

DATUM IS ONLY SKIN DEEP:
IN VIVO MEASUREMENTS OF FACIAL TISSUE THICKNESS IN CHIMPANZEES

A Thesis

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ABSTRACT

This study is an ultrasonic investigation of chimpanzee (*Pan troglodyte*) facial tissue depth variability as well as a comparison between chimpanzee tissue depth standards and modern human (*Homo sapiens*) tissue depth standards. This research intends to broaden the extent of knowledge available regarding nonhuman primate anatomy. In addition, this research hopes to provide valuable information regarding facial reconstructions of early hominins.

The subjects utilized for this study were 44 male and female chimpanzees between the ages of two to forty-five years. The chimpanzees were made available by the University of Louisiana at Lafayette New Iberia Research Center (NIRC) in New Iberia, Louisiana. Ultrasonic measurements were taken on 15 points across the chimpanzee face. The bony landmarks included were the supraglabella, glabella, nasion, mid-philtrum, chin-lip fold, mental eminence, supraorbital, suborbital, supra M2, sub M2, lateral nostril, zygomatic, occlusal line, root of zygoma, and gonion. Age, weight, sex, and frontal and lateral photographs were also collected for each subject.

Results of Pearson's correlation coefficient analysis tests denote that age is a significant variable to consider when assessing tissue depths for different bony landmarks on the face of the chimpanzee. Chimpanzee tissue depth measurements were also compared to human standards reported by other researchers. Descriptive statistical analyses conclude that meaningful differences, as well as similarities, exist between chimpanzee and human tissue depth standards.

Although race has been found to be a significant variable in regards to human facial tissue depth, chimpanzees did not exhibit a large amount of variation when compared to human black, white, and mixed race populations.

The results obtained in this preliminary investigation provide valuable information regarding comparative anatomy between human and nonhuman primates. Use of these findings could also make facial reproductions on early hominins more accurate by providing tissue depth standards for a species that may be more similar in appearance to our earliest known ancestors.

CHAPTER 1: INTRODUCTION

Facial tissue depth standards have been established for numerous modern human (*Homo sapiens*) populations. The purpose of creating these standards is to aid in two-dimensional and three-dimensional forensic reconstructions with the aim of assisting with victim identification. However, after an exhaustive literature review, no data for facial tissue depth measurements could be found for species other than humans. The obvious explanation for the lack of tissue depth standards for species other than humans is that facial reconstruction is not necessary for victim identification in other species.

The focus of facial tissue depth research on humans has limited available data for reconstructing the physical appearance of the earliest human ancestors. The possibility that facial tissue depth measurements in nonhuman primates may provide better standards for early hominin reproductions has been overlooked. As renowned anthropologist Earnest Hooton (1955 p.5) so plainly asserted, “We do not know enough about the anatomy and dentition of existing primates safely to interpret those of fossil primates, proto-human or infra-human.”

This study reports facial tissue thicknesses for chimpanzees (*Pan troglodytes*) of various age and sex. These measurements were then used for interspecific and intraspecific comparison. Variations in the nasal, maxillary, and mandibular regions between humans and chimpanzees were expected as a result of the greater degree of prognathism in chimpanzees. Variation was also suspected between juvenile and adult chimpanzees as well as male and female chimpanzees due to weight differences and disparity in bone structure (Ferrario et al., 1997; Simpson and Henneberg, 2002).

The hypotheses addressed in this study include: (i) variation in facial tissue thickness will exist between chimpanzees of different ages. This hypothesis was formed from the assumption that tissue thickness changes as an individual matures (Ferrario et al., 1997, 1998; Garlie and Saunders, 1999; Manhein et al., 2000; Rhine and Campbell, 1980; Rhine and Moore, 1984). (ii) Male and female chimpanzees will vary in tissue thickness in certain areas. Previous studies in humans have shown that the tissue measurements of adult males and females differ significantly in the forehead, nasal, and cheek regions (Manhein et al., 2000; Simpson and Henneberg, 2002; Wilkinson, 2002). (iii) Variation will be observed between chimpanzee and human tissue measurements. This hypothesis stems from the assumption that differences in the craniometric

dimensions of the two species will result in disparity in soft tissue measurements. Differences in cranial measurements for humans were found to suggest soft tissue differences in a study by Simpson and Henneberg (2002) in which significant correlations were detected between soft tissue depth and craniometric size. (iv) Facial tissue depth standards for chimpanzees can be used to approximate *in vivo* facial appearance of early hominins. This hypothesis was developed from the idea that early hominins – specifically australopithecines – were morphometrically similar to nonhuman primates (Falk, 1989; Larsen, 2003; Tobias, 1996).

CHAPTER 2: APPLICATION OF TISSUE DEPTH STANDARDS

Facial Tissue Thickness

Facial tissue depth standards primarily guide forensic anthropologists, investigators, artists, and sculptors in the technique of forensic facial reproduction. Presently, soft tissue measurements are used in reconstructions instead of skeletal dimensions. Cranial morphology does influence soft tissue growth (Ferrario et al., 1997), and preliminary linear regression equations using craniometric dimensions to estimate soft tissue depth have been proposed (Simpson and Henneberg, 2002). However, craniometric dimensions have not yet been verified as reliable predictors of soft tissue appearance (Ferrario et al., 1997; Simpson and Henneberg, 2002).

The first facial tissue depth measurements were collected from cadavers by means of the double-edged knife technique. This technique combines needles and rubber stoppers or soot to determine tissue thickness. The standards produced by this technique were introduced during the latter part of the 19th century (His, 1895; Stewart, 1979).

Techniques developed in the 20th and 21st centuries have increased the quantity and accuracy of tissue depth standards. X-rays, ultrasounds, CT scans, and MRIs have enabled researchers to obtain more accurate measurements (De Greef and Willems, 2005). Additionally, these non-invasive methods allow researchers to acquire tissue depth measurements from living subjects, thus eliminating the potential for post-mortem changes in tissue (Simpson and Henneberg, 2002) or tissue deformation from needle pressure (Rhine and Campbell, 1980).

Age, sex, and race must be taken into consideration when determining tissue thickness in humans. Standards have been presented for populations worldwide including: white children from various countries (Dumont, 1986; Garlie and Saunders, 1999; Hodson et al., 1985; Manhein et al., 2000; Wilkinson, 2002), black children (Manhein et al., 2000; Williamson et al., 2002), Hispanic children (Manhein et al., 2000), female Japanese children (Utsuno et al., 2004), white adults (Manhein et al., 2000; Rhine and Moore, 1984), black adults (Manhein et al., 2000; Rhine and Campbell, 1980), Japanese adults (Suzuki, 1948), male adult Zulu (Aulsebrook et al., 1996), Northwest Indians (Sahni et al., 2002), Southwest American Indians (Rhine, 1983), adult Egyptians (El-Mehallawi and Soloman, 2001), and mixed race populations (Phillips and Smuts, 1996). These studies have demonstrated that facial tissue depths vary significantly between

adults and children in specific areas of the face as well as among different subgroups within a population.

Geneticists have suggested that anatomically modern humans first appeared between 100,000 and 200,000 years ago (Balter, 2002). This indicates that one cannot assume modern facial tissue depth standards apply to hominin fossils greater than 200,000 years old. Furthermore, modern facial tissue depth standards may not be applicable for fossils less than 100,000 years old. When data from modern populations were compared with data from just 100 years ago, an increase in facial tissue depths was reported (Manhein et al., 2000). These differences in facial tissue depth may be attributed to improved accuracy of measurements or to better health and nutrition in contemporary populations. Regardless of the cause, this secular change demonstrates that further data ought to be collected to have alternative standards for producing three-dimensional facial reproductions on early hominins.

Facial Reproduction

Facial reproduction is a method of recreating the soft tissue likeness of the face from skeletal remains. Facial reproduction is most often used in forensic applications to produce a likeness of an unidentified person with the purpose of generating leads for law enforcement to investigate. Also, facial reconstructions are occasionally completed for historic features. For example, the first scientific attempt at three-dimensional facial reconstruction was performed by W. His (1895). Soft tissue data collected from cadavers were used to a complete three-dimensional facial reconstruction using the skeletal remains of composer Johann Sebastian Bach (His, 1895).

In the early 20th century, Russian anthropologist Mikhail Gerasimov (1971) created a method of three-dimensional facial reconstruction involving the clay recreation of musculature. Gerasimov used this Russian or anatomical method to reconstruct early humans; however, this method requires extensive knowledge of anatomy and hundreds of hours of labor (Taylor, 2001).

The tissue depth method or American method of facial reconstruction relies on soft tissue depth markers placed on skulls and then covered and sculpted with uniform strips of clay. Forensic artists in America commonly employ the American method to aid in criminal investigations (Taylor, 2001).

The combination method employs both the Russian and American methods. Reconstruction artists employ the combination method to amalgamate the partial recreation of

musculature with the use of tissue depth markers (Taylor, 2001). This combination method is thought to limit artist bias and is less time consuming than using the Russian method alone (Prag and Neave, 1997).

Computer software is also being developed in order to aid in computer-aided two-dimensional and three-dimensional facial reconstructions; automated skull analysis with three-dimensional imaging modalities; virtual sculpturing and soft-tissue engineering; extraction of facial features and development of morphological measures; virtual-reality techniques; imaging-based tissue depth measurement and markers; statistical shape models; cranial reconstructive surgery; surgical prediction systems; evaluation principles and studies; archaeological, forensic and medical case studies; as well as technical innovations and implementations. The purpose of incorporating computer software is to design a process of facial reconstruction that is more flexible, repeatable, and accurate than clay reconstructions (De Greef and Willems, 2005).

Application of Facial Reconstruction to Prehistoric Material

When archaeologists excavate skulls, they take craniometric dimensions, many of which correspond to the sites in which this researcher takes facial tissue depth measurements.

Craniometric measurements of prehistoric skulls have included bi-zygomatic, bi-gonial, total face height, upper face height, nasal breadth, nasal height, orbital breadth, orbital height (Krogman, 1935), maxillo-alveolar breadth, maxillo-alveolar length, and greatest width of mandible at gonial angles (Neumann, 1938).

Currently, morphometric analysis can be used to compare individual skeletal material to sample populations. Statistical analysis can help determine populational affinity, and the use of craniometrics can ascertain biological relationships to a compelling degree of likelihood (Owsley and Jantz, 2001). While soft tissue measurements presently are not available for prehistoric populations, facial measurements are critical in determining populational relationships (Krogman, 1962).

During June of 1967, archaeologists excavated the skeletal remains of a Greek woman – now affectionately know as the ‘Rich Athenian Lady’ - that date to the Aegean Early Iron Age (Liston and Papadopoulos, 2004). A two-dimensional facial reconstruction was completed on the Rich Athenian Lady using twenty-one tissue depth standards from heavy, white, modern women (Liston and Papadopoulos, 2004). The image that was created is intended to depict the

average appearance of the Rich Athenian Lady. However, as Manhein et. al (2000) have demonstrated, modern tissue depths differ from the tissue depths of earlier populations.

In 1996, forensic artist Karen Oeh (2006) performed three-dimensional reconstructions on two Native American skulls. These skulls were excavated from the campus of Santa Clara University in California and were thought to belong to the Ohlone tribe. Oeh (2006) used Rhine's tissue thickness standards for Southwest Indians to create the facial reproductions. The reconstructions were intended to represent the appearance of these individuals from nearly 1,300 years ago. Again, modern tissue standards have been applied to a pre-modern population.

Early hominin facial reconstructions have been attempted; however, these reconstructions are usually done by commercial artists or sculptors that lack training in forensic artistry (Wirts, 2006). The images of australopithecines that are found in museums and illustrations found in literature are artist interpretations that have not taken into consideration variations in facial soft tissue depth standards between and among species.

Advances are currently being made regarding three-dimensional computer imaging of hominin fossils (Mafart et al., 2004; Weber, 2002). Once three-dimensional computer imaging of fossils and three-dimensional computer-aided facial reconstruction software are effectively combined, several faces will be able to be applied and compared to the same skull (Mafart et al., 2004).

This research will produce facial tissue depth standards for modern chimpanzees, and thus, contribute to the further understanding of human and nonhuman comparative anatomy. Additionally, the standards presented here may assist reconstruction artists who intend to apply the American or combination method to early hominin skulls, as well as contribute to the facial tissue depth standards used in computer software for facial reconstructions.

CHAPTER 3: RELATIONSHIP OF HUMAN AND NONHUMAN PRIMATES

Chimpanzees and Humans

The current consensus in anthropology is that chimpanzees and humans diverged from a common ancestor between five and six million years ago (Lewin and Foley, 2004). In the early 1900s, Schwalbe and Weinert concluded that humans and chimpanzees were the last to divide phylogenetically, while others argued that gorillas were humans' nearest relative (Schultz, 1936). Nevertheless, DNA evidence shows that humans and chimpanzees have 99.4% identical coding sequence levels (Wildman et al., 2003), while humans and gorillas share 98.3% nucleotide identity (Hacia, 2001). This fact provides support for Schwalbe and Weinert's position. The genetic relationship between chimpanzees and humans is briefly reviewed in the following sections.

DNA

DNA (deoxyribonucleic acid) consists of nucleotides comprised of deoxyribose sugar, a phosphate group, and a nitrogen base - either adenine (A), thymine (T), guanine (G), or cytosine (C). The DNA molecule is composed of two strands of nucleotides bound together and shaped like a spiral staircase, also known as a double helix.

When comparing DNA sequences between different species, the process begins by separating the double helix in a laboratory. Single strands from each species are then combined together using heat. When this process was completed for chimpanzees and humans, researchers found that the two DNA sequences fit together almost perfectly (Washburn and Moore, 1974). The reported 99.4% DNA match for humans and chimpanzees indicates that only a 0.6% difference exists between the two species' DNA. A difference of 1.7% exists between humans and gorillas (Washburn and Moore, 1974). These differences indicate that humans and chimpanzees shared a common ancestor after gorillas had split off into their own lineage.

Proteins

DNA establishes the structure of proteins in the body. These proteins are created by extensive chains of amino acids. When the sequence of amino acids in a protein is determined, comparisons can be made between species in order to establish ancestral relationships. The hemoglobin chains for several animals, including humans, chimpanzees, gorillas, monkeys, and horses, were determined and compared. Humans and chimpanzees exhibited identical amino

acid chains. Humans and gorillas showed two differences in the hemoglobin chains. Humans and monkeys displayed twelve differences, and humans and horses showed forty-three differences (Washburn and Moore, 1974). The evidence from protein comparisons furthers the notion that humans and chimpanzees are more closely related to each other than are humans and gorillas or chimpanzees and gorillas.

Immunochemical Methods

Determining the sequence of amino acids in a protein is a time-consuming process. A faster technique was developed that used antibodies. In this technique, human serum was injected into rabbits to develop antihuman antibodies within the rabbits. The antihuman serum was then extracted from the rabbits and used to test the serum of other animals. Animals that are more closely related to humans will have stronger reactions to the antibody than those with more distant relationships. Results from such immunochemical studies support the aforementioned human-chimpanzee-gorilla relationships (Washburn and Moore, 1974).

Heterochrony

A relationship between humans and chimpanzees is also evident in heterochronic studies. Penin et al. (2002) compared ontogenetic changes in the skulls of chimpanzees and humans. Their results support a theory of neoteny in the human skull. Neoteny is created by a delay in the rate of development of the shape of a characteristic (McKinney and McNamara, 1991). Neoteny can literally be translated to mean 'holding on to youth' (Jones, 1995), and can be defined simply as the retention of juvenile features by an adult descendant (Montagu, 1955). Brain and cranial growth for chimpanzees and humans begins at relatively the same time during the fetal stage; however, human growth becomes prolonged and continues several years after birth. This paedomorphosis, which is a reduction in the development of a characteristic between ancestor and descendant (Reilly et al., 1997), results in adult human skulls having a shape which is comparable to that of juvenile chimpanzees, but equivalent in size to adult chimpanzees.

Chimpanzees and Australopithecines

Since the discovery of the Taung child in 1924, a polarized debate has ensued regarding the evolutionary significance of the australopithecines (Tobias, 1996). The debate centers on the extent of the relationship of *Australopithecus afarensis* and *Australopithecus africanus* to *Homo* or to the African apes. Arguments have ranged from the idea that *Australopithecus* is by no means a chimpanzee (Romer, 1930), to the belief that *Australopithecus* is nothing but a type of

anthropoid ape (Falk, 1989). Clark (1955) suggested morphological traits do indeed put *Australopithecus* closer to the *Homo* clade. However, Tobias (1996) proposed *Australopithecus* is an intermediary between African apes and *Homo*. The current theory among anthropologists maintains that *Australopithecus* is most certainly the evolutionary precursor to *Homo*, and this ancestry is evident through morphometric analysis (Larsen, 2003).

Phillip Tobias (1996) summarized that endocranial casts of *A. africanus* retained three Gorillinae features, three Homininae features, three intermediate features and one feature that remained indeterminate. Tobias (1996) explained that four calvarial (brain-case) features of *A. africanus* were more human-like; nine calvarial features retained apish traits; and one feature remained intermediate. Seven characteristics of the facial skeleton of *A. africanus* were examined and two features were found to remain Gorillinae; four features displayed Homininae attributes; and one feature remained indeterminate (Tobias, 1996). Furthermore, post-cranial analyses were completed on *A. africanus* and all followed the pattern of exhibiting a combination of Gorillinae, Homininae, intermediate, and indeterminate characteristics (Tobias, 1996).

Tobias (1996) also summarized the facial skeleton of *A. africanus*. The face of *A. africanus* exhibits prognathism in the maxillary and mandibular regions which is similar to the African apes. The upper face of *A. africanus* is medium in height, which is more closely related to modern humans than the larger height found in African apes. Neither *A. africanus* nor apes possess a malar notch. *A. africanus* exhibits a gracilizing tendency in the face, most likely due to the smaller canine size.

The results from the comparative skeletal analyses among *Australopithecus*, *Homo*, and members of Gorillinae (specifically *Pan*) lead this researcher to believe that since ape-like and intermediary characteristics are evident in *Australopithecus*, perhaps facial soft tissue depth standards for modern chimpanzees will be applicable to the skulls of australopithecines. Thus, the standards created in this research may provide more representative data for reconstructing the appearance of ancient hominins.

The australopithecines considered in this study consist of the early bipedal hominins (*A. anamensis*, *A. afarensis*, *A. africanus*, and *A. bahrelghazali*). *Ardipithecus ramidus*, *Orrorin tugenensis*, and *Sahelanthropus tchadensis* may have had tissue depths more comparable to that of chimpanzees; however, with the exception of brain size for *Sahelanthropus*, sexual dimorphism and cranial capacity of these species are unknown. *Paranthropus robustus*,

Paranthropus aethiopicus, and *Paranthropus boisei* are also expected to have possessed some similarities with chimpanzee tissue depths; however, this study intends to focus on the relationship of facial soft tissue depths between chimpanzees and the earliest australopithecines.

Age Ranges for Chimpanzees and Humans

A universally accepted age range comparison between chimpanzees and humans has not been established to date. In general, juveniles are defined as being not yet sexually mature, but able to survive the death of a caretaker. Adolescents have reached puberty but are not capable of reproduction. Adolescence ends and young adulthood begins when the individual is postpubertal and fertile (Pereira and Altmann, 1985).

Yerkes (1939) defines the juvenile period for chimpanzees to range between three to seven or eight years of age. The adolescent period ranges from seven or eight to eleven or twelve years, and the adult stage ranges from eleven or twelve to nineteen years. By age twenty, the chimpanzee is comparable to a human of forty to fifty years of age.

Schultz (1969) used the eruption of the permanent teeth to compare age categories for humans and chimpanzees. He suggests the juvenile chimpanzee age range of four to eleven years corresponds to the juvenile human age range of six to twenty years. Shultz (1969) also compared the adult period of chimpanzees, which he defines as twelve to forty years of age, to the adult period of humans ages twenty-one and up.

Watts (1985) defines the adolescent period for chimpanzees to range from age eight to age thirteen. Menarche, fusion of the distal humerus, and adolescent growth spurt begin around age eight for female chimpanzees, and fusion of the distal humerus and growth spurt begin around age nine for male chimpanzees. In contrast, human females begin menarche around age thirteen and the distal humerus fuses around age twelve. Male humans begin their adolescent growth spurt at age twelve and the distal humerus fuses around age fifteen. The overall comparison by Watts (1985) suggests that an eighteen-year-old human is comparable to a thirteen-year-old chimpanzee.

Dr. Babette Fontenot, veterinarian and head of the New Iberia Research Center Division of Behavioral Sciences, New Iberia, Louisiana, suggests the juvenile stage for chimpanzees ranges from ages two to six; adolescence spans from seven to nine years of age; young adulthood ranges from ten to fifteen years old; adulthood extends from sixteen to thirty years of age; and an aged chimpanzee would be thirty-one years and older (personal communication, April, 2006).

Shefferly (2006) corroborates Fontenot's statements by listing juvenility in chimpanzees to range from two to six years, adolescence from seven to nine years, and sexual maturity ranging from ten to fifteen years of age.

For comparative purposes, chimpanzee age categories selected for this study roughly correspond to those used for humans in Manhein et al. (2000). Therefore, Shefferly's (2006) and Fontenot's age ranges were chosen since those of Yerkes (1939) appear too broad, Schultz (1969) does not recognize an adolescent stage, and Watts (1985) only reports ranges for adolescents. Hence, juvenile chimpanzees ages two to six are compared to juvenile humans ages three to eight; adolescent chimpanzees ages seven to nine are compared to humans ages nine to thirteen; young adult chimpanzees that are ten to fifteen years old are compared to humans ages fourteen to eighteen; chimpanzees sixteen to thirty years of age are compared to humans ages nineteen to forty-five; and aged chimpanzees thirty-one years and older are compared to humans older than age forty-five. With regard to the comparison of chimpanzees to a mixed race population, only chimpanzees ages ten and older are used since Phillips and Smuts (1996) did not use any subjects under twelve years of age.

CHAPTER 4: MATERIALS AND METHODS

Equipment

Tissue depth data were collected via ultrasonic imaging. Courtesy of the Forensic Anthropology and Computer Enhancement Services (FACES) Lab at Louisiana State University, an Aloka SSD-500 OB/GYN system monitor, an Aloka UST-5521-7.5 Mhz transducer, a Sony Video Graphic Thermal printer and Sony thermal paper were utilized to obtain measurements. Protocol for this study followed Manhein et al. (2000). Printouts from ultrasound system recorded individual identification number, date, time, and point measurement in millimeters for each chimpanzee. The point measurements are determined from images produced using a transducer coated with a thick layer of ultrasonic coupling gel and represented the distance from skin surface to bone. These images were then printed and stored.

Sample Population

Subjects for this project were made available by the New Iberia Research Center in association with the University of Louisiana at Lafayette. Data collection was completed at the New Iberia Research Center under the supervision of Dr. M. Babette Fontenot DVM, Ph.D., who is the Division Head of Behavioral Sciences, and Dr. Dana Hassleschwert, DVM, who is the Division Head of Veterinary Sciences. Prior to beginning the project, the research protocol passed all Institutional Animal Care and Use Committee criteria and was in accordance with the University of Lafayette's Animal Welfare Assurance Policy as well as the Public Health Policy on Humane Care and Use of Laboratory Animals.

Beginning in January, 2006, measurements were taken from 44 captive chimpanzees ranging in age from two to forty-five. All adult subjects fell within a normal weight range for captive chimpanzees, which is between 34kg and 80kg for males and 26kg and 68kg for females (Shefferly, 2006). Due to high variation in body size among juvenile, adolescent, and young adult chimpanzees, a normal weight range could not be established. However, all subjects under the age of sixteen were visually assessed and found to be of typical body size, that is, neither emaciated nor obese. The name, identification number, case number, age, and weight were recorded for each subject. Where possible, country of origin and generational relationship were noted as well.

This research coincided with the schedule of annual physicals for the chimpanzees. Following the protocol for routine physical examinations, the chimpanzees were anesthetized by veterinarians at the New Iberia Research Center using 3.0 mg/kg of Telazol in order to eliminate the possibility of movement by the subject during measurement. Anesthetizing the subjects also ensured the safety of the researchers.

Most of the chimpanzees were measured in the supine position due to the fact that the subjects were anesthetized and positioning them upright proved to be difficult. However, a three subjects were also measured in the seated, upright position to ensure that measurements were not altered by posture. Frontal and lateral photographs of the subjects were taken prior to obtaining measurements. No harm was experienced by any of the animals during this study.

Measurements

Originally, measurements from twenty-two anthropological points were to be taken and compared to nineteen of the standards for children and adult humans reported by Manhein et al. (2000). Measurement comparisons were also done against the thickness standards for mixed race South Africans presented by Phillips and Smuts (1996).

The original points to be measured were the supraglabella, glabella, end of nasals, nasion, lateral nostril, mid-philtrum, chin lip fold, supraorbital, suborbital, supracanine, subcanine, posterior maxilla, superior mid-mandible, inferior mid-mandible, lateral eye orbit, anterior zygoma, root of zygoma, gonion, mental eminence, beneath the chin, upper lip margin, and lower lip margin. However, the anesthesia used on the subjects only lasted between five and seven minutes, which was not enough time to complete all twenty-two measurements.

After careful consideration of the most crucial points and a conversation with forensic anthropologists Mary Manhein and Ginesse Listi, as well as forensic artist Eileen Barrow, fifteen points (Figures 1 and 2) were decided upon (Table 1). The end of nasals had to be eliminated as it was a 'sneeze button' for the chimpanzees. When the measurement at the end of nasals was attempted, the subject would go into a sneezing fit, thus rendering the measurement useless. The canine, maxillary and mandibular measurements were truncated to supra M2 and sub M2 measurements. The lateral eye orbit was eliminated as it was found to correspond to the glabella measurement (Manhein et al., 2000). The measurement beneath the chin was removed due to the fact that the mental eminence in chimpanzees is in the same position as the beneath the chin measurements in human subjects. The upper and lower lip margins were not taken because of

the chance of the subject biting down while anesthetized. However, measurements of occlusal lines were attempted.

Table 1 – *Data point numbers on skull of chimpanzees and descriptions.*

1 Supraglabella	Midpoint of forehead region, superior to glabella
2 Glabella	Mid-point of supraorbital tori
3 Nasion	Directly between eyes
4 Mid-philtrum	Centered between nose and mouth
5 Chin-lip fold	Centered below bottom lip
6 Mental eminence	Forward-most projecting point of chin; located inferiorly on chimpanzees
7 Supraorbital	Centered on superior eye orbit, on superior bony margin
8 Suborbital	Centered on inferior eye orbit, on inferior bony margin
9 Supra M2	Lateral cheek (maxilla) superior
10 Sub M2	Lateral cheek (mandible) inferior to second molar, lined up with point 9
11 Lateral nostril	Approximately 5mm lateral to nostril
12 Zygomatic	Zygomatic arch inferior to lateral border of eye
13 Occlusal line	Axis line of the contacting surfaces of the posterior teeth, located at midpoint of anterior mandibular ramus
14 Root of zygoma	5mm anterior and superior to tragus
15 Gonion	Outer point of mandible at which jaw angles upward

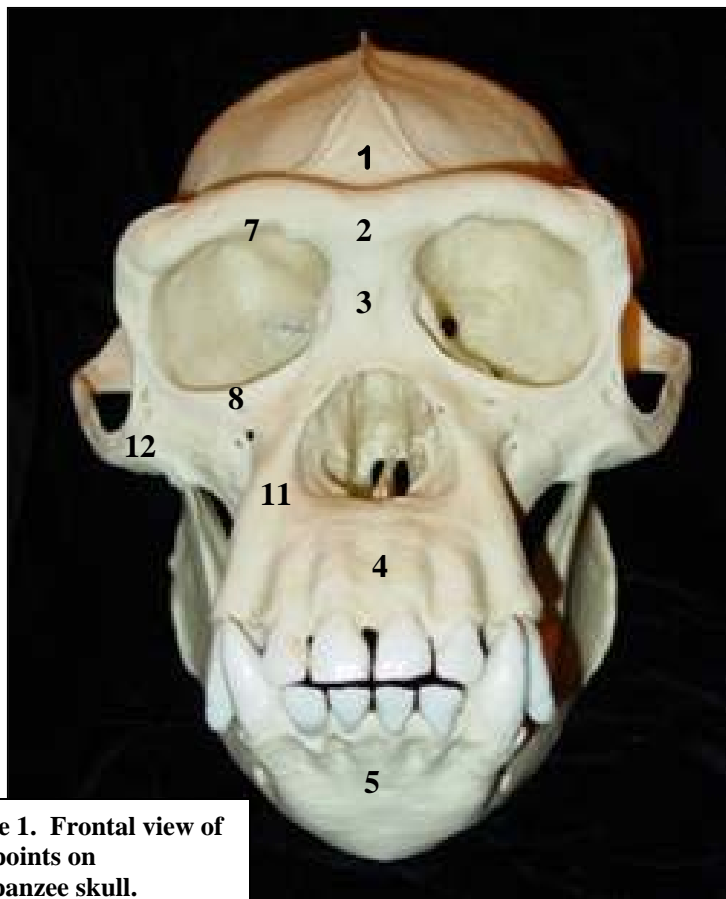


Figure 1. Frontal view of data points on chimpanzee skull.

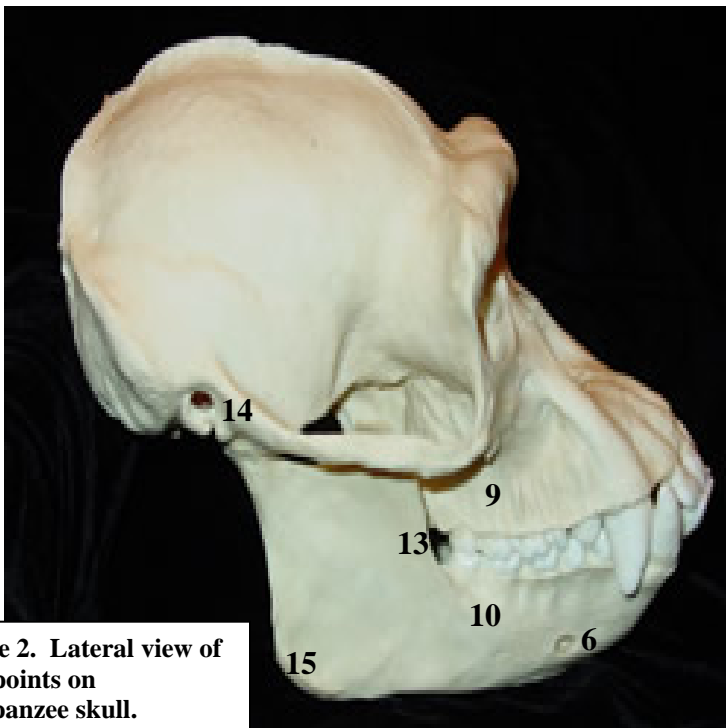


Figure 2. Lateral view of data points on chimpanzee skull.

These fifteen points can be located with ease in both chimpanzees and humans. The *Atlas of Primate Gross Anatomy* (Swindler and Wood, 1973) has been referenced for accuracy. The glabella in humans is not anatomically noted on chimpanzees; however, the midpoint of the torus supraorbitalis in chimpanzees corresponds with the location of the glabella. Therefore, the torus supraorbitalis will be measured in place of the glabella. Hair growth did not greatly affect the measurements. Generally, the hair was able to be parted in order to obtain a measurement. If the hair became matted with the ultrasonic coupling gel, or if the hair was too thick to attain an accurate measurement, then the point was eliminated for that subject.

Statistical Analysis

Data were entered into Microsoft Excel 2003 spreadsheets and SPSS/PC + software for statistical analysis. Mean, standard deviation and ranges of facial tissue measurements were reported for groups of different ages and sex.

Age groups were divided into five categories: juveniles (ages 2-6), adolescents (ages 7-9), young adults (ages 10-15), adults (ages 16-30), and older adults (ages ≥ 31). These categories are comparable to Manhein et al.'s (2000) age and sex categories of adults and children of white, black and Hispanic origin. Further comparisons will be made with Phillips and Smuts' (1996) categories of a mixed race population. Pearson's correlations and Wilcoxon-Mann-Whitney analyses were calculated to determine statistical significance between the variables of age, sex, species, and point measurements. A paired *t*-test was run on three chimpanzees measured both supine and erect to assess variation in measurements due to position.

CHAPTER 5: RESULTS

Table 2 provides an overview of the number of measurements obtained for each bony landmark. Due to the hazard of working with live chimpanzees, the complete set of fifteen measurement points was unable to be taken on all of the subjects either because the anesthesia began to wear off or because the subject was shifting in reaction to the transducer.

The first comparisons drawn are intraspecific among chimpanzees below the age of sixteen. Table 3 provides the means, standard deviations, and ranges for chimpanzees between the ages of two and fifteen. Variation in soft tissue depth is evident between the sexes as well as between the different age categories.

Table 4 presents the results of Pearson's correlations for chimpanzees of combined sex and ages with ages two to fifteen collapsed. A significant relationship between age and sex exists at seven out of the fifteen points. The supraglabella, mid-philtrum, chin-lip fold, supraorbital, supra M2, zygomatic, and gonion all show a significant correlation between tissue thickness and age.

Next, comparisons are drawn interspecifically between chimpanzees and humans. Table 5 compares the results of Manhein et al's. (2000) humans ages three to eight and chimpanzees ages two to six. Female chimpanzees and female humans have the least amount of difference at the glabella, nasion, lateral nostril, root of zygoma, and gonion. Male chimpanzees and male humans display the least amount of difference at the glabella, suborbital, lateral nostril, root of zygoma, and gonion. The greatest difference between chimpanzees and humans is seen at the supra M2 in both sexes.

Table 6 compares the results of Manhein et al's. (2000) humans ages nine to thirteen and chimpanzees ages seven to nine. Again, the greatest difference between chimpanzees tissue depth standards and the human depth standards reported by Manhein et al. (2000) can be seen at the supra M2. The mid-philtrum and chin-lip fold also show a considerable difference between chimpanzees and humans.

Table 7 compares the results of Manhein et al's. (2000) humans ages fourteen to eighteen and chimpanzees ages ten to fifteen. The difference between humans and chimpanzees at the supra M2 remains marked. The comparison of several tables infer that the difference at the mid-philtrum in sub-adults between the two species increases with age.

Table 2 – N per point measurements by age group and sex for chimpanzees.

POINT #	N Ages (2-6)		N Ages (7-9)		N Ages (10-15)		N Ages (16-30)		N Ages (31+)		Total
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
1	3	3	3	2	5	5	11	8	1	2	43
2	4	3	3	2	5	5	11	8	1	2	44
3	3	3	3	2	5	5	11	8	1	2	43
4	4	2	3	2	5	5	11	8	1	2	43
5	3	3	3	2	5	5	10	7	0	2	40
6	4	3	3	2	5	5	10	7	0	1	40
7	3	3	3	2	5	5	8	8	0	2	39
8	1	2	3	2	5	4	9	8	0	2	36
9	3	2	3	2	5	3	8	8	0	2	36
10	3	3	3	2	5	4	8	8	0	2	38
11	2	2	3	2	5	2	8	7	0	2	33
12	3	3	3	2	5	4	10	8	0	1	39
13	2	3	3	2	3	2	7	3	0	2	27
14	3	3	2	2	3	3	8	8	1	1	34
15	3	3	3	2	5	3	10	6	1	2	38

Table 3 – Tissue depth means (mm) for male and female chimpanzees ages 2-15.

Point Numbers/ Descriptions	2-6 Years						7-9 Years						10-15 Years					
	Female (N = 3*)			Male (N = 4*)			Female (N = 2*)			Male (N = 3*)			Female (N = 5*)			Male (N = 5*)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Supraglabella	3.67	0.58	3-4	4.67	0.58	4-5	4.50	2.12	3-6	4.00	1.00	3-5	5.00	0.71	4-6	5.40	1.34	4-7
2 Glabella	4.00	1.00	3-5	4.75	1.26	3-6	5.00	0.00	5	5.67	0.58	5-6	4.60	1.34	3-6	5.00	0.71	4-6
3 Nasion	5.33	2.31	4-8	4.00	0.00	4	3.50	0.71	3-4	3.67	0.58	3-4	4.40	1.14	3-6	4.20	1.10	3-6
4 Mid-philtrum	10.00	1.41	9-11	13.00	1.83	11-15	13.50	0.71	13-14	15.67	2.08	14-18	16.20	4.21	10-21	18.00	6.63	11-29
5 Chin-lip fold	10.00	1.73	9-12	11.67	0.58	11-12	14.00	1.41	13-15	13.33	0.58	13-14	14.20	1.10	13-16	14.40	1.67	12-16
6 Mental eminence	6.33	0.58	6-7	10.00	6.38	4-16	8.50	3.54	6-11	8.33	3.51	5-12	8.00	5.20	5-17	6.20	1.92	4-9
7 Supraorbital	6.33	2.31	5-9	6.00	1.73	5-8	6.50	0.71	6-7	8.00	1.00	7-9	7.40	1.67	6-10	7.40	1.34	6-9
8 Suborbital	4.50	0.71	4-5	5.00	---	5	5.50	0.71	5-6	5.00	2.00	3-7	5.50	1.29	4-7	4.40	0.89	3-5
9 Supra M2	8.50	0.71	8-9	9.00	1.00	8-10	10.00	1.41	9-11	12.33	2.08	10-14	12.33	5.13	8-18	11.20	2.39	8-14
10 Sub M2	8.67	1.53	7-10	11.00	2.00	9-13	10.00	2.83	8-12	11.00	2.65	8-13	10.25	2.87	8-14	10.40	1.14	9-12
11 Lateral nostril	7.00	0.00	7	8.00	1.41	7-9	6.50	0.71	6-7	7.33	2.52	5-10	7.00	1.41	6-8	8.60	0.89	8-10
12 Zygomatic	7.33	3.22	5-11	5.67	0.58	5-6	7.00	1.41	6-8	8.00	1.00	7-9	7.75	2.50	5-11	8.20	2.39	5-11
13 Occlusal line	11.67	4.16	7-15	8.00	2.83	6-10	10.50	6.36	6-15	6.00	0.00	6	7.50	4.95	4-11	9.33	7.57	4-18
14 Root of zygoma	5.00	3.46	3-9	5.00	1.00	4-6	5.00	1.41	4-6	6.00	2.83	4-8	5.33	1.16	4-6	5.67	1.16	5-7
15 Gonion	13.67	1.53	12-15	12.67	2.08	11-15	16.00	1.41	15-17	16.00	1.73	14-17	18.00	2.65	16-21	19.80	1.79	18-22

* N listed is maximum # of subjects. Please refer to Table 2 for specific N per point.

Table 4– Pearson’s correlations between tissue thickness and age for chimpanzees (ages 2-15).

Point Numbers/ Descriptions	Pearson Correlation	Significance (1-tailed)	N
1 Supraglabella	.433*	.025	21
2 Glabella	.236	.145	22
3 Nasion	.004	.493	21
4 Mid-philtrum	.547**	.005	21
5 Chin-lip fold	.708**	.000	21
6 Mental eminence	.009	.484	22
7 Supraorbital	.420*	.029	21
8 Suborbital	.089	.367	17
9 Supra M2	.476*	.023	18
10 Sub M2	.016	.474	20
11 Lateral nostril	.247	.178	16
12 Zygomatic	.416*	.034	20
13 Occlusal line	.111	.347	15
14 Root of zygoma	.285	.143	16
15 Gonion	.760**	.000	19

* $p < .05$

** $p < .01$

Table 5 - Tissue depth means (mm) comparison between chimpanzees (ages 2-6 years) and Manhein et al. (2000) white and black humans (ages 3-8 years).

Point Numbers/ Descriptions	Female					Male				
	Chimpanzees (N = 3*)	White Humans (N = 43)	Diff	Black Humans (N = 52)	Diff	Chimpanzees (N = 4*)	White Humans (N = 36)	Diff	Black Humans (N = 37)	Diff
1 Supraglabella	3.67	---	---	---	---	4.67	---	---	---	---
2 Glabella	4.00	3.90	0.10	4.00	0.00	4.75	4.00	0.75	4.10	0.65
3 Nasion	5.33	5.00	0.33	4.90	0.43	4.00	5.70	-1.70	5.40	-1.40
4 Mid-philtrum	10.00	8.30	1.70	8.90	1.10	13.00	9.00	4.00	9.00	4.00
5 Chin-lip fold	10.00	7.60	2.40	8.20	1.80	11.67	8.10	3.57	8.60	3.07
6 Mental eminence	6.33	7.40	-1.07	8.30	-1.97	10.00	8.30	1.70	8.30	1.70
7 Supraorbital	6.33	4.40	1.93	4.50	1.83	6.00	4.60	1.40	4.50	1.50
8 Suborbital	4.50	5.60	-1.10	5.60	-1.10	5.00	5.50	-0.50	4.50	0.50
9 Supra M2	8.50	22.70	-14.20	23.00	-14.50	9.00	23.30	-14.30	22.10	-13.31
10 Sub M2	8.67	10.50	-1.83	9.80	-1.13	11.00	10.40	0.60	8.70	2.30
11 Lateral nostril	7.00	7.00	0.00	7.00	0.00	8.00	7.20	0.80	7.30	0.70
12 Zygomatic	7.33	8.40	-1.07	8.30	-0.97	5.67	8.40	-2.73	7.80	-2.13
13 Occlusal line	11.67	---	---	---	---	8.00	---	---	---	---
14 Root of zygoma	5.00	4.60	0.40	4.70	0.30	5.00	4.80	0.20	4.20	0.80
15 Gonion	13.67	13.90	-0.23	13.50	0.17	12.67	13.70	-1.03	12.80	-0.13

* N listed is maximum # of subjects. Please refer to Table 2 for specific N per point.

Table 6 - Tissue depth means (mm) comparison between chimpanzees (ages 7-9 years) and Manhein et al. (2000) white and black humans (ages 9-13 years).

Point Numbers/ Descriptions	Female					Male				
	Chimpanzees (N = 2*)	White Humans (N = 51)	Diff	Black Humans (N = 59)	Diff	Chimpanzees (N = 3*)	White Humans (N = 45)	Diff	Black Humans (N = 62)	Diff
1 Supraglabella	4.50	---	---	---	---	4.00	---	---	---	---
2-Glabella	5.00	4.40	0.60	4.30	0.70	5.67	4.60	1.07	4.50	1.17
3-Nasion	3.50	5.50	-2.00	5.40	-1.90	3.67	5.70	-2.03	5.40	-1.73
4-Mid Philtrum	13.50	9.40	4.10	9.60	3.90	15.67	9.70	5.97	10.00	5.67
5-Chin-lip fold	14.00	9.00	5.00	10.30	3.70	13.33	9.60	3.73	9.80	3.53
6-Mental Eminence	8.50	8.80	-0.30	10.00	-1.50	8.33	8.70	-0.37	9.90	-1.57
7-Supraorbital	6.50	5.10	1.40	5.30	1.20	8.00	5.20	2.80	5.20	2.80
8-Suborbital	5.50	5.60	-0.10	6.10	-0.60	5.00	5.90	-0.90	5.80	-0.80
9-Supra M2	10.00	24.30	-14.30	24.50	-14.50	12.33	24.70	-12.37	23.60	-11.27
10-Sub M2	10.00	11.70	-1.70	10.80	-0.80	11.00	12.10	-1.10	10.30	0.70
11-Lat. Nostril	6.50	7.70	-1.20	7.60	-1.10	7.33	7.40	-0.07	7.40	-0.07
12-Zygomatic	7.00	9.50	-2.50	8.90	-1.90	8.00	9.10	-1.10	8.30	-0.30
13-Occlusal line	10.50	---	---	---	---	6.00	---	---	---	---
14-Root of Zygoma	5.00	5.20	-0.20	4.80	0.20	6.00	5.40	0.60	5.00	1.00
15-Gonion	16.00	14.40	1.60	14.60	1.40	16.00	15.40	0.60	14.70	1.30

* N listed is maximum # of subjects. Please refer to Table 2 for specific N per point.

Table 7 - Tissue depth means (mm) comparison between chimpanzees (ages 10-15 years) and Manhein et al. (2000) white and black humans (ages 14-18 years).

Point Numbers/ Descriptions	Female					Male				
	Chimpanzees (N = 2*)	White Humans (N = 51)	Diff	Black Humans (N = 59)	Diff	Chimpanzees (N = 3*)	White Humans (N = 45)	Diff	Black Humans (N = 62)	Diff
1-Supraglabella	5.00		---	---		5.40		---	---	---
2-Glabella	4.60	4.60	0.00	4.70	-0.10	5.00	5.00	0.00	5.30	-0.30
3-Nasion	4.40	5.40	-1.00	5.30	-0.90	4.20	6.30	-2.10	6.10	-1.90
4-Mid Philtrum	16.20	9.40	6.80	9.90	6.30	18.00	11.20	6.80	12.10	5.90
5-Chin-lip fold	14.20	9.70	4.50	10.10	4.10	14.40	10.40	4.00	12.60	1.80
6-Mental Eminence	8.00	8.70	-0.70	10.00	-2.00	6.20	9.30	-2.80	9.50	-3.30
7-Supraorbital	7.40	5.70	1.70	5.70	1.70	7.40	5.70	1.70	5.80	1.60
8-Suborbital	5.50	6.00	-0.50	6.40	-0.90	4.40	5.30	-0.90	6.00	-1.60
9-Supra M2	12.33	26.80	-14.47	27.60	-15.27	11.20	27.40	-16.20	26.00	-14.80
10-Sub M2	10.25	13.40	-3.15	12.00	-1.75	10.40	12.30	-1.90	11.20	-0.80
11-Lat. Nostril	7.00	7.70	-0.70	8.10	-1.10	8.60	7.80	0.80	7.90	0.70
12-Zygomatic	7.75	9.50	-1.75	9.20	-1.45	8.20	8.00	0.20	7.30	0.90
13-Occlusal line	7.50	---	---	---	---	9.33	---	---	---	---
14-Root of Zygoma	5.33	6.80	-1.47	6.20	-0.87	5.67	6.00	-0.33	6.00	-0.33
15-Gonion	18.00	17.00	1.00	16.20	1.80	19.80	18.10	1.70	17.90	1.90

* N listed is maximum # of subjects. Please refer to Table 2 for specific N per point.

The relationship between facial soft tissue thickness and sex is demonstrated in Tables 8 and 9. Table 8 presents Mann-Whitney statistics for chimpanzees ages two to fifteen. In this age category, no significant relationship was found between soft tissue thickness and sex. Table 9 presents Mann-Whitney statistics for chimpanzees ages sixteen and older. Significant relationships between soft tissue thickness and sex were found to exist at the nasion and lateral nostril for adult chimpanzees, with males presenting larger tissue thicknesses at these points.

Next, intraspecific comparisons are presented for adult chimpanzees ages sixteen and older. Table 10 provides the means, standard deviations, and ranges for male and female chimpanzees between the ages of sixteen to thirty and thirty-one and older. As with younger chimpanzees, variation can be seen between the sexes as well as between the different age categories. No standard deviations were calculated for male chimpanzees ages thirty-one and older given that only one subject was available for analysis.

Table 11 presents the results of Pearson's correlations for chimpanzees of combined sex and ages for ages sixteen to forty-five. A significant relationship between tissue thickness and age in adult chimpanzees was evident only at the supra M2.

Table 12 compares the results of Manhein et al's. (2000) humans ages nineteen to forty-five and chimpanzees ages sixteen to thirty. The supra M2 landmark continues to show considerable difference between humans and chimpanzees, as well as the mid-philtrum. The glabella remains comparable in size between the two species. Table 13 compares the results of Manhein et al's. (2000) humans ages forty-six and older to chimpanzees ages thirty-one and older. The large disparity between humans and chimpanzees remains at the landmarks of the mid-philtrum and supra M2. The glabella is less comparable between the two species in this eldest age range; however, this is most likely due to sample size. Only one male chimpanzee was available for this age range of which just six of the fifteen points were obtainable. Manhein et al. (2000) did not have any black males over the age of forty-six in their sample, so only female differences were observable.

Table 14 compares the results of Phillips and Smuts' (1996) tissue depth standards for a mixed race population to male and female chimpanzees. The supra M2 comparison between a mixed race human population and chimpanzees presents a much smaller difference than does the supra M2 comparison between Manhein et al.'s (2000) measurements and chimpanzees. The greatest soft tissue depth difference between humans from a mixed race population and

chimpanzees can be found at the occlusal line. Substantial differences between humans from a mixed race population and chimpanzees can also be observed at the mid-philtrum, root of zygoma, and gonion in both sexes.

Manhein et al. (2000) and Phillips and Smuts (1996) obtained their measurements from subjects who were in a seated, upright position. The chimpanzees used in this study were measured in a supine position. A paired student's *t*-test was performed on a small subset of chimpanzees to detect whether a significant difference existed between measurements if a subject is in a supine versus erect position. While some variation does exist for chimpanzees when placed in a supine and seated posture, paired *t*-test results indicate that these variations are not significant ($N = 3, p > .05$).

Table 8 – Mann-Whitney U statistics for tissue thickness and sex in chimpanzees (ages 2-15)

Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mann-Whitney U	48	41	47	44	54	58	48	26	31	33	13	48	18	27	35
Significance	0.584	0.176	0.491	0.453	0.943	0.894	0.615	0.307	0.492	0.192	0.052	0.908	0.231	0.556	0.442

Table 9 – Mann-Whitney U statistics for tissue thickness and sex in chimpanzees (ages 16+)

Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mann-Whitney U	59	46.5	35	56	34	25	42	34	33	39	15	41	16	25	49
Significance	0.649	0.211	0.041	0.513	0.221	0.100	0.866	0.212	0.335	0.673	0.040	0.490	0.803	0.157	0.938

Table 10 – Tissue depth means (mm) for male and female chimpanzees ages 16-31+.

Point Numbers/ Descriptions	16-30 Years*						31+ Years*					
	Female (N = 8)			Male (N = 11)			Female (N = 2)			Male (N = 1)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Supraglabella	4.13	0.84	3-5	4.64	1.21	3-7	5.00	1.41	4-6	5.00	----	--
2 Glabella	5.00	1.20	3-7	4.82	0.98	3-6	6.00	0.00	6	4.00	----	--
3 Nasion	4.50	1.20	3-7	3.73	0.91	2-5	4.50	0.71	4-5	3.00	----	--
4 Mid-philtrum	14.00	1.77	12-17	16.27	2.65	12-20	20.00	4.24	17-23	14.00	----	--
5 Chin-lip fold	11.14	3.72	7-18	14.30	2.45	11-18	15.50	0.71	15-16	----	----	--
6 Mental eminence	10.71	4.75	6-18	7.40	4.27	4-18	5.00	----	5	----	----	--
7 Supraorbital	7.00	1.69	5-9	6.88	2.03	4-10	6.00	1.41	5-7	----	----	--
8 Suborbital	5.38	1.51	4-8	4.44	1.01	3-6	4.50	2.12	3-6	----	----	--
9 Supra M2	12.50	2.78	10-17	14.13	2.48	9-17	11.50	2.12	10-13	----	----	--
10 Sub M2	9.63	0.92	8-11	10.88	2.42	8-16	11.50	0.71	11-12	----	----	--
11 Lateral nostril	8.14	1.86	5-10	10.25	1.49	8-12	9.00	1.41	8-10	----	----	--
12 Zygomatic	8.00	2.14	4-11	7.20	1.81	5-10	5.00	----	5	----	----	--
13 Occlusal line	16.00	1.73	14-17	14.86	4.41	8-20	11.50	9.19	5-18	----	----	--
14 Root of zygoma	4.75	1.28	3-11	5.50	1.20	4-7	4.00	----	4	5.00	----	--
15 Gonion	19.50	2.67	16-24	20.00	2.87	17-26	20.00	0.00	20	19.00	----	--

* N listed is maximum # of subjects. Please refer to Table 2 for specific N per point.

Table 11 – Pearson’s correlations between tissue thickness and age for chimpanzees (ages 16+).

<u>Point Numbers/ Descriptions</u>	<u>Pearson’s Correlation</u>	<u>Significance</u>	<u>N</u>
1 Supraglabella	.160	.233	23
2 Glabella	.182	.202	23
3 Nasion	.050	.410	23
4 Mid-philtrum	.046	.417	23
5 Chin-lip fold	.366	.056	20
6 Mental eminence	-.351	.070	19
7 Supraorbital	-.277	.126	19
8 Suborbital	-.269	.126	20
9 Supra M2	-.417*	.038	19
10 Sub M2	.023	.462	19
11 Lateral nostril	-.172	.255	17
12 Zygomatic	-.277	.118	20
13 Occlusal line	-.436	.078	12
14 Root of zygoma	-.136	.295	18
15 Gonion	-.038	.437	20

* $p < .05$

Table 12 - Tissue depth means (mm) comparison between chimpanzees (ages 16-30 years) and Manhein et al. (2000) white and black humans (ages 19-45 years).

Point Numbers/ Descriptions	Female					Male				
	Chimpanzees (N = 8*)	White Humans (N = 67)	Diff	Black Humans (N = 39)	Diff	Chimpanzees (N = 11*)	White Humans (N = 38)	Diff	Black Humans (N = 22)	Diff
1-Supraglabella	4.13	---	---	---	---	4.64	---	---	---	---
2-Glabella	5.00	4.75	0.25	4.55	0.45	4.82	5.25	-0.43	5.25	-0.43
3-Nasion	4.50	5.40	-0.90	5.60	-1.10	3.73	6.20	-2.47	6.15	-2.42
4-Mid Philtrum	14.00	8.25	5.75	9.00	5.00	16.27	11.25	5.02	12.00	4.27
5-Chin-lip fold	11.14	9.95	1.19	11.75	-0.61	14.30	12.10	2.20	12.70	1.60
6-Mental Eminence	10.71	9.20	1.51	11.00	-0.29	7.40	11.00	-3.60	12.20	-4.80
7-Supraorbital	7.00	5.60	1.40	6.05	0.95	6.88	5.60	1.28	6.35	0.53
8-Suborbital	5.38	5.90	-0.52	6.55	-1.17	4.44	6.00	-1.56	6.40	-1.96
9-Supra M2	12.50	25.70	-13.20	26.70	-14.20	14.13	26.55	-12.42	27.75	-13.62
10-Sub M2	9.63	13.15	-3.52	12.85	-3.22	10.88	15.20	-4.32	13.70	-2.82
11-Lat. Nostril	8.14	8.30	-0.16	8.40	-0.26	10.25	8.65	1.60	9.75	0.50
12-Zygomatic	8.00	9.00	-1.00	10.00	-2.00	7.20	8.00	-0.80	7.35	-0.15
13-Occlusal line	16.00	---	---	---	---	14.86	---	---	---	---
14-Root of Zygoma	4.75	6.15	-1.40	6.00	-1.25	5.50	7.20	-1.70	6.55	-1.05
15-Gonion	19.50	16.35	3.15	16.60	2.90	20.00	19.80	0.20	20.90	-0.90

* N listed is maximum # of subjects. Please refer to Table 2 for specific N per point.

Table 13 - Tissue depth means (mm) comparison between chimpanzees (ages 31+ years) and Manhein et al. (2000) white and black humans (ages 46+ years).

Point Numbers/ Descriptions	Female					Male†		
	Chimpanzees (N = 2*)	White Humans (N = 67)	Diff	Black Humans (N = 39)	Diff	Chimpanzees (N = 1*)	White Humans (N = 38)	Diff
1 Supraglabella	5.00	---	---	---	---	5.00	---	---
2-Glabella	6.00	5.00	1.00	4.80	1.20	4.00	5.80	-1.80
3-Nasion	4.50	6.10	-1.60	6.00	-1.50	3.00	6.90	-3.90
4-Mid Philtrum	20.00	8.00	12.00	8.20	11.80	14.00	8.70	5.30
5-Chin-lip fold	15.50	10.60	4.90	10.00	5.50	---	11.90	---
6-Mental Eminence	5.00	11.50	-6.50	10.80	-5.80	---	11.40	---
7-Supraorbital	6.00	6.40	-0.40	5.80	0.20	---	6.65	---
8-Suborbital	4.50	7.15	-2.65	5.80	-1.30	---	5.90	---
9-Supra M2	11.50	28.30	-16.80	26.80	-15.30	---	25.90	---
10-Sub M2	11.50	15.20	-3.70	13.40	-1.90	---	13.40	---
11-Lat. Nostril	9.00	10.30	-1.30	8.40	0.60	---	10.60	---
12-Zygomatic	5.00	10.60	-5.60	9.80	-4.80	---	7.30	---
13-Occlusal line	11.50	---	---	---	---	---	---	---
14-Root of Zygoma	4.00	6.70	-2.70	6.00	2.00	5.50	5.30	-0.30
15-Gonion	20.00	15.80	4.20	14.80	5.20	20.00	16.50	2.50

* N listed is maximum # of subjects. Please refer to Table 2 for specific N per point.

† No black males over age 46.

Table 14 – Tissue depth means comparison between Hanebrink’s chimpanzee (ages 10+ Years) and Phillips and Smuts’ (1996) mixed race population (ages 12-71 Years).

Point Numbers/ Descriptions	<u>Female</u>			<u>Male</u>		
	Chimpanzees (N = 15)*	Mixed Race Humans**	Diff	Chimpanzees (N = 17)	Mixed Race Humans**	Diff
1-Subraglabella	4.53	4.88	-0.35	4.88	5.36	-0.48
2-Glabella	5.00	5.64	-0.64	4.82	5.47	-0.65
3-Nasion	4.47	4.68	-0.21	3.82	4.00	-0.18
4-Mid Philtrum	15.53	10.13	5.40	16.65	12.25	4.40
5-Chin-lip fold	12.86	11.70	1.16	14.33	12.02	2.31
6-Mental Eminence	9.23	9.57	-0.34	7.00	8.94	-1.94
7-Supraorbital	7.00	5.79	1.21	7.08	5.46	1.62
8-Suborbital	5.29	6.42	-1.13	4.43	5.97	-1.54
9-Supra M2	12.31	12.99	-0.68	13.00	12.68	0.32
10-Sub M2	10.07	11.88	-1.81	10.69	13.13	-2.44
11-Lat. Nostril	8.09	---	---	9.62	---	---
12-Zygomatic	7.69	9.30	-1.61	7.53	6.49	1.04
13-Occlusal line	12.29	21.26	-8.97	13.20	19.06	-5.86
14-Root of Zygoma	4.83	8.44	-3.61	5.50	9.10	-3.60
15-Gonion	19.18	13.50	5.68	19.88	14.20	5.68

* N listed is maximum # of subjects. Please refer to Table 2 for specific N per point.

** N = 16

CHAPTER 6: DISCUSSION

Manhein et al.'s (2000) study was chosen for comparison due to the similar methodology used. Also, the same sonographic equipment was used in both studies, thus limiting error due to variation in equipment. Additionally, both studies compare several age groups and both sexes.

The study by Phillips and Smuts (1996) was chosen in order to include a wider range of race categories for comparison. Although their study consisted of a fairly small sample size, this researcher concluded that multiracial comparisons would be vital in understanding variation between humans and chimpanzees. Since racial classifications do not exist for *Pan troglodyte*, a comparison with different human racial populations as well as a mixed race population would produce the most comprehensive assessment.

Overall, male and female chimpanzees ages two to fifteen have similar tissue depth measurements to Manhein et al.'s (2000) male and female humans in black and white race categories ages three to eighteen at the glabella, lateral nostril, and root of zygoma. Chimpanzee ages sixteen and older have similar tissue depths to humans ages nineteen and older at the glabella and lateral nostril. These results indicate that humans and chimpanzees have comparable tissue depths in all stages of life at the glabella and lateral nostril.

Male and female chimpanzees ages two to fifteen generally show greater tissue depth than humans ages three to eighteen at the mid-philtrum, chin-lip fold and supraorbital. Male and female chimpanzees ages seven and older have thicker tissue depth than male and female humans ages nine and older at the gonion. Male and female chimpanzees ages sixteen and older have greater tissue depth than male and female humans ages nineteen and older at the mid-philtrum and-chin lip fold. These results indicate that during all stages of life, male and female chimpanzees have larger tissue depths than modern humans at the mid-philtrum and chin-lip fold. With the exception of the two to six age range, chimpanzees exhibit greater depth at the gonion than humans. Although statistical significance was not evident between age and the supraorbital bony landmark, these results suggest that tissue depth at the supraorbital region may decrease as the chimpanzee matures. Comparisons with Phillips and Smuts' (1996) mixed race population further support the evidence of thicker tissue depth in chimpanzees at the mid-philtrum, chin-lip fold, and gonion.

Male and female humans ages three to eighteen generally show greater tissue depth than chimpanzees ages two to fifteen at the supra M2, sub M2, and zygomatic. Male and female humans ages nineteen and older present greater tissue depth than chimpanzees ages sixteen and older at the supraorbital, suborbital, supra M2, sub M2, zygomatic, and root of zygoma. These results suggest that during all stages of life, male and female chimpanzees have smaller tissue depths than modern humans at the supra M2, sub M2, and zygomatic. Additionally, these results indicate that tissue depth at the suborbital and root of zygoma may decrease with age in chimpanzees. The nasion and mental eminence measurements display a considerable degree of variation between and within species; and consequently, no trends are evident at these points when compared between chimpanzees and humans.

Phillips and Smuts' (1996) tissue depths for male and females ages twelve and older from a mixed race population suggest that humans have thicker tissue depths than chimpanzees at the suborbital, sub M2, occlusal line, root of zygoma. Phillips and Smuts' (1996) measurements differ greatly from Manhein et al.'s (2000) measurements at the supra M2 site. Manhein et al.'s mean tissue depths at the supra M2 range between 19.7 and 32 millimeters for all subjects, while Phillips and Smuts (1996) report the mean supra M2 tissue depth to be 12.99 millimeters for females and 12.68 millimeters for males. The supra M2 measurements by Phillips and Smuts do not show a great amount of difference from the measurements in this present study. These discrepancies may be attributable to different measurement techniques, physical differences in the populations studied, or sample size; however, Manhein et al. (2000) suggest smaller tissue depth standards in the cheek region can lead to a gaunt appearance during reconstruction.

The fact that no significance was found to exist between facial soft tissue depth and sex in chimpanzees between the ages of two and fifteen, and significance was found at only two points in chimpanzees ages sixteen and older suggest a lesser degree of sexual dimorphism in chimpanzees than in humans.

The results of this study indicate that age is a significant variable contributing to facial tissue depth thickness in chimpanzees. Age is a particularly significant factor for chimpanzees under the age of sixteen. The relationship between tissue depth and age is much less apparent in adult chimpanzees than in chimpanzees under the age of sixteen.

Chimpanzees possess similar tissue depths to humans at some bony landmarks, while other landmarks were found to be larger or smaller in chimpanzees than in humans. Although

race has been found to be a significant variable with regard to human facial tissue depth (Manhein et al., 2000), chimpanzees did not exhibit a large difference when compared to human white, black, and mixed race populations – with the exception of the supra M2.

The tissue depths in the forehead region of chimpanzees and humans (supraglabella and glabella) were found to be similar. This outcome is surprising due to the presence of the supraorbital torus in chimpanzees. As was expected, chimpanzees show increased tissue depths in comparison with modern humans in the frontal maxillary and mandibular regions (mid-philtrum and chin-lip fold), as well as the gonion. The greater degree of prognathism in chimpanzees is suspected to be the cause of these variations. Additionally, chimpanzees may frequently extend their lips outward in order to retrieve food from trees. This behavior will lead to increased muscle mass in the frontal maxillary and mandibular regions (Personal communication, Dr. Babette Fontenot, March, 2006). Although the anterior regions of the maxilla and mandible show greater thickness in chimpanzees, the bony landmarks in the cheek region (supra M2, sub M2, zygoma) indicate that humans have thicker facial tissue than chimpanzees. These results may be attributable to ontogenetic disparities between the two species. Further exploration into the effects of heterochrony on the cheek region may be necessary to understand these variations.

Since the supraglabella, glabella, nasion, and lateral nostril measurements for chimpanzees and modern humans are very similar, either may be applied to an early hominin skull. The faces of australopithecines are markedly prognathic. As a result, chimpanzee tissue depth standards for the mid-philtrum, chin-lip fold, supra M2, sub M2, and gonion should be more appropriately applied to an australopithecine reconstruction than modern human tissue depth standards.

The upper eye orbits of australopithecines as well as the brow ridge appear more ape-like in shape and size than they do human-like. Subsequently, chimpanzee depth standards for the supraorbital should be more closely related to australopithecines than are modern human measurements. The zygomatic arch in australopithecines is more similar morphometrically to apes than to modern humans and, therefore, chimpanzee depth standards for the zygomatic and root of zygoma may be appropriate for early hominin skulls.

Australopithecines and modern humans do not show sexual dimorphism in the suborbital region, while chimpanzees do exhibit sex differences in this bony region. This difference in

likely due to a reduced canine size in australopithecines and modern humans (Tobias, 1996). Therefore, the chimpanzee standards for the suborbital region do not appear to be applicable to early hominins. Although supracanine and subcanine measurements were not obtained in this study, modern human tissue standards in the canine region may be appropriate for early hominin skulls due to the reduction in canine size in australopithecines.

Due to some morphometric similarities between chimpanzees and australopithecines, the depth standards obtained in this present study - with the assistance of computer-aided facial reconstruction software - will be valuable in ascertaining the physical appearance of early hominins.

Limitations

Using captive chimpanzees for measurements may result in a population variation that is not applicable to chimpanzees in their natural habitat. A cross-species comparison of chimpanzee measurements with that of a human population may be difficult since categories of race are not specified for nonhuman primates. Different researchers use different bony landmarks when conducting tissue depth studies. Standardizing bony landmarks may assist researchers in compiling data that are more comparable. The differences in sample size between this present research and the sample sizes of Manhein et al. (2000) and Phillips and Smuts (1996) may result in some inconsistencies. Despite these limitations, this study should produce valid and reproducible standards of facial tissue depth determination.

CHAPTER 7: CONCLUSION.

This study has summarized tissue depth data for chimpanzees of various ages and both sexes. These data should prove useful for investigations into the comparative facial anatomy of chimpanzees and humans. Additionally, these data may contribute to understanding the facial anatomy of early hominins.

Future research on chimpanzee tissue depths might include an increase in sample size. Actual three-dimensional reconstructions on the cast of an australopithecine skull using modern tissue depth standards as well as the standards obtained for chimpanzees may help to demonstrate the differences in physical appearance produced by different standards. While further exploration is needed, this research has provided insight into previously unreported data on chimpanzee anatomy.

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