephalometrics radiograph is a suitable and constantly used radiograph for the evaluation of craniofacial morphometry of different analyses. According to Ferrario et al (1993), a cephalometric radiograph is used for careful monitoring of growth changes, clinical practices, treatment planning, therapeutic procedures, and the final evaluation of the treatment results. Cephalometric analysis can evaluate the dentofacial and skeletal relationship in the five main functional parts of the face: These are (a)the cranium and the cranial base; (b)the skeletal maxilla; (c)the skeletal mandible; (d) the maxillary dentition and the alveolar process and (e) the mandibular dentition and the alveolar process.

There were various craniofacial analysis studies have been done to set up the different craniofacial norms for various races, these are: For Caucasian -McNamara (1984); For Japanese and Japanese-Americans- Uesato et al (1978); For Japanese-Miyajima et al (1996); For Negroes- Drummond (1968); For Chinese- Lew et. al. (1992), Cooke and Wei (1988); For Malaysian Malay- Hassan (1998); For Malay- Foo, and Woon (1983, 1984); For Malaysian Indian and Malaysian Chinese- Kathiravan et al (2012); For Indian- Nanda, and Nanda (1969); For Bangladeshi -Alam et al (2012, 2013).

Mills (Mills 1982) stated that in the facial structure and the dentition of a person, human genetics has a major role. A variety of data concerning cephalometric studies for the Saudi population are available in orthodontic or other professional journals. Shalhoub et al. (1987) analyzed 48 adult Saudis live in Riyadh (normal facial proportions) and compared the Saudi sample with a North American sample and evaluated cephalometric standards for adult Saudis. Nashashibi et al (1990) evaluated a cephalometric study between Saudi boys and British boys (age 12 years) by using Steiner's analysis. They concluded that Saudi boys' faces and dentition are slightly protrusive than British. Al-Jasser (2000) conducted a study of 87 Saudi samples (age 21-27 years) with normal facial proportions. He compared the Saudi sample with Steiner's European-American (Caucasian) research sample. The outcome revealed that, relative to the European-American study, the Saudis had similar skeletal proportions, but shorter lower facial height. McNamara analysis for the Saudi population was used by Al Deaij (2001); Hashim (2003); Hashim and Al Barakali (2003); Namankani and Bukhary (2005); Bukhary (2005); Hassan (2006). 65 Saudis (36 male and 29 female, adult sample) lateral cephalometric x-ray with acceptable normal profiles and occlusions were evaluated by Al

Barakati and Talic (2007) through McNamara analysis. They found that the Saudis have bimaxillary protrusion with a convex profile, less chin prominence, more vertical mandibular plane angle. Cephalometric x-ray of Saudi boys (10 - 14 years old) were measured by Sarhan and Nashashibi (1988) with appropriate standard profiles and compared them with British boys. They concluded that the Saudi sample had more protruded incisors with a slightly prognathic face, Ar-Go-Me and Na- S- Ar angles were greater than the British samples. 70 Saudi samples from the Western province of Saudi Arabia (32 females and 38 males; aged 18 - 28 years) were analyzed by Hassan (2006) with normal facial profiles. He compared them to Caucasian standards. Compared to the European-Americans sample, he identified retrognathic mandibles with increased ANB angle and bimaxillary facial protrusion. 56 adult Saudis cephalometric x-ray (30 males and 26 females) were analyzed by Hashim and Al-Barakati (2003) with acceptable facial profiles and compare to the Caucasian American sample. They discovered that Saudi females had a convex facial profile with a smaller, lower lip and shorter soft tissue facial plane angle than the Saudi males. In nearly all soft tissue measurements, they found a remarkable variation between Saudi and Caucasian Americans. By Tweed analysis, Hashim and Hayder (2002) assessed 50 lateral cephalographs of Saudi males (aged 12 to 30 years) with 25 samples of Class I occlusion and 25 samples of Class II occlusion. They concluded that in the majority of cases, the H-line contacted the lower lip. Al Barakati (2010) evaluated 62 lateral cephalometric radiographs of Saudis (31 male, 31 females with 22-24 years old) and compare them with adult Caucasians by COGS analysis. He evaluated that in males the Ar-Ptm, Ptm-N length, and mandibular plane angle were increased; the male had a less protruding chin, less procline maxilla, slightly proclined lower incisor than the adult Caucasian sample. 100 adult Saudi patients (50 males and 50 females age 17- 22 years) with acceptable occlusion using Jarabak analysis were studied by Al-Shahrani et al (2018). They found that males showed a significant difference compared to Jarabak's values in the S-Ar-Go angle, N-S, S-Ar, Ar-Go, Go-Me, N-Me, and Jarabak ratio. Saudi females had a comparatively less significant difference in S-Ar-Go angle, N-S, and S-Go measurements in relation to Jarabak's values. Kundi et al (2018) evaluated 80 digital lateral cephalograms of adult Saudi (43 men and 37 women with 19-25 years old) using Steiner's analysis. They concluded that morphological variations between Saudi men and women were not unique. In the Saudi sample, the SNA and SNB were increased compared to Steiner's standard values and inter-incisor angle was lower that indicated Saudi adults had a bimaxillary proclination tendency.

Hajighadimi et al. (1981) conducted a study of Tweed and Steiner analysis for Iranian children and tested 67 children. They concluded that Iranian soft tissue structures were more convex than the standard value of Tweed and Steiner analysis. Iranian females' teeth were more procline than males. Bishara et al. (1990) compared the Egyptian young population with Iowa's young sample. They found almost the same craniofacial measurement between these two samples. Hamdan and Rock (2001) analyzed the Jordanian sample by Eastman analysis and concluded that the Jordanian sample showed different values for hard tissue and dental measurements than Eastman standards. Al-Jame et al (2006) evaluated 162 Kuwaiti lateral cephalograms samples (82 boys and 80 girls 13 years old) with acceptable facial profiles and analyzed the skeletal structures. They found that Kuwaiti children had proclined teeth with more convex facial structure, less prominent chin, and long Go-Me plane. Al-Gunaid et al (2007) evaluate 50 young

Yemeni males (average 23.1 years old) with acceptable dentition and pleasant facial appearance and compared them with Caucasian samples using Burstone (1980) and Holdaway (1983) analysis. They found a significant difference between Yemeni and Caucasian samples.

Several lateral cephalometric x-ray publications were published in many journals about Saudi ethnic group despite that the Caucasian ethnic group is still using for the Saudi population as a standard measurement for any craniofacial treatment. Previous studies about Saudi ethnic groups were done in a different area of Saudi Arabia and less sample size which did not represent the Saudi ethnicity. The purpose of this study is to evaluate the craniofacial morphometric norms for the Saudi adult population by 10 different cephalometric analyses and come to the conclusion about Saudi cephalometric norms. In the near future, it can be used as referral standard norms for the Saudi population.

1.2 Kingdom of Saudi Arabia

Saudi Arabia is the second largest country in the Arabian Peninsula. Geographically, this country is located in southwest Asia with approximately 2,150,000 km2 of land area. It is surrounded by Jordan, Iraq, Kuwait, Qatar, Bahrain, the United Arab Emirates, the Sultanate of Oman, Yemen, the Red Sea, the Gulf of Eilat and the Persian Gulf Sea. Saudi Arabia is a country without a river. Its population is 50% younger than 25 years old (Human Development Report 2019). According to the latest United Nations data, the Saudi Arabian population is 34.14 million in mid-2020, with 10.7 million people being non-Saudi citizens, that is 30% of the Saudi Arabia population. Ethnically, 90% of Saudi citizens are Arabs and 10% are Africans and Asians. Saudi Arabia has a diverse topography due to its large land area. The official language of Saudi Arabia is Arabic. The Kingdom is generally hot in summer and cold in winter with few rain showers. In summer, temperatures can regularly exceed 50°C in most of the area of this kingdom. Saudi Arabia has the roots of several ancient cultures, is an ancient trading center, and is the birthplace of the religion of Islam with the holy Muslim cities of Makkah and Madinah. Human habitation of Saudi Arabia dated back to about 125,000 years ago (Nature, 2011), which are the earliest traces of civilizations in the world. This is evidence that the first modern humans spread eastward across Asia left Africa about 75,000 years ago across the Bab-el-Mandeb, which connects the Horn of Africa and Arabia. (S.J. Armitage, S.A. Jasim, A.E. Marks, A.G. Parker, V.I. Usik, H.P. Uerpmann, 2011).

1.3 Problem Statement

Proper alignment of teeth is a fundamental goal of orthodontic treatment. Orthodontic treatment will get the best result when the hard, soft tissue and dental structures of the individual ethnic group of the patients are reflected in treatment planning. Before starting the treatment orthodontist should analyze the craniofacial and dental features of the patient, which will prevent any unwanted effect in the normal cranial, facial, and dental features. The early cephalometric analysis value was dependent on the Caucasian race and other races and Saudis were treated according to these races. Recently orthodontic treatment has gotten commoner in Saudi Arabia. Thus, it becomes essential to determine the cephalometric parameters for this population for proper treatment protocol and to get maximum treatment outcomes.

1.4 Justification of the study

The craniofacial morphometric study is essential for research and clinical treatment purposes. The purpose of this study is to evaluate the craniofacial morphometry of the Saudi adult population cephalometrically. And to determine the cephalometric norms of men and women, adults from Saudi Arabia who was selected based on having a normal occlusion. This study is accomplished by using a comparatively huge sample size of the Saudi population than other previous cephalometric studies. The Saudi samples were selected cautiously by their Saudi nationality (by their national ID Number), grandparents, and parents are Saudis and acceptable skeletal and facial profile. Due to an increasing number of adults Saudi orthodontic patients, it is necessary to establish the cephalometric standard norm of the Saudi population which can be significant for treatment purposes for them.

Cephalometrics x-ray can help to find the causes and location of hard, soft tissue, and dental landmarks. Orthodontic treatment planning will be planned more specifically with the help of specific data of the norm. This x-ray gives a better option for orthodontic treatment and brings better outcomes for the Saudi population. It will also help to create a more reliable treatment protocol not only for the Saudi population but also for global researches.

1.5 Objectives of the study

1.5.1 General objective

The principal aim of this study is to determine the craniofacial morphometry of the Saudi population by lateral cephalometric radiograph.

1.5.2 Specific objectives

I. To determine the craniofacial morphometry of the Saudi male population based on different cephalometric analysis.

II. To determine the craniofacial morphometry of the Saudi female population based on the different cephalometric analysis.

III. To compare the craniofacial morphometry between the Saudi male and female population based on the different cephalometric analyses.

1.5.3 Null Hypothesis

I. There is no significant difference in the craniofacial morphometry of the Saudi male population.

II. There is no significant difference in the craniofacial morphometry of Saudi female population.

III. There is no significant difference in the craniofacial morphometry between the Saudi male and female populations.

CHAPTER TWO

LITERATURE REVIEW

The definition of orthodontics proposed by the American Board of Orthodontics (ABO) and later adopted by the American Association of Orthodontists states:

"Orthodontics is that specific area of the dental profession that has as its responsibility the study and supervision of the growth and development of the dentition and its related anatomical structures from birth to dental maturity, including all preventive and corrective procedures of dental irregularities requiring the repositioning of teeth by functional and mechanical means to establish normal occlusion and pleasing facial contours."

Ricketts (1960) states that people first like to fulfill their basic needs of life such as food and shelter, then they start thinking about their beautification, comfort, and other needs. Due to an increase in global communication, better socio-economic condition, and social demand, people are now focusing on their facial aesthetic features. So, the human facial profile takes a special place in human life. Cephalometry is one of the necessary division of physical anthropology in which head and facial measurements can be calculated. The craniofacial structures are depending on racial and ethnic groups, climate, geographical, socio-economic condition, nutritional and genetic factors, Radovic et al (2000). Measurements of the different types of heads and faces are important for studies of human development, variation in the population, and clinical purposes. A morphological and anthropological finding indicates that each ethnic norm has its standard norm value not only within the same ethnicity but also in each subgroup. It is unacceptable to implicate the measurement of one ethnic group to another or to utilize the standards measurement of one sub-race to another sub-race even in a similar race. Several researchers, Brodie et al (1938); Bjork (1948); Down (1948); McNamara (1984); Steiner (1953); Tweed (1954) established different cephalometric norms for a ‘perfect facial profile or occlusion’ of their samples which were only for Caucasian or white North Americans. Different racial groups have their craniofacial characteristics. According to Lew et al (1992), most of the cephalometric studies had proven that the standard value should be based on ethnicity, sex, and age. Cephalometric analyses are concerned with the determination of particular landmarks and estimate the different angular and linear measurements. There are about 50 methods of assessing skeletal pattern. Some analyses focus on the dental arrangement, some analyses contain extensive dental and skeletal structures with the future prognosis of the hard and soft tissues. Several researchers established the parameter of dentofacial structure which is considered normal different parts of the dentofacial, cranial structures like the mandible. According to Nanda and Nanda (1969); Shalhoub et al (1987) cephalometric analysis should be derived from the same population with race, age, and sex. For example, by analysis of the stable mandibular structures, the orthodontist can estimate the growth of the mandibular and the possibility of future rotation. Orthodontists need to pay attention to both present facial structures and the consequence of the final skeletal and soft tissue growth and changes during treatment planning. These can be done by a comparative study of the patient’s present radiographic measurements with his or her norms values. Most of the reference norms are Caucasian samples. Caucasian norms cannot be used as the standard norm for other ethnic and racial groups.

The facial esthetic is incomplete without facial profile analysis. Mohammad et al. (2011) found, in the Malaysian Malay people both jaws and lips were proclined than Caucasian. A comprehensive study of the cephalometric norms of Malays and the Caucasians has been done by Hassan (1998). Kathiravan et al (2012) found dissimilarity ($p < 0.001$) in the lip position of the Malaysian Indian and Malaysian Chinese population. In the Indians, the upper lips were -2mm ± 1.02mm behind the E line and the Chinese upper lips were -0.04mm ± 1.00 mm behind the E line. The Chinese had a protrusive lower lip and it was 1.66mm ± 0.91mm in advance of the E line. The Indian lips were 0.13mm ± 0.99mm and it was almost on the E line. According to Chan et al, (1972), the facial pattern of Asians (e.g.: Chinese and Indians) was measurably different from the Caucasians and the different cephalometric measurements of Caucasians might not be normal in another racial group.

2.1 Human Races

Nowadays, all humans living in the world belong to a single species is **"*Homo sapiens*."** Smith et al (1997) defined the 'races' as geographically circumscribed species with sharp boundaries that separate them from the other species. Race or racial groups of humans usually depends on a person's physical structure, skin, hair, eye colour, ethnicity, nationality, regional culture, ancestry, and language. Richardson (1980) defined the term "ethnic group" as a nation or population with a common bond such as geographical boundary, common culture or language, or being racially or historically related". Genetic, natural, and social environments are influenced by the biological differences between human beings. There are many physical differences between the races of different geographic areas of the world. Some are strongly inherited and some are influenced by nutrition, social lifestyle, and environment such as size and shape of the body (AAPA Statement on Biological Aspects of Race-1996). Four major racial groups are depending on geographical location, cultural variation, and language. These are the Asiatic (or Mongoloid), Black (or Negroid), White (or Caucasian), and Australoid (Australian Aborigine and Papuan) race. Each group provides its characteristics in which physical variability is distinguished from one other. Farkas et al (1988) and Hajnis K et al (1994) were measured head width and calculated the head index for young persons of both sexes of three major groups of mankind, i.e., the Caucasian, Negroid, and Mongoloid. Results showed that North-American whites (Caucasian) have a long and medium-wide head (mesocephalic head), African Americans (Negroid) have a long and narrow head (dolichocephalic head), the Chinese (Mongoloid) have a short and wide head (brachycephalic head). There is no significant difference in head height was found in subjects of the three races study.

Depending on some traits as skin pigmentation, the shape of the head, form, and colour of hair, and shape of the nose, most anthropologists historically agreed about four relatively distinct groups.

The Caucasoid race: Present in Europe, America, and the Middle East. They have pale reddish white to dark wheatish skin colour, medium to tall stature with mesocephalic head. Light blond to dark brown hair colour, fine texture, and straight or wavy. Light blue to dark brown eyes with prominent. Facial or alveolar prognathism and long narrow nose with a high bridge and high forehead.

The Mongoloid race: Usually present in East Asia, Malaysia, China, Japan, and the adjacent islands. This race has saffron to yellowish or light wheatish or reddish-brown skin colour, medium height with a high incidence of the brachycephalic head. Dark, straight, and coarse hair, body hairless. Black to the dark brown eye and almond shape. Wide and short projecting cheekbones and low and broad nasal bridge. The forehead is slightly lower than Caucasoid.

The Negroid race: Usually present in Sub Sahara Africa and West Indies. They have brown to black skin colour, dolichocephalic head shape, and thick, inverted lips. Black, curly and wooly hair. Large and broad skeletal structure. Forehead most often high, the eyes are dark, bimaxillary prognathism, high cheekbones, strong white teeth common in most of the Negro population. Wide nose with low nose bridge and broad nostrils.

The Australoid (Australian Aborigine and Papuan) race: The Australoid race is depended on geographical location and regional culture rather than genetic and biological traits. This race present in Australia, Melanesia, and parts of Southeast Asia (Huxley 1870). They have dark skin with wavy or curly hair, a mesocephalic head, and a moderate broad nose.

2.2 Physical Anthropology

Anthropometry derived from the Greek word Anthropos means "human" and metron, which means "measure". It is a biological science of measuring the size, weight, and proportions of the human body, Farkas (1994).Anthropometry the method of describing or comparing the measurement of the human body. Anthropometry method used since the 18th century for classifying the different human races (Joseph M, Dawbarn C,1970). Hippocrates first established physical anthropology (460-375 BC) and is known as "The Father of Physic". He described the various forms of skull especially the macrocephalic form, but did not employ characteristics measurements. According to Eickstedt (Eickstedt, 1926), anthropometry is a standardized scientific method for calculating the human physical diameter. When anthropometric methods are applied in the medical practice, there are characteristic differences are distinguishing between various races. Human physical variability was an interesting subject for scientists (Pandey 2006). Human physical dimensions are depended on ecological, biological, geographical, racial, sex, age, and nutritional factors (Radovic et al 2000). Anthropometrical variation is an interesting subject for physical anthropology, genetics, anatomy, dentistry, and also for industrial purposes (Roberts, 1956 & Kohn, 1991). Physical Anthropology depends on the geographic boundary, culture, language, or racial groups, or historically related areas of people, socio-economic conditions, and genetics. The climate, nutritional factors also influences the physical anthropology of the racial groups and growth and development of the facial morphology. Anthropological studies are used to access the variation between different races, ethnic groups, sex, human facial growth and clinical treatment, cranial and facial measurements.

2.3 Craniometry

According to the Edinburgh Encyclopedia of 1813 “Craniometry is the art of measuring skulls of animals to discover their specific differences”. So that craniometry is the technique in which dry skull was used for direct measurement of the osteological landmarks of the skull. A scientific approach to the scrutiny of human craniofacial patterns was first recorded by anthropologists & anatomists and they recorded the various dimensions of ancient dry skulls. Then Craniometry was applied to living subjects. The modern and quantitative study of craniology started in the nineteenth century. It is a specialized branch of anthropometry. Craniometry is used in dentistry, especially in orthodontics to measure the teeth-jaws relationship and cranium measurement of gender, age, and genetics of the population before discovered and introduction of cephalometry x-ray. The technique the measurement of the head of the living sample from the bony landmark located by palpation or pressing through the supra adjacent tissue is called cephalometry. The craniometric measurement can help to compare human ethnicity and identify age, sex, and race.

2.4 Origin of Cephalometry

According to Moyers et al (1988), cephalometry is the art of abstracting the human head into a measurable geometric design. Cephalometry is one of the important branches of anthropology in which the human head and face diameter are measured. In the early stage of anthropology, cephalometry was not associated with orthodontics. But it was introduced for the human development and growth of craniofacial anatomical study

(Wahl, 2006). Leonardo da Vinci (1452-1519) used various lines to measure the human head form (Finlay 1980). He metrically showed the lines and segments ratio and described the procline and retrocline facial forms by changing the angle between vertical and horizontal axes. Head and face shape depend on climate, race and ethnicity, surroundings, nutritional factor, genetic influences, socio-economic conditions, Radovic et al (2000).The cephalometric radiology combination of the advantages of craniometry and anthropometry. Proffit and Fields (2000) stated that a cephalometric radiograph is important for orthodontic patients to evaluate the clinical examination, the study of craniofacial growth, and the direct measurement of skeletal and soft tissue structure of human being.

Figure 2.1 Human head measurement by Leonardo da Vinci

Source: Leonardo da Vinci Study of Proportion of a man's profile

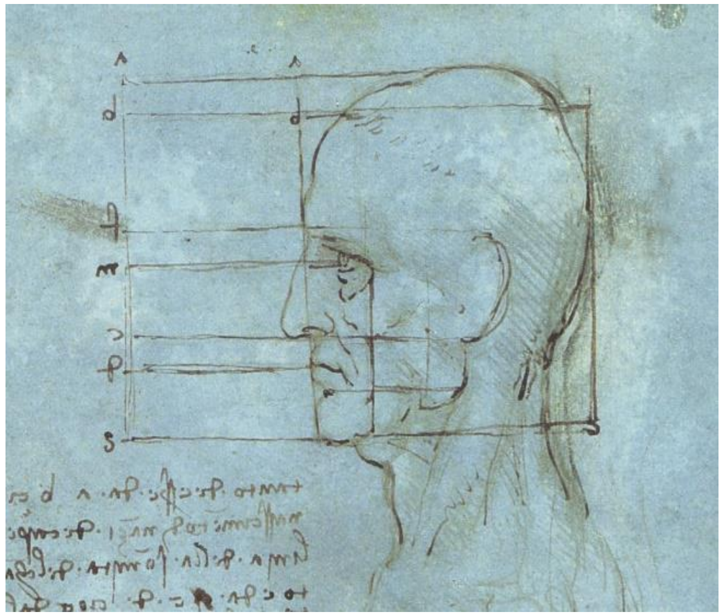

Figure 2.2 Human head proportion
Source: Leonardo da Vinci. The proportions of the head, ca.1490 Courtesy of the Galleria dell' Academia, inv.236v, Venice

2.5 Facial Profiles

The facial profile is an important characteristic for determining facial attractiveness and physical appearance. In 1907, Dr. Edward Angle concluded that facial balance and harmony depend on the shape and beauty of the mouth, proper alignment of teeth, and established the best harmony and it was depending on growth, development, and function (Angle 1907). Facial harmony depends on skeletal structures, teeth, and soft tissue of the face (Langlade1993, Hambleton1964). An aesthetically pleasant, harmony and balanced face is the main goal of orthodontic treatment. Growth of dentofacial structures or orthodontic treatment can change the soft tissue profile that is closely related to dental and skeletal changes (Subtelny 1961). Different types of schemes are established to assess facial profile characteristics. These are anthropometry (Farkas 1981), photogrammetry (Gavan et al.1952; Stoner 1955; Neger 1959), computer imaging (Guess and Solzer, 1989), and cephalometry (Garner 1974; Roos 1977, Czarnecki et al.1993). These researchers found that the interrelationships of the nose length, protrusion of lip, and chin position are the facial characteristics to evaluate the perception of facial balance and harmony.

The conception of facial beauty is related to ethnic differences, age, sex, cultural difference, and human characteristic feature (Mandall et al.2000; Şahin Sağlam and Gazilerli, 2001). Different researcher groups had defined various measurements and landmarks for facial harmony (Burstone 1958; Merrifield 1966; Ricketts 1960; Holdaway 1983). They introduced several angles to evaluate facial aesthetics. According to Holdaway (Holdaway 1983), the H-angle is formed by the chin to the upper lip line and the NB line. H-angle is 7 – 15 degrees for the ideal face, it indicates the skeletal convexity of the patient's face. Merrifield (1966) introduced the Z-angle and it was related to the lower face. The Z-angle is formed by the Frankfort horizontal plane and profile plane. The profile plane is formed by the highest point of the soft tissue chin and the most prominent part of the upper lip. Legan and Burstone (1980) introduced the angle of convexity. It is formed by soft tissue glabella, subnasale area, and soft tissue pogonion. According to Powell analysis, an ideal facial profile is made up of the nasofrontal, naso-facial, naso-mental, and mento-cervical angles (Powell and Humphreys, 1984). Ricketts (1960, 1981) introduced the esthetic plane and it was from the vermillion border of the lower lip to the E-line (soft tissue pogonion—nose tip). For young patients, Ricketts found the esthetic line was 0 mm ±3 mm. According to Martin (Martin1964), Mandibular retrognathism is both socially and esthetically acceptable for Asian. But the same profile is considered unattractive for the Caucasian race (Lew et al 1992). Steiner (Steiner 1962) suggested the S-line. This S-line is formed by soft tissue chin to the midpoint of the nasal columella and intersecting the upper lip. If the lips touch the S line, the profile will be straight; the profile will convex if the lips are presented in front of the S- line and the profile will concave if the lips are presented behind the S-line.

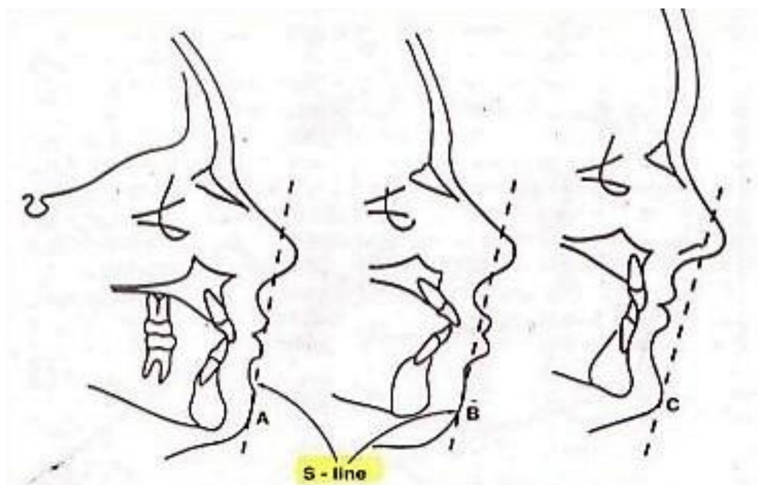

Figure 2.3 S-line. **A:** Straight profile; **B:** Convex profile; **C:** Concave profile

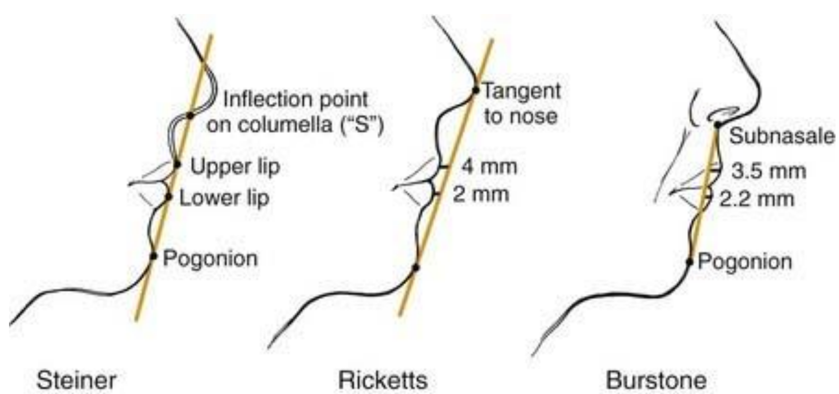

Figure 2.4 Steiner, Ricketts and Burstone analysis of the ideal relationship of the chin with lips

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2.6 Craniofacial Structures

The craniofacial structure is a combination of 25 bones.10 cranial bones and 15 facial bones. The cranial bones are: one frontal, one occipital, one pair of sphenoids, ethmoid, parietal and temporal bones.

The facial bones are Nasal, lacrimal, maxilla, inferior nasal conchae, zygoma, vomer and palatine, mandible. Except for vomer, all facial bones are paired.

2.7 Craniofacial Growth And Development

The craniofacial area is one of the essential parts of the human body, it undergoes different types of changes during development. Various external (environment, air pollution, socio-economic condition, etc.) and internal (genetic) factors affect the growth and development of craniofacial structures. These factors are responsible for the specific craniofacial characteristics of different races or within the same race.

Craniofacial development is a complicated and expanded series of steps. It requires a series of cell interactions to initiate and differentiation of various embryonic cells. The Head, face, and oral cavity formed the craniofacial complex and give unique identities to the individuals. The craniofacial structures are important parts for the analysis of racial structure, functions, and development. The upper part of the facial skeleton is related to the anterior cranial fossa and the lower part of the facial skeleton such as the mandible is articulated with the posterior cranial fossa through the temporomandibular joint.

2.7.1 Prenatal Growth

In the second month of embryonic life, chondrocranium appears first. In the 8th week of embryonic life, 41 ossification centers appear in the chondrocranium. In the 5th and 6th weeks of embryonic life, a mesenchymal mass appears at the cephalic end of the notochord and forms the early cartilaginous part of the base of the skull that is neurocranium. Then the chondrocranium transfers to basicranium. The craniofacial areas of the body consist of two components: the neurocranium and the viscerocranium. The viscerocranium, the skeleton of the face is neural crest cell origin and it goes through both intramembranous (cranial vault, maxilla, and mandibular body) and endochondral ossification (mandibular condyle and cranial base).

The craniofacial complex initially consists of a series of bulges or prominences and undergo development, fusion, and expansion. All the dental tissues except enamel are of neural crest cell origin. After delaminating from the neural crest cell, they transfer epithelial cells to mesenchymal cells and drift anteriorly to the developing brain and the pharyngeal arches. Five prominences construct the face; these are the frontonasal, two medial nasals, two lateral nasals, two maxillary, and two mandibular prominences (Bronner et al.2010). The frontonasal prominence is derived from the first pharyngeal (branchial) arch. This prominence forms the premaxillary area such as the forehead, the middle of the nose, the philtrum, and the primary palate. The lateral nasal prominences give rise to the ala of the nose (Larson, 2001). The maxillary prominences are derived from the dorsal part of the first pharyngeal (branchial) arch and form the sides of the middle and lower face, the lateral borders of the lips, and the secondary palate.

Mandibular prominence is derived from the ventral area of the first pharyngeal (branchial) arch and forms the lower jaw. The medial nasal prominences form the nasolacrimal duct.

There are six pharyngeal arches. The fifth arch disappears quickly. In each arch, there is specific cartilage. The first arch produces bilateral “Meckel’s cartilages” and forms the mandible, the malleus, and incus, base of the medial pterygoid plate and sphenoid spine. Reitchert’s cartilage is the second arch cartilage and produces part of the body and the lesser horns of the hyoid bone, styloid process, and stapes. The third arch produces the body and greater horns of the hyoid bone. The fourth and sixth arches produce thyroid and cricoid cartilages respectively.

2.7.2 Postnetal Growth

A baby born with a large cranial vault with a huge orbits relatively narrow mandible and maxilla is compared to an adult.86% of total post netal growth complete in the first year of age and 94% of total growth complete by 5 years of age (Costello BJ et al 2012). 82% to 92% of facial development, mostly complete by age 5 years (Farkas et al 1992, Yang et al 2012, Taylor 2001). At age 5 years, approximately 85% of the mandible and maxilla form. At an early age, the cranial vault size is larger than facial size, but the ratios between cranial volume and facial volume are gradually decreased with age (Cohen Jr.MM 2014). The fastest growth is completed at the age of 7 years (Farkas et al 1992, Yang et al 2012, Taylor 2001). The face is expanding during primary tooth eruption and at the stage of mixed dentition, face length increased. Length of face increase doubles than the width between 4 to 13 years age (Cohen Jr.MM 2014). Craniofacial growth is decreased significantly after 20 years of age (Darwis 2003, Fudalej et al 2007).

According to Ferguson (2016) during birth, near about 45% of craniofacial bone growth was completed. Cobourne & DiBiase (2010) evaluated that humans are spending about 30% of their whole life growing. The first 20 years of growth after birth is postnatal growth. It is divided into three periods: 1.Infancy, 2.Childhood, and 3.Adolescence.The first postnatal period of life is infancy (0 to 1 year). Childhood is divided into 3 phases: a) an early phase (1 to 6 years); b) a middle phase (6 to 10 years); c) a Late phase (10 to 15 or 16 years). The face is a significant change in postnatal life. It takes a longer period and under the influence of pubertal growth. The cranial vault comes into the adult size and the face comes around 95% of its final size at adolescence and it leads to physical and reproductive maturity (Bogin 1988). At birth, the facial dimensions of the largest to smallest are width, height, and depth.

The growth of the craniofacial structures can be divided into four regions:

i. The cranial vault: the bone of the upper and outer surface of the brain.

ii. The cranial base: the floor of the bone under the brain, it divides the cranium and the face.

iii. The naso-maxillary complex: the nose, maxilla, and the associated structures.

iv. The mandible.