RADIOGRAPHIC ANALYSIS OF SUBADULT FACIAL SOFT TISSUE DEPTHS

RADIOGRAPHIC ANALYSIS OF FACIAL SOFT TISSUE DEPTHS FROM A SUBADULT POPULATION: AN AID TO FORENSIC FACIAL REPRODUCTION

By

TODD NORMAN GARLIE, B.A. (HONS)

A Thesis

Submitted to the School of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree

Master of Arts

McMaster University

MASTER OF ARTS (1995) McMaster University
(Anthropology) Hamilton, Ontario

TITLE: **Radiographic analysis of facial soft tissue depths from a subadult sample: An aid to forensic facial reproduction**

AUTHOR: **Todd Norman Garlie, B.A. (Honours) (Memorial University)**

SUPERVISOR: **Professor Shelley Saunders**

NUMBER OF PAGES: **xiii, 111**

ABSTRACT

The analysis of facial tissue depths and the application of facial reproduction techniques have been attempted during the last century with the intent to recreate the features of famous people and archaeological specimens, and more recently to identify individuals in medicolegal cases. There are however, questions surrounding the accuracy and feasibility of such attempts. A longitudinal, subadult radiographic sample is analyzed and examines correlations between tissue thicknesses, sex, age and body build. Several parents of the children are also examined. The results of this study provides data on facial tissue depths for a subadult and adult samples, thus adding to the literature. Results indicate that differences occur at several metric points along the midline of the face between males and females. A trend indicating an increase in facial tissue thickness as individuals become older was found. Furthermore, a relationship between facial tissue thickness and body build was demonstrated.

KEY WORDS: Forensic Anthropology, Facial Reproduction, Personal Identification, Longitudinal Data Set, Radiographs, Subadults, Weight, Sex, Age,

Acknowledgements

I would like first to acknowledge my gratitude to Dr. Shelley Saunders, my Thesis supervisor, for the time and energy she gave to this research project. I wish to also express my thanks to Dr. Peter Ramsden and Dr. Michael Spence, my other committee members, for their help in this venture .

I am grateful as well to my fellow graduate students, Chris Dudar, Anne Keenlyside and Dongya Yang for their encouragement and comments throughout . I would especially like to thank Rob Hoppa, for his support and statistical commentary, and Marcia Hoyle for her encouragement throughout.

My greatest appreciation is extended towards my wife, Karen, who has stood beside me throughout the whole process with great support and lack of complaint. Even for continuing into the Ph.D program.

Further thanks go to Gertrude Jorgenson and Joanne Hofmiester of the Burlington Growth Center, who provided invaluable services, support and conversation throughout the data collection process.

This study was made possible from use of material from the Burlington Growth center, Faculty of Dentistry, University of Toronto, which was supported by funds provided by Grant (1) (No. 605-7-299) National Health Grant (Canada), (data collection); (2) Province of Ontario Grant PR 33 (duplicating) and (3) the Varsity Fund (for housing the collection).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

A skull may tell of age, of sex, of race, and thus in part contribute to cranial identification. But it may do more: it may provide a further individualization, for it may give clues as to cephalic identification. This is to say that the dead skull is, in a sense, the matrix of the living head; it is the bony core of the fleshy head and face in life. Upon the cranial framework (which is really subjacent to all soft tissues) we may build bit by bit, until details of physiognomy take shape, and a reasonably acceptable facsimile of a living human head emerges (Krogman 1978:244).

CHAPTER 1

INTRODUCTION

The personal identification of partially or completely skeletonized human remains is usually conducted by forensic specialists who rely on characteristics such as sex, stature, age at death, population origins, and features of trauma and pathology unique to individual remains (Krogman 1978; Stewart, 1979). If, for some reason, such characteristics are obscured or even absent, the result will be a failure to identify the individual. When this happens, forensic anthropologists adopt alternative methods for personal identification. Three of these alternative methods are; 1) the comparison of the skull to a portrait of the suspected deceased; 2) the comparison of the skull to photographs of the suspected deceased; and 3) the reproduction of facial features upon the skull of the deceased (Krogman 1978:244). The last method, facial reproduction, attempts to produce a reasonable likeness of an individual by building up layer upon layer, with clay, the structures of the soft tissues of the face. This is achieved by employing standard facial tissue depths that have been collected through a variety of methods and published since the turn of the century. This procedure offers significant potential for identification of unknown human remains when usual methods fail (Caldwell 1986:229; Craig 1993; Rhine 1980:847; Rogers 1987:59; Ubelaker 1992:155). The

application of standard tissue depths for the purpose of forensic facial reproduction[1] has become increasingly important for depicting the facial features of unknown human skulls (Ubelaker 1992:155) and it is this method that is examined here.

The practice of reproducing facial features on human skulls has interested researchers for years. Early attempts, during the late 1800s, saw reproductions performed on the skulls of well known historical figures such as Bach, Kant and Schiller (see Welcker 1883 and His 1895; cf. Krogman and Işcan 1986:414) as well as on a variety of archaeological specimens (see Kollmann and Büchly 1898; Runestad 1993; von Eggeling 1909 cf. Wilder 1912:419-420). An increased interest in forensic anthropology during the 1960's has brought this procedure to the forefront in an attempt to identify unknown human remains from a forensic context, when other methods have failed (Rhine 1990:960).

The significance of this procedure lies in the fact that correlations exist between the soft tissue thicknesses on the face and the underlying bone (Caldwell 1986:229). Ubelaker (1992:155), though supporting the underlying importance of facial reproduction, admits that there are some aspects of the soft tissues, such as the nose, eyes, and lips that do not directly correlate with the underlying bony structure of the skull. Furthermore, individuals who attempt such facial reproductions must realize that several important variables, such as sex, population origin, age and body build, that affect tissue depths must be considered (Caldwell 1986:235). Opponents of this technique argue that the use of facial reproductions to

---

[1]Facial reproduction has often been termed facial reconstruction, plastic reconstruction, facial restoration, reconstitution, and forensic sculpture among other terms. This paper will use the term facial reproduction as defined by Rhine (1990).

determine the identity of unknown human remains is futile (see Brues 1958:561; Montagu 1948:321-322; Rathbun 1984:347; Suk 1935). For example, Suk (1935) demonstrated that the use of cadavers to measure facial tissue depths was not completely accurate, as it missed the underlying metric points by almost 3mm (cf. Dumont 1986:1463-1464). Certainly problems exist with the technique; however, continued research on the methods of this procedure, should help to produce more accurate facial reproductions.

THE PROBLEM

Two basic premises exist requiring further research into the application of facial reproduction techniques. First, there are measurable differences in the thickness of soft tissues[2] covering the skull and second, much of the facial tissue on a living individual appears to correlate with the underlying bony structures on the skull (Caldwell 1986:229). Attempts have been made during this century to record reliable facial tissue depths at specific points on the head. Unfortunately, many of the recorded tissue depths currently in use were collected at the turn of the century on small samples of white, European adult cadavers (see Kollmann and Büchly 1898; His 1895; Welcker 1883). It is critical, therefore, that tissue depths be obtained from larger samples of living individuals of various ages and population origins.

Methodologies for the collection of tissue thickness data also need to be critically examined. Measurements have traditionally been taken on cadavers of unknown freshness

---

[2]The soft tissues refer to the skin, fat, and muscle tissue covering the skull. The use of radiographic films in this study does not allow for distinction of these layers which will therefore continue to be referred to as "soft tissues" throughout this study.

(see Welcker 1883; His 1895; Kollmann and Büchly 1898) and controlled freshness[3] (Rhine and Campbell 1980; Vanderlinden et al. 1993) using a calibrated instrument. Other techniques, however, are now available for measuring the overlying soft tissues on the human skull. These include radiography (see Altemus 1969; Dumont 1986) and ultrasonography (see Hodson 1985; Lebedinskaya 1993) on living individuals. Furthermore, it is necessary to assess the relationships between tissue thickness and age, sex, population origin, and body build, among other variables. These factors are important if researchers hope to achieve accurate facial reproductions of individuals from unknown skulls. The current research addresses problems of methodology and sampling found in the literature. It also analyzes a longitudinal subadult radiographic data set to examine the relationship between facial tissue thickness and age. The relationship between facial tissue thickness and sex among subadults is also explored. Measurements from subadult facial tissue thicknesses are then compared to a sample of adult measurements.

Four general hypotheses tested in this study are: 1) Male subadult facial tissue thicknesses are greater than female subadult facial tissue thicknesses. 2) Subadult facial tissue thicknesses increase as individuals age. 3) Adult facial tissue thicknesses are larger than subadult facial tissue thicknesses. 4) Facial tissue thicknesses vary with body build.

---

[3]the term "unknown freshness" refers to the fact that the cadavers used were unknown in terms of their time of death and length of storage before being studied. The term "known freshness" refers to the fact that the researchers attempted to utilize cadavers for which the time of death and length of storage were known. They attempted to use only the most recent individuals (in terms of time of death).

RESEARCH GOALS

The present research uses a radiographic data set compiled during a longitudinal growth study conducted from 1952 to 1972 (Nikiforuk 1977). Facial tissue thicknesses were collected from a sample of children aged 8 to 20 years (males n=17 - 43 and females n=10 - 38). Tissue thicknesses were also collected from a sample of these children's parents (males n=29 and females n=34) for comparison. This research aims to accomplish the following goals;

1) To address methodological and sampling problems found in the literature.

2) To produce a set of standardized measurements for a specific population.

3) To examine the relationship of facial tissue thickness between males and females.

4) To examine the variation in facial tissue thickness as individuals grow.

5) To compare facial tissue thicknesses between a sample of children and their parents.

6) To examine the relationship between facial tissue thicknesses and the height/weight ratio of subadults.

Chapter two surveys the literature dealing with methodology, sample quality, and sample size. There is also a review of the problems for the collection of facial soft tissue depths and some of the methods adopted to overcome those problems and produce more accurate results.

CHAPTER 2

LITERATURE REVIEW

Introduction

Facial reproduction and the collection of facial soft tissue thicknesses had an early beginning. Those procedures designed to reproduce the facial features of historical persons and archaeological specimens (see Harslem-Riemschneider 1921-22; His 1895; Kollmann and Büchly 1898; Welcker 1883; Stadtmuller 1921-22/23-25; Ziedler 1919-21 cf. Krogman and Işcan 1986), are closely linked to recent studies in forensic anthropology that attempt to identify unknown skeletal remains of contemporary individuals from murder scenes, missing persons cases, or mass disasters (see Dumont 1986; Helmer et al. 1993 in Işcan and Helmer 1993; Hodson 1985; Lebedinskaya 1993 in Işcan and Helmer 1993; Rhine and Campbell 1980; Rathbun 1984; Snow et al. 1970; Vanderlinden et al. 1993). A survey of the relevant literature has outlined several methodologies for the collection of facial tissue depths, and to date, the majority of these have used cadavers as samples (His 1895; Kollmann and Büchly 1898; Moore 1981; Welcker 1883; Rhine and Campbell 1980; Suzuki 1949; Vanderlinden et al. 1993; Welcker 1883). Recent studies have adopted the use of ultrasonic and radiographic technology to determine the depth of facial tissues from living individuals

(Altemus 1969; Dumont 1986; Helmer et al. 1993; Hodson et al. 1985; Lebedinskaya 1993).

Cadaver Studies

The use of cadaver samples to determine facial tissue depths has been the key method of data collection since the turn of the century. H. Welcker (1883) established an interest in facial reproduction by fashioning the faces of Schiller and Kant onto their presumed skulls, based on tissue depth data he collected. To obtain this data, Welcker measured facial tissue thickness from 13 middle aged male cadavers by inserting a small knife, of known length, into the tissue until reaching bone (see Table 2). By measuring the remaining length of the knife at nine points along the mid-line of the face, he ascertained each tissue depth (cf. Krogman and Işcan 1986; Stewart 1979; and Wilder 1912:417). The results of Welcker's research are presented in Appendix A for comparison.

In 1895, Wilhelm His advanced the study of facial reproduction by reproducing, upon a skull, the face of Johann Sebastian Bach. This reproduction was based upon tissue thickness data he collected. Utilizing many of the same metric points defined by Welcker (1883), His developed additional points along the lateral margins of the face. His work resulted in an increased sample size and the inclusion of a female data set (see Table 1). To collect tissue measurements, His used a small needle with a rubber disk attached (see Appendix A for results). Once inserted, the facial tissue would displace the rubber disk and the distance below could then be measured. He further showed that variations in tissue thickness occur between cadavers of varying conditions by comparing 24 male victims of

suicide to nine males who died of a "wasting disease". The addition of a female sample also enabled His to make general inferences regarding correlations between tissue thickness and sex (cf. Krogman and Işcan 1986; Stewart 1979; Wilder 1912:417).

Later Kollmann and Büchly (1898) provided additional data on tissue depths for producing facial reproductions (refer to Appendix A) by examining the bodies of 21 males and seven females in various conditions and including three other metric points (see Table 1). Furthermore, they combined their results with those of His to increase the data set to 45 males and eight females. They included only the four females whose bodies appeared well nourished. Kollmann and Büchly (1898) also employed the use of a needle to collect their data, though instead of using a needle with a rubber disk attached, they blackened one with soot from a candle flame before each measurement. When inserted the soot was displaced and measurements could then be taken from the cleansed area (cf. Rogers 1987; Stewart 1979; Wilder 1912:417-419).

In 1912, Harris Wilder reviewed other research completed in the early part of this century by Birkner (1903-1905), Fischer (1903), and von Eggeling (1909), who collected tissue thickness data from other population groups. Birkner studied the heads of six individuals of Chinese origin and concluded that the soft tissues of the head vary much more than the skull in regard to racial background. Fischer collected data from two Papuan individuals and von Eggeling analyzed facial tissues from the heads of four Hereros. These last three studies consisted of very small samples and are not very useful for application to facial reproduction techniques. However, they are presented in Table 1 for description. All

three authors utilized a soot-covered needle, similar to the method developed by Kollmann and Büchly (1898), to collect their data (see Appendix A for results)(cf. Wilder 1912:421).

From this survey of early literature, several methodological problems, along with problems of sample size and quality, become apparent. Furthermore, the samples from these studies were biased, representing males more than females. Another problem was that facial tissue depths were retrieved from cadavers of unknown condition. Because the loss of bodily fluids after death results in an alteration of tissue thickness (Todd 1928), the tissue depths estimated from cadavers may be smaller than those from living individuals. The use of a knife or needle to collect tissue depths also presents difficulties. First, the insertion of a needle or knife into the face may displace the soft tissues, producing inaccurate measurements. Second, using a needle covered with soot may also result in unreliable measurements due to accidental shifting of the soot.

The data sets from these studies may also be considered biased because they only include older, middle aged individuals, often male, and they do not represent younger individuals. Recent studies continue to provide additional data on soft tissue depths, following similar methods outlined in studies from the turn of the century.

Suzuki (1949) analyzed a sample of 48 male and seven female cadavers of Japanese origin, utilizing 25 metric points on the head (see Table 1). He measured tissue depths at each point using a 6cm needle with a metal sheath and a disk at one end (see Appendix A for results). He concluded that nutrition was an important variable influencing tissue thickness, especially in the lateral and orbital regions of the face. The points along the mid-line were less

affected by this variable. Further, women generally had thinner facial tissues than men except around the eyes, cheeks and mouth (Suzuki 1949).

Later, Sutton (1969) followed similar methods of data collection, though his research was related more to the orthodontic field than to forensic science. His research attempted to examine variations in tissue thickness covering the zygomatic region (i.e. cheek bones). Sutton insisted that it was important for researchers to be aware of the variability of tissue thickness found in this area of the face. Earlier investigators (i.e. Woods 1950; Lunstrom and Lysell 1953) considered that a measurement of 6mm was sufficient for the thickness of the tissue covering the zygoma. Sutton, however, argued that 6mm was a huge underestimation.

For his study, Sutton collected four measurements from each of 104 cadavers undergoing dissection in the Anatomy Department at the University of Melbourne and averaged his results, using the means for comparison (see Table 1 for description). He employed a methodology developed by earlier individuals for collecting tissue depths (see His 1895, Kollmann and Büchly, 1898) and also included two measurements for determining bizygomatic breadth. This was accomplished by palpating the underlying bone and then measuring the breadth between the two points by compressing the calipers until encountering bone. He calculated bizygomatic breadth by subtracting the mean tissue depths from the mean bizygomatic breadth (Sutton 1969). To test the reliability of the tissue thickness readings he compared the mean measurements from the four zygion readings. Sutton found no significant differences and thus the means for each group of four readings were used to indicate soft tissue depth. The reliability for bizygomatic readings were also tested comparing

the mean differences between the first and second measures. Again, Sutton found no significant differences between the two and thus used the mean of the two readings for the bizygomatic breadth.

Sutton (1969) tested the relationship of tissue thickness over the zygions to body build by dividing his sample into the specific categories of thin, medium and fat. His sample included 30% thin individuals (20 male, 11 female), 44% medium individuals (30 male, 16 female), and 26% fat individuals (19 male, 8 female) respectively. The mean measures for each category were: 8.0mm, 12.4mm, 21.1mm for males and 9.6mm, 15.1mm, 20.8mm for females. He obtained significant differences between all three categories ($p < .001$), with 92% of his sample exceeding the recommended 6mm in the zygomatic region. Only eight individuals fell into this recommended tissue depth and all were from the thin category. Sutton further determined that sex differences were significant, with males having thinner tissue thicknesses in two of the body build categories, thin and medium ($p < .001$). There was, however, no difference seen between males and females in the fat category. He further found no significant differences between the mean differences of the right and left zygoma. Twelve individuals had measurements equal on both sides and 50 individuals from the rest of the sample appeared to be thicker on the right side, but not significantly.

The relationship between bizygomatic breadth and body build was tested by comparing the means of the bizygomatic readings for each of the body build categories. Sutton found significant differences occurring between the medium and fat categories for both males and females and also between the thin and medium categories for males. He further

found sex differences for the bizygomatic readings, with males having the larger readings. These differences occurred in all three body build categories.

Several problems are apparent from looking at the methodology and samples Sutton used. First, his sample of cadavers were of undetermined freshness and had been dissected to such an extent that information concerning weight was unavailable. Furthermore, the date and cause of death for these cadavers was unknown, thus the loss of bodily fluids could have significantly altered tissue thickness and resulted in unreliable measurements. The process of embalming may also have altered the thickness of the facial tissues. Sutton classified his samples as thin, medium or fat based on the cadaver's condition and his own judgement. Since these cadavers were in various stages of dissection, and weight was difficult to determine, inferences on the relationship between weight and the thickness of facial tissues should be suspect. Sutton's byzygomatic breadth measurements may also be suspect because measures taken by different individuals may yield different results due to varying pressures placed upon the callipers.

More recently, Rhine and Campbell (1980) have included data on facial tissue thicknesses. They focused their research on an African American cadaver sample to address the lack of information concerning tissue depths for this population group. Much of the data used for facial reproductions has been based on measurements from adult white males and females at the turn of the century (see His 1895; Kollmann and Büchly 1898). Rhine and Campbell, in their study, examined 59 African American individuals and 32 white individuals for comparison (see Table 1).

To collect data on tissue thicknesses, Rhine and Campbell employed methods similar to those developed by His (1895). Utilizing cadavers, they attempted to control for the condition of the sample by obtaining bodies that were less than twelve hours old that had been refrigerated. When inserting the needle, Rhine and Campbell compensated for tissue deformation by tapping the skin back up to the stopper. From this study, they concluded that female tissue depths are quite similar to those of males, except for the areas around the eyes and cheeks. Their data also indicated that there may be significant differences in tissue depths between persons of different population origins (see Appendix A for results) (Rhine and Campbell 1980).

Though Rhine and Campbell attempted to control for the freshness of the cadavers there may still a problem, due to the loss of fluids, that may alter tissue thickness. Further, they have stated that their data comes from a fairly large sample of individuals in good health, but have included results from only 59 individuals. Their sample, though providing more data, is not much larger than those of other studies. Rhine and Campbell also argue that increased stature and weight during the last century may have altered the average values of tissue thickness (i.e. values being larger in contemporary populations). Population differences may also account for larger tissue depth values.

Later, Moore (1981), following Rhine and Campbell's example of analyzing facial tissue thickness from other populations, examined variation of facial tissue thicknesses from individuals of European, African American, and Native American (primarily Southwestern) descent. Employing methods similar to those of earlier studies, he inserted a needle, eased

the rubber disk on to the skin and then levelled the skin using his fingers. He then studied the measurements, under magnification, and recorded them to the nearest .25mm. Moore also employed anthropometric measurements by using standard sliding calipers.

From his research using a variety of univariate statistical tests, Moore (1981) concluded that facial soft tissue thickness has increased over the last 100 years for modern North Americans of European descent compared to the German individuals studied at the turn of the century by researchers such as Kollmann and Büchly (1898). Moore's research, also provides data on African American and Native American tissue depths. He further concluded, that when producing facial reproductions, tissue thickness data should be specific to the population origin of the individual. Body build, age, sex, and possibly asymmetry should also be taken into consideration, argues Moore, for these variables all affect, to some degree, the thickness of tissue covering the skull.

Quite recently, Vanderlinden and colleagues (1993) presented a brief abstract of work on the collection of facial tissue thicknesses at the University of Toronto. They are attempting to provide a comparable data set on a Canadian sample of cadavers, to address specific deficiencies in other studies, and to initiate a long term study to better examine the relationship between facial soft tissues and the underlying bony structure. These researchers have attempted to overcome some of the inherent problems with using cadavers by including only unembalmed cadavers donated for scientific purposes. Furthermore, they intend to collect data on such variables as the condition, age, nutritional status, and cause of death for each cadaver. This is important if comparisons and correlations are going to be made

between and within samples.

Table 1: Sample Sizes from various Facial Tissue Thickness Studies

AUTHOR	DATE	MALE	FEMALE	TOTAL	COMMENTS
Cadaver Studies					
Welcker	1883	13	------	13	
His	1895	24	4	28	9 males not included died of a wasting illness
Kollmann and Buchly	1898	21	4	25	data combined with His (1895) and used as basis for much of present day reproductions.
Birkner	1903 -1905	6	------	6	Beheaded Chinese
Fischer	1905	2	------	2	Papuans
von Eggeling	1909	3	------	3	Hereros
Suzuki	1948	48	7	55	Japanese
Rhine and Campbell	1976- 1978	68	23	91	African American and European Origins
Ultrasound Studies					
Dumont	1986	93	101	194	Minimum of 9 and maximum of 18 individuals in each category. Cross-sectional study.
Lebedinskaya	1993				1695 individuals from various Russion populations
Radiographic Studies					
Altemus	1963	36	5 1	87	25 male and 25 female African American children
Hodson et al	1985	28	22	50	Children ages 4-15 years. Cross-sectional study
Garlie	1994-95	47	43	90	Subadults aged 8-20 years. Longitudinal study

Ultrasound and Radiographic Studies

Introduction

The review of the above literature outlined several deficiencies that affect the accuracy of the collected tissue thickness measurements and the potential outcome of facial reproductions. These problems include methodological weaknesses and data sets that are biased in terms of quality, size, sex and population origin. Due to these shortcomings, the use of ultrasound and radiography for the collection of tissue thickness data has been adopted by some researchers in an attempt to more accurately assess tissue thickness and represent such variables as sex, age, and population relationships (Altemus 1963; Dumont 1986; Hodson et al. 1985; Lebedinskaya et al. 1993).

Ultrasound studies

Current studies have adopted ultrasound technology in an attempt to retrieve more reliable readings on tissue depths for application to forensic facial reproduction. Hodson and colleagues' (1985) study examined ultrasonography and compared it to the use of cadavers, radiography, ruler probe and lean meter measurements to collect tissue thickness data. They have argued that ultrasound technology surpasses the use of cadavers, ruler probe, and lean meter measurements, but is comparable to the use of radiography. They insisted that ultrasound technology is safer than the use of radiographic techniques, but admit to some level of potential danger with its use.

Their research project was developed in order to present a collection of average facial

tissue thicknesses for an underrepresented group, children of northern European descent. Furthermore, they also wanted to ascertain the relationship between facial tissue thickness and sex and age from a living population. The sample used for this project included a cross-sectional database of 22 females and 28 males and excluded children with obvious weight problems or medical disorders (see Table 1). Utilizing twenty metric points on the skull, both median and lateral, they concluded that only one measurement, mid-philtrum, showed a statistically significant difference ($p < .05$) between the sexes. All other differences were not significant. However, they determined that three points showed statistically significant thickening as males and females grow. These were mid-philtrum ($p < .01$), the mental sulcus ($p < .05$), and the frontal eminence ($p < .05$). Other measurements, though not statistically significant, showed a decrease in tissue thickness. These were suborbital, inferior malar, supra M2, mid-temporal, and gonion. The authors then split the age groups by sex and analyzed their data for those under twelve and those over twelve. Results indicated significant thickening for the older female group at mid-philtrum ($p < .03$) and a significant thickening of the mental sulcus for the older male group ($p < .01$), but no difference was seen in the frontal eminence. From these results, Hodson and colleagues insist that more research needs to be completed with older children to gain an understanding of tissue thickness as individuals mature.

Further research into the collection of facial tissue depths using ultrasound technology has been completed by Lebedinskaya and colleagues (1993). They have argued that ultrasound is somewhat superior to the use of radiographs and far better than the use of

cadavers to collect data on tissue depths. Radiographs, they argue, are useful only when the researcher can control for anode and subject distance. They maintain that these must remain consistent throughout the study if the results are to be reliable. Lebedinskaya and colleagues concluded that ultrasound enables researchers to study larger populations with relative ease, and without affecting the health of individuals involved.

Lebedinskaya and co-authors' investigation included 1695 individuals of various population origins, and obtained measurements from 17-20 points on the face (Table 1). Employing univariate and multivariate statistics they concluded that positive correlations exist between much of the facial soft tissue and some of the underlying bony matrix. Unfortunately, their research showed a lack of correlation between facial soft tissues and bone surrounding the oral and nasal regions of the face.

Radiographic Studies

The use of radiographic technologies has also been adopted in recent studies with the intent to collect facial tissue depths from groups of living individuals. Altemus' (1969) study was an early attempt at collecting tissue thickness data using this technology. His research examined soft tissue depths around the oral cavity to help diagnose and treat orthodontic disorders. Altemus was concerned with examining various measures of soft tissue depth to determine if there were measurable differences in these tissues. His study compared two groups of children of similar ages, one composed of 37 children of European descent, the Howard group (11 males and 26 females), ranging in age from 13.4 to 15.6 years, and the

second, the Burnstone group, composed of 50 African American children (25 male and 25 female) ranging in age from 12-16 years (see Table 1). He measured the horizontal and vertical extensions of the soft tissues from tracings of radiographs (Altemus 1969). From comparing the means and standard deviations from the two groups of measurements he concluded that the measures from the points glabella, menton and incision-stomion are similar. However, the means from the Howard group were larger than those from the Burnstone group at all other metric points except for subnasale, which was smaller. Altemus further suggested that a large amount of variability exists in tissue depths covering the skulls of individuals.

More recently, Dumont (1986) used radiography to examine soft tissue depths in children for application to forensic facial reproduction. Her study was an attempt to provide data on facial tissue depths for forensic purposes by obtaining measurements from a cross-sectional lateral radiographic data set. She wanted to determine whether variation in tissue thickness exists between children of different ages, sex and dental occlusal patterns.

Her data set consisted of a cross-sectional study of 194 individuals (101males and 93 females) aged 9-15 years old (see Table 1). Dumont measured nine metric points on each of the children, presumed to be of European descent and middle class. She determined that three variables for males (inferior nasal spine, prosthion, and chin fold) and two for females (inferior nasal spine and chin fold) had regression slopes significantly different from zero, thus there was a measurable difference in tissue depths for age. Dumont then divided her sample into two age groups 9-11 and 12-15 in order to ascertain the impact of sex on tissue thickness

changes at these points. Using student's T-tests she saw no significant differences ($p < .05$) between males and females who were in the younger group and thus combined the results to increase the sample size. In the older group, however, she did see significant differences ($p < .05$), with males exhibiting thicker tissue. After assessing age as not significant for the variables glabella, nasion, mid-nasal, rhinion, menton, or gnathion, Dumont performed student's T-tests comparing males and females aged 9-15 years. Three of these points, glabella, menton, and gnathion, were considered not significant ($p < .05$) and thus combined to increase the sample. The rest of the above variables appeared significant ($p < .05$), again with males having thicker tissue. Dumont also chose four variables; prosthion, chin fold, menton, and gnathion, to test the relationship between dental occlusion and tissue thickness. She performed student's T-tests between these variables and three groups of dental classification (class I, class II, class III)[1]. Only the variable gnathion proved significant ($p < .05$) between class I and class II. Sample size was small for class III (n=7), though Dumont suggests results may be quite different if the sample was increased.

Dumont (1986) concluded that age, sex and possibly dental occlusion have some influence on facial tissue thickness. She further noted that males have thicker tissue in some areas and females have thicker tissue in other areas. Dumont also insisted that puberty has some effect on the divergence of tissue depth. Further, the differences found in tissue depth

---

[4]These are terms used by the dental community to categorize how the first mandibular and first maxillary molars touch when the teeth are at rest. Class I describes the preferred occlusal pattern, indicating the paracone of the first maxillary molar in contact with the buccal groove of the first mandibular molar. Class II describes a position of overbite, where the metacone of the first maxillary molar is in contact with the buccal groove of the first mandibular molar. Class III describes a position of underbite, where the paracone of the first maxillary molar is in contact with the distobuccal groove of the first mandibular molar (Dumont 1986)

readings between her sample and other studies may be a result of using radiographs from living individuals rather than using cadavers where tissue alteration may have occurred.

The use of radiographic and ultrasound technology for the collection of tissue thickness data appears to be more reliable than does the use of cadavers. The use of these methods present many advantages. First, measurements are taken from living individuals instead of cadavers (Altemus 1963; Dumont 1986:1468; Hodson et. al. 1985:1101; Lebedinskaya et al. 1993). This allows the researcher to examine actual tissue thicknesses rather than ones that have been altered due to the process of embalming or drying. This may result in measurements being larger than ones found in studies dealing with cadaver samples (Dumont 1986:1468). Second, researchers are able to produce large data sets of individuals from various ethnic backgrounds and age ranges with relative ease and within a short period of time (see Dumont 1986:1468; Lebedinskaya et al. 1993). This allows for significant comparisons to be made between and within populations on variables such as age and weight. These methods should provide for more accurate applications to facial reproduction in the future. Furthermore, radiographic and ultrasonic films are easier to acquire, and store more readily than do cadaver samples (Hodson 1986:1468). This creates data sets that can be examined or reexamined by other researchers to assess accuracy or attempt answers to other questions. The use of these methods also allows researchers to view the underlying metric markers and take measurements directly off the films or make tracings from the films and then obtain measurements, rather than having to palpate for these underlying markers and use a needle to obtain the required measurements, as is done with cadaver samples (Dumont

1986:1468).

Radiographic and ultrasonic methods are clearly a more accurate way of assessing facial tissue thickness than the use of cadaver samples. Though radiographs present a slight risk to an individual's health over prolonged exposure and can only be viewed in two dimensions they have an advantage over the use of ultrasound technology. To obtain an ultrasound reading the researcher has to place a transducer on the soft tissue and push, keeping the transducer in contact with the skin for the period of the measurement. This may produce inaccurate tissue depth readings. Radiographs do not have to contend with this problem.

CHAPTER 3

MATERIALS AND METHODS

Materials

The sample employed for this research project was drawn from a longitudinal growth study completed over a 20 year period, from 1952 to 1972, in Burlington, Ontario, Canada. The collection, currently housed at the Burlington Growth Centre, in the Faculty of Dentistry at the University of Toronto, Toronto, Canada was compiled through a study begun by Drs. Moyers, Grainger and Mitton in 1952 with the financial help of the Federal Department of Health and Welfare (Grant 605-7-299). Initially, the study comprised 75 children between the ages of three and 12. The following year it grew to include 1380 children and 312 parents of these children (Nikiforuk 1977). Table 3 presents the complete Burlington Growth Study sample. This data set, then, included approximately 90% of the children of Burlington at the time of the study and, as such, should be considered representative of the large majority of Ontario children in the 1950's (De Vito 1988:12). The portion of the sample obtained for this data set includes 43 female and 47 male radiographic tracings of individuals at yearly intervals from 8 to 20 years and 63 parent tracings, 29 male and 34 female (see Figure 1 and Table

2)(total radiographs, subadults n=615 and adults n=63). This portion of the larger data set was chosen because it encompassed the complete number of non-treated children[1] in the growth study plus some minimally treated individuals. The parent sample in this study represents the total number available that are related to the subadult sample. Each individual case contains two lateral, two oblique, and one posteroanterior cephalogram, along with a carpal radiograph to determine the skeletal development of each person. Furthermore, the height and weight records for each individual and associated dental casts are available. Photographs of some individuals are also available (Nikiforuk 1977).

The nature of this growth study provides an excellent opportunity to examine variables that are associated with potential variation in tissue thicknesses. The Burlington growth study was able to control for such factors as population origins, nutrition and health data, and genetic relatedness, as well as the sex and age of individuals, among other important variables (Popovich and Grainger 1954-59). At the time the growth study began, the town of Burlington consisted of approximately 5000 people of northwestern European origins, mainly from Britain, and had a slightly higher income than the national Canadian average (Nikiforuk 1977). The sample, therefore, is relatively homogenous in terms of geographic origins and economic status. Furthermore, this set of radiographs has a constant enlargement factor of 9.84% that should be taken into account when comparing results from this study to data from other studies. The radiographic records from the Burlington Growth Center have

---

[1]The term "non-treated" refers to the fact that there were no orthodontic treatments performed on these children. Minimally treated refers to individuals who only had minor orthodontic treatments completed (i.e. fillings).

also been carefully monitored to control for anode and subject distance over the period of the study. This results in cephalometric films that are quite consistent and provide reliable data for this type of research. Although there have been many orthodontic studies completed on this data set, this is the first research that studies soft tissue depths in a forensic framework.

Methods

Facial soft tissue thicknesses were collected from the Burlington Growth Study sample during the summer of 1994. Initially, the intent was to measure depths directly from the cephalic films (i.e. x-rays). Due to measurement error, it was decided to follow the general orthodontic practice of tracing the cephalic films and then collect tissue depth measurements, thus retaining a permanent record of the data and reducing measurement error.

To obtain suitable tracings from the radiographs, a sheet of frosted acetate paper (.003mm thick) was clipped to the film and placed on a light table, allowing light to penetrate through the x-ray, and illuminate the bony portions of the skull and the associated soft tissues. With this completed, the margins of the skull and the soft tissues were traced using a pencil, with a hardness of .04, that was continually sharpened. To reduce tracing errors, Enlow (1968:268) has suggested that pencils be kept sharpened to less than (.20 mm) thick. Only radiographs showing clear images of the underlying bone and outer soft tissues were included in this study. Once the cephalograms were traced, 14 metric points along the mid-line of the face were placed directly on the tracings (see Figure 2). These points, 1-14, are named as follows: 1) Supraglabella; 2) Glabella; 3) Nasion; 4) Mid-Nasal; 5) Rhinion; 6) Nasal Length;

7) Mid-Philtrum; 8) Prosthion; 9) Alveolar; 10) Infradentale; 11) Chin Lip Fold; 12) Pogonion; 13) Gnathion; 14) Menton. Measurements descriptions are listed in Appendix B. Measurements were obtained using a pair of calibrated 6" Fowler electronic digital calipers with fresh batteries that measured to the nearest one-hundredth of a mm (.01mm). The measurements were then transcribed onto a data collection form (see Figure 3). An intraobserver test was conducted to compare measurements from two sets of the same films (n=20), with measurements taken four weeks apart. Utilizing SPSS(Statistical Package for the Social Sciences, version 6.0 and 6.1) a Paired t-test was completed ($p<.05$) to compare the two groups. Results of this test are discussed in the next chapter.

Measurements collected from 14 sites along the mid-line of the face, when available, resulted in a database of approximately 10,000 measurements. Univariate and multivariate statistical analyses of this database employ the use of an IBM computer and SPSS (Statistical Package for the Social Sciences, version 6.0 and 6.1). Results are presented in Chapter Five.

Table 2: Distribution of radiographic tracings for subadult and adult database

AGE	8	9	10	11	12	13	14	16	17	18	20	
Subadults												
Male	19	42	22	23	43	23	38	38	17	20	38	
Female	23	36	21	21	35	20	37	38	10	19	32	
Total	42	78	43	44	78	43	75	76	27	39	70	**615**

Adults		
Male	29	
Female	34	
Total	63	**63**

Table 3: Complete inventory of radiographs for the Burlington Growth Study

3-Year - Serial Experimental Group(Records Taken to August 31, 1971)

AGE	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
MALES	132	167	161	154	149	144	141	141	136	127	125	122	35	116	86	101	32	68			
FEMALES	100	136	132	130	126	122	121	117	116	115	113	109	0	103	47	86	31	57	1		
TOTAL	232	303	293	284	275	266	262	258	252	242	238	231	35	219	133	187	63	125	1		
C-6 SERIAL CONTROL																					
MALES				168	2		138	3	3	133	3	91	3	105	1			53	4		
FEMALES				129	1		107	1	1	101	1	70		76	2			49	2	1	
TOTAL				297	3		245	4	4	234	4	161	3	181	3			102	6	1	
C-8 SERIAL CONTROL																					
MALES						96				1	4	12	1	20				24	2		
FEMALES					1	123	3	1		6	3	17	2	25				21	8		
TOTAL					1	219	3	1		7	7	29	3	45				45	10		
C-10 SERIAL CONTROL																					
MALES								111		1				19	3			4			
FEMALES								106	2			1	2	12				1	1		
TOTAL								217	2	1		1	2	31	3			5	1		
C-12 SERIAL CONTROL																					
MALES									1	113	1			1	2	1		56	8		
FEMALES									1	99	1			1	2			37	4	1	1
TOTAL									2	212	2			2	4	1		93	12	1	1
FAMILY STUDY SIBS (These figures do not include those from above)																					
MALES		2	4	19	8	28	29	31	7	35	5	36	1	33	1	3	3	3	1		
FEMALES	1	3	4	25	11	37	43	45	3	44	8	43	3	43	1		1	3	1		
TOTAL	1	5	8	44	19	65	72	76	10	79	13	79	4	76	2	3	4	6	2		

PARENTS
MALES 151 FEMALES 161 TOTAL 312

CHILDREN
TOTAL 1380

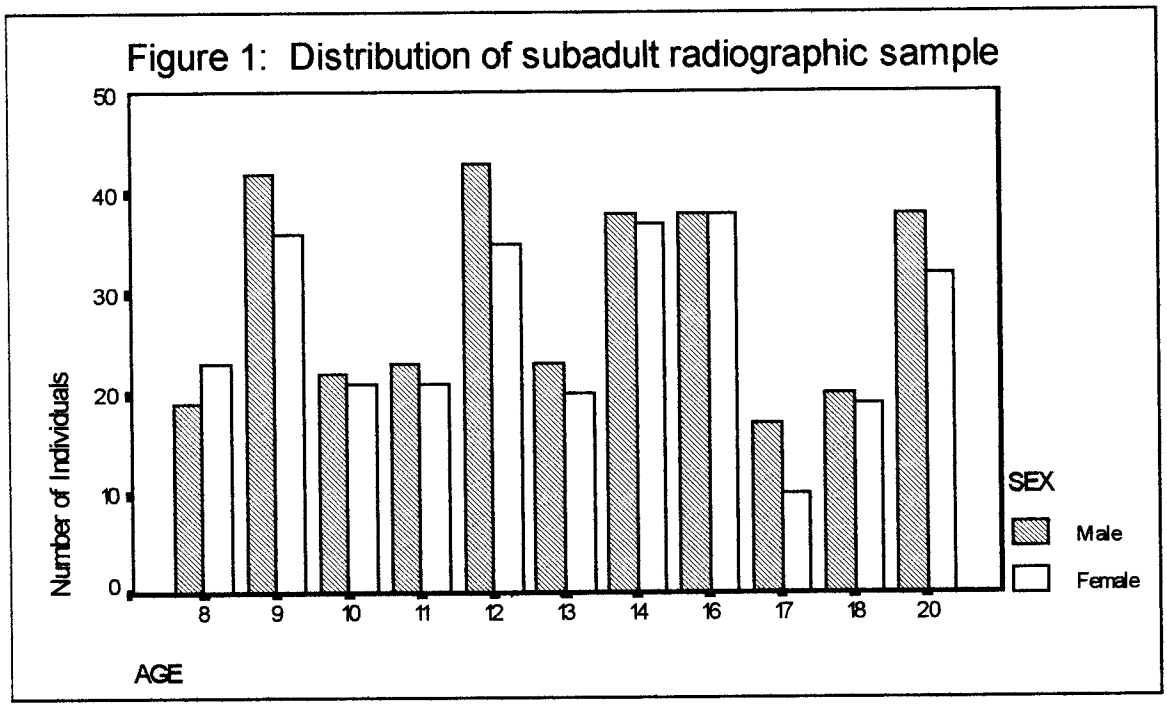
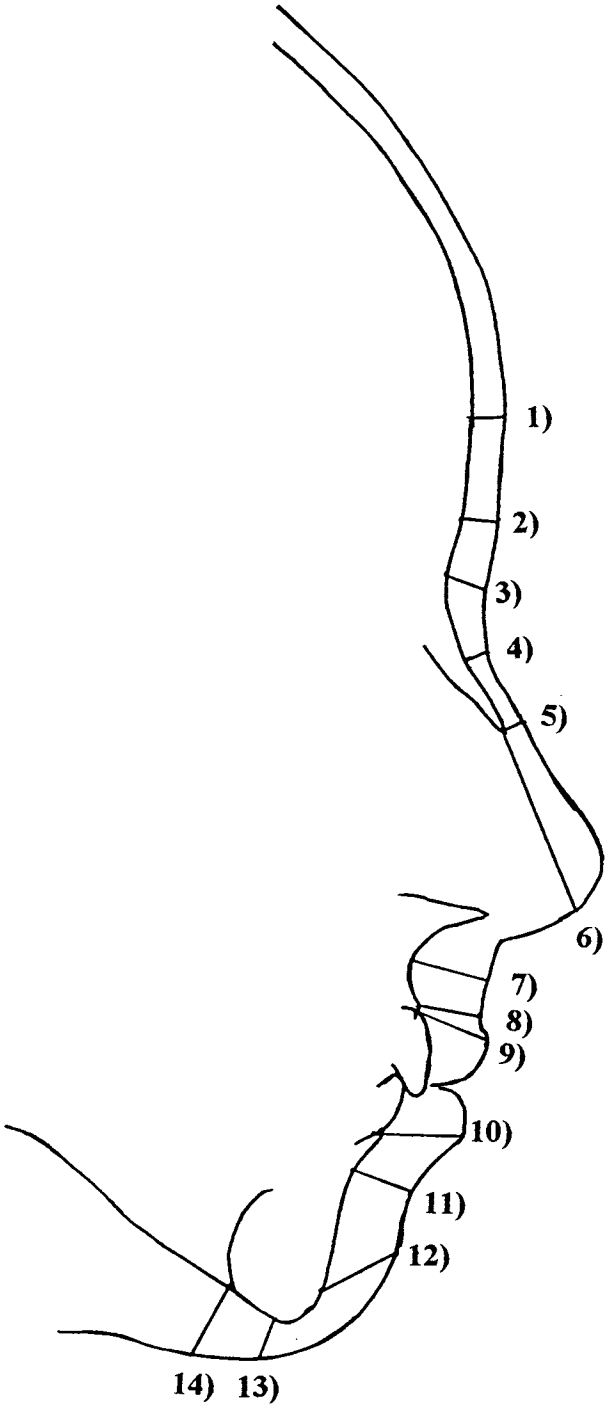


Figure 1: Distribution of subadult radiographic sample
Number of Individuals
50
40
30
20
10
0
8
9
10
11
12
13
14
16
17
18
20
AGE
SEX
Male
Female

Figure 2: Metric points used to assess facial tissue thickness



Midline
(lateral radiographs)

1) Supraglabella
2) Glabella
3) Nasion
4) Mid-Nasal
5) Rhinion
6) Nasal Length
7) Mid-Philtrum
8) Prosthion
9) Alveolar
10) Infradentale
11) Chin Lip Fold
12) Pogonion
13) Gnathion
14) Menton

Figure 3: Data collection form

BURLINGTON GROWTH STUDY
DATA COLLECTION FORM

Todd Garlie
McMaster University
Summer 1994

Radiograph Case # _____

Date and Time of Measurement _____

Age in Years ___ **Sex ___**
Birth Date _____ Group _____
Record Date _____ **Weight ____**
Specific Age ___ **Stature ____**

TISSUE THICKNESSES (to closest .01mm)

MIDLINE
(lateral radiographs)

1) Supraglabella _____
2) Glabella _____
3) Nasion _____
4) Mid-Nasal _____
5) Rhinion _____
6) Nasal Length _____
7) Mid-Philtrum _____

7) Prosthion _____
8) Alveolare _____
9) Infradentale _____
10) Chin Lip Fold _____
11) Pogonion _____
12) Gnathion _____
14) Menton _____

CHAPTER 4

ERROR STUDY

Introduction

When conducting a research project that requires the collection and analyses of metric data from a large population, errors may occur that affect the outcome of the results. The sources of such errors need to be defined so that the collected data provide reliable conclusions. For this study, measurement precision and tracing accuracy have been identified as potential sources of error and thus have been controlled for, to decrease the chance of producing such errors.

Measurement and tracing error can be divided into either systematic error or observer error (Hunter and Priest 1960; cf. De Vito 1988:25) and is often present in studies of this nature. Systematic errors occur when measuring instruments produce repeatedly precise but inaccurate measurements due to some mechanical problem, thus resulting in errors being recorded throughout the entire database. To decrease the chance of producing this type of error, the calipers used in this study were calibrated prior to the start of the project by an independent and qualified party not involved with this research.

Observer errors occur with problems in the development and maintenance of accurate measuring techniques, and from mistakes in reading and recording measurements (De Vito 1988). In this study, observer errors may have arisen from difficulties with the identification and measurement of metric points on the cephalometric films. The ability to identify and replicate these measurements is important for the collection of accurate data and for the comparison of results with similar studies. The identification and measurement of metric points in this study follow those outlined by the Faculty of Dentistry (Nikiforuk 1977) (see Appendix B for definitions of metric points). An apparent problem observed while measuring soft tissue thicknesses from this sample was the points from which to acquire the measurements. When measurements were taken at 90 degrees from the skeletal metric points to the soft tissue, as is found with some researchers, the measurement did not always encompass the definition of those points. When measurements followed the guidelines of the definitions, the measurements often appeared skewed from the perpendicular. This problem is shown in Figure 4. The studies reviewed do not appear to consider this problem when presenting their results. This study follows the definitions outlined in Appendix B, taking into consideration the problem outlined in Figure 4.

Additional observer errors may occur when measurements are taken directly from cephalometric films. One problem is the need for repeatability of the measurements. Measurements taken from the cephalograms provide no specific reference marks to which other researchers could return and measure the same points. Due to problems with definitions and sometimes the lack of clarity of the metric points, measurements may be inaccurate. A

further problem when attempting to collect data from the x-rays is the danger of destroying the films by measuring them directly using calipers. To circumvent such problems it was decided to adopt the orthodontic practice of tracing the x-ray films. This prevents any chance of destroying the cephalometric films and permits the placement of markers at specific points so as to replicate the measurements at any time. Furthermore, it allows for a permanent record of the data set. Unfortunately this opens up the possibility of introducing additional errors into the database. One such problem relates to the accuracy of the tracing and how representative it is of the original radiograph. To control for tracing accuracy the orthodontic method of using of a constantly sharpened pencil with a hardness of .04 and the maintenance of a line less than .2mm thick was followed (Enlow 1968).

Observer errors can also result from the reading and recording of measurements. These errors occur when reading the digital display from the calipers incorrectly or recording incorrect measurements onto the data sheets, entering the data into the computer incorrectly or transposing the individual numbers. To control for these types of errors, measurements were read from the calipers and recorded, then the measurements were compared back to the figure displayed on the calipers. When entering data from the data sheets into the computer database, measurements were entered several at a time and then double checked before continuing on. Once all the data was entered into the computer, several random checks were completed looking for errors that may have occurred.

Areas where error could have been introduced were controlled for and double checked during the collection process. Only radiographs that met the measurement criteria

of this study were included. An error study was conducted to test the accuracy of various measurements collected.

Methods

With potential sources of error identified and controlled for, statistical tests were used to evaluate the amount of error (or repeatability of measures) present for three databases. The first assessed the precision of the measurements collected from a sample of radiographs (n=20). The second judged the precision of the measurements taken from tracings of the radiographic sample (n=20). The last tested the accuracy of tracings from the sample of radiographs (n=20) by comparing two sets of measurements from the same individuals. Each error study included measurements from the 14 variables outlined in Appendix B. There was a four week interval between the time the original measurements and the repeated measurements were collected. An IBM computer and SPSS (Statistical Package for the Social Sciences version 6.0 and 6.1) were used to perform Student's T-tests on these three databases. Results of these error studies are presented below with a discussion following.

Results

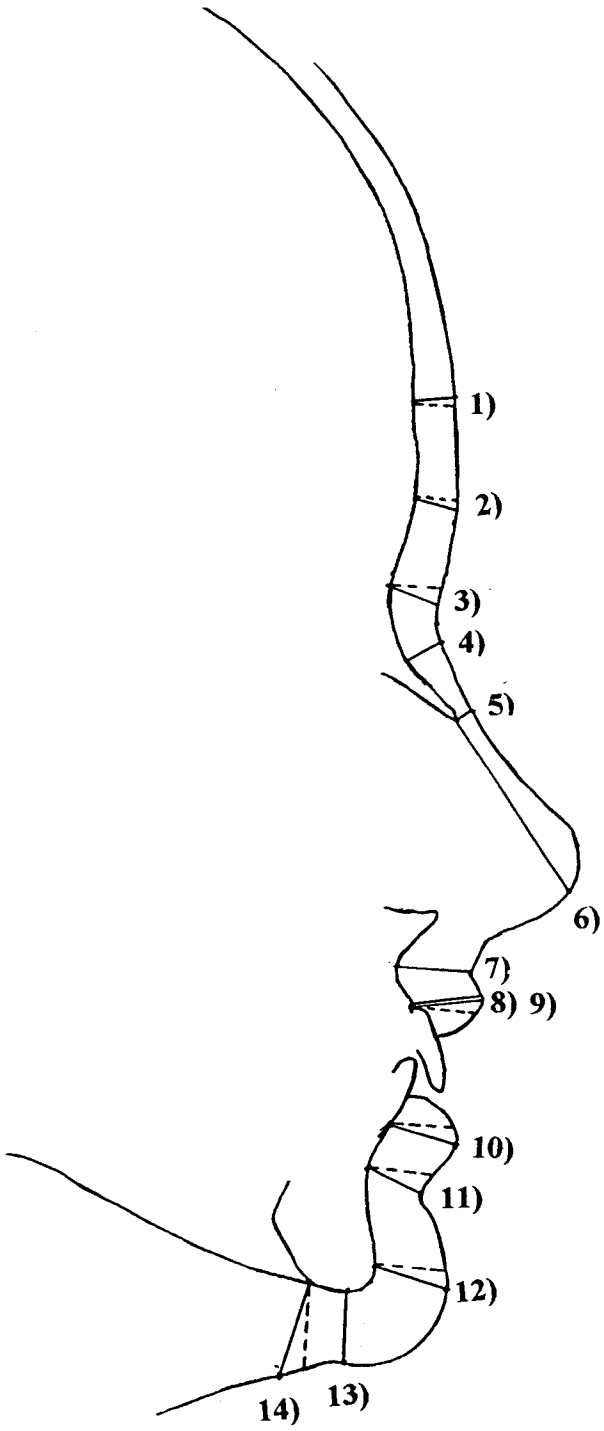
Results from the first error study, measurements taken directly from radiographic films, are presented in Table 4. The means, ranges, standard deviations, degrees of freedom, t-values, two-tail significance values, and the correlations resulting from this test are

displayed. Five variables from this error study, nasion, mid-nasal, rhinion, prosthion, and chin lip fold, reveal that the differences between the first and second measurement are significant ($p < .05$). Further, the correlation of these measurements are low, ranging from .65 to .96 (see Table 4), indicating a poor relationship between the original measures and the repeated measures.

Results from the second error study, precision of collecting measurements from tracings of the radiograph sample, are presented in Table 5. Again, the means, standard deviations, degrees of freedom, t-values, significance values and the correlations of measurement are shown. The results indicate that three measurements, glabella, rhinion, and pogonion are significantly different between the first and second set of measurements ($p < .05$). The correlation of measurements for this error study are high, ranging from .97 - 1.00, indicating a close relationship of the measurements (see Table 5).

Results for the last error study, to determine the accuracy of radiographic tracings, are presented in Table 6. The means, standard deviations, degrees of freedom, t-values, significance values, and the correlation of measurements are again exhibited. The results indicate that two points, supraglabella and rhinion appear significant ($p < .05$). Further, the correlation of the measures is high, with only two exceptions, inferring a good relationship between the original and the repeated measures taken from a first and second tracing.

Figure 4: Problem of perpendicular measurements



Midline
(lateral radiographs)

1) Supraglabella
2) Glabella
3) Nasion
4) Mid-Nasal
5) Rhinion
6) Nasal Length
7) Mid-Philtrum
8) Prosthion
9) Alveolar
10) Infradentale
11) Chin Lip Fold
12) Pogonion
13) Gnathion
14) Menton

Table 4: T-test results for radiograph measurements

Variable	Mean	Sd	Range	Variance	Mean'	Sd'	Range'	Variance	T-Value	DF	p-values	Correlation
Supraglabella	5.36	0.86	2.91	0.74	5.18	0.80	2.81	0.64	1.39	19	0.18	0.76
Glabella	6.41	1.04	3.41	1.07	6.23	0.94	2.89	0.89	1.79	19	0.09	0.90
Nasion	8.50	0.90	3.35	0.81	7.89	0.84	2.73	0.70	3.76	19	*0.00	0.65
Mid-nasal	5.35	1.63	7.27	2.66	4.90	1.07	4.50	1.16	2.33	19	*0.03	0.87
Rhinion	2.79	0.70	2.74	0.49	2.48	0.63	2.48	0.40	3.56	19	*0.00	0.84
Nasal length	29.97	2.99	9.49	8.93	30.17	2.58	8.43	6.66	-0.49	10	0.63	0.89
Mid-philtrum	17.21	3.13	10.69	9.81	16.78	2.64	9.61	6.97	1.40	19	0.18	0.90
Prosthion	14.26	2.86	11.16	8.18	13.68	2.54	10.33	6.45	2.44	19	*0.03	0.93
Alveolar	15.87	3.08	13.43	9.51	16.13	3.28	13.64	10.76	-1.09	19	0.29	0.95
Infradentale	15.95	2.68	11.01	7.16	16.09	2.59	10.55	6.73	-0.44	19	0.67	0.87
Chin lip fold	12.14	2.02	8.82	4.09	11.58	1.74	6.93	3.04	2.97	19	*0.01	0.91
Pogonion	12.75	2.61	7.75	6.83	12.47	2.44	8.49	5.96	1.67	19	0.11	0.96
Gnathion	9.72	2.37	8.80	5.62	9.57	2.60	10.04	6.76	0.57	19	0.57	0.89
Menton	10.21	2.39	9.88	5.71	10.70	2.53	11.09	6.40	-1.77	19	0.09	0.88

*($p<.05$)

Table 5: T-test results for radiographic tracing measurements

Variable	Mean	Sd	Range	Variance	Mean'	Sd'	Range'	Variance'	T-value	DF	P-values	Correlation
Supraglabella	4.67	0.51	2.04	0.26	4.68	0.54	1.91	0.29	-0.41	19	0.69	0.98
Glabella	6.10	0.98	4.09	0.96	6.03	0.93	3.74	0.87	2.42	19	*0.03	0.99
Nasion	8.53	1.53	5.06	2.33	8.50	1.52	4.88	2.32	1.34	19	0.20	1.00
Mid-nasal	3.67	0.46	1.77	0.21	3.63	0.45	1.68	0.20	1.95	19	0.07	0.98
Rhinion	2.20	0.41	1.43	0.17	2.10	0.46	1.72	0.21	3.41	19	*0.00	0.97
Nasal Length	27.32	1.86	7.50	3.47	27.31	1.87	7.59	3.48	0.46	19	0.65	1.00
Mid-Philtrum	12.72	1.78	6.80	3.18	12.72	1.79	6.93	3.21	0.08	19	0.93	1.00
Prosthion	11.61	2.02	8.58	4.06	11.54	1.99	8.34	3.97	1.76	19	0.09	1.00
Alveolar	14.59	2.42	8.63	5.85	14.60	2.41	8.84	5.82	-0.40	19	0.70	1.00
Infradentale	14.94	3.09	11.14	9.54	14.98	3.11	11.36	9.69	-0.75	19	0.46	1.00
Chin lip fold	9.51	1.52	6.95	2.30	9.45	1.54	7.14	2.39	2.06	19	0.05	1.00
Pogonion	10.78	1.86	8.69	3.47	10.68	1.85	8.67	3.41	3.44	19	*0.00	1.00
Gnathion	7.67	1.41	5.22	1.99	7.61	1.43	5.10	2.04	2.13	19	0.05	1.00
Menton	10.34	3.14	11.58	9.83	10.31	3.15	11.44	9.92	0.89	19	0.38	1.00

*($p<.05$)

Table 6: T-test results for radiographic tracing comparisons

Variable	Mean	Sd	Mean'	Sd'	T-values	DF	P-values	Correlation
Supraglabella	5.78	0.93	5.57	1.03	3.75	20	*0.00	0.97
Glabella	6.37	1.22	6.65	1.45	-1.12	20	0.28	0.64
Nasion	9.48	1.74	9.60	1.92	-0.54	20	0.60	0.84
Mid-nasal	6.62	7.84	4.87	1.48	1.00	20	0.33	-0.01
Rhinion	2.43	0.88	2.56	1.01	-2.17	20	*0.04	0.97
Nasal-length	36.58	3.83	36.30	3.69	2.11	14	0.05	0.99
Mid-philtrum	15.22	2.29	15.26	2.62	-0.22	20	0.83	0.95
Prosthion	11.38	2.35	11.48	2.49	-0.59	18	0.56	0.96
Alveolare	14.33	2.57	14.36	2.44	-0.12	17	0.90	0.96
Infradentale	17.03	2.56	16.80	2.67	1.92	20	0.07	0.98
Chin lip fold	12.05	1.82	11.98	1.69	0.65	20	0.52	0.96
Pogonion	13.73	2.64	13.38	2.80	2.09	20	0.05	0.96
Gnathion	9.05	2.92	8.85	2.65	1.67	20	0.11	0.98
Menton	12.73	3.81	12.73	4.23	0.02	18	0.98	0.97

*($p<.05$)

Discussion

Results from the first two error studies provide evidence that measurements collected from tracings of radiographs are more consistent than those collected from the actual radiographs. Although three variables for the second error study appear significantly different ($p < .05$), the actual differences between the means of the original measurements and the repeat measurements are quite small. For instance, for variable 2 the difference is .07mm , variable 5 is .01mm and variable 12 is .10mm. Mean differences direct from the radiographic films are much larger, with variable 3: .61mm, variable 4: .46mm, variable 5: .30mm, variable 8: .57mm, and variable 11: .56mm. Furthermore, the correlation coefficients of the measurements between the two studies supports the use of tracings. Table 5 indicates that repeat measures from the tracing of radiographic films are closer to the original measures than those results found in the measurement of radiographic films directly (see Table 4).

The third error study provides evidence that the use of tracings is accurate for determining the thickness of facial soft tissues from radiographs, as is done by the orthodontic practice (Enlow 1968; Popovich and Grainger 1954-59). Only two variables appear significantly different ($p < .05$). The differences between the means for the two variables is a little high, variable 1 being .20mm and variable 5 .13mms. The correlation coefficients for these two variables, however, are high with .97 for both (see Table 6).

Summary

Systematic and observer errors in this study have been identified and controlled for

to limit the amount of error present and obtain the most reliable results possible. Results from three error studies have indicated that data collected from tracings of radiographs rather than directly from radiographs present fewer errors, and more consistent data. Therefore, the rest of the data collection for this study will use measurements collected from tracings of the radiograph sample. The results of the complete database of subadult and adult measurements are presented in the next chapter.

CHAPTER 5

RESULTS

Introduction

An examination of the descriptive statistics for this data set reveal that the acquired sample for this study is normally distributed. The error study conducted in chapter four illustrated that tracings of radiographs obtained from the Burlington Growth Study offered consistent results allowing for the continued analysis of the entire database. Remaining analysis comprise facial tissue measurements taken from the tracings of a radiographic sample of male and female subadults and a sample of parents related to this group. The 14 variables used for this analysis are described in Appendix B. They include; supraglabella, glabella, nasion, mid-nasal, rhinion, nasal length, mid-philtrum, prosthion, alveolar, infradentale, chin lip fold, pogonion, gnathion, and menton. Statistical results of the research questions examining the relationships between tissue thickness and the factors of sex, age, height/weight ratio, and comparison between subadult and adult tissue thicknesses are presented. Further, a comparison of the adult means of this study to other studies is presented. A discussion follows in the Chapter Six.

The relationship between male and female subadult facial tissue thicknesses is the first

factor analyzed in this study. Table 7 displays the means, standard deviations and number of individuals present in this study. Graphic representation, in the form line graphs, of the recorded means for each sex are displayed in figures 5.1 - 5.14. These data indicate that male subadults tend to have greater mean tissue thicknesses than female subadults. A one-way ANOVA (Analysis of Variance) was performed using SPSS version 6.1 to address whether the differences seen between male and female subadults for the recorded mean tissue depths are statistically significant. ANOVA results are presented in Tables 8.1 - 8.14, displaying the mean squares, sample variance, and significant f-values ($p<.05$). Table 8.1 indicates that two age groups, 16 and 20, are significantly different for supraglabella between males and females ($p<.05$). Glabella reveals four age groups to be significant; 9, 13, 16, and 20 ($P<.05$) (see Table 8.2). The third variable, nasion resulted in five significant age groups ($p<.05$). These are; 9, 12, 13, 16, and 20 (see Table 8.3). Mid-nasal exhibited six significant age groups; 9, 14, 16, 17, 18, and 20 ($p<.05$)(see Table 8.4). The fifth variable, rhinion revealed four age groups to be significant, 16, 17, 18, and 20 ($p<.05$) (see Table 8.5). Nasal length presented significant differences among six groups ($p<.05$). These include; 8, 9, 12, 17, 18, and 20 (see Table 8.6). Mid-philtrum indicated that all but two age groups were significant ($p<.05$). These are; 9, 10, 12, 13, 14, 16, 17, 18, and 20 (see Table 8.7). Prosthion revealed 8 out of eleven age groups as significant ($p<.05$). These encompass; 9, 10, 12, 13, 14, 16, 18, and 20 (see Table 8.8). Alveolar further showed that 9, 12, 14, 16, 17, 18 and 20 are significant ($p<.05$)(see Table 8.9). The tenth variable, infradentale, demonstrated that 10 of 11 age groups are significant ($p<.05$)(see Table 8.10). Age 8 was the only age group not significant.

The variable chin lip fold exhibited seven significant age groups (p.<.05). These consist of; 10, 11, 14, 16, 17, 18 and 20 (see Table 8.11). Pogonion established that ages 9, 14, 16, 17, 18, and 20 are significant (p<.05)(see Table 8.12). Variable 13, gnathion displayed three significant age groups, 17, 18, and 20 (p<.05)(see Table 8.13). The last variable, menton, also resulted in three significant age groups, 12, 17, and 20 (p<.05)(see Table 8.14). Table 9 summarizes the significant values for each variable and age group from the above ANOVA results.

Male subadults, for this sample, appear to exhibit thicker facial tissue measurements along the midline of the face in all age groups. However, at many of the midline points and for many of the age groups this difference is not always clear. From an examination of the results summarized in Table 9 and the graphical representations (figure 5.1 - 5.14) some of the statistically significant results may be confusing. For instance, some of the results reveal that 95% confidence intervals overlap between male and female subadults. This has the effect of reducing the likelihood that real differences in tissue thickness are seen between the sexes. However, several of the results can be accepted, with male subadults having greater tissue thicknesses than female subadults. These differences in tissue thickness appear after the age of fourteen, although there are some differences around the age of nine. This may be explained by an early growth spurt, sometimes seen in male subadults (Tanner and Cameron 1980). However, according to Bogin (1988) this early growth spurt is usually seen around 7 or 8 years of age. If a childhood growth spurt is producing early sex differences, then the difference in the age of onset may be a result of different sampling distributions.

Table 7: Subadult means, standard deviations and number of individuals

Age		8		9		10		11		12	
Sex		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Variable											
Supraglabella	mean	5.02	4.64	4.92	4.69	4.94	4.92	5.07	5.08	5.09	5.14
	sd	0.6	0.68	0.56	0.72	0.53	0.58	0.59	0.64	0.76	0.7
	number	19	23	42	36	22	21	23	21	43	35
Glabella	mean	6.28	6.27	6.1	5.71	6.13	5.95	6.24	6.08	6.25	6.12
	sd	1.23	1.02	0.85	0.79	0.88	0.8	1.05	1.02	0.81	0.83
	number	19	23	42	36	22	21	23	21	43	35
Nasion	mean	9.17	8.18	9.34	8.65	9.44	8.76	9.59	8.91	9.6	8.77
	sd	1.44	1.9	1.36	1.4	1.59	1.8	1.42	1.57	1.57	1.5
	number	19	23	42	36	22	21	23	21	43	35
Mid-nasal	mean	4.24	3.9	4.24	3.82	4.26	3.96	4.29	3.97	4.33	3.92
	sd	0.76	0.86	1.03	0.78	0.85	0.7	0.97	0.88	1.15	0.8
	number	19	23	42	36	22	21	23	21	43	35
Rhinion	mean	2.62	2.53	2.39	2.59	2.56	2.5	2.63	2.42	2.4	2.44
	sd	0.44	0.61	0.57	0.58	0.54	0.45	0.51	0.41	0.66	0.56
	number	19	23	42	36	22	21	23	21	43	35
Nasal Length	mean	28.59	27.24	28.79	27.75	29.78	29.4	30.36	30	31.48	30.18
	sd	1.83	1.69	1.73	2.27	1.65	2.07	1.75	2.25	1.76	2.56
	number	19	23	42	36	22	21	23	21	43	35
Mid-philtrum	mean	13.14	12.12	13.92	12.58	14.22	12.65	14.46	13.5	14.92	13.79
	sd	1.55	1.83	1.52	1.43	1.29	1.53	1.65	1.74	1.75	2.14
	number	19	23	42	36	22	21	23	21	43	35
Prosthion	mean	12.05	11.26	12.77	11.15	12.41	11.03	12.43	11.66	12.42	11.3
	sd	1.9	2.05	1.44	1.53	1.47	1.96	1.67	1.75	1.78	2.06
	number	19	23	42	36	22	21	23	21	43	35
Alveolare	mean	15.17	14.21	15.9	14.07	15.62	13.71	15.34	14.71	15.6	14.17
	sd	2.25	2.17	1.71	1.85	1.68	2.26	2.04	2.1	2.1	2.67
	number	19	23	42	36	22	21	23	21	43	35
Infradentale	mean	14.81	13.77	15.94	13.97	15.72	13.63	15.86	14.48	15.45	14.22
	sd	1.47	2.81	2.29	2.14	1.65	2.73	1.73	2.63	2.02	3.02
	number	19	23	42	36	22	21	23	21	43	35
Chin Lip Fold	mean	9.55	9.61	10.42	9.96	10.62	9.77	10.97	9.8	10.61	9.98
	sd	1.35	1.3	1.45	1.85	1.39	1.3	2.3	1.41	1.54	1.37
	number	19	23	42	36	22	21	23	21	43	35
Pogonion	mean	11.24	10.58	11.66	10.93	12.12	10.9	12.56	11.38	11.95	11.25
	sd	1.66	1.82	2.15	2.02	2.26	1.66	2.78	1.87	2.1	1.94
	number	19	23	42	36	22	21	23	21	43	35
Gnathion	mean	8.18	7.58	7.89	7.35	7.77	7.92	8	8.43	8.58	8.29
	sd	2.12	1.89	1.85	2.15	1.61	2.5	1.95	2.49	2.28	2.14
	number	19	23	42	36	22	21	23	21	43	35
Menton	mean	10.74	11.37	10.38	10.49	11.05	10.93	11.22	9.84	10.98	9.57
	sd	2.32	3.91	2.94	3.05	2.95	3.18	2.86	2.08	3.01	2.77
	number	19	23	42	36	22	21	23	21	43	35

Table 7: Continued

13		14		16		17		18		20	
Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
5.31	5.44	5.45	5.57	5.76	5.41	5.67	5.76	5.87	5.41	5.76	5
0.65	0.75	0.75	0.76	0.79	0.69	0.97	0.93	1.15	0.72	0.79	0.67
23	20	38	37	38	38	17	10	20	19	38	32
6.75	6.09	6.85	6.38	6.97	6.14	6.5	6.2	6.37	6.04	6.35	5.75
1.21	0.8	1.22	0.84	1.13	0.8	1.12	0.7	1.03	0.97	1.1	0.78
23	20	38	37	38	38	17	10	20	19	38	32
9.74	8.52	9.33	8.67	9.71	8.64	8.85	7.89	9.33	8.61	9.58	8.23
1.25	1.59	1.63	1.28	1.45	1.41	1.45	0.97	1.67	1.58	1.37	1.8
23	20	38	37	38	38	17	10	20	19	38	32
4.33	3.88	4.58	3.99	4.75	3.98	4.72	3.51	4.52	3.75	4.78	3.82
1.07	0.83	1.13	0.86	1.22	0.77	1.21	0.82	0.77	0.69	1.24	0.98
23	20	38	37	38	38	17	10	20	19	38	32
2.66	2.43	2.6	2.47	2.72	2.36	2.77	2.16	2.77	2.28	2.77	2.2
0.57	0.52	0.75	0.5	0.69	0.46	0.71	0.6	0.75	0.58	0.76	0.6
23	20	38	37	38	38	17	10	20	19	38	32
32.95	32.23	33.81	31.88	34.99	33.54	37.33	34.55	38	34.48	38.14	34.22
1.88	3.03	1.88	2.81	3.28	2.53	2.07	3.28	1.96	2.44	2.26	2.86
23	20	38	37	38	38	17	10	20	19	38	32
15.7	14.11	16.22	14.58	17.81	14.36	17.59	15.35	16.95	15.07	18.12	14.6
1.89	1.46	1.88	1.7	1.93	1.96	1.94	1.91	1.72	1.72	1.8	1.76
23	20	38	37	38	38	17	10	20	19	38	32
12.98	11.81	13.19	12.1	14.37	11.74	13.96	12.83	14.04	12.45	14.74	11.71
1.91	1.78	1.79	1.95	1.47	2.17	1.52	1.76	1.67	1.91	1.68	1.85
23	20	38	37	38	38	17	10	20	19	38	32
15.91	14.88	16.26	15.18	17.57	14.63	17.21	15.3	18.05	15.68	17.61	14.58
1.39	2.04	1.9	2.12	1.78	2.73	1.71	2.29	2.4	1.6	1.95	2.33
23	20	38	37	38	38	17	10	20	19	38	32
16.37	14.5	17.21	15.39	17.94	15.63	17.92	16	17.92	15.43	18.07	15.19
2.64	2.46	2.42	1.77	1.88	2.37	1.24	0.72	2.45	1.96	1.9	2.27
23	20	38	37	38	38	17	10	20	19	38	32
11.07	10.42	11.94	10.55	12.57	10.89	12.54	10.71	12.41	11.23	12.84	11.02
1.18	1.5	1.79	1.2	1.73	1.63	1.1	0.84	1.22	1.5	1.19	1.3
23	20	38	37	38	38	17	10	20	19	38	32
12.63	11.57	13.39	12.05	13.73	12.22	13.55	11.74	13.58	11.89	14.11	11.91
2.23	1.82	2.72	1.64	2.56	2.13	1.5	1.24	2.45	1.97	2.09	1.95
23	20	38	37	38	38	17	10	20	19	38	32
8.8	9.01	8.97	8.56	9.02	8.42	9.46	7.88	9.97	8.42	10.06	8.11
2.03	2.44	2.02	2.28	1.73	2.15	1.97	1.95	2.44	2.36	2.12	2.49
23	20	38	37	38	38	17	10	20	19	38	32
12.17	10.51	10.73	10.27	10.13	10.2	12.31	9.57	11.72	9.99	12.77	9.36
3.14	2.98	2.47	2.69	2.52	2.41	3.42	2.21	2.77	3.08	4.34	2.07
23	20	38	37	38	38	17	10	20	19	38	32

Figure 5.1: Mean tissue depths and 95% confidence intervals for supraglabella

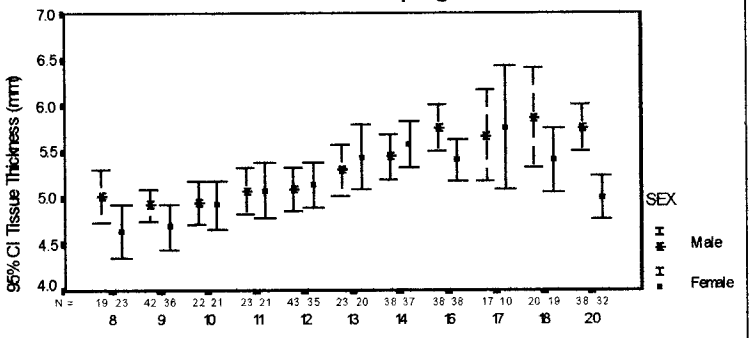


Figure 5.2: Mean tissue depths and 95% confidence intervals for glabella

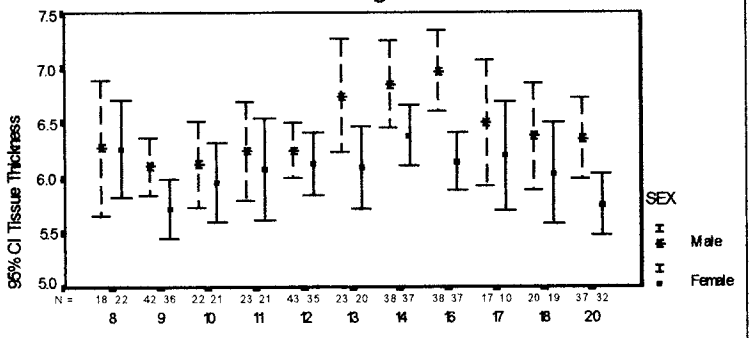


Figure 5.3: Mean tissue depths and 95% confidence intervals for Nasion

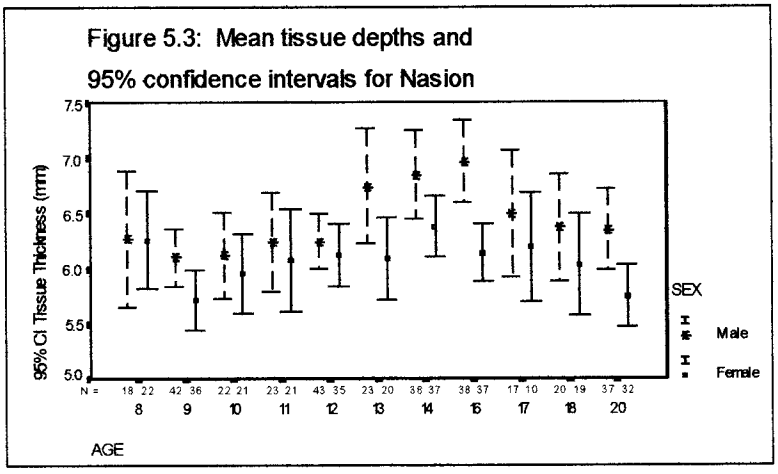


Figure 5.4: Mean tissue depths and 95% confidence intervals for mid-nasal

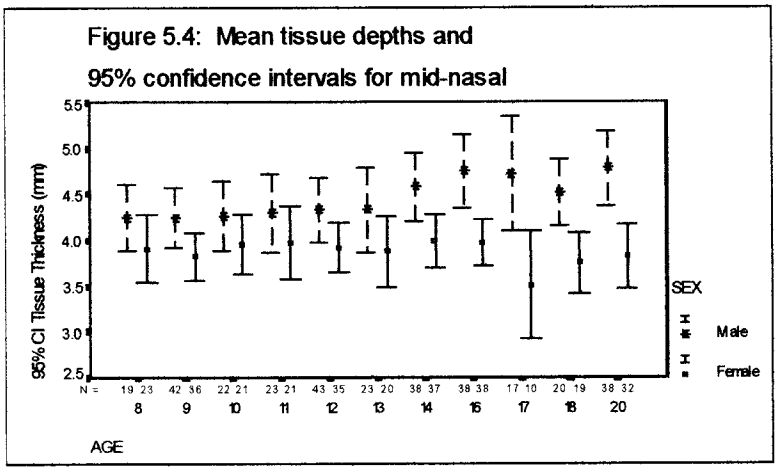


Figure 5.5: Mean tissue depths and 95% confidence intervals for rhinion

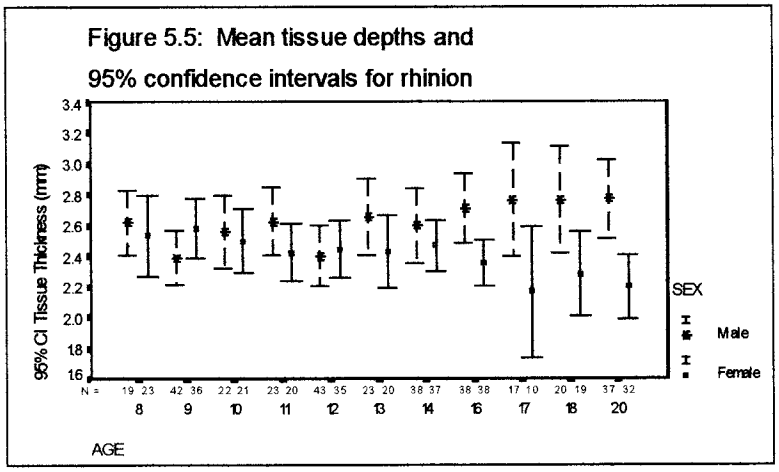


Figure 5.6: Mean tissue depths and 95% confidence intervals for nasal length

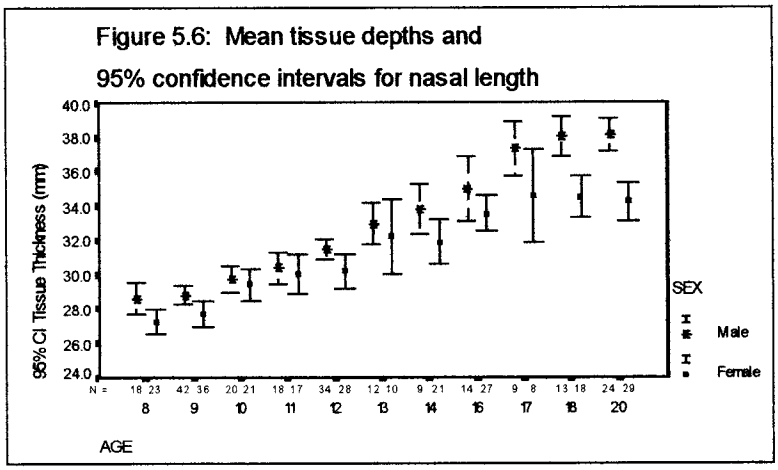


Figure 5.7: Mean tissue depths and 95% confidence intervals for mid-philtrum

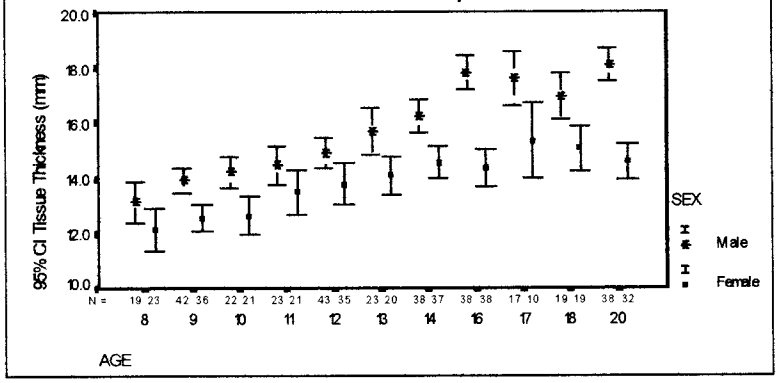


Figure 5.8: Mean tissue depths and 95% confidence intervals for prosthion

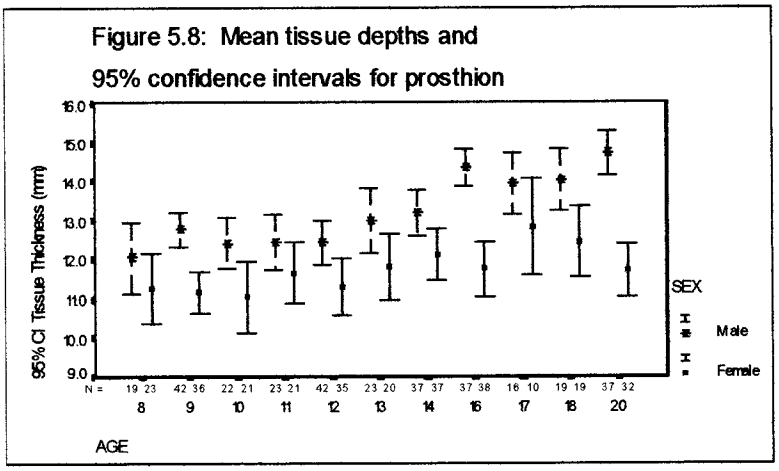


Figure 5.9: Mean tissue depths and 95% confidence intervals for alveolar

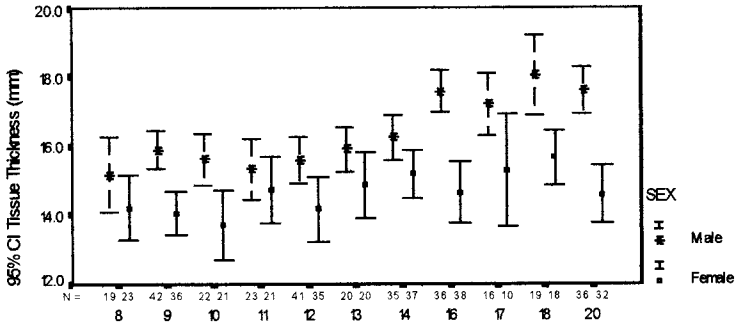
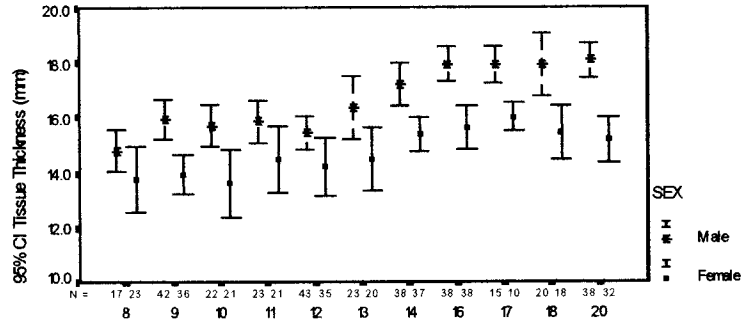


Figure 5.10: Mean tissue depths and 95% confidence intervals for infradentale



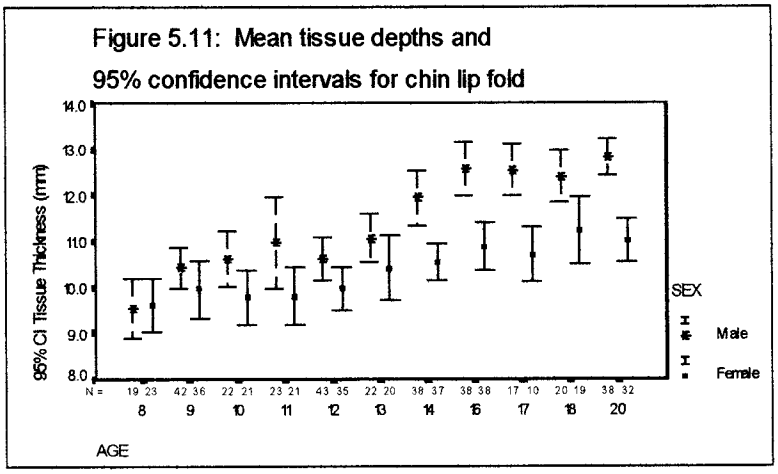


Figure 5.11: Mean tissue depths and
95% confidence intervals for chin lip fold
95% CI Tissue Thickness (mm)
14.0
13.0
12.0
11.0
10.0
9.0
8.0
N = 19 23 42 36 22 21 23 21 43 35 22 20 38 37 38 38 17 10 20 19 38 32
8 9 10 11 12 13 14 15 17 18 20
AGE
SEX
Male
Female

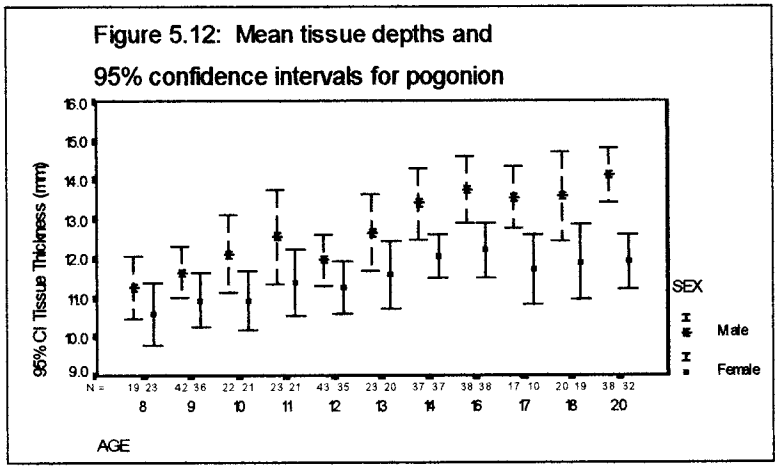


Figure 5.12: Mean tissue depths and
95% confidence intervals for pogonion
95% CI Tissue Thickness (mm)
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
N = 19 23 42 36 22 21 23 21 43 35 23 20 37 37 38 38 17 10 20 19 38 32
8 9 10 11 12 13 14 15 17 18 20
AGE
SEX
Male
Female

Figure 5.13: Mean tissue depths and 95% confidence intervals for gnathion

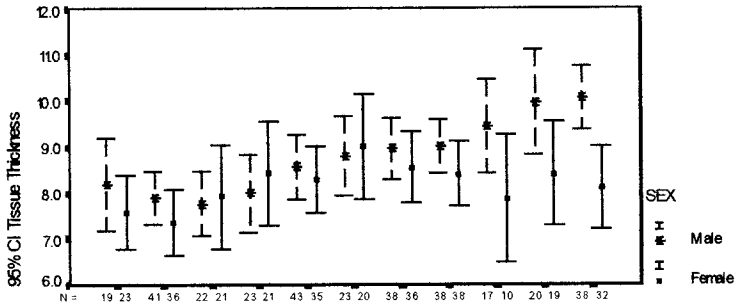


Figure 5.14: Mean tissue depths and 95% confidence intervals for menton

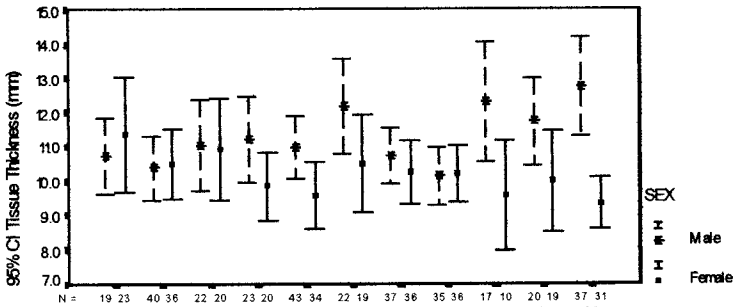


Table 8.1: ANOVA Results for Supraglabella

AGE	MS	Variance	F-Value
8	1.45	0.78	0.07
9	1.03	1.11	0.12
10	0.00	0.94	0.91
11	0.00	0.58	0.94
12	0.04	0.95	0.79
13	0.19	0.58	0.54
14	0.29	1.00	0.48
16	2.30	0.29	0.04
17	0.05	0.95	0.81
18	2.02	0.10	0.15
20	10.04	0.27	0.00

Table 8.2: ANOVA Results for Glabella

AGE	MS	Variance	F-Value
8	0.00	0.45	0.98
9	2.94	0.93	0.04
10	0.32	0.74	0.50
11	0.28	0.92	0.61
12	0.30	0.77	0.51
13	4.56	0.23	0.05
14	4.05	0.03	0.06
16	12.86	0.22	0.00
17	0.59	0.42	0.44
18	1.08	0.77	0.31
20	6.23	0.09	0.01

Table 8.3: ANOVA Results for Nasion

AGE	MS	Variance	F-value
8	10.18	0.45	0.07
9	9.07	0.65	0.03
10	4.91	0.54	0.20
11	5.11	0.96	0.14
12	13.37	0.82	0.02
13	15.88	0.65	0.01
14	8.28	0.15	0.05
16	21.71	1.00	0.00
17	5.76	0.12	0.08
18	5.07	0.94	0.18
20	31.75	0.11	0.00

Table 8.4: ANOVA Results for Mid-Nasal

AGE	MS	Variance	F-Value
8	1.21	0.78	0.19
9	3.40	0.19	0.05
10	0.97	0.79	0.21
11	1.19	0.63	0.25
12	3.26	0.12	0.08
13	2.19	0.38	0.13
14	6.72	0.23	0.01
16	11.42	0.03	0.00
17	9.13	0.39	0.01
18	5.65	0.76	0.00
20	15.93	0.27	0.00

Table 8.5: ANOVA Results for Rhinion

AGE	MS	Variance	F-Value
8	0.08	0.72	0.61
9	0.76	0.97	0.13
10	0.04	0.58	0.71
11	0.44	0.71	0.16
12	0.04	0.69	0.75
13	0.55	0.74	0.19
14	0.33	0.03	0.37
16	2.47	0.02	0.01
17	2.28	0.65	0.03
18	2.28	0.16	0.03
20	5.71	0.34	0.00

Table 8.6: ANOVA Results for Nasal Length

AGE	MS	Variance	F-value
8	18.30	0.63	0.02
9	21.27	0.09	0.02
10	1.43	0.15	0.53
11	1.12	0.16	0.60
12	25.68	0.01	0.02
13	2.81	0.26	0.50
14	23.42	0.10	0.07
16	19.40	0.43	0.12
17	32.65	0.10	0.05
18	93.86	0.40	0.00
20	202.22	0.42	0.00

Table 8.7: ANOVA Results for Mid-Philtrum

AGE	MS	Variance	F-value
8	10.72	0.34	0.06
9	35.19	0.99	0.00
10	26.57	0.49	0.00
11	10.21	0.87	0.07
12	24.71	0.22	0.01
13	26.76	0.55	0.00
14	50.91	0.61	0.00
16	226.39	0.52	0.00
17	31.71	0.86	0.01
18	33.75	0.88	0.00
20	214.81	0.67	0.00

Table 8.8: ANOVA Results for Prosthion

AGE	MS	Variance	F-value
8	6.46	0.35	0.21
9	50.50	0.64	0.00
10	20.71	0.05	0.01
11	6.56	0.97	0.14
12	23.93	0.21	0.01
13	14.67	0.90	0.05
14	21.74	0.65	0.02
16	129.51	0.01	0.00
17	7.92	0.51	0.09
18	23.87	0.48	0.01
20	157.25	0.75	0.00

Table 8.9: ANOVA Results for Alveolare

AGE	MS	Variance	F-value
8	9.50	0.58	0.17
9	65.27	0.61	0.00
10	39.35	0.11	0.00
11	4.29	0.97	0.32
12	38.52	0.07	0.01
13	10.80	0.17	0.07
14	20.70	0.39	0.03
16	159.26	0.01	0.00
17	22.32	0.23	0.02
18	51.80	0.38	0.00
20	155.53	0.31	0.00

Table 8.10: ANOVA Results for Infradentale

AGE	MS	Variance	F-value
8	10.68	0.00	0.17
9	74.77	0.88	0.00
10	46.83	0.05	0.00
11	20.82	0.17	0.04
12	29.39	0.00	0.03
13	37.39	0.93	0.02
14	62.59	0.03	0.00
16	101.78	0.46	0.00
17	22.27	0.21	0.00
18	58.39	0.66	0.00
20	144.72	0.59	0.00

Table 8.11: ANOVA Results for Chin Lip Fold

AGE	MS	Variance	F-value
8	0.04	0.95	0.88
9	4.22	0.27	0.22
10	7.68	0.70	0.05
11	14.96	0.13	0.05
12	7.75	0.58	0.06
13	4.41	0.15	0.13
14	36.53	0.03	0.00
16	53.96	1.00	0.00
17	21.24	0.29	0.00
18	13.54	0.66	0.01
20	57.40	0.47	0.00

Table 8.12: ANOVA Results for Pogonion

AGE	MS	Variance	F-value
8	4.55	0.51	0.23
9	10.06	0.66	0.13
10	15.81	0.13	0.05
11	15.36	0.36	0.11
12	9.42	0.44	0.13
13	12.00	0.68	0.10
14	33.39	0.02	0.01
16	43.26	0.32	0.01
17	20.75	0.36	0.00
18	27.76	0.42	0.02
20	83.91	0.22	0.00

Table 8.13: ANOVA Results for Gnathion

AGE	MS	Variance	F-value
8	3.72	0.92	0.34
9	5.52	0.49	0.24
10	0.25	0.02	0.81
11	2.05	0.17	0.52
12	1.58	0.34	0.57
13	0.44	0.36	0.77
14	3.06	0.45	0.42
16	6.74	0.23	0.19
17	15.70	0.89	0.05
18	23.39	0.56	0.05
20	66.05	0.27	0.00

Table 8.14: ANOVA Results for Menton

AGE	MS	Variance	F-value
8	4.15	0.05	0.54
9	0.26	0.63	0.86
10	0.15	0.45	0.90
11	20.28	0.37	0.08
12	37.73	0.82	0.04
13	28.24	0.49	0.09
14	3.92	0.51	0.45
16	0.07	0.97	0.91
17	47.36	0.30	0.03
18	29.19	0.53	0.07
20	196.60	0.01	0.00

Table 9: Summary of ANOVA results for all variables and age groups

Variable / Age	8	9	10	11	12	13	14	16	17	18	20
Supraglabella								*Yes			YES
Glabella		*Yes				*Yes		YES			*Yes
Nasion		*Yes			*Yes	*Yes	*Yes	YES			YES
Mid-nasal		*Yes					*Yes	YES	YES	YES	YES
Rhinion								*Yes	*Yes	*Yes	YES
Nasal length	YES	*Yes			*Yes				*Yes	YES	YES
Mid-philtrum		*Yes	*Yes		*Yes	YES	YES	YES	*Yes	YES	YES
Prosthion		YES	*Yes		*Yes	*Yes	*Yes	YES		*Yes	YES
Alveolare		YES			*Yes		*Yes	YES	*Yes	YES	YES
Infradentale		YES	YES	*Yes	*Yes	*Yes	YES	YES	YES	YES	YES
Chin lip fold			*Yes	*Yes			YES	YES	YES	*Yes	YES
Pogonion		*Yes					*Yes	YES	*Yes	*Yes	YES
Gnathion									*Yes	*Yes	YES
Menton									*Yes		YES

The association between facial tissue thickness and the growth of individuals was another factor explored. The question of whether tissue thickness increases as individuals grow was tested. The mean tissue depths, standard deviations and numbers of individuals, aged eight through 20 years of age are presented in Table 7. Figures 5.1 - 5.14 present graphically the recorded mean depths of male and female subadults showing changes in age for each of the 14 variables. These figures (5.1 - 5.14) exhibit a trend for increased facial tissue depths as individuals grow. To test whether these trends show significant changes, a regression analysis was performed using SPSS version 6.1, regressing absolute age on the range of tissue thicknesses for each variable with the sexes separated. The results of this analysis are presented in Table 10, showing the correlation coefficients, coefficients of determination and significant F-values for male and female subadults. Graphical representation, in the form of scattergrams, is presented in Figures 6.1 - 6.14, showing the relationship of absolute age change to tissue thicknesses for each of the 14 variables.

The results of this analysis indicate that for subadult males only nasion exhibited a regression slope not significantly different from 0 (see Figure 6.3). The coefficient of determination was small, indicating poor relationship between growth and tissue thickness (see Table 10). The other 13 variables, supraglabella, glabella, mid-nasal, rhinion, nasal length, mid-philtrum, prosthion, alveolar, infradentale, chin lip fold, pogonion, gnathion, and menton displayed regression slopes significantly different from 0 (see Figures 6.1 - 6.14). However, all but two variables, nasal length and mid-philtrum had low coefficients of determination, indicating that absolute age changes explain only a small proportion of the

variability in the measures. Nasal length and mid-philtrum contained acceptable coefficients of determination indicating a stronger correlation between growth and tissue thickness (see Table 10). When female subadults were examined four variables, glabella, nasion, mid-nasal, and gnathion, that had regression slopes that were not significantly different from 0 (see Figures 6.1, 6.3, 6.4, and 6.13). Coefficients of determination were again low for these variables, demonstrating weak correlations (see Table 10). The other 10 variables, supraglabella, rhinion, nasal length, mid-philtrum, prosthion, alveolar, infradentale, chin lip fold, pogonion, gnathion and menton all exhibited regression slopes significantly different from 0 (see Figures 6.2, 6.5 - 6.12 and 6.14). The coefficients of determination were also very low for these variables except for nasal length and mid-philtrum, which had quite large coefficients of determination, showing a good correlation between growth and tissue thickness (see Table 10).

From these results it seems that male and female subadults have similar changes in the growth of the nose and the thickness of the tissues of the upper lip. Results indicate that nasal length and mid-philtrum (upper lip) have a strong correlation with the growth of individuals, though female subadults had smaller measurements than male subadults (Figures 6.6 and 6.7). Although other tissue thickness points along the midline of the face appear to increase with growth, results show low correlations between tissue thickness and age. This may be the result of sample size, or just variation in tissue thickness between individuals. The growth of the nose and upper lip appear in this sample to correspond to the results of Burke and Hughes-Lawson's (1989) study, which measured developmental changes in the facial soft

tissues using stereophotogrammetry. Their findings suggested that female facial tissue changes were generally smaller than males, though changes occurred in similar regions of the face.

Table 10: Results of regression analysis for absolute age

VARIABLE	Male			Female		
	R-values	Rsq-values	P-values	R-values	Rsq-values	P-values
Supraglabella	0.40	0.16	*0.00	0.24	0.06	*0.00
Glabella	0.13	0.02	*0.02	0.01	0.00	0.81
Nasion	0.02	0.00	0.69	0.05	0.00	0.36
Mid-Nasal	0.18	0.03	*0.00	0.03	0.00	0.56
Rhinion	0.17	0.03	*0.00	0.21	0.04	*0.00
Nasal Length	0.87	0.75	*0.00	0.71	0.50	*0.00
Mid-Philtrum	0.66	0.44	*0.00	0.43	0.18	*0.00
Prosthion	0.44	0.19	*0.00	0.16	0.03	*0.01
Alveolare	0.40	0.16	*0.00	0.14	0.02	*0.02
Infradentale	0.43	0.19	*0.00	0.25	0.06	*0.00
Chin Lip Fold	0.53	0.28	*0.00	0.32	0.11	*0.00
Pogonion	0.36	0.13	*0.00	0.23	0.05	*0.00
Gnathion	0.34	0.11	*0.00	0.09	0.01	0.11
Menton	0.17	0.03	*0.00	0.14	0.02	*0.02

*(p<.05)

Figure 6.1: Scattergram of tissue thickness with regression coefficients by absolute age for supraglabella

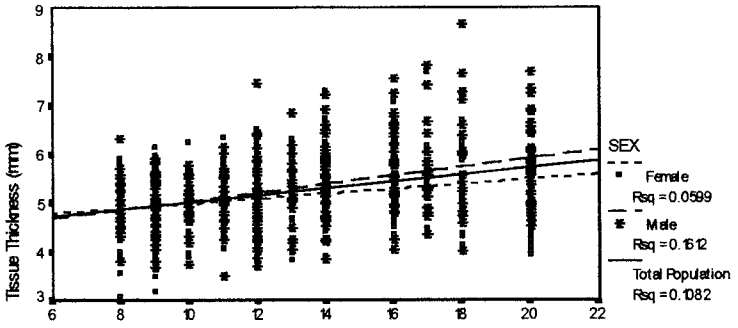


Figure 6.2: Scattergram of tissue thickness with regression coefficients by absolute age for glabella

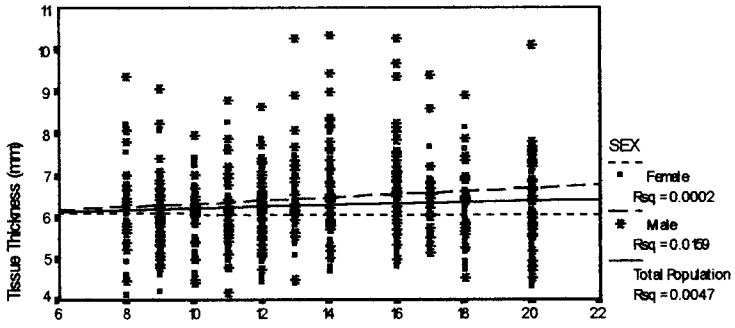


Figure 6.3: Scattergram of tissue thickness with regression coefficients by absolute age for nasion

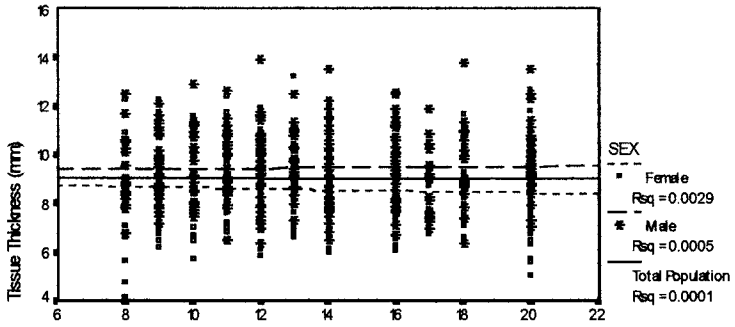


Figure 6.4: Scattergram of tissue thickness with regression coefficients by absolute age for mid-nasal

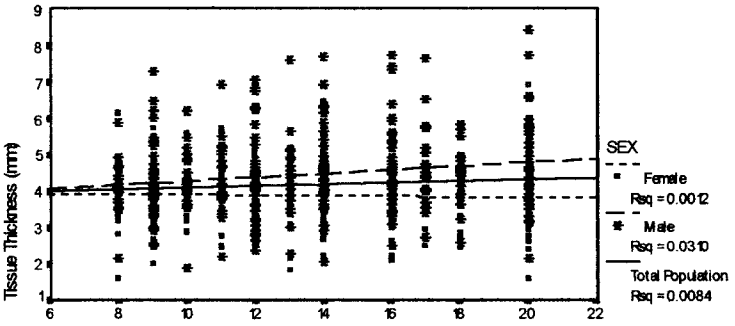


Figure 6.5: Scattergram of tissue thickness with regression coefficients by absolute age for rhinion

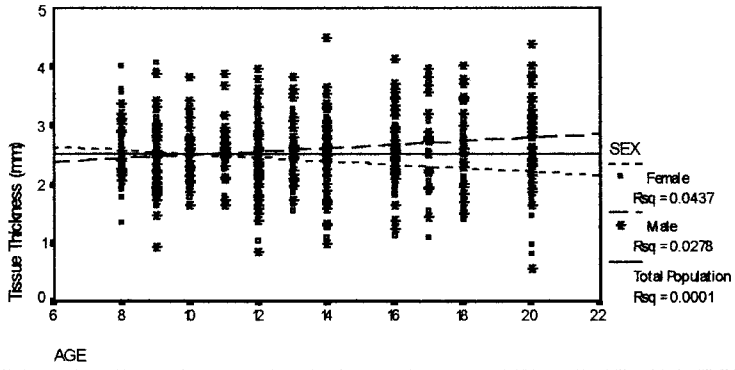


Figure 6.6: Scattergram of tissue thickness with regression coefficients by absolute age for nasal length

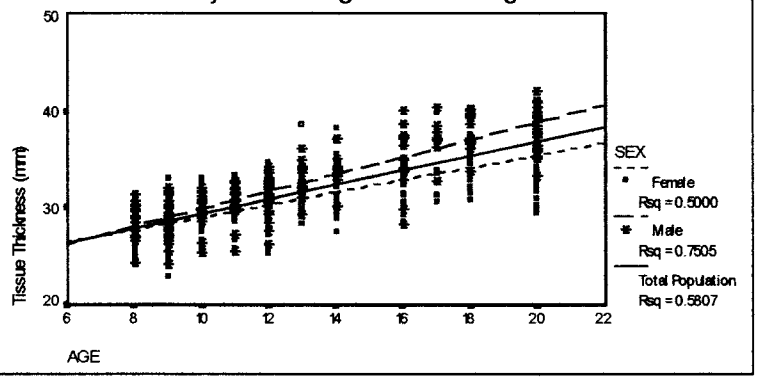


Figure 6.7: Scattergram of tissue thickness with regression coefficients by absolute age for mid-philtrum

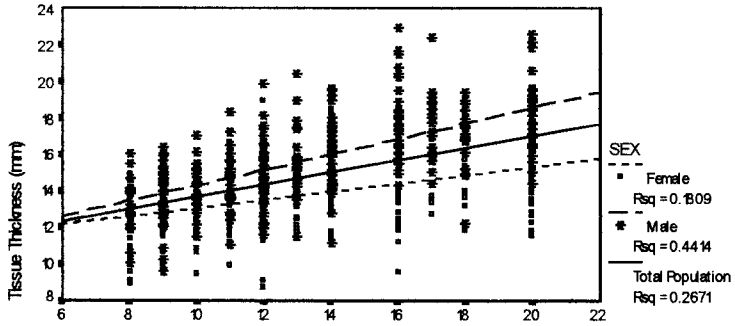


Figure 6.8: Scattergram of tissue thickness with regression coefficients by absolute age for prosthion

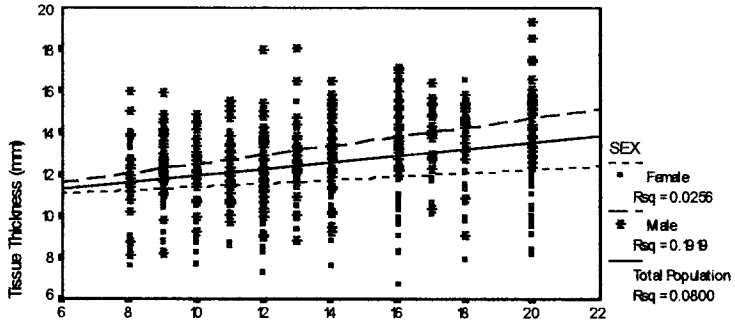


Figure 6.9: Scattergram of tissue thickness with regression coefficients by absolute age for alveolare

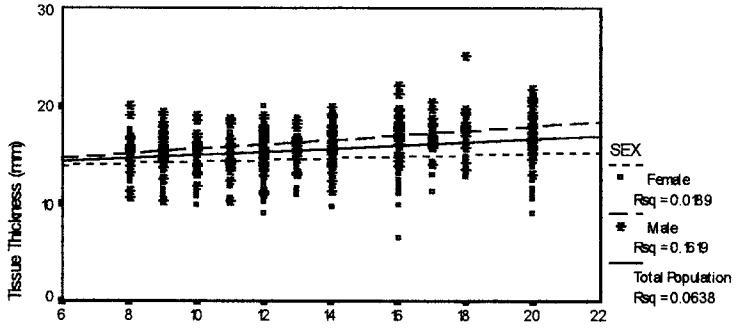


Figure 6.10: Scattergram of tissue thickness with regression coefficients by absolute age for infradentale

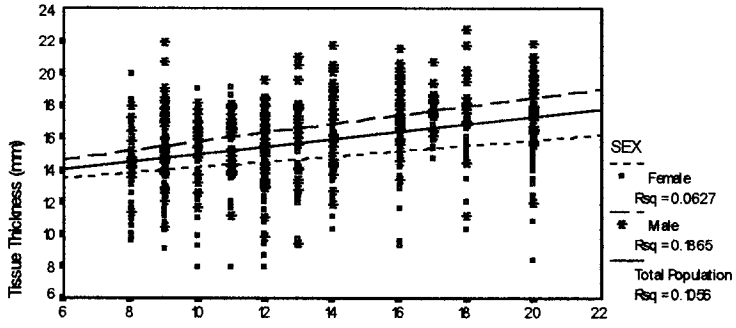


Figure 6.11: Scattergram of tissue thickness with regression coefficients by absolute age for chin lip fold

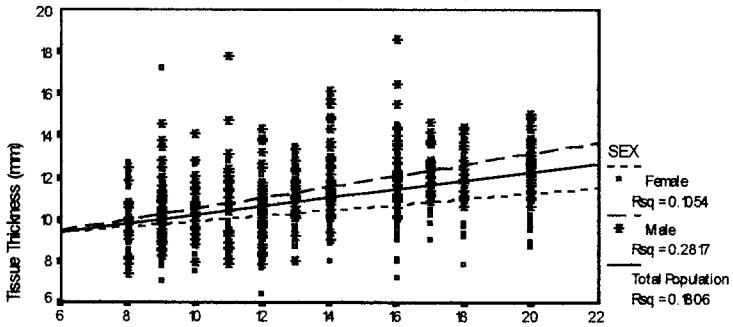


Figure 6.12: Scattergram of tissue thickness with regression coefficients by absolute age for pogonion

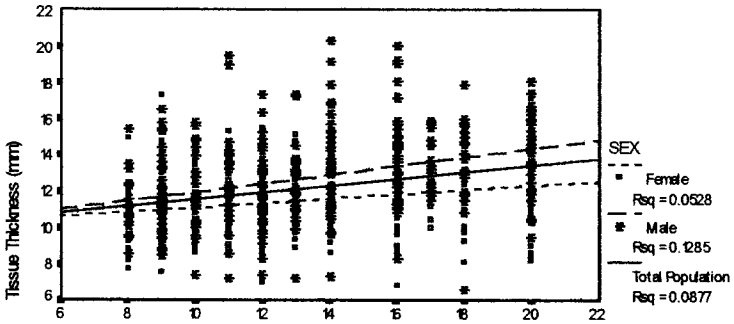


Figure 6.13: Scattergram of tissue thickness with regression coefficients by absolute age for gnathion

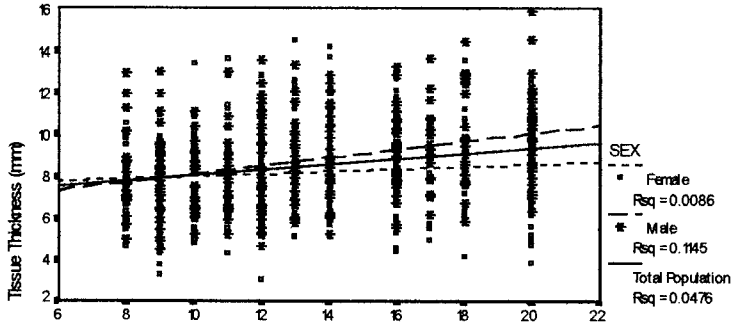
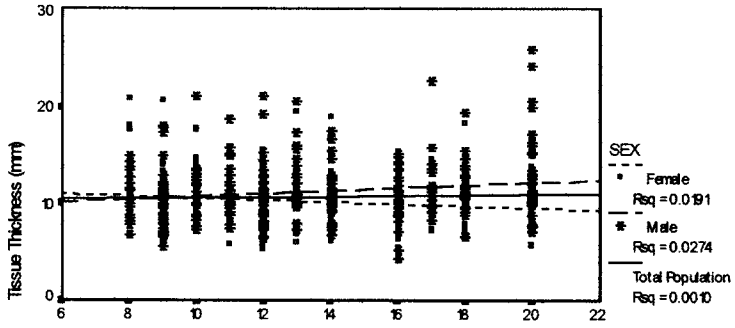


Figure 6.14: Scattergram of tissue thickness with regression coefficients by absolute age for menton



Due to poor correlations between absolute age and tissue thickness as demonstrated by the small coefficients of determination for male and female subadults (see Table 10) a regression analysis was run testing skeletal age rather than chronological age against the range of tissue thicknesses for each of the 14 variables as a comparison. Skeletal age was determined for this sample through the radiographic analyses of ossification in growth centers of the carpal(hand) bones. This was completed by members of the Burlington Growth Study during the data collection period (1952 - 1973)(Nikifourk 1977). Results of this analysis are presented in Table 11. Graphical representations, in the form of scattergrams, are presented in Figures 7.1 - 7.14 . Generally, the coefficients of determination for the regression analyses of skeletal age are quite similar to the values presented for the regression analyses on absolute age above (see Table 10 and 11). For males, nasion was the only variable showing no significant regression slope ($p>.05$)(see Table 11). The other 13 variables, supraglabella, glabella, mid-nasal, rhinion, nasal length, mid-philtrum, prosthion, alveolar, infradentale, chin lip fold, pogonion, gnathion, and menton all presented significant regression slopes for males ($p<.05$) with many of them showing very low coefficients of determination (see Table 11). Only nasal length and mid-philtrum presented coefficients of determination that were of use, indicating a relationship between growth and tissue thickness changes. Glabella, nasion, and mid-nasal, on the other hand, exhibited no significant regression slopes for females ($p>.05$)(see Table 11). Supraglabella, rhinion, nasal length, mid-philtrum, prosthion, alveolar, infradentale, chin lip fold, pogonion, gnathion, and menton however, all displayed significant regression slopes for female subadults ($p,<05$). Again the coefficients of determination were

quite low, with only nasal length and mid-philtrum demonstrating coefficients of determination that indicated a good correlation between growth and tissue thickness changes (see Table 11).

These results indicate a similar trend to that found for absolute age changes in facial tissue thickness of male and female subadults. Both the length of the nose and the thickness of the upper lip show a strong relationship with growth. Furthermore, in this analysis female subadult measurements are smaller than male subadults, as was found with absolute age change. On the other hand the other metric points, measured along the midline of the face, show a poor relationship between skeletal development and soft tissue thickness.

Table 11: Results of regression analysis for skeletal age

	Male			Female		
VARIABLE	R-values	Rsq-values	P-values	R-values	Rsq-values	P-values
Supraglabella	0.47	0.22	*0.00	0.34	0.12	*0.00
Glabella	0.16	0.02	*0.01	0.04	0.00	0.50
Nasion	0.04	0.00	0.48	0.00	0.00	0.94
Mid-Nasal	0.20	0.04	*0.00	0.00	0.00	0.96
Rhinion	0.17	0.03	*0.00	0.19	0.04	*0.00
Nasal Length	0.90	0.80	*0.00	0.74	0.54	*0.00
Mid-Philtrum	0.68	0.46	*0.00	0.47	0.22	*0.00
Prosthion	0.44	0.19	*0.00	0.18	0.03	*0.00
Alveolare	0.39	0.15	*0.00	0.16	0.02	*0.01
Infradentale	0.43	0.19	*0.00	0.29	0.09	*0.00
Chin Lip Fold	0.51	0.26	*0.00	0.36	0.13	*0.00
Pogonion	0.39	0.15	*0.00	0.29	0.09	*0.00
Gnathion	0.37	0.13	*0.00	0.11	0.01	0.05
Menton	0.18	0.03	*0.00	0.12	0.01	0.05

*(p<.05)

Figure 7.1: Scattergram of tissue thickness with regression coefficient by skeletal age for supraglabella

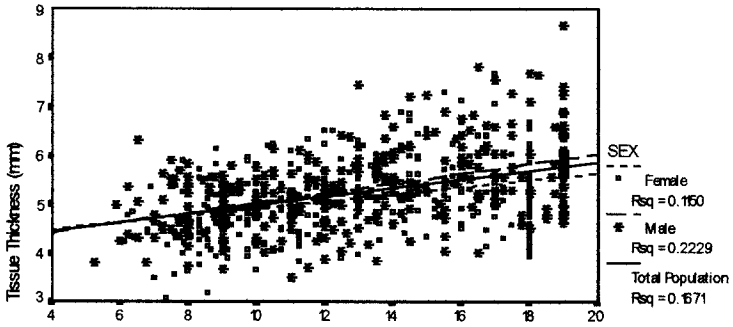


Figure 7.2: Scattergram of tissue thickness with regression coefficients by skeletal age for glabella

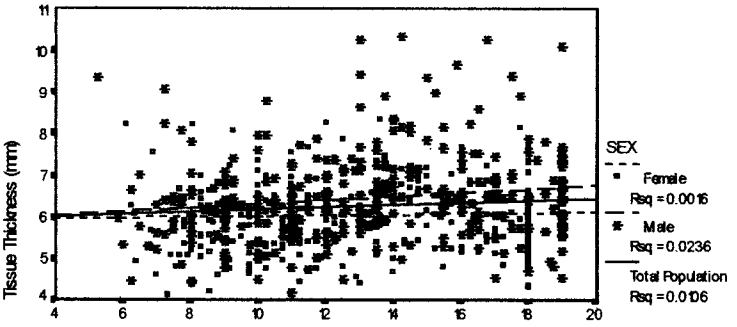


Figure 7.3: Scattergram of tissue thickness with regression coefficients by skeletal age for nasion

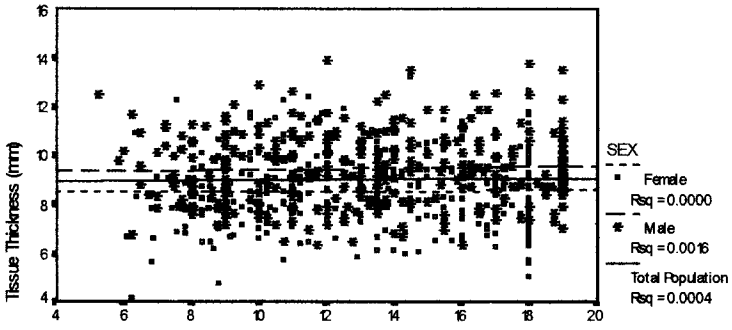


Figure 7.4: Scattergram of tissue thickness with regression coefficients by skeletal age for mid-nasal

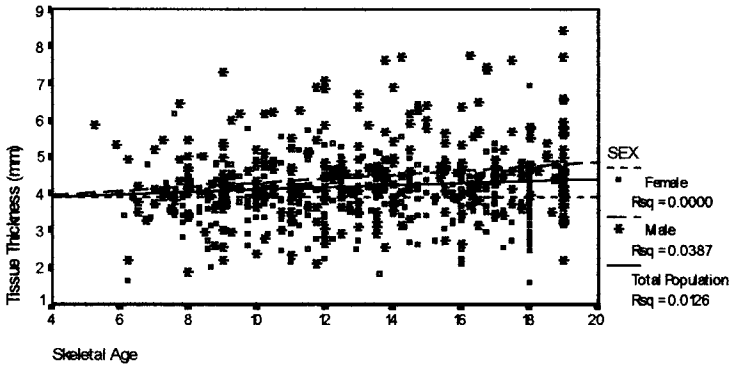


Figure 7.5: Scattergram of tissue thickness with regression coefficients by skeletal age for rhinion

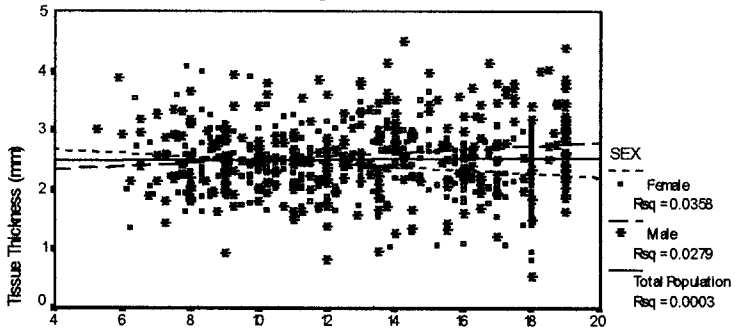


Figure 7.6: Scattergram of tissue thickness with regression coefficients by skeletal age for nasal length

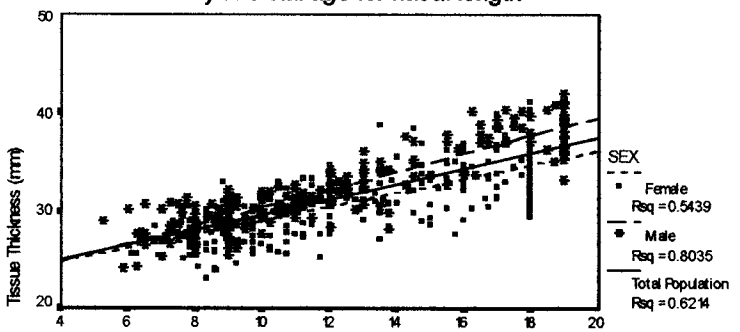


Figure 7.7: Scattergram of tissue thickness with regression coefficients by skeletal age for mid-philtrum

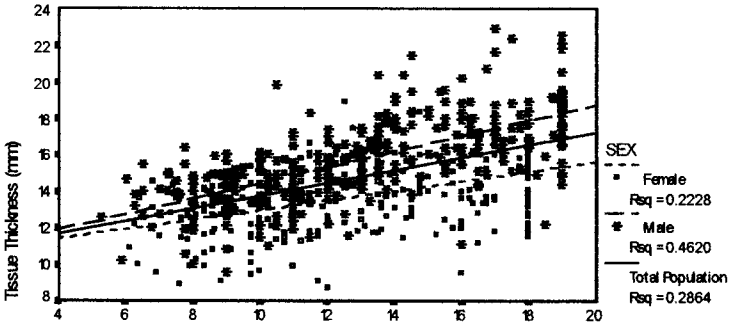


Figure 7.8: Scattergram of tissue thickness with regression coefficients by skeletal age for prosthion

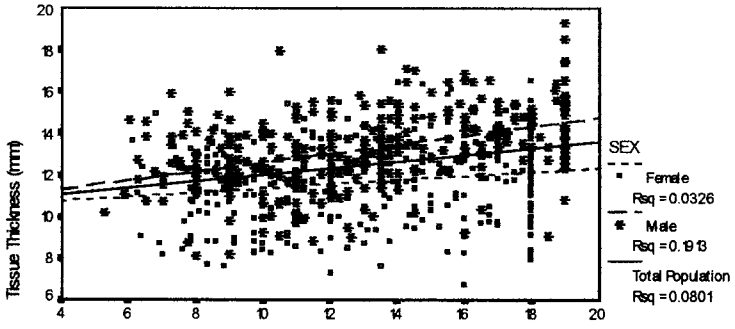


Figure 7.9: Scattergram of tissue thickness with regression coefficients by skeletal age for alveolare

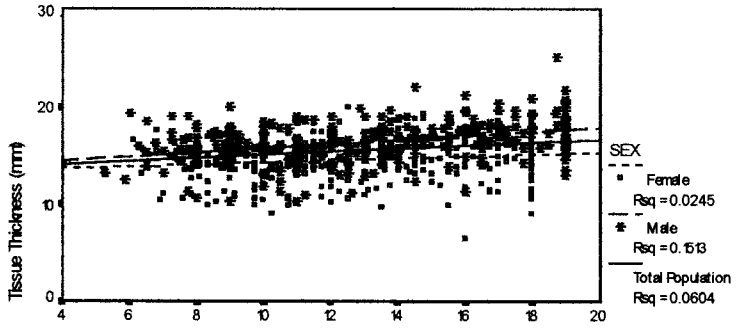


Figure 7.10: Scattergram of tissue thickness with regression coefficients by skeletal age for infradentale

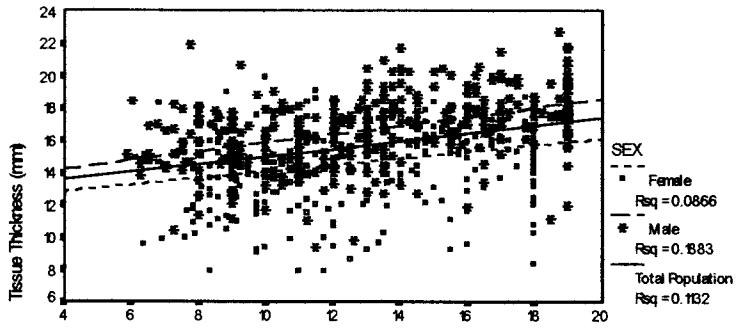


Figure 7.11: Scattergram of tissue thickness with regression coefficients by skeletal age for chin lip fold

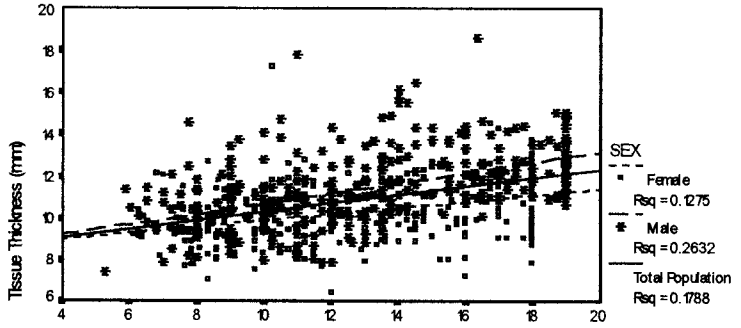


Figure 7.12: Scattergram of tissue thickness with regression coefficients by skeletal age for pogonion

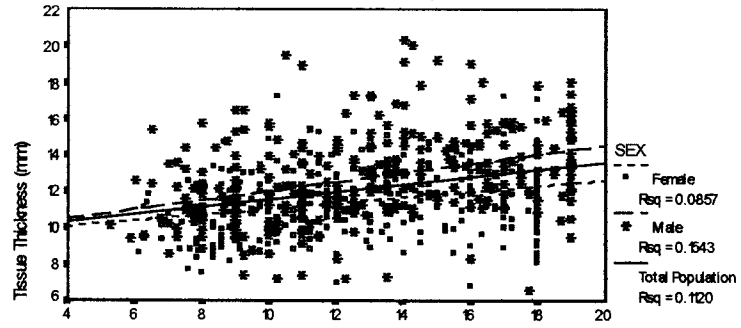


Figure 7.13: Scattergram of tissue thickness with regression coefficients by skeletal age for gnathion

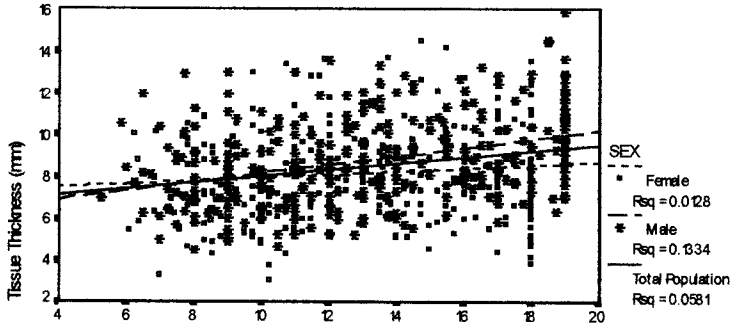
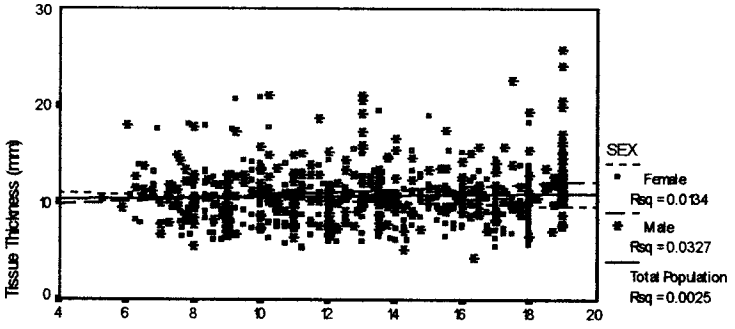


Figure 7.14: Scattergram of tissue thickness with regression coefficients by skeletal age for menton



The comparison of adult and subadult facial tissue thickness was also addressed in this study. The question of whether adult facial tissue thicknesses are greater than subadult facial tissue thicknesses was examined. Table 12 presents the recorded means, standard deviations, and numbers of individuals for adults in this sample. Subadult means, standard deviations and sample numbers are presented in Table 7. To test whether significant differences were present between these two groups of means an independent t-test was performed using SPSS version 6.1. The results are presented in Table 13 and demonstrate that 9 of the 14 variables show significant differences between male subadults and adults, with adults having greater tissue measurements ($p<.05$). These variables are: supraglabella, mid-nasal, nasal length, mid-philtrum, infradentale, chin lip fold, pogonion, gnathion, and menton. Glabella, nasion, rhinion, prosthion, and alveolar reveal no significant differences ($p>.05$)(see Table 13). Females results however, revealed that 7 out of the 14 variables were significant between subadult and adult, with adult females being larger for 4 of the 7 variables ($p<.05$)(see Table 13). These included: rhinion, nasal length, prosthion, alveolar, chin lip fold, pogonion, and menton. Supraglabella, glabella, nasion, mid-nasal, mid-philtrum, infradentale, and gnathion displayed no significant differences ($p>.05$).

These results clearly indicate that male adult measurements are greater than male subadult measurements. Measurements for females however, tend to be much more variable with adult females having greater tissue thickness at some metric points and female subadults having larger measurements at other metric points. This corresponds to similar findings by Dumont (1986) who suggested that adults had thicker tissue measurements at some points

but not others. She, unfortunately performed no statistical tests to see the actual differences and never examined sexual variation for her adult sample.

Table 12: Adult summary statistics

Variable		Supraglabella	Glabella	Nasion	Mid-Nasal	Rhinion	Nasal Length	Mid-Philtrum
SEX	mean	6.09	6.41	10.02	5.16	2.66	38.28	17.54
Male	sd	0.94	1.2	1.76	1.71	0.75	3.19	1.94
	number	29	29	29	29	29	12	29
	sd	0.77	1.21	1.83	1.1	0.62	3.32	1.69
	number	34	34	34	34	34	25	33

Variable		Prosthion	Alveolare	Infradentale	Chin Lip Fold	Pogonion	Gnathion	Menton
SEX	mean	13.89	16.97	18.11	13.59	15.3	11.19	15.69
Male	sd	1.82	2.16	2.04	1.4	2.45	2.87	5.75
	mean							
Female	sd	9.61	12.34	15.12	11.42	12.52	8.2	11.63
		32	30	34	34	34	31	30

Table 13: T-test results for comparison of subadult and adult mean tissue depths

	Males							Females						
	Subadult			Adult				Subadult			Adult			
Variable	Mean	Sd	Number	Mean	Sd	Number	P-value	Mean	Sd	Number	Mean	Sd	Number	P-value
Supraglabella	5.35	0.81	323	6.08	0.95	28	*0.00	5.16	0.77	292	5.16	0.79	35	0.99
Glabella	6.45	10.77	321	6.31	1.09	28	0.53	6.06	0.86	290	6.13	1.30	35	0.74
Nasion	9.46	1.47	323	9.84	1.88	28	0.20	8.57	1.54	292	8.73	1.85	35	0.58
Mid-Nasal	4.47	1.08	323	5.15	1.65	28	*0.04	3.89	0.81	292	4.07	1.20	35	0.40
Rhinion	2.60	0.66	322	2.64	0.78	28	0.75	2.41	0.54	291	2.07	0.62	35	*0.00
Nasal length	32.26	3.99	213	38.93	2.94	11	*0.00	31.03	3.57	238	35.92	3.21	26	*0.00
Mid-philtrum	15.79	2.37	322	17.44	1.98	28	*0.00	13.83	1.98	292	13.83	1.95	34	1.00
Prosthion	13.25	1.86	317	13.62	1.99	26	0.33	11.65	1.93	292	9.95	1.78	33	*0.00
Alveolar	16.39	2.10	309	16.69	2.25	25	0.50	14.58	2.28	291	12.72	2.25	31	*0.00
Infradentale	16.69	2.31	319	17.99	2.08	27	*0.01	14.72	2.46	291	15.30	1.81	35	0.18
Chin lip fold	11.45	1.83	322	13.51	1.48	27	*0.00	10.36	1.51	292	11.55	1.14	35	*0.00
Pogonion	12.79	2.44	322	15.15	2.57	26	*0.00	11.52	1.93	292	12.71	1.94	35	*0.00
Gnathion	8.79	2.12	322	10.89	2.92	21	*0.00	8.18	2.27	291	8.41	2.44	31	0.59
Menton	11.20	3.12	315	15.56	5.84	19	*0.01	10.18	2.81	284	11.71	3.49	30	*0.00

*(p<.05)

The adult tissue thickness measurements presented above have also been included in Table 14 as a comparison to other studies using adult measurements (Birkner 1905; Dumont 1986; Fischer 1905; His 1895; Kollmann and Büchly; Rhine and Campbell 1980; Suzuki 1949; Von Eggeling 1909; and Welcker 1883). This analysis compares the mean tissue measurements without any statistical testing due to the lack of information provided by these other studies. To compare the means of this study with ones from other studies, the enlargement factor of 9.84% from the radiographs of this study must by subtracted from the means (see Table 14). Dumont (1986) is excluded from this comparison since she provided no information on the enlargement factor of her radiographic sample.

The results indicate that for glabella this study presents larger measurements than all the other studies except for Rhine and Campbell (1980). Variable two, nasion, is clearly larger for this study. However, Birkner's (1905) study reveals a larger measurement for mid-nasal than this study. Von Eggeling (1909) and Rhine and Campbell (1980) demonstrate thicker tissue depths at rhinion and reveal mid-philtrum measurements similar to ones from this study. The variables prosthion and chin lip fold display similar tissue depths among several of the studies. Pogonion again reveals the same similarities, although female measurements from this study are typically smaller than those of all the studies, except Suzuki (1949). The greatest difference in tissue depths is seen in this study, at menton, revealing a measurement almost twice as large as seen in any of the other studies.

The variations of tissue thickness measurements demonstrated in the above comparison are likely a result of population differences. This study includes measurements

from adults of northern European descent, whereas the other studies include populations of Asian or African American origin. Further differences between these results and those of other studies may occur due to measurements being taken from living individuals rather than from cadaver samples. Another factor potentially responsible for the variations occurring between this study and some of the earlier studies is the change in growth patterns between the two temporally distinct samples (Moore 1981).

Table 14: Comparison of mean tissue thickness data between studies

	Garlie 1995		Welcker 1883	His 1895		Kollmann and Buchly 1898		Birkner 1905	Fischer 1905	Von Eggeling 1909	Suzuki 1949		Rhine and Campbell 1980	
			Germans	Germans		Swiss		Chinese			Japanese		African American	
	Male	Female		Male	Female	Male	Female				Male	Female	Male	Female
Variable														
Glabella	5.77	5.45		5.1	4.75	4.29	3.9	5.45	4.1	5.36	3.8	3.2	6.25	6.25
Nasion	9.03	7.71	5.9	5.55	5	4.31	4.1	6.6	2.95	4.76	4.1	3.4	6	5.75
Mid-nasal	4.65	3.63	3.3	3.37	3	3.13	2.57	5.43	2.45	3.76				
Rhinion	2.4	1.83	2.2			2.12	2.07	2.38	2.9	3.43	2.2	1.6	3.75	3.75
Mid-philtrum	15.8	12.29		11.49	9.75	11.63	10.1	11.2	9.6	12.16			12.25	11.25
Prosthion	12.5	8.7	11	9.51	8.26	9.46	8.1	11.65	9.8	13.63			14	13
Chin lip fold	12.3	10.3	10.6	10.26	9.75	9.84	10.95	11.02	9.15	10.46	10.5	8.5	12	12
Pogonion	10.1	7.39	8.5	11.43	10.73	9.02	9.37	10.95	9.1	9.8	6.2	5.3	12.25	12.25
Menton	14.2	10.49		6.18	6.5	5.98	5.86	6.07	5.65	5.26	4.8	2.8	8	7.75

The relationship between body build (or rather the ratio of height to weight) and facial tissue thicknesses for subadults was further examined. The question of whether heavier/shorter individuals have thicker facial tissue thickness than thinner/taller individuals was addressed. Graphical representation, in the form a scattergrams, is presented in Figures 8.1 - 8.4 to show the relationship between the height/weight ratio and tissue thickness in subadults. A linear regression analysis was performed using SPSS, version 6.0. The results are presented in Table 15, showing the correlation coefficients, coefficients of determination and the significant f-values. These results demonstrate that all 14 variables exhibit regression slopes significantly different from 0 for male subadults (see Table 15). The coefficients of determination for supraglabella, nasal length, and mid-philtrum are quite high, indicating a good correlation between the height/weight ratio and tissue thickness changes for these three variables. The remaining 11 variables exhibit small coefficients of determination. For female subadults three variables display regression slopes that are not significantly different from 0. These are; nasion, mid-nasal, and menton (see Table 15). Supraglabella, glabella, rhinion, nasal length, mid-philtrum, prosthion, alveolar, infradentale, chin lip fold, pogonion, and gnathion display regression slopes significantly different from 0. Overall the coefficients of determination for these variables reveal that there is poor correlation between the height/weight ratio and tissue thickness changes. Only supraglabella, nasal length and mid-philtrum show coefficients of determination that indicate a good relationship between the height/weight ratio and tissue thickness changes.

The results generally indicate a poor relationship between facial tissue thicknesses and

the height/weight ratio of individuals. Though some of the results for male and female subadults show small correlations at the forehead, length of nose and upper lip, the coefficients are quite low and should not be accepted as a good relationship. The remaining midline measurements have even lower correlations, thus indicating a very poor relationship between these variables and the height/weight ratios of the sample.

Table 15: Results of regression analysis for height/weight ratio

Variable	Male			Female		
	R-values	Rsq-values	P-values	R-values	Rsq-values	P-values
Supraglabella	0.59	0.35	*0.00	0.52	0.27	*0.00
Glabella	0.34	0.11	*0.00	0.16	0.03	*0.01
Nasion	0.22	0.05	*0.00	0.07	0.01	0.20
Mid-nasal	0.33	0.11	*0.00	0.08	0.01	0.15
Rhinion	0.30	0.09	*0.00	0.15	0.02	*0.01
Nasal Length	0.79	0.63	*0.00	0.70	0.49	*0.00
Mid-philtrum	0.71	0.50	*0.00	0.49	0.24	*0.00
Prosthion	0.50	0.25	*0.00	0.21	0.04	*0.00
Alveolare	0.44	0.19	*0.00	0.18	0.03	*0.00
Infradentale	0.53	0.28	*0.00	0.32	0.10	*0.00
Chin lip fold	0.51	0.26	*0.00	0.41	0.16	*0.00
Pogonion	0.41	0.17	*0.00	0.40	0.16	*0.00
Gnathion	0.37	0.14	*0.00	0.23	0.05	*0.00
Menton	0.28	0.08	*0.00	0.05	0.00	0.38

*($p<.05$)

Figure 8.1: Scattergram of tissue thickness with regression coeffecients by body build ratio for supraglabella

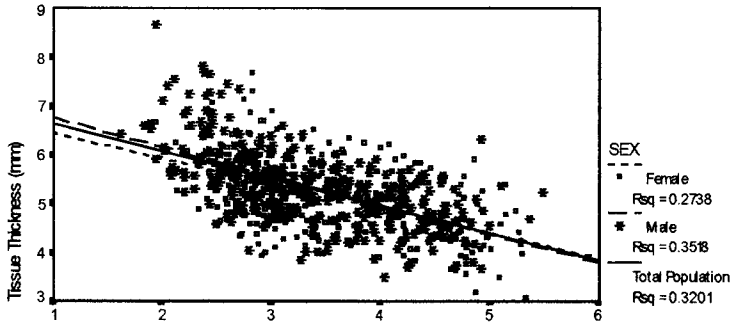


Figure 8.2: Scattergram of tissue thickness with regression coeffecients by body build ratio for glabella

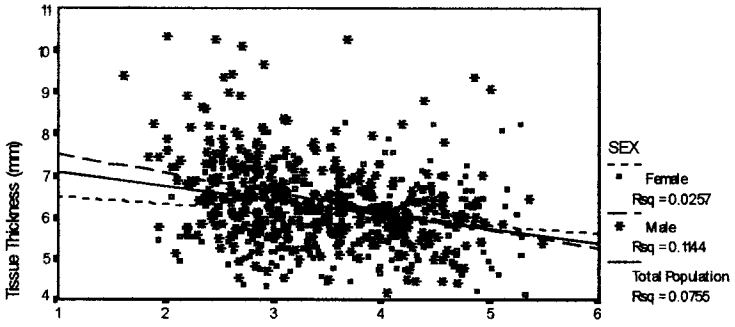


Figure 8.3: Scattergram of tissue thickness with regression coeffecients by body build ratio for nasion

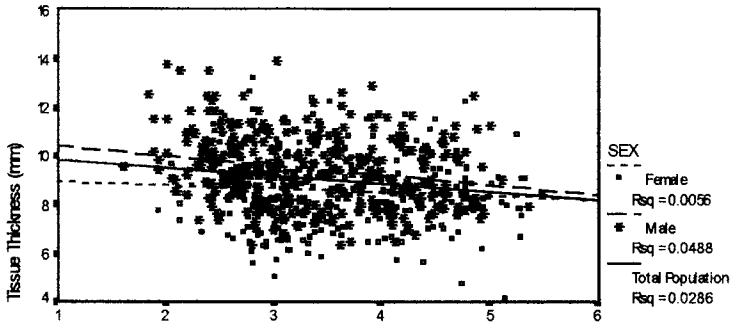


Figure 8.4: Scattergram of tissue thickness with regression coeffecients by body build ratio for mid-nasal

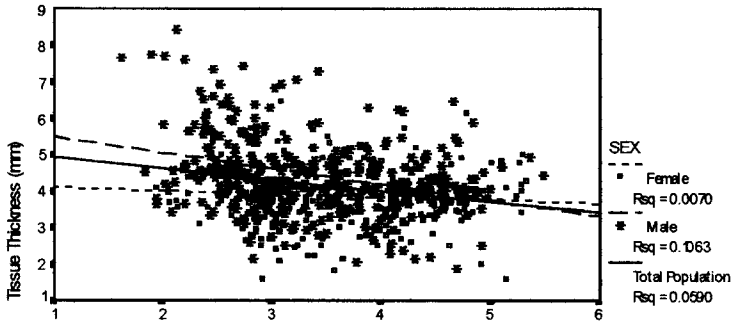


Figure 8.5: Scattergram of tissue thickness with regression coeffecients by body build ratio for rhinion

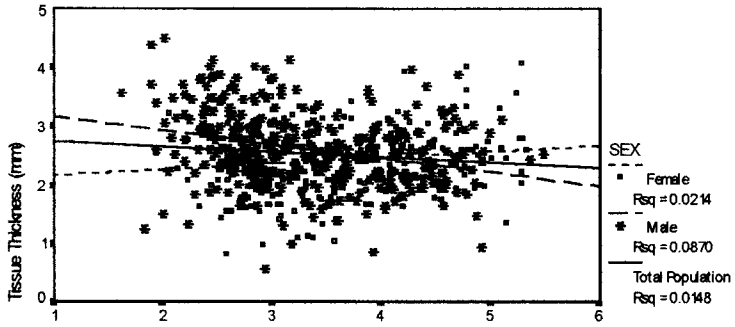


Figure 8.6: Scattergram of tissue thickness with regression coeffecients by body build ratio for nasal length

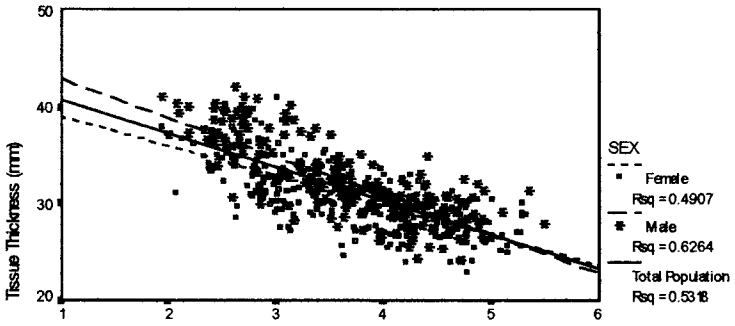


Figure 8.7: Scattergram of tissue thickness with regression coeffecients by body build ratio for mid-philtrum

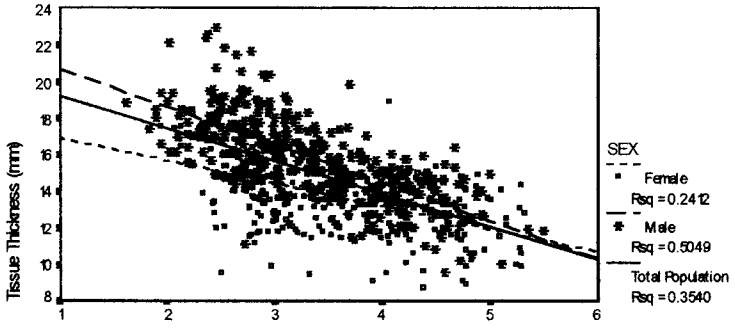


Figure 8.8: Scattergram of tissue thickness with regression coeffecients by body build ratio for prosthion

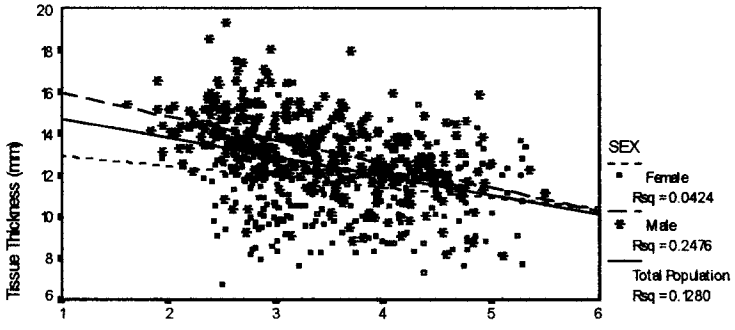


Figure 8.9: Scattergram of tissue thickness with regression coeffecients by body build ratio for alveolar

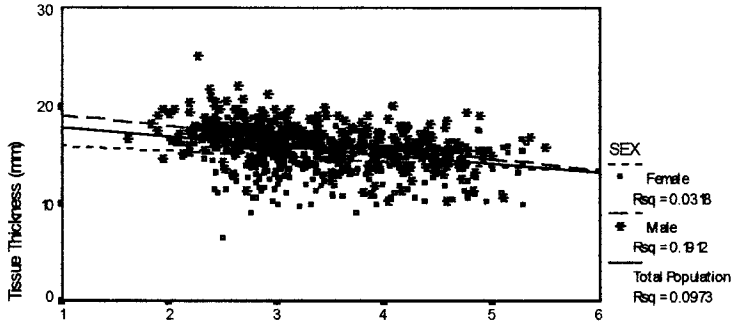


Figure 8.10: Scattergram of tissue thickness with regression coeffecients by body build ratio for infradentale

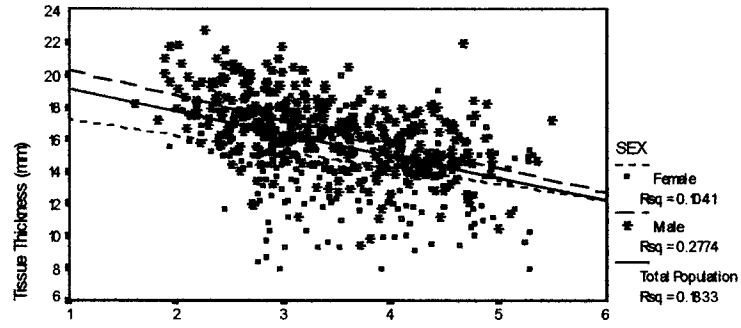


Figure 8.11: Scattergram of tissue thickness with regression coeffecients by body build ratio for chin lip fold

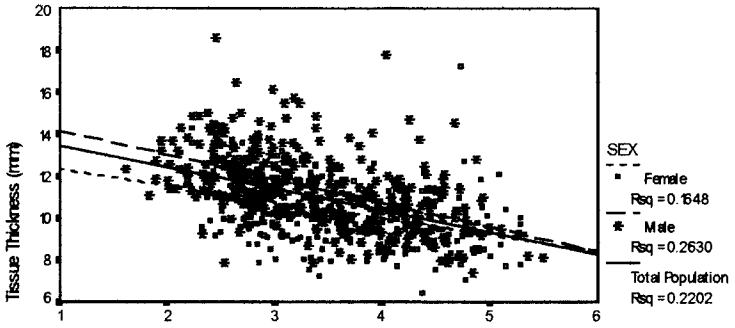


Figure 8.12: Scattergram of tissue thickness with regression coeffecients by body build ratio for pogonion

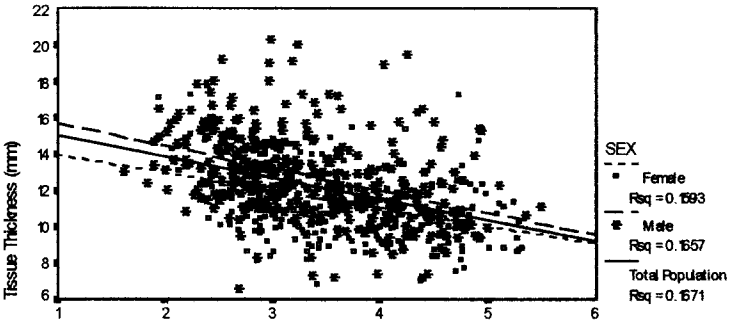


Figure 8.13: Scattergram of tissue thickness with regression coeffecients by body build ratio for gnathion

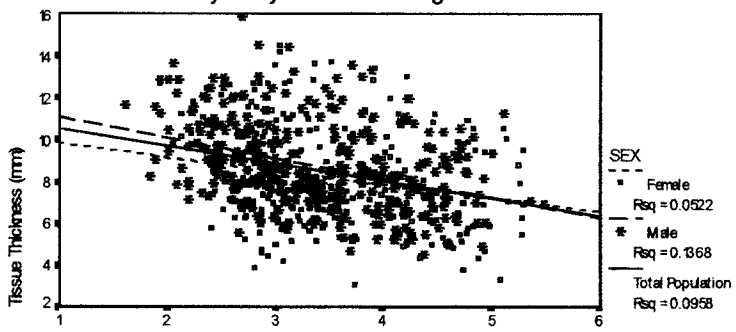
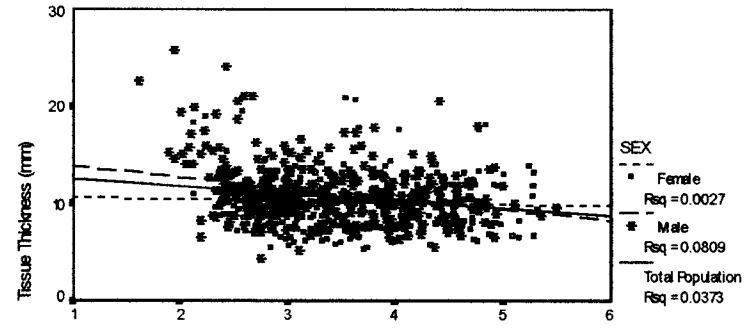


Figure 8.14: Scattergram of tissue thickness with regression coeffecients by body build ratio for menton



CHAPTER 6

DISCUSSION

The statistical results presented in chapter 5 indicate that the facial tissue thicknesses of subadults and adults, for this sample, vary with respect to sex, age and height to weight ratio for specific variables and age groups. This chapter discusses these results in light of the research questions formulated at the outset of this thesis: 1) Are male subadult facial tissue thicknesses greater than female subadult facial tissue thicknesses? 2) Do subadult facial tissue thicknesses increase as individuals grow? 3) Are adult facial tissue thicknesses greater than subadult facial tissue thicknesses? 4) Do height/weight ratios influence the thickness of subadult facial tissues? These questions are dealt with in the order in which they appear.

With respect to the presence of sexual dimorphism in facial tissue thicknesses, it is clear from the Burlington Growth Study sample, that male subadults consistently have greater mean facial tissue thicknesses than their female counterparts (see Table 7). In fact only 4% of the mean measurements show females as having greater tissue depth than males, and less than half of these thicknesses are more than .1mm thick. Statistical results, in the form of ANOVAs, provide further evidence of this sexual dimorphism between males and females,

especially after the age of 14 (see Table 9). The tissue thickness differences occurring after age 14 are linked to the divergence of growth in males and females after puberty (Bogin 1988). Although some significant differences are seen prior to age 14 these may be attributed to individual variability (i.e. beginning the pubertal growth spurt early). At age 9 however, a pattern of difference occurs for several of the variables and may indicate the presence of a mid-growth spurt for males. Though this may be the case, the mid-growth spurt most often occurs in males around 7 or 8 years of age (Bogin 1988). Other unknown factors may be the cause of this pattern.

The findings of this study tend to agree with Dumont's (1986) study demonstrating that males have greater tissue depths than females. However, she found that significant differences occurred in six variables, nasion, mid-nasal, rhinion, inferior nasal spine, prosthion, and chin fold. The others, glabella, menton, and gnathion showed no difference in respect to sex. This may have been the result of her sample which included fewer individuals than this study for each age-sex grouping and the combining of age groups to increase her sample. The current study adhered to separating the age and sex groups for analyses. Furthermore, individuals over 15 years of age were included in this study, thereby increasing the sample. Hodson and colleagues (1985) similarly examined subadult facial tissue thicknesses. However, their results do not agree with this study, for they demonstrated that only mid-philtrum was significantly thicker in males. The other 19 variables tested revealed no significant differences between the sexes. The contradiction in results between Hodson and her co-workers and this study are likely a result of sampling. The sample in Hodson and co-workers' study was

composed of 50 individuals age 4 - 15 years old, with the majority being younger than twelve years of age. Furthermore, Hodson and colleagues combined the measurements of males and females aged 4 - 15 (males n=28 and females n=22) to get the means for each of their 20 variables. This has the effect of either lowering or raising the true mean by adding individuals of different age groups. Dumont and colleague's use of ultrasound for the collection of tissue depths is another possible reason for differences occurring between the two studies.

The second question examined whether variations in facial tissue depths occur as children grow, using both absolute age and skeletal age as grouping variables. Absolute age was determined by rounding, to the nearest whole number, the age of the child, ignoring the differences in days and months; thus 8.25 years became 8 years. Skeletal age however, did not incorporate a whole number, but a specific number based on the ossification of the carpal (hand) bones. Therefore, the recorded number includes the use of decimals, for example 8.25 years. The statistical results for these variables are displayed in Tables 10 and 11, and they indicate that several variables exhibit regression slopes significantly different from 0. This would seem to indicate that there is an increase in tissue thicknesses as individuals grow. However, the majority of the variables tested also resulted in small coefficients of determination, indicating that a weak correlation exists between the growth of an individual and their tissue thickness, for this sample. To state this another way: the scatter of the data points around the lines of regression are loose and thus the relationship between the variables tested is weak. This finding is consistent among several of the scattergrams presented in this study. The results for absolute age indicated that only nasal length demonstrated a high

correlation between growth and tissue depth, exhibiting an r^2 value of .73 or 73% for males and .49 or 49% for females. Mid-philtrum exhibited a smaller coefficient of determination of .44 or 44% for males, and even lower for females, though the scatter of points around the line of regression was fairly good. Skeletal age produced very much the same pattern of results as absolute age, with correlations of determination a little higher. Nasal length demonstrated r^2 values of .80 or 80% in males and .54 or 54% in females. Mid-philtrum produced an r^2 value of .46 or 46% in males, but again was much lower in females. The remaining variables of this sample, both for absolute age and skeletal age, resulted in very small coefficients of determination and should not be considered effective indicators of relationship between growth and facial tissue thickness. It is evident that other factors are involved and need to be identified and tested.

The results from this research differ from Dumont's (1986) study where she concluded that inferior nasal spine, prosthion and chin fold show significant changes with age. She indicated that these variables exhibited regression slopes significantly different from 0 and thus a increase in tissue thickness as individuals grow. Unfortunately, Dumont provided no information regarding correlation coefficients or coefficients of determination to ascertain how her data were plotted along lines of regression. Therefore it is difficult to determine if there is a strong or weak relationship present for her results. Hodson and colleagues (1985) also determined that three variables were significant with age, using a Spearman's ranked test of correlation coefficients. These are; mid-philtrum, mental sulcus and frontal eminence. Their results agree somewhat with this study, which found some evidence that mid-philtrum

increases with age. The frontal eminence could not be compared for it is located on the lateral portions of the head and not along the mid-line, as is the case for the variables in this study. Hodson and colleagues' sample was composed of a different sample distribution and thus will account for some of the differences found in the results between the studies.

From the comparison of adult and subadult mean facial tissue thicknesses it is clear that there is variability between males and females. The results of this analysis demonstrated that male adult facial tissue thicknesses are consistently larger than male subadults. Table 15 demonstrates that supraglabella, mid-nasal, nasal length, mid-philtrum, infradentale, chin lip fold, pogonion, gnathion, and menton are significantly different ($p<.05$). The other variables, nasion, rhinion, prosthion, and alveolar, though not significantly different were larger for the adult males. Glabella was the only variable that was larger in the subadult male, possibly due to a uniquely large individual in this group skewing the mean. For females, rhinion, nasal length, prosthion, alveolar, chin lip fold, pogonion, and menton have significant p-values ($p<.05$). Rhinion, prosthion, and alveolar demonstrate significantly greater tissue thicknesses in subadult females compared to adult females. The other 4 variables, nasal length, chin lip fold, pogonion and menton reveal significantly thicker tissue depths in adult females. The remaining variables show no significant differences. These differences may occur due to differential growth patterns of the face. Subadults have greater tissue thicknesses occurring in the mid-facial area, where as adults have greater tissue thicknesses occurring in the lower facial area around the mandible. Only nasal length does not conform to this, but, as indicated earlier, this seems to be related to age changes (i.e nasal length increases as age increases).

Therefore it is no surprise that nasal length is larger in adult females compared to subadult females.

Dumont (1986) also included values from an adult sample with which to compare her subadult sample. Though not performing any statistical tests on these measurements, she concluded that adult measurements are thicker at rhinion, menton, and gnathion, but thinner at glabella, nasion and mid-nasal. Though producing similar findings, they differ from the current study in that for adult males, all but one variable, glabella, showed thicker tissue measurements. For females on the other hand, three variables were thicker in the subadult females, whereas the rest were larger in the adult females. The differences in results are likely due to the small size of Dumont's sample, consisting of 10 adult females and 8 adult males. The present database consists of 28 males and 34 females, thus increasing sample size.

The results from the comparison of adult tissue thicknesses of this study to other studies involving adult measurements demonstrated a significant degree of variability. The mean tissue depths for this study typically were larger than most of the those from the other studies. Rhine and Campbell (1980), Birkner (1905) and Von Eggeling (1909) present means that are larger than ones in this study for some variables. This may be due to the fact that these studies include individuals from different population backgrounds, thus increasing variability between populations. Birkner's (1905) study and Von Eggeling's (1909) study include very small samples and thus, the individuals may be unrepresentative of their populations. However, this may account for some of the differences between their studies and this one. The majority of the variables for this study display thicker tissue thicknesses

than the other studies due to the fact that measurements are taken from living individuals as opposed to cadavers.

The ratio of height to weight was further tested to look for any relationships with facial tissue thicknesses. The findings for this analysis indicate a poor relationship between tissue thickness and the height/weight ratio. This was suggested by very small correlations of determination for the majority of the variables tested. Though all of the variables, for male subadults, revealed regression slopes that were significantly different from 0, only nasal length and mid-philtrum exhibited adequate coefficients of determination, r^2=.63 or 63% and r^2=.51 or 51% respectively. For females, 11 variables demonstrated regression slopes significantly different from 0 , but only nasal length revealed an acceptable correlation of determination, r^2=.50 or 50%. Although these results are somewhat unencouraging, a trend in the pattern of data presented suggests that individuals with a large height/weight ratio tend to have thinner facial soft tissue. These results cannot be compared to other studies since no other researchers have examined body composition, although they have suggested its importance when referring to facial reproduction techniques and tissue depth measurements (Caldwell 1986; Rhine and Campbell 1980).

CHAPTER 7

CONCLUSIONS

By examining a longitudinal sample of subadult and adult radiographs it becomes clear from this study that variation in facial tissue depths occurs with respect to sex, age, and body build for specific midline variables. Male subadults consistently display greater tissue thicknesses than female subadults, especially after the adolescent growth spurt. Adult males also reveal larger tissue measurements than adult females. Furthermore, it is clear from examining absolute and skeletal age changes from 8 to 20 years of age with respect to tissue thickness that there is a very weak relationship between them. Though there seems to be a slight trend to increased tissue thicknesses as children grow into adolescents, there is no clear relationship between these variables. Comparisons made between adult facial tissue depths and subadult facial tissue depths have clearly indicated that adult males are larger than subadult males except at glabella. Females, however, displayed much more variation. Three measurement points of the subadult females were significantly larger than on the adult females, whereas adult females demonstrated four other points which were significantly larger than female subadults. The use of a height/weight ratio to examine tissue thickness changes also proved to be a weak indicator of change. Although some variables indicated a trend of

tissue thickness decreasing as the height/weight ratio increased, the majority of them revealed weak relationships between height/weight and tissue thickness.

The results from this study indicate that some consideration should be given to what measurements can be used for facial reconstruction. For adolescents and young children there does not seem to be much reason to separate male and female measurements. However, as the age of an individual increases there is divergence in facial tissue thicknesses between males and females. This split seems to occur around the time of the adolescent growth spurt. Therefore it is necessary to apply separate male and female standards for older children.

Several techniques have been outlined and examined for the collection of facial tissue depths; the radiographic method was preferred for this study. The use of cephalometric films was chosen for it provided a fast and accurate way to collect tissue depths from living individuals. Furthermore, radiographic data sets are often available though dental practices or hospitals, providing very large samples. The composition of the sample is also better distributed among the populations, providing the ability to include different age, sex, and population distributions that cannot be achieved with cadaver samples. The storage of such radiographic material is ultimately easier and provides a opportunity to return to the database and collect more data or run further analytical tests, something that cannot be completed on a cadaver sample.

APPENDIX A

Comparison of mean tissue thickness data between studies

	Garlie 1995		Welcker 1883	His 1895		Kollmann and Buchly 1898		Birkner 1905	Fischer 1905	Von Eggeling 1909	Suzuki 1949		Rhine and Campbell 1980	
			Germans	Germans		Swiss		Chinese			Japanese		African American	
	Male	Female		Male	Female	Male	Female				Male	Female	Male	Female
Variable														
Glabella	5.77	5.45		5.1	4.75	4.29	3.9	5.45	4.1	5.36	3.8	3.2	6.25	6.25
Nasion	9.03	7.71	5.9	5.55	5	4.31	4.1	6.6	2.95	4.76	4.1	3.4	6	5.75
Mid-nasal	4.65	3.63	3.3	3.37	3	3.13	2.57	5.43	2.45	3.76				
Rhinion	2.4	1.83	2.2			2.12	2.07	2.38	2.9	3.43	2.2	1.6	3.75	3.75
Mid-philtrum	15.8	12.29		11.49	9.75	11.63	10.1	11.2	9.6	12.16			12.25	11.25
Prosthion	12.5	8.7	11	9.51	8.26	9.46	8.1	11.65	9.8	13.63			14	13
Chin lip fold	12.3	10.3	10.6	10.26	9.75	9.84	10.95	11.02	9.15	10.46	10.5	8.5	12	12
Pogonion	10.1	7.39	8.5	11.43	10.73	9.02	9.37	10.95	9.1	9.8	6.2	5.3	12.25	12.25
Menton	14.2	10.49		6.18	6.5	5.98	5.86	6.07	5.65	5.26	4.8	2.8	8	7.75

APPENDIX B

DEFINITIONS FOR FACIAL MEASUREMENTS

MID-LINE (lateral radiographs)

SUPRAGLABELLA (sg) -- Measurement take at a point 1.5cm above glabella and perpendicular to that point on frontal bone to the soft tissue margin

GLABELLA (g) -- taken perpendicular from the most anterior point on the frontal bone to the outside margin of soft tissue.

NASION (n) -- most anterior point of the nasio-frontal suture to outside margin of soft tissue (the outside margin is considered 2-3 mm lower than the bony point).

MID-NASAL (mn) -- marked at 90 degrees from the mid point between nasion and rhinion to the soft tissue margin.

RHINION (r) -- measured 90 degrees from the most anterior inferior point on the nasal bone to the soft tissue margin.

NASAL LENGTH (nl) -- determined by the distance from the tip of rhinion to the most anterior-inferior portion of the fleshy nose.

SUB-SPINALE (mid-philtrum) (ss) -- measurement taken from the deepest point on the alveolar projection of the premaxilla between the anterior nasal spine and prosthion along the mid-line to the exterior margin of soft tissue.

PROSTHION (pr) -- (prealveolar point): measurement taken at 90 degrees from the most anterior point on the upper alveolar process along the mid-line to the exterior of the soft tissue margin.

ALVEOLAR (ids) -- (the upper alveolar point): taken from the apex of the septum between the upper central incisors to the upper lip margin of the soft tissue.

INFRADENTALE (idi) -- (the lower alveolar point): taken from the apex of the septum between the lower central incisors to the lower lip margin of the soft tissue.

CHIN LIP FOLD (clf) -- taken at 90 degrees from the deepest point between infradentale and pogonion to the outside margins of soft tissue.

POGONION (pg) -- taken from the most anterior point on the bony chin along the mid-line to the external anterior margin of the soft tissue (slightly higher than the bony point).

GNATHION (gn) -- measured from the mid-point between pogonion and menton along the contour of the chin or the lowest median point on the lower border of the mandible to the margins
of the soft tissue (the soft tissue mark is considered anterior and inferior to the bony point).

MENTON (m) -- measured 90 degrees from the lower most inferior point on the mandibular symphysial shadow to the exterior borders of the soft tissue.

REFERENCES CITED

Altemus L.A.
1963 Comparative integumental relationships. ***Angle Orthod*** 33:217-221.

Birkner F.
1905 Beitraghe zur passenanatomie der Chinesen. ***Korrespondenz Deutsches Gesicht Anthropologie Ethnologie Urgeschte***.

Bogin B.
1988 ***Patterns of Human Growth***. Cambridge: Cambridge University Press.

Brues A.
1958. Identification of skeletal remains. ***Journal of Criminal Law***. 48:551-563.

Burke P.H. and C.A. Huges-Lawson
1989 Developmental changes in the facial soft tissues. ***American Journal of Physical Anthropology***. vol.79:281-288.

Caldwell P.
1986 New questions and some answers on facial reproduction techniques. In: ***Forensic Osteology***. K. Reichs (ed.). Springfield, IL: C.C. Thomas. pp. 229-255.

Craig E. A.
1993 Facial reconstruction. ***Journal of Forensic Sciences***. 37(6):1442:44.

De Vito C.
1988 ***Discriminant function analysis of deciduous teeth to determine sex***. Unpublished M.A. thesis: McMaster University, Hamilton, Ontario.

Dumont E.R.
1986 Mid-facial tissue depths of white children: An aid in facial feature reconstruction. ***Journal of Forensic Sciences***. 31(4): 1463-1469.

Enlow D.
1968 ***The human face: An account of the postnatal growth and development of the craniofacial skeleton***. New York: Harper and Row, Publishers (Hoeber Medical Division).

Fischer E.
1905 Anatomische untersuchungen an dem kopfweichteilen zweier Papua. ***Korrespondenz Deutsches Gesicht Anthropologie Ethnologie Urgeschte***. 36: 118-122.

Harslem Riemschneider, L.
1921-22 Die gesichtsmuskulator von 14 Papua und Melanesienen. ***Zeitschrift fur Morphologie und Anthropologie***. 22: 1-44.

Heglar R.
1980 Juvenile facial restoration: Paediatric and cephalometric expectations. ***American Academy of Forensic Science Program***. 163 (abstract).

His W.
1895 Johann Sebastian Bach's gebeine und antlitz nebst bemerkungen uber dessen bilder. ***Abhandlund Durch Mathematik und Physik***. 22: 380- 420.

Hodson G., Liebermann L.S. and Wright P.
1985 In Vivo Measurements of Facial Tissue Thickness in American Caucasoid Children. ***Journal of Forensic Sciences***. 30(4): 1100-1112

Işcan, M. and R. Helmer (eds.)
1993 ***Forensic analysis of the skull***. New York: A John Wiley and Sons Inc., Publisher.

Kollmann J. and Büchly W.
1898 Die persistenz der rassen und die reconstruction der physiognomie prahistorischer schadel. ***Archiv fur Anthropologie***. 25: 329-359.

Krogman W.
1978 ***The human skeleton in forensic medicine.*** *Springfield:* C.C. Thomas, Publisher. 244-276.

Krogman W. and Işcan, M.Y.
1986 ***The human skeleton in forensic medicine***. Springfield: C.C. Thomas, Publisher. 413-457.

Lebedinskaya G.V., Balueva, T.S., and E.V. Veselovskaya
1993 Principles of facial reconstruction. In: ***Forensic analysis of the skull***. Işcan, M.Y. and Helmer, R.P.(eds). New York: A John Wiley and Sons Inc., Publisher. 184-198.

Lieber R.L.
1990 Statistical significance and statistical power in hypothesis testing. *Journal of Orthopaedic Research*. 8:304-309.

Montagu M.
1947 A study of man embracing error. ***Technological Review***. 49:345-362.

Moore C.E.
1981 ***A problem in Human Variation: The facial tissue thicknesses of Caucasoids, Negroids, and Mongoloids***. Unpublished Ph.D. Dissertation: University of New Mexico, Albuquerque, New Mexico.

Nikiforuk G.
1977 ***Burlington Growth Centre pamphlet***. Faculty of Dentistry, University of Toronto.

Popovich F. and Grainger R.M.
1954-59***Burlington Orthodontic Research Centre, progress report series #1, 2, 3, 4***.

Rathbun T.
1984 Personal identification: Facial reproductions. In: ***Human identification: Case studies in forensic anthropology***. T. Rathbun and J. Buikstra (eds.). Springfield, IL: C.C. Thomas. pp. 347-356.

Rhine J.S.
1990 Coming to terms with facial reproduction. ***Journal of Forensic Sciences***. 35(4): 960-963.

Rhine J.S. and Moore C.E.
1982 Facial reproduction tables of facial tissue thicknesses of American Caucasoids in forensic anthropology. ***Maxwell Museum Technical Series #1***. Albuquerque.

Rhine J.S. and Campbell H.R.
1980 Thickness of facial tissues in American blacks. ***Journal of Forensic Sciences***. 25(4): 847-858.

Rogers S. L.
1987 ***Personal identification from human remains***. Springfield, Illinois: CC Thomas Publisher.

Runestad T.
1993 The many faces of John Gurche. ***Museum Quarterly***. Denver Museum of Natural History.

Tanner J.M. and Cameron N.
1980 Investigation of the mid-growth spurt in height, weight, and limb circumferences in single-year velocity data from the London 1966-67 growth survey. ***Annals of Human Biology***. vol.7:565-77.

Snow C. Gatliff B.P. McWilliams K.R.
1970 Reconstruction of facial features from the skull: An evaluation of its usefulness in forensic anthropology. ***American Journal of Physical Anthropology***. 33: 221-228.

SPSS for Windows (Statistical Package for the Social Sciences, versions 6.0 and 6.1).

Stewart T.
1979 ***Essentials of Forensic Science***. Springfield: C.C. Thomas, Publisher. 255-274.

Suk V.
1935 Fallacies of anthropological identifications and reconstructions. A critique based on anatomical dissections. ***Publ. Fac. Sci. University of Masaryk, Prague***. 207: 1-18.

Sutton Phillip R.N.
1969 Bizygomatic diameter: The thickness of the soft tissues over the zygions. ***American Journal of Physical Anthropology***. 30: 303-310.

Suzuki K.
1948 On the thickness of the soft parts of the Japanese face. ***Journal of the Anthropological Society of Nippon***. 60: 7-11.

Todd T.W. and Lindal A.
1928 Thickness of subcutaneous tissues in the living and the dead. ***The American Journal of Anatomy***. 41(2).

Ubelaker D.H. and G. O'Donnell
1992 Computer-assisted facial reproduction. ***Journal of Forensic Sciences***. 37(1): 155-162.

Vanderlinden L. D. Gustavsen M. Zylstra.
1993 Work in progress to refine data on facial soft tissue depth for forensic application. ***The Journal of Anthropology at Toronto***. vol. 4: pp. 58-60.

Von Eggeling H.
1909 Aatomische untersuchungen an den kopfen von vier Hereros, einem Herero und einem Hottentottenkind. ***Medizinisch-Naturwissenschaftliche Gesellschaft***..

Welcker H.
1883 ***Schiller's schadel und todtenmaske, nebst mittleilumge uber schadel undtodtenmaske Kants***. Braunschweig.

Wilder H.H.
1912 The physiognomy of the Indians of southern New England. ***American Anthropologist***. 14: 415-436.

Woods G.
1950 Changes in width dimensions between certain teeth and facial points during human growth. ***American Journal of Orthodontics***. 36:676-700.

Ziedler H.F.B.
1919-21Beitrage zur anthropologie der gerichtsweichtailen der neger. ***Zeitschrift fur Morphologie und Anthropologie***. 21: 153-184.