The Application of Facial Reconstruction Based Upon Ultrasound Measurement of Soft Tissue Thickness To Selected Problems in Human Paleontology

by

Lyla Pinch

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ABSTRACT

The Application of Facial Reconstruction
Based Upon Ultrasound Measurment of Soft Tissue Thickness
To Selected Problems in Human Paleontology

This thesis addresses the problem of reconstructing the faces of human forebears using modern facial tissue thickness standards. A review of the literature on facial reconstruction introduces the development of the method. Its use in reconstructing modern and historic persons, techniques used to obtain facial tissue thickness standards, criticisms of the method and standards currently available are discussed. From this evidence, the author suggests that the accuracy of facial reconstruction may be improved by using ultrasound to measure facial tissue thickness, and that reconstructions of fossil hominids should take non-human primate standards into consideration.

Experiments to test ultrasound and obtain chimpanzee tissue thickness measurements are undertaken and the results used to reconstruct the facial features of an hyper-robust and a robust australopithecine. Facial reconstruction results are discussed and related to the problem of identifying sexual dimorphism in fossil hominid specimens. The thesis concludes with recommendations based on the experimental work and appendices with guidelines for facial reconstruction practitioners.

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PREFACE

The Twenty-one Points on the Face

The 21 points on the face mentioned in this thesis have been developed from the first work of Welcker (1883). Welcker selected nine points on the midline of the face and gave their minimum, maximum and average values from nine male cadavers. His (1895) added to this with four unilateral measurements from 24 male and 4 female subjects. Kollmann and Buchly (1898) added one median measurement and two lateral measurements and combined their data with that of His. These points have been used until recently for three-dimensional facial reconstructions (see Figure 1).

The "gauntness" noted by facial reconstruction practitioners in reconstructions carried out using Kollmann and Buchly's measurements may have been due to the fact that Kollmann and Buchly's measurements did not include those points in the cheek region - above and below the second molars, and on the inferior border of the mandible - introduced by Suzuki in 1948. Rhine and Campbell (1980) attempted to "fill in" this area with measurements taken on an American Black sample. Although facial reconstruction difficulties with this "terra incognita" are not yet resolved, and are dealt with in this thesis at some length, the measurements taken by Rhine, Moore and Weston (1982), Moore (1981) Rhine and Campbell (1980) and Suzuki (1948) (see Tables 1 and 2) probably offer the facial reconstruction practitioner the best chances of success because they include the most points for facial tissue thickness measurement.

Taxonomic Terminology

The taxonomic terminology used in this thesis is derived from Day (1977). Wherever outdated terms such as "*Sinanthropus*", "*Zinjanthropus*" and "*Pithecanthropus*" are mentioned, they are placed in quotation marks to indicate their slippage from current use.

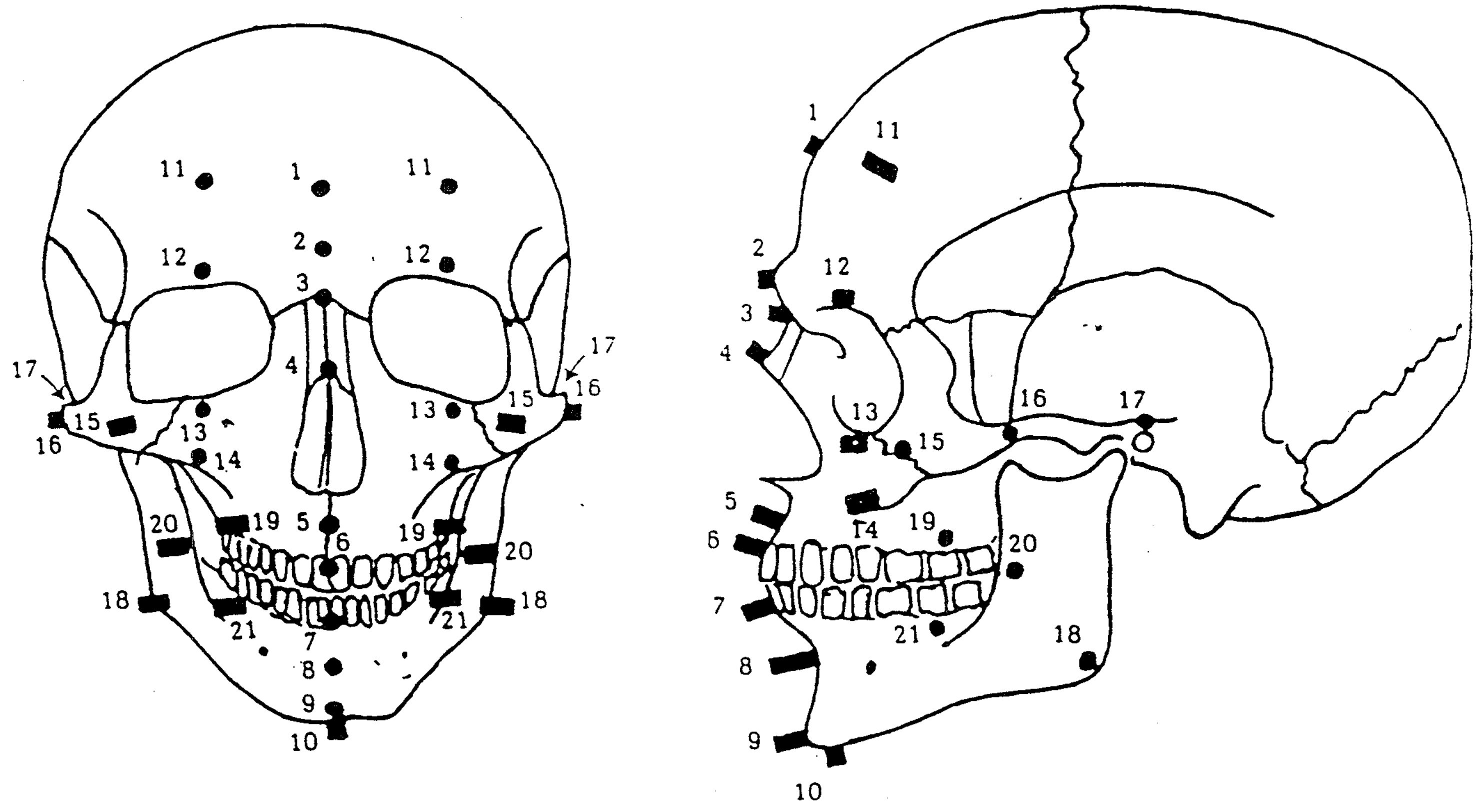
Olduvai hominid 5 was first named "*Zinjanthropus boisei*" by L.S.B. Leakey, who stated...."I am not in favour of creating too many new generic names among the *Hominidae* but I believe it is desirable to place the new find in a separate and distinct genus" (L.S.B. Leakey, 1959). OH 5 is now categorized as an *A. boisei* (hyper-robust) specimen in the anthropological literature.

I have called my four OH 5 facial reconstructions Zinj I, Zinj II, Zinj III and IV and my two SK 48 facial reconstructions Swartkrans I and II, instead of SK 48(I), OH 5(I), OH5(II) etc. to spare the reader from being forced to keep track of lengthy numerical sequences.

Usage of the Term "Race"

Much controversy surrounds the term "race", which has generally been eliminated from usage by physical anthropologists. In forensic anthropology, however, categorization of individuals according to "racial type" continues as a method of personal identification. The morphological and metrical bases for typing, for instance, are presented in detail by Krogman (1962:188-207) and Stewart (1979:227-238).

In this thesis, I use "race" in the same way as Stewart (1979:227); that is, "...a [species] sub-division based upon appearance (phenotype)..."



The twenty-one points on the face used in the facial reconstructions in this thesis (Rhine and Campbell, 1980).

Figure 1: Facial Tissue Depth Locations

Location	Black		European [14]			Japanese [19]		
	Male	Female	Point	Male	Female	Point	Male	Female
Midline								
Supraglabella	4.75	4.50	st_1	3.50	3.50	m	3.00	2.00
Glabella	6.25	6.25	st_2	4.75	4.25	gl	3.80	3.20
Nasion	6.00	5.75	nw	5.00	4.50	n	4.10	3.40
End of nasal	3.75	3.75	ns	2.00	2.00	rhi	2.20	1.60
Mid-philtrum	12.25	11.25	ow	11.50	10.00	...	...	...
Upper lip margin	14.00	13.00	lg	9.50	8.25	...	...	...
Lower lip margin	15.00	15.50	...	...	...	...	...	...
Chin-lip fold	12.00	12.00	k_1	10.00	10.00	ml	10.50	8.50
Mental eminence	12.25	12.25	k_2	10.25	10.00	pg	6.20	5.30
Beneath chin	8.00	7.75	k_3	6.00	6.25	gn	4.80	2.80
Lateral								
Frontal eminence, left	8.25	8.00	...	...	...	...	...	...
Frontal eminence, right	8.75	8.00	...	...	...	...	...	...
Supraorbital, left	4.75	4.50	oa	5.75[a]	5.25[a]	...	...	...
Supraorbital, right	4.75	4.50	...	...	...	sc	4.50	3.60
Suborbital, left	7.50	8.50[b]	ua	4.25	4.50	...	...	...
Suborbital, right	7.75	8.25	...	...	...	or	3.70	3.00
Inferior malar, left	16.25	17.25	...	...	...	...	...	...
Inferior malar, right	17.00	17.75	...	...	...	...	...	...
Lateral orbits, left	13.00	14.25[b]	wb	6.75	7.75	...	...	...
Lateral orbits, right	13.25	12.75	...	...	...	ma	5.40	4.70
Zygomatic arch, left	8.75[b]	9.25[b]	jb_1	4.25	5.25	...	...	...
Zygomatic arch, right	8.50	9.00	...	...	...	zy	4.40	2.90
Supraglenoid, left	11.75	12.00	jb_2	6.75	7.00	...	...	...
Supraglenoid, right	11.75	12.25	...	...	...	...	...	...
Occlusal line, left	19.50[b]	18.25	...	...	...	...	...	...
Occlusal line, right	19.00	19.25	...	...	...	...	...	...
Gonion, left	14.25	14.25	go	10.50	9.50	...	...	...
Gonion, right	14.75	14.25	...	...	...	go	6.80	4.00
Sub-M_2, left	15.75	16.75	...	...	...	...	...	...
Sub-M_2, right	16.50	17.25	...	...	...	m_1	10.20	9.70
Supra-M^2, left	22.25[b]	20.75	...	...	...	...	...	...
Supra-M^2, right	22.00	21.25	...	...	...	m^1	14.50	12.30
Sample size	44	15		45	8		9[c]	7
Average age	38.0	32.8		over 40			over 40	

TABLE 1

Comparison of Facial Tissue Thicknesses

Comparison of facial tissue thicknesses of American Blacks (Rhine and Campbell, 1980), Europeans (Kollmann and Buchly, 1898) and Japanese (Suzuki, 1948).

TABLE 2

American Caucasoid Standards

Most recent facial tissue thickness standards based on needleprobe measurement (from Rhine, Moore and Weston, 1982).

No.	Measurement (in mm)	Emaciated		Normal		Obese	
		Male	Female	Male	Female	Male	Female
1.	Supraglabella	2.50	2.50	4.25	3.50	5.50	4.25
2.	Glabella	3.00	4.00	5.25	4.75	7.50	7.50
3.	Nasion	4.25	5.25	6.50	5.50	7.50	7.00
4.	End of Nasals	3.00	2.25	3.00	2.75	7.50	4.25
5.	Mid Philtrum	7.75	5.00	10.00	8.50	11.00	9.00
6.	Upper Lip Margin	7.25	6.25	9.75	8.50	11.00	11.00
7.	Lower Lip Margin	8.25	8.50	11.00	10.00	12.75	12.25
8.	Chin-Lip Fold	10.00	9.25	10.75	9.50	12.25	13.75
9.	Mental Eminence	8.25	8.50	11.25	10.00	14.00	14.25
10.	Beneath Chin	5.0	3.75	7.25	5.75	10.75	9.00
11.	Frontal Eminence	3.25	2.75	4.25	3.50	5.50	5.00
12.	Supraorbital	6.50	5.25	8.25	6.75	10.25	10.00
13.	Suborbital	4.50	4.00	5.75	5.75	8.25	8.50
14.	Inferior Malar	8.50	7.00	13.50	12.50	15.25	14.00
15.	Lateral Orbit	6.75	6.00	9.75	10.50	13.75	13.25
16.	Zygomatic Arch	3.50	3.50	7.00	7.00	11.75	9.50
17.	Supraglenoid	5.00	4.25	8.25	7.75	11.25	8.25
18.	Gonion	6.50	5.00	11.00	9.75	17.50	17.50
19.	Supra M^2	8.50	12.00	18.50	17.75	25.00	23.75
20.	Occlusal Line	9.25	11.00	17.75	17.00	23.50	20.25
21.	Sub M_2	7.00	8.50	15.25	15.25	19.75	18.75

PART ONE: INTRODUCTION TO FACIAL RECONSTRUCTION

Chapter I

INTRODUCTION TO FACIAL RECONSTRUCTION

Almost since its introduction in the late 1800's, facial reconstruction - the re-creation of the features of the deceased upon the skull - has captured public interest. Its use in murder trials like the Buck Ruxton Case (Glasister and Brash, 1937), appearance on television programs such as "Quincy", and in the best-selling novel, "Gorky Park" (Smith, 1982) have kept attention focused on this forensic technique. Because of its high profile, facial reconstruction has been subject to scrutiny: How accurate is it? Is it an art or a science? What are some of its problems? This introduction will attempt to answer some of these questions as a preface to the experimental work described in this thesis.

1.1 FACIAL RECONSTRUCTION: ART OR SCIENCE?

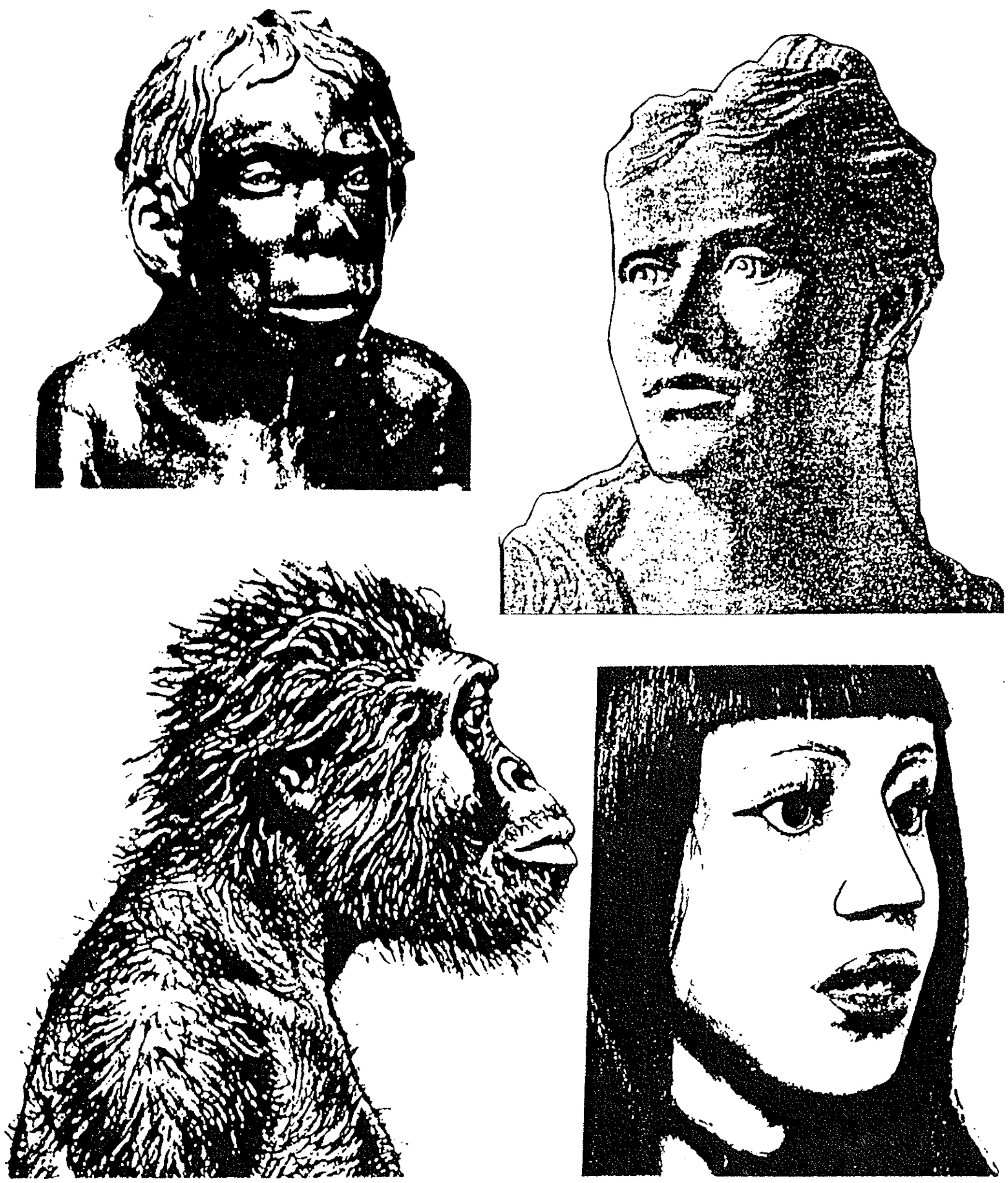
Facial reconstruction is considered to be both an art and a science because it is based on scientific methods and requires some artistic skill. Facial reconstruction is an art because the most esthetically satisfying results are produced by individuals who, as artists, may spend more time than non-artists noting variation in human facial features.

All of the facial reconstruction practitioners I am familiar with - Richard Neave, Betty Gatliffe, D.G. Cherry, Ernest Pascoe and Jay Matternes - are either commercial or medical illustrators or sculptors who work under the guidance of physical anthropologists. The latter have recognized the artistic skill necessary to shape an ear, mould a nose or produce a life-like line of expression that makes a facial reconstruction "come to life."

This "artistic" side of facial reconstruction has had its share of supporters and detractors: Buchly, the sculptor who worked with the the anthropologist Kollmann, received mixed reviews for his reconstruction of the female neolithic skull from the Auvernier Station, Switzerland (see Figure 2). Suk (1935) commented; "To our mind, this reconstruction is one of the best ones, very likely because it has been made by a real artist." Gerasimov (1971:XVII) was less enthusiastic about Buchly's contribution. He said;

> "Kollmann's scheme for the head......was 'corrected' and 'enlivened' by Buchly - he furnished the nose, mouth, ears and hair. Despite the interference of the sculptor [Buchly], Kollmann's work can rank as one of the most remarkable achievements in the history of scientifically-based reconstructions of faces from skulls."

Despite criticism of the license introduced by some artists into facial reconstruction, its method is firmly rooted in science. Scientific methods employed in facial reconstruction include using muscle markings on the skull as



Examples of facial reconstructions of humans and hominids (top l to bottom l, clockwise): Taung child by Gerasimov (1964); neolithic woman by Kollmann and Buchly (1898); Egyptian girl from mummified remains by Neave (1979); "Lucy" by Matternes (Johanson and Edey, 1981).

Figure 2: Reconstructions of Humans and Hominids

indicators of the size and placement of facial muscles and developing standards of facial tissue thicknesses that correspond to sex, body build and racial type.

In addition, researchers such as Krogman (1973), McGregor (1910) and Wilder and Wentworth (1918) have developed a number of guidelines for estimating the size and positioning of the nose, eyes and ears on the face. Physical anthropologists have contributed their ability to sex, age and attribute race to skeletal remains based on dentition and morphological features of the skull. All of this work has done much to enhance facial reconstruction's standing as a science, yet there is still much that can be done.

1.2 INCREASING THE ACCURACY OF FACIAL RECONSTRUCTION

J.S. Rhine, an anthropologist with special interests in facial reconstruction, wrote in 1980: "Despite the potential of facial reproduction, and its continuing success, there remains a reservoir of reluctance to accept the method as fully validated" (Rhine and Campbell, 1980).

Developing new ways of improving the accuracy of facial reconstruction is the basis of this thesis. It includes the introduction of a new technique for measuring facial tissue thickness that may expand the number of standards currently available and also eliminate some of the problems that contribute to the production of error inherent in other measurement techniques.

This thesis also offers solutions to some of the problems faced by facial reconstruction practitioners - problems that include using standards that are based on very small samples, standards that are unsuitable as to race, are drawn from deceased, rather than living populations, and are in some cases, considerably outdated.

Another problem faced by facial reconstruction practitioners is having to rely on modern human standards to reconstruct the facial features of hominids millions of years old. Modelling the facial features of a modern individual on a modern skull no doubt produces a more reliable result than using modern standards to reconstruct a fossil hominid face. The skull of the latter is often eroded, incomplete, warped or otherwise damaged. Sex and age are very difficult to determine, and the skull may be pieced together according to different criteria by different individuals, as in the case of Olduvai hominid 5 described later on in this thesis. Previous attempts to reconstruct hominids have incorporated modern human tissue thickness standards, with the exception of Gerasimov's reconstruction of the Taung specimen. Molecular studies have suggested that Pan, Homo and Gorilla gorilla share a common ancestor (Yunis and Prakash, 1982) Thus, when dealing with individuals millions of years old, it could be more appropriate to use either non-human primate standards or a combination of modern human and non-human primate standards rather than to rely solely upon modern human standards. This situation emphasizes the need for facial reconstruction practitioners to have tissue thickness standards such as those of Pan available in order to produce a very scientifically-rigorous likeness of a fossil hominid specimen.

The latter part of this thesis describes an experiment to obtain facial tissue thicknesses of Pan. These measurements are then used to produce six facial reconstructions based upon one robust and one hyper-robust australopithecine specimen (Australopithecus robustus and Australopithecus boisei). The results are compared and conclusions drawn. A related problem - identifying sexual dimorphism in fossil hominids - is discussed at length. Before describing these experiments, some background on the development of the practice of facial reconstruction will introduce the subject.

PART TWO: THE HISTORY OF FACIAL RECONSTRUCTION

Chapter II

EARLY EXAMPLES OF FACIAL RECONSTRUCTION

The first attempt at facial reconstruction is generally attributed to Welcker (1883), who reconstructed the faces of Schiller, Raphael and Kant. This work was followed by that of His (1895), who guided the sculptor Seffner in recreating the face of J.S. Bach directly upon the skull found in a Leipzig churchyard (Wilder and Wentworth, 1918:96).

Interest in facial reconstruction waned over the following few decades and then revived in the 1970's, perhaps as a result of the proliferation of "mummy projects" sponsored by various museums throughout the world. The Manchester Museum, the Royal Ontario Museum and the Bristol Museum, for example, conducted public dissections of Egyptian mummies too decayed to survive their parasitic invasions. These projects concluded with facial reconstructions of the deceased.

Most of these facial reconstructions were based on facial tissue thickness standards which were developed in the late 1800's and have been in use up until recently (as outlined above).

Chapter III

DEVELOPMENT OF FACIAL TISSUE THICKNESS STANDARDS

Thus far, all facial tissue thickness standards have been developed from cadaver samples. His (1895) used the average of measurements taken from 24 European male and four female cadavers. Kollmann and Buchly (1898) added measurements from 21 European male and four female cadavers to this sample. Subsequently, standards for 16 Papuans and Melanesians (Fischer, 1905; Harselm-Rheimschneider, 1921, 1922), six beheaded Chinese (Birkner, 1905), three Herero males (Von Eggeling, 1902), 15 male and three female assorted New Hollanders, Javanese, Melanesians and Cameroons (Stadtmuller, 1923, 1925) and 48 male and seven female Japanese (K. Suzuki, 1948) were established.

Work on developing new facial tissue thickness standards was continued by Rhine, Campbell, Moore and Weston. Rhine and Campbell (1980) Rhine, Moore and Weston (1982) and Moore (1981) gathered facial tissue thickness standards from 125 male and 30 female American Caucasoids, 58 male and 23 female American Blacks and 19 male and six female Mongoloids (American Indians).

Rhine, Moore and Weston's 1982 sample of American Caucasoids had facial tissue thicknesses that were, on the whole, larger than those on Kollmann and Buchly's Europeans (see Tables 1 and 2). These differences could be accounted for by several factors:

1)According to Moore, better living conditions over the past 80 years mean.... "We are thus seeing fuller and rounder faces for every body shape or physical profile than for the Germans of nearly a century ago" (Moore, 1981).

2)Sample size probably has an effect on the data. Rhine, Moore and Weston's 1982 Caucasoid sample is almost twice the size of Kollmann and Buchly's 1898 European sample. Rhine, Moore and Weston (ibid.) state that a statistical analysis of their sample demonstrated that the data were reliable.

3)It must be assumed that conditions for preserving cadavers in the late 1800's were rather different. Refrigeration had not yet been invented and formaldehyde was probably used to preserve biological specimens in medical schools. Cadavers could dry out or swell up, affecting tissue thickness. According to Suk, "..the whole aspect of the face may be completely changed in a few hours, simply due to loss of water" (Suk, 1935). Neave remarked that his facial reconstructions based on the Kollmann and Buchly data were somewhat "cadaverous" in appearance (Neave, personal communication of August 5th, 1984).

Rhine and Campbell's measurements were taken on subjects deceased no more than 12 hours or in refrigeration no more than 24 hours. Subjects showing any evidence of facial tissue distortion due to trauma or disease were eliminated (Rhine and Campbell, 1980).

Moore, in his preliminary study of the facial tissue thickness of 32 American Caucasoids, noted that..

> "Our rejection of all but fresh cadavers has probably produced higher values. Many earlier investigators had been unable to gain access to cadavers before many hours or even days, had passed. Our access to a complete medicolegal investigation system, including rapid transportation to a central receiving station, assured a sufficient number of cadavers of recent demise" (Moore, 1981).

If fresh cadavers produce larger readings than those left for long periods of time, then readings from living individuals should produce even larger values. According to morticians, moisture loss after death is related to conditions of preservation, but is generally estimated to be at the low rate of 2% over a 24-hour period. Unfortunately, I have not as yet collected a large enough sample of living human facial tissue thickness measurements to compare the facial tissue thicknesses of deceased to living individuals, so this theory that moisture loss from tissues will produce lower readings cannot yet be tested.

Some other standards have been compared, however; notably those of different races. These differences are important to consider in the problem of reconstructing fossil hominids.

3.1 COMPARING TISSUE THICKNESS STANDARDS OF VARIOUS RACES

Rhine and Campbell (1980) compared the tissue thickness measurements of a sample of American Blacks and a sample of American Caucasoids with Kollmann and Buchly's 1898 European data and Suzuki's 1948 Japanese sample (see Tables 1 and 2).

The researchers found their American Black sample measurements to be the largest of all three groups: The 32 individuals in Rhine and Campbell's Caucasoid sample fell between their group of Blacks and Kollmann and Buchly's Europeans. Rhine and Campbell concluded that using the correct facial tissue thickness measurements that correspond to the race of the identified skull is crucial to obtaining an accurate facial reconstruction:

> "The Japanese faces appear to be so much smaller than those of European whites that to use thickness data interchangeably between races to reproduce faces will likely lead to a grievous error in the finished work" (Rhine and Campbell, ibid.).

This brief outline of facial tissue thickness standards and their development suggests the difficulties that exist in obtaining an accurate facial reconstruction from the available data. The following section shows what some researchers have done to test the accuracy of the method.

Chapter IV

ASSESSING THE ACCURACY OF FACIAL RECONSTRUCTION

Concern about the accuracy of the results of facial reconstruction has been expressed by such investigators as Suk (1935), Stewart (1954) and Brues (1958). Brues commented:

> "There are certain disadvantages to this method. In order to complete such a reconstruction, it is necessary for the artist to create out of whole cloth a nasal tip, lips, etc. He will have to compromise with ignorance by making these structures rather average and non-committal. If the individual actually had rather marked peculiarities in just these features...the identification may be missed. In the drawing the artist can make these really unknown features hazy, so as to avoid this difficulty; but the sculpture allows of no such compromise, so that the latter procedure is probably best left to the ample literature of detective fiction" (Brues, 1958).

Suk took issue with anthropologists who claimed that the surface features of the skull could dictate the form of the soft tissue. Suk experimented with comparing the shape and size of the nose with the bony landmarks. By marking the location of the soft tissue on cadavers and then stripping the skull of skin, he found differences between the subnasal point of the external nose and the location of the nasal spine. He concluded that there was a lack of correspondence between the index of the bony nose and the external nose of an individual;

> "...any exact identification of a skull as pertaining to a certain person is quite out of the question. And any identification based on the comparison of a skull and portraits is utterly unscientific, for it lacks all, even the very gross landmarks which would permit any approach to exactness" (Suk, 1935).

Welcker (1883) and Wilder (1912) and Wilder and Wentworth (1918) among others, tried to eliminate some of the guesswork associated with reconstructing the soft parts of the face; Welcker attacked the problem of the positioning of the ear and Wilder and Wentworth, the formation of the nose and the setting of the eyes. McGregor (1926), established some guidelines for the size and positioning of these features that are still used today.

Wilder and Wentworth, writing in 1918, asserted that the only feature for which there was no bony correlate was the outer ear: "There are undoubtedly many more correlations between the soft features and the underlying hard parts than we know about at present, since in a region where the two are so intimately related as in the face, any change in the former must bring about some change in the latter" (Wilder and Wentworth, 1918:107).

Wilder and Wentworth related the results of a test by Von Eggeling who reconstructed the face of a hanged criminal. The death mask was compared to facial reconstructions done by a sculptor and an art instructor. Gratifying results were achieved by the latter, who had anatomical knowledge, and who used the measurements and guidelines exactly (ibid.:98-101).

In the ensuing years, other tests of the accuracy of facial reconstruction were carried out, notably those by Krogman, Neave, and Gatliffe, Snow and McWilliams.

Krogman photographed the face of an anatomical subject, stripped the face of flesh and re-applied the facial features to the skull using the combined Kollmann and Buchly and His data. He noted differences in the size and positioning of the nose, ears and mouth. Bipalpebral breadth was underestimated and bigonial breadth was overestimated (Krogman, 1973:265).

Neave conducted a similar experiment using two medical school cadavers. Although he too, experienced problems with extrapolating size and shape of nose from the landmarks on the skull, Neave concluded that, "An individual will still easily be recognized in spite of these changes" (Neave, personal communication). Gatliffe, Snow and McWilliams (1970) performed the first test of the accuracy of facial reconstruction. Photos of two three-dimensional reconstructions - one of a female and one of a male subject and fourteen possible match-up photos of actual individuals - were posted in a central location in a public building. Ballots were provided for response. Even though the photos and facial reconstructions were poorly reproduced on the poster, the correct subject was chosen 68% of the time in the case of the male subject ($p < .005$) and 26% of the time in the case of the female subject ($p < .05$). The authors noted that the reason the facial reconstruction of the female subject scored lower than the male, may have been because it was based on a set of standards averaged from only three subjects.

Neave and Krogman have both commented that the reconstructed face is often slimmer than the original: "The system works," remarked Neave, "..although where direct comparison can be made, the reconstruction is always much thinner than the original person" (Neave, personal communication, August 5th, 1984; Krogman, 1973).

The latter may be the result of moisture loss from the cadavers whose facial tissue thickness measurements formed the set of standards. Rhine and Campbell (1980) suggested Kollmann and Buchly's facial tissue thickness standards were "...taken on a small sample with inadequate controls over freshness of the cadavers." Rhine and Campbell attempted to compensate for this discrepancy by using cadavers that were unembalmed and no more than 24 hours old (as previously noted).

4.1 SUMMARY

This brief review of some of the criticisms of facial reconstruction suggests that Kollmann and Buchly's standards (used by all practitioners for Caucasoid subjects up until 1980) are inadequate in terms of sample sizes and freshness of cadaver samples. It also demonstrates that most of the difficulty with reconstructions concerns facial features that leave few or very minute markings on the skull. It is also possible that there may be problems inherent in the actual technique of taking the facial tissue thickness measurements. This possibility will be examined in the next chapter.

PART THREE: INTRODUCING ULTRASOUND

Chapter V

METHODS OF OBTAINING TISSUE THICKNESS STANDARDS

Various techniques have been used to obtain facial tissue thickness measurements from cadaver samples. Welcker (1883) inserted a thin blade into the skin until it touched the surface of the bone. He marked the depth (apparently by holding his fingers where the blade pierced the skin) and withdrew it. His (1895) used an oiled sewing needle fitted with a small rubber disk which was lowered to meet the skin surface after insertion. Kollmann and Buchly (1898) used a soot-blackened needle, the skin surface displacing the soot so that the actual inserted (clean) portion of the needle could be measured when removed. Rhine and Campbell (1980) used the needle and rubber stopper method to collect their American Blacks standards, but made sure the skin was not depressed by the stopper by levelling the skin back up with the fingers of the free hand. This latter method of obtaining measurements by using a needle is referred to as the needle probe technique.

Invasive techniques such as needleprobe are still currently in use. However, with the advent of new medical technology such as ultrasound and Computer-Assisted Tomography (CAT scans), I decided to experiment with the former to determine whether it could be used to obtain facial tissue thickness measurements that are as accurate or more accurate than those obtainable from traditional measurement methods. CAT scans, although useful under some circumstances, require large and expensive equipment and expose the subject to radiation. On the other hand, ultrasound measurements can be taken with small, portable units that provide all the data necessary for this type of research. Ultrasound is considered to pose no risk for head and neck application.

5.1 BENEFITS OF USING A NON-INVASIVE TECHNIQUE

By using a non-invasive technique like ultrasound for measuring facial tissue thickness, living individuals can be measured. The benefits are considerable:

1) Large samples can be measured in relatively short periods of time.

2) Samples can be matched specifically to the facial reconstruction; i.e., if the skull is that of a four year-old female Caucasoid subject, measurements can be taken from any number of female Caucasoids of that age and averages calculated.

3) Pathologies and problems with fluid-filled or emaciated cadavers can be eliminated.

In the past, experimenters have been limited to measuring accident victims or elderly individuals, most often the sample available from city morgues or medical schools. Gatliffe, Snow and McWilliams (1970) discussed some of the difficulties resulting from using standards drawn from such samples in their test of facial reconstruction. In this case, the female subject was correctly identified much less often than the male:

> "The female restoration subject (no. 3) was 67 years old at the time of her death; the male (no. 4) only 36 years of age. The photograph used for comparison in the former case had been taken when the subject was in her early 40's. Remodelling and atrophic changes in the facial skeleton associated with age may have profound and hitherto unassessed effects on the accuracy of the reconstruction" (Gatliffe, Snow and McWilliams, 1970).

This latter comment illustrates the need for larger and more detailed standards which would be easier to obtain with ultrasound than traditional measuring techniques. Before applying ultrasound measurements to facial reconstruction, however, it is necessary to examine whether measurements obtained from the two sources - needleprobe and ultrasound - are in fact, comparable.

5.2 USING ULTRASOUND TO MEASURE FACIAL TISSUE THICKNESS

Ultrasonics, or ultrasound, has been used in medicine since the middle part of this century (Newell, 1963). Its use is generally divided into two categories; medical treatment and medical diagnosis. The former application uses high-intensity ultrasound to destroy tissue, as in the destruction of the function of the vestibular nerve in the semi-circular canal of an ear afflicted with Meniere's Disease. The latter application uses low-intensity ultrasonics to obtain a visual image of tissue differences, e.g. to detect the presence of tumors, blockages, stones, and other irregularities (Newell, 1963).

5.3 PHYSICAL ASPECTS OF ULTRASOUND

Ultrasound works on the same principles as audible sound; it is transmitted via vibrations along a fixed pathway. Sound travels in tissue at the same rate as it does in water, namely 1,500 meters per second. By applying a sound source (transducer) of a certain intensity to a surface, such as skin, a short pulse of sound is transmitted through the tissue until it meets high intensity tissue, such as bone, sending back an echo. In our experiment, the sound was transmitted through skin, muscle, fat, and other tissue until it met bone - the same material a needleprobe would pass through to obtain a standard measurement. The lapse of time between the transmission and the return of the echo signals indicates the depths of the reflecting surfaces. The information is displayed on a cathode-ray tube as vertical deflections of a horizontal trace (Figure 3).

The machine we used for this experiment (Smith Kline Mark 1 with a 3.5 MHZ transducer) allowed each measurement to be recorded photographically on Polaroid film, thus providing a permanent record.

5.4 PROBLEMS ENCOUNTERED USING ULTRASOUND

Ultrasound cannot measure air, and therefore in instances where air pockets may exist, it is possible that a reading may not correspond to a needleprobe taken at the same point. This problem is taken into consideration in our experiment. The results are discussed and a solution to the problem is proposed.

Chapter VI

AN EXPERIMENT TO TEST NEEDLEPROBE AGAINST ULTRASOUND

6.1 MATERIALS AND METHOD

In order to test the accuracy of the needleprobe technique against ultrasound, two human cadavers were obtained. These cadavers were provided through the University of Manitoba Medical School for this purpose. The two Caucasoid subjects, one a 55-year old obese female and the other an obese male in his mid-60's, had been embalmed shortly before the experiment. Embalming was considered to have no effect on the experiment, since we were simply comparing one measurement against another at the same location on the face. However, the fact that these individuals were embalmed allowed us to compare their facial tissue measurements with those of Rhine, Moore and Weston (1982) only in a very general way.

The 21 points on the face were located on each cadaver. Two different methods of measuring the facial tissue were employed. The first method was used on the male cadaver. First, all the needleprobe measurements were taken using a clean dissection needle fitted with a rubber stopper. The needle was inserted into the skin at the first point until it met bone. The stopper was moved down the needle until it met the skin, and the skin was carefully levelled up if it had been depressed around the needle insertion area. The needle was then removed and the measurement recorded. This procedure was followed for all the 21 points on the face. Once all the needleprobe measurements had been taken, the ultrasound transducer was applied to the same 21 points and the facial tissue thickness measurements recorded photographically.

The second method was used on the female cadaver. The needleprobe was used to measure point number one on the face. As soon as the needleprobe was withdrawn and the measurement recorded, the ultrasound transducer was placed on the still-visible needle exit mark and the ultrasound measurement taken. It was felt that this latter method would be more accurate than the former because there was greater likelihood that the same spot was indeed being measured. The same procedure was followed sequentially for the other 20 points on the face.

6.2 RESULTS

The needleprobe and ultrasound results and Rhine, Weston and Moore's needleprobe measurements for obese subjects are plotted on graphs in Figures 4 and 5. No consistent correlation is evident between each of the three sets of figures on the male cadaver. My needleprobe and ultrasound measurements are less than 2 mm apart on points 3, 4, 5, 8 and 11. Rhine, Moore and Weston's measurements and my ultrasound are less than 2 mm apart at points 2, 3, 6, 8, 13, 16 and 17, but are still further apart than the aforementioned measurements. My male needleprobe measurements are 2 mm or less apart from those of Rhine, Moore and Weston at points 2, 3, 8, 11, 12 and 15. A very crude overall correlation is evident. It should be noted here, however, that we are comparing a single set of figures with a set of averaged figures, so individual variation, as well as the bloated condition of the cadavers, must be taken into consideration.

Comparing my needleprobe measurements with ultrasound on the female cadaver, it can be seen that a positive correlation exists up to point number 12, with points 1, 2 and 3 less than 1 mm apart. After point 12, a negative correlation begins to appear. Very little correlation appears to exist between Rhine, Moore and Weston's figures and the ultrasound measurements, but they are less than 2 mm apart at points 2, 3, 4, 7, 11, 12, 13, and 17. There is a crude correlation between the two sets of needleprobe measurements - mine and Rhine, Moore and Weston's - but it falls off sharply in the mid-philtrum, lip-margin region (points 5, 6, 7). This is similar to the results from the male cadaver.

6.3 DISCUSSION

This experiment included the use of many variables in the preliminary testing of ultrasound versus needleprobe in the measurement of human facial tissue thickness.

Figures 4 and 5 show that the correlation between needleprobe and ultrasound is positive in the midline area but tends to become negative in the bilateral region.

The general lack of correlation between measurements from the male cadaver suggests the first method of taking measurements - all needleprobe followed by all ultrasound measurements - is not as likely to produce reliable results as is the second method; i.e., alternating needleprobe measurements with ultrasound on each point on the face.

Ultrasound measurements come closest to needleprobe measurements when they are taken on relatively flat areas of bone overlain with thin tissue, such as on the supraglabella (point 1) and the frontal eminence (point 11).

Where measurements are taken near a shelf of bone, such as on the mental eminence (point 9), inferior malar (point 14) and zygomatic arch (point 16), less correlation between the needleprobe and ultrasound results because of the possibility of sound waves passing over the shelf.

Rhine and Campbell (1980) refer to the area between the malars and the inferior border of the mandible as the "terra incognita" of the cheek region, noting that; "This region is so troublesome to novice reproducers of the face." This region has also proved troublesome in my experiment. Considerable differences between needleprobe and ultrasound readings were apparent in measurements from this region. Several factors could account for these differences: 1) The ultrasound probe stops measuring when it hits air, therefore the measurements taken in this area would not be comparable to those taken with needleprobe. 2) The embalming procedure may, in some unknown way, confound readings. 3) There may also be some difficulty in locating the alveolare with the needleprobe. 4) the subjects may have been edentulous. The four sets of needleprobe measurements - mine and those of Rhine, Moore and Weston - were, however, much more comparable to each other than they were to the ultrasound measurements.

6.4 CONCLUSIONS

Ultrasound has been used successfully for medical treatment and diagnosis. Its usefulness as a technique for the accurate measurement of facial tissue in living humans has been investigated in this experiment.

When compared to needleprobe measurements, ultrasound measurements are closest in the midline region. Negative correlations become evident when comparisons are made in the bilateral region.

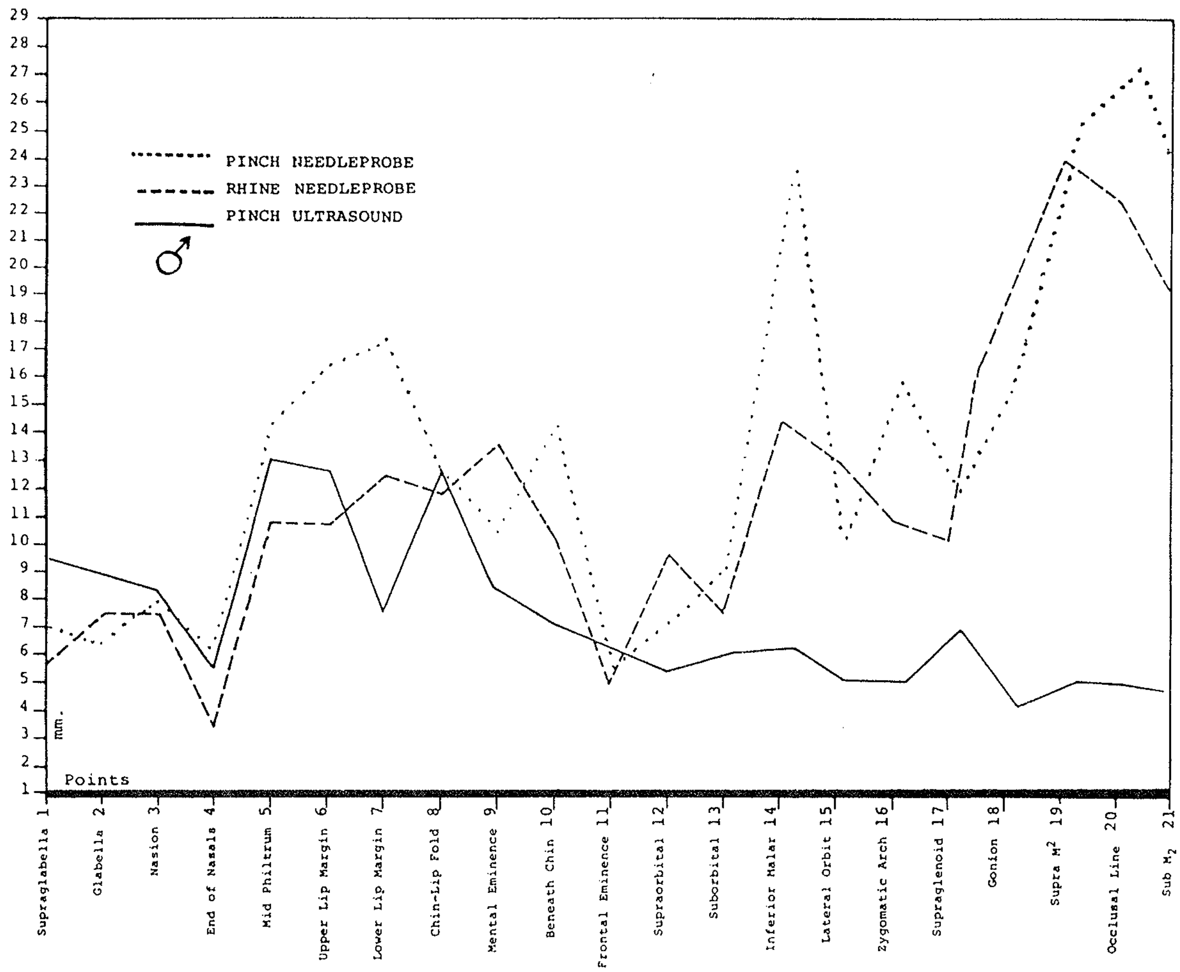
According to Newell (1963), the most accurate ultrasound readings are apt to be obtained at shallow tissue depths, and this fact is borne out in my experiment.

Comparison of the cadaver needleprobe measurements with those of Rhine, Moore and Weston (1982), shows a very rough, but consistent correlation, especially when measurements are taken with needleprobe alternated with ultrasound, as demonstrated on the female subject.

In conclusion, ultrasound appears to be a viable method of obtaining facial tissue thickness measurements, and offers many advantages over traditional invasive practices. There appear to be some problems using ultrasound in areas on the face underlain by air pockets. An experiment to try and overcome this difficulty is described in the following chapter, and the results are offered as a solution to the problem.

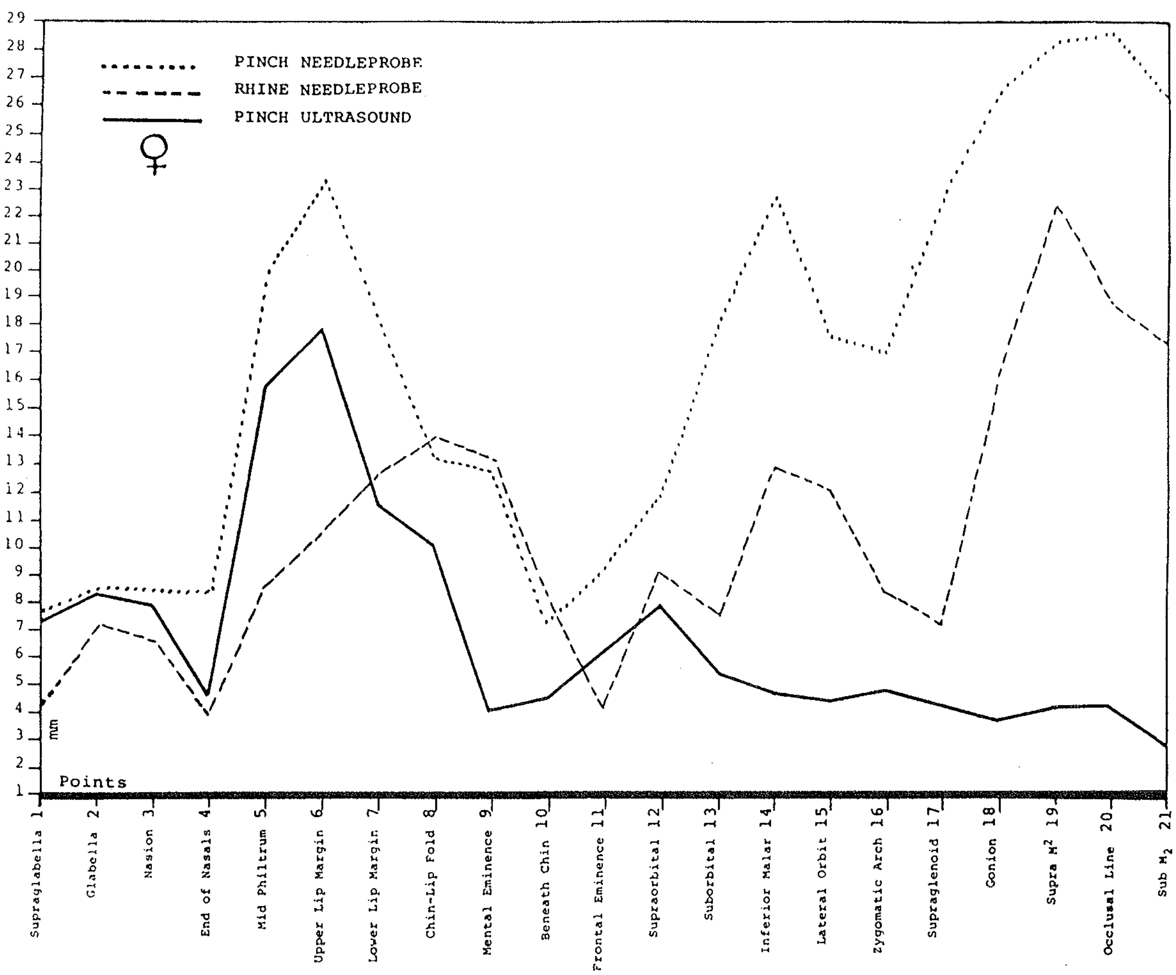
Polaroid film showing area from which measurement was taken.

Figure 3: Tissue Thickness Measurement By Ultrasound



Obese male Caucasoid subject; facial tissue thickness measured by ultrasound and needleprobe and compared to Rhine, Moore and Weston's (1982) figures.

Figure 4: Male Subject Measured by Ultrasound



Obese female Caucasoid subject, facial tissue measured by ultrasound and needleprobe and compared to Rhine, Moore and Weston's (1982) figures.

Figure 5: Female Subject Measured by Ultrasound

Chapter VII

AN EXPERIMENT IN FACIAL RECONSTRUCTION TO TEST ULTRASOUND

7.1 INTRODUCTION

The previous experiment pointed out a discrepancy in the ultrasound measurements in the region just in front of the inferior border of the mandible. Since this appears to be the major impediment to using ultrasound as a tissue thickness measurement technique, I considered it worthwhile to engage in further experimentation to try and eliminate this problem. I felt that one way to look at this region would be to carry out a facial reconstruction using data collected by ultrasound from a living subject.

7.2 METHOD AND MATERIALS

To this end, facial tissue thickness measurements were taken from a normal human female subject. When these measurements are compared to those of Rhine, Moore and Weston (1982), all measurements are close except those on the inferior border of the mandible, and below and above the second molar. Because this area is underlain with air pockets, it is assumed that the measurement given by ultrasound constitutes only the thickness of the cheek, and is therefore not comparable to the needleprobe measurements.

In order to determine what percentage of the needleprobe measurements (composed of cheek, alveolar tissue and air) the thickness of the cheek (ultrasound measurement) comprises, ultrasound measurements from points 21, 20 and 19 (corresponding to the aforementioned area) were taken on both right and left sides of two living normal subjects (one male, one female). These measurements were compared to normals from Rhine, Moore and Weston's sample, and a percentage (cheek: cheek, air, alveolar tissue) obtained. This figure was 42%. The average deviation was -9.75 ± 1.48 mm.

The complete set of ultrasound measurements taken from the normal human female subject were used as the basis of a facial reconstruction on a skull assessed as normal female. At points 19, 20 and 21 on the right side of the face, the ultrasound measurements were factored to approximate needleprobe measurements. On the left side of the face, the ultrasound measurements alone were used.

7.3 RESULTS

The result is shown in Figure 6. The side of the face with tissue applied on the basis of the needleprobe measurements has a more natural, less concave appearance than the side reconstructed using ultrasound measurements.

Figure 7 shows the facial tissue thickness of the subject plotted on a graph and compared to the needleprobe measurements of Rhine, Moore and Weston (1982) for normal female subjects. All measurements are roughly comparable, except those at points 18, 19, 20 and 21. Since there is no air pocket under point 18, it must be assumed that the difference in measurements represents normal human variation.

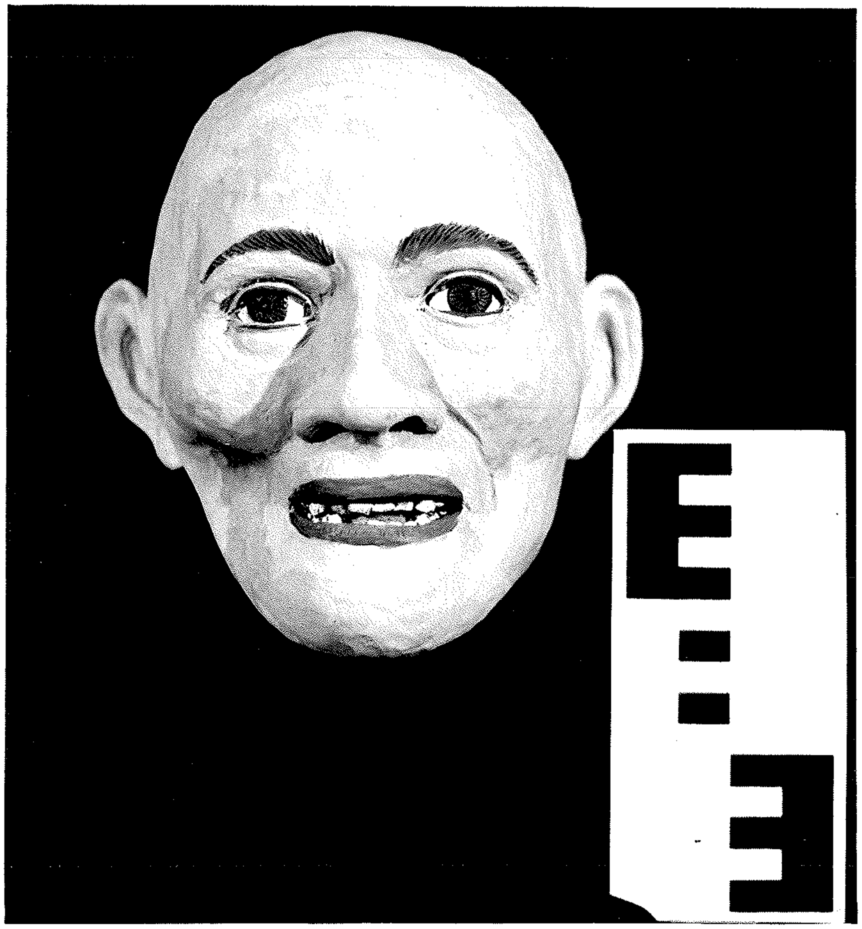
7.4 CONCLUSIONS

It is proposed that the discrepancy in the cheek region can be overcome by factoring ultrasound measurements to make them comparable to needleprobe measurements. Modern CAT scans can provide measurements which correspond to those of needle probe, and can also measure just the thickness of the cheek. This technology is currently being investigated to verify the percentage (42%) I obtained by comparing ultrasound to needleprobe at points 19, 20 and 21. Since the same difficulty in obtaining measurements at these points was experienced on the living subject as well as on the cadaver, it appears that the problem does not lie with the choice of subject, and is probably related to ultrasound.

7.5 SUMMARY

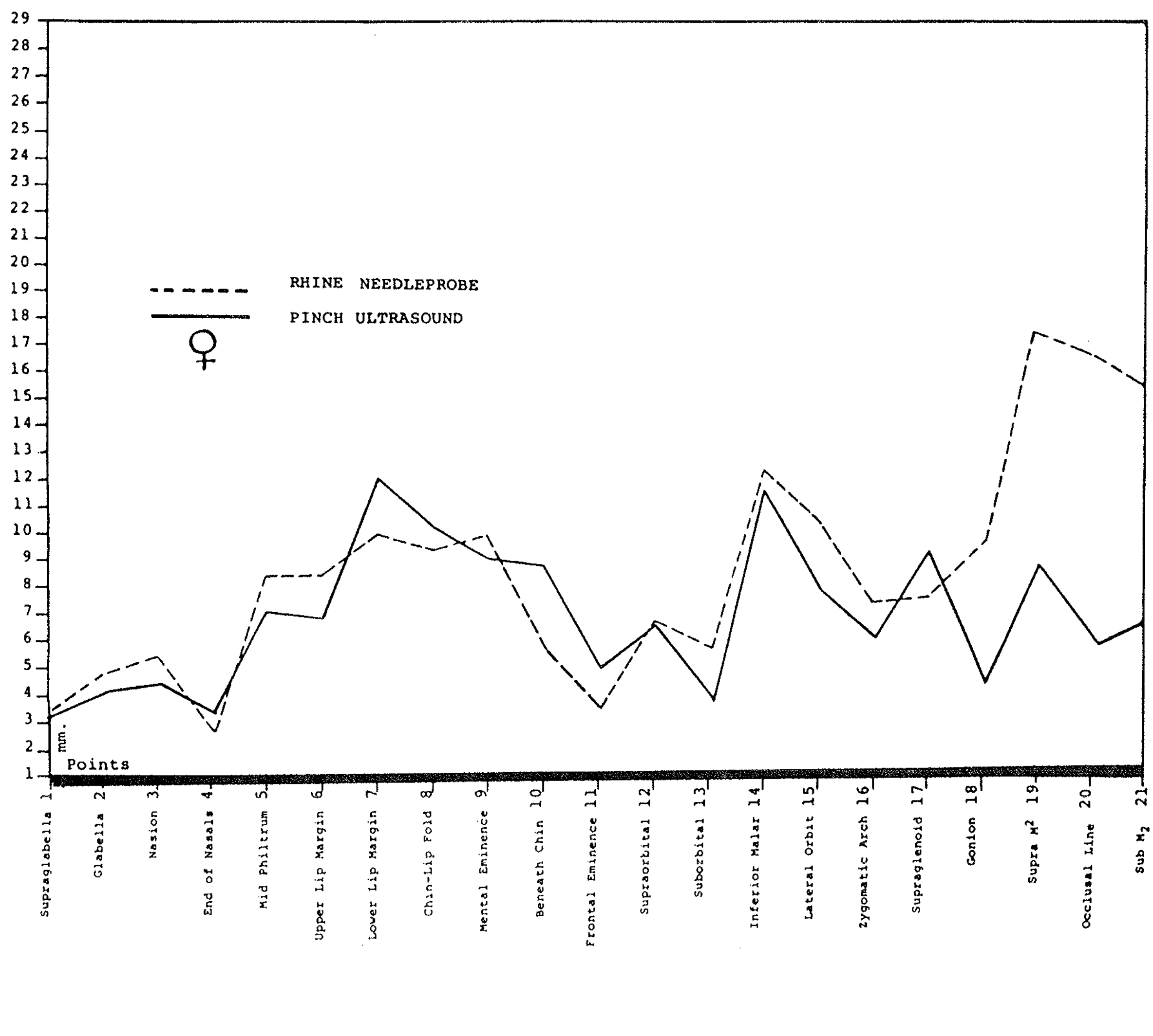
This experiment demonstrated that it is feasible to use ultrasound to obtain facial tissue thickness measurements from living humans. The same discrepancy exists in the cheek area as was evident in the experiment with the cadavers. It is suggested that factoring the measurements obtained in this area by .42 will make them equivalent to needleprobe measurements. It is not known, however, what is the basis for the difference between ultrasound and needleprobe measurements overall. This may be solved by reading facial tissue thickness measurements on CAT scans.

One of the major drawbacks of the needleprobe technique is that it takes a long time to obtain a set of standards because of the nature of the sample. Now that ultrasound has been proven feasible, I could attempt to collect data on living non-human primates - a group that would be very time-consuming and difficult to measure using needleprobe. These data would then be used to reconstruct the faces of fossil hominids.



Normal female Caucasoid subject reconstructed using ultrasound figures on the right side of the face and factored (needleprobe) figures on the left. Discrepancy in the cheek region is apparent.

Figure 6: Reconstruction Based on Ultrasound



Normal female Caucasoid subject; facial tissue thickness measurements taken with ultrasound and compared to Rhine, Moore and Weston's (1982) figures.

Figure 7: Tissue Thicknesses of Living Subject

PART FOUR: OBTAINING NON-HUMAN PRIMATE STANDARDS

Chapter VIII

THE NEED FOR NON-HUMAN PRIMATE STANDARDS

The specimens I wished to reconstruct in my experiment represented individuals who had human, as well as non-human primate features. Thus it seemed that an accurate facial reconstruction would have to take into consideration both human and non-human primate musculature, facial features and tissue thicknesses.

It has generally been accepted that the chimpanzee and the gorilla are our closest non-human primate relatives. Although there are several chimpanzee colonies in existence, gorillas are not currently available for research. Chimpanzees are a logical choice for this experiment for several other reasons: Chimpanzee body size is closer to humans' than that of the gorilla or orangutan (Schultz, 1956:905) and the pattern of facial growth in _Pan_ is more like that in _Homo_ than in other non-human primates (Krogman, 1969). Molecular studies by Balner (1981), Yunis and Prakash (1982) and Goodman, Baba and Darga (1983) and morphological comparisons by Cronin (1983), Fleagle (1983) and others have confirmed that the chimpanzee is our closest non-human primate relative.

Cramer and Zhilman (1978) have suggested the size range of *Australopithecus* is similar to that of the chimpanzee. On this evidence, and that presented above, I decided to pursue chimpanzee standards as the basis for my facial reconstructions of australopithecines.

Chapter IX

AN EXPERIMENT TO OBTAIN CHIMPANZEE STANDARDS

9.1 INTRODUCTION

Once the decision was made to measure facial tissue thicknesses of chimpanzees, a source for these animals was investigated. A primate colony was located at the Holloman Air Force Base in Alamogordo, New Mexico. Administered by New Mexico State University, The Primate Research Institute houses the world's largest research and breeding colony of chimpanzees. There are 200 animals on site, 150 on loan and approximately 30 births per year. The colony was founded as the United States Air Force Aeromedical Research Facility and played an important role in the entry of humans into space. Since the chimpanzee is recognized by most authorities as the closest non-human primate relative of humans, therefore it is considered to be a suitable human surrogate in research at the Primate Research Institute.

My sample consisted of fourteen male and fifteen female chimpanzees. The males ranged in age from 82 to 321 months of age and from 50.2 to 96.4 kg. in weight; the females ranged in age from 101 to 327 months of age and from 41.6 to 57.2 kg. in weight (Table 3). Being able to measure the facial tissue thicknesses of adequate samples of both male and female chimpanzees allowed me to compare the facial tissue thicknesses of the two sexes. Moore (1981) and Rhine and Campbell (1980) had large enough samples to carry out similar comparisons on American Blacks and American Caucasoids. No previous sample had a female group greater than seven individuals. (Suzuki, 1948).

Oestrus cycles of females were also recorded in this study. Facial tissue thicknesses of non-oestrus females were compared with those of females in oestrus to see if greater thickness was correlated with oestrus. Oestrus or menstruation has never been taken into consideration in facial tissue thickness studies. This factor can now feasibly be examined using ultrasound to measure living human populations.

The wide range of ages in this group allowed us to compare facial tissue thickness as a factor of age in both males and females. This subject has been commented upon by Gerasimov (1971:53), Gatliffe, Snow and McWilliams (1970), Brown (1953), and Hooton and Dupertuis (1951) among others. Weight as a factor of age in both sexes was also assessed and compared to Brown's results in his study of humans (op. cit.)

The purpose of this experiment was to, 1) establish a set of chimpanzee standards that could be used in fossil hominid facial reconstructions and, 2) assess the differences, if any, between human and chimpanzee facial tissue thickness measurements. Our results are compared to Moore's (1981) and Rhine, Moore and Weston's (1982) Caucasoid standards. The former were used because they were the only standards available that included standard deviations.

9.2 MATERIALS AND METHOD

This experiment was conducted in August 1983, during the chimpanzees' annual health check-up. The facial tissue thicknesses of twenty-nine chimpanzees (15 female and 14 male) were measured, using the same ultrasound machine as in the aforementioned experiments. The 21 points where measurements were taken on the face are shown in Fig 1. Three researchers participated in the experiment. One researcher was responsible for placing the transducer on each of the twenty-one points on the face of each chimpanzee, the second researcher monitored the ultrasound unit and took the photographs and the third researcher recorded and numbered the photographs and keyed them to a master list.

The procedure followed was this; after their health check-up and while still under sedation, the chimpanzees were wheeled one at a time into an adjacent operating room. The ultrasound transducer was placed on point number one on the face; when a substantial peak appeared on the cathode ray tube, a photograph was taken. Each photo was then marked with the roll and photo number which corresponded to the subject being measured. The points measured were recorded on a master list. This procedure was followed sequentially for the remaining 20 points on the face. Sub- and Supra M1 measurements were taken due to the difficulty pinpointing M2 with the transducer.

Once all the subjects were measured, the results were calculated. An example of the film (Polaroid Type 667) and the area from which the measurement is taken is shown in Figure 3.

9.3 RESULTS

Results of facial tissue thickness measurements of the 14 male and 15 female chimpanzees are shown on Tables 4 and 5. A comparison is made with Moore's 1981 study of male and female Caucasoid subjects.

9.3.1 Chimpanzee vs. Human Facial Tissue Thicknesses

The range in tissue thickness measurements appears to be much smaller in chimpanzees than in humans, even though tissue thickness is greater overall. In human males, tissue thickness ranged from a minimum of 3.01 ± .10mm (end of nasals) to a maximum of 18.78 ± .71 mm (supra M2). In chimpanzee males, the range was from a minimum of 9.07 ±

2.56 (suborbital) to a maximum of 10.10 ± 2.16 mm (lateral orbit). In human females, tissue thicknesses ranged from a minimum of 2.68 ± .19 mm (end of nasals) to a maximum of 17.82 ± 1.34 mm (supra M2). In chimpanzee females, the range was from a minimum of 9.69 ± 2.05 mm (suborbital) to a maximum of 11.24±1.78 mm (chin-lip fold).

In human males, the largest facial tissue thickness measurements tended to be in the philtrum-to-chin area and in the cheek-masseter area. In the chimpanzee males, the heaviest measurements were found in the forehead region, on the cheekbones and in the cheek-teeth area. The thickest tissue in human females is found in the chin and cheekbone-masseter area. In chimpanzee females, the thickest measurements were on the forehead, chin and zygomatic arch-masseter area. Chimpanzees, on the whole, exceeded humans considerably in measurements on the glabella region (see especially points 1, 2, 11, 12).

9.3.2 Sexual Dimorphism

Figure 8 shows the degree of dimorphism in facial tissue thicknesses in chimpanzees. Females generally have thicker facial tissues than males, even though their body size is smaller on the average. Males and females differ most radically in the mid-philtrum, chin-lip and zygomatic arch areas. Males have a much thinner tissue covering over the front teeth and on the zygomatic arch area than do females.

9.3.3 Correlations with Weight and Age Data

Weight and age were correlated with tissue thickness values in both male and female subjects using the Spearman's r test. The results are shown in Tables 6 and 7.

In male chimpanzees, weight was positively correlated with age ($p < .05$). Weight and tissue thickness were negatively correlated at all points on the face, and at the .05 level on the lower lip margin, inferior malar and zygomatic arch (midway). Negative correlations were also noted between age and tissue thickness at all points on the face, and at the .05 level on the suborbital and occlusal line points.

In contrast to males, females showed positive correlations between weight and tissue thickness at 10 of the 21 points on the face. In females, weight was even more strongly correlated with age than in males ($p < .025$). A positive correlation at the .05 level was noted on the suborbital point, and at the .0025 level on the frontal eminence and chin-lip fold areas. Age was found to be strongly correlated negatively with upper lip margin ($p < .0025$) and supra M1 thickness measurements ($p < .025$).

9.3.4 Tissue Thickness and Oestrus Cycles

Although there is no *a priori* reason to assume that the condition of oestrus influences facial tissue thickness, since the data were available, it was a simple matter to test for it.

Records of the oestrus cycles of the female chimpanzees were kept at the Primate Research Institute. Of the fifteen female chimpanzees, there were only four possible individuals to check. One (Lolita) was considered to be in the midst of oestrus, while three others (Lupe, Monica and Kitty) were just coming out of their cycle. When the facial tissue thickness measurements of these individuals were compared with those of non-oestrus females, there was no indication that the oestrus females differed systematically.

9.4 DISCUSSION AND CONCLUSIONS

Facial tissue thicknesses in chimpanzees has been found to be greater overall than in humans, but the range in measurements obtained is much less in chimpanzees than in humans.

The greatest tissue thicknesses measured on our experimental subjects occurred 1) in the forehead region and 2) on the lower face. The forehead thickness is confirmed by Ford and Perkins (1970) and was suggested by Gerasimov (1971:52):

> "...all individuals, independently of race, with a markedly developed glabella, have in that region thicker soft parts than persons with a feebly developed supraorbital area."

My finding that female chimpanzees have thicker facial tissue than males, even though their body build is smaller, agrees with some findings in humans: Rhine and Campbell (1980) found in their sample of American Blacks...

> "In most tissue thickness dimensions, the female faces are as large or slightly less than the measurements for the corresponding location on the male faces. The greatest exception appears to be in the region beneath the eyes and on the sides of the face. In as much as the female skulls are smaller and more lightly constructed than those of males, the greater tissue thickness would exaggerate the fullness at these points (N=15)."

In Kollmann and Buchly's 1898 study of Europeans, of the 15 points measured on the female faces (N=8), seven were smaller than males while five were larger. The larger measurements were taken in the same area as those on Campbell and Rhine's Black females.

Suzuki's 1948 study of the Japanese face revealed all female measurements to be larger than those of males (N=7).

Moore's 1981 study of facial tissue thicknesses of Mongoloids (American Indians) showed the two female subjects studied to have smaller facial tissue thicknesses than the males on all points on the face except on the nasion and in the lip area (see Table 8). However, since the sample size in this study is so small (N=2), these findings cannot really be considered representative.

Finally, Rhine, Moore and Weston's 1982 published standards from their American Caucasoid sample revealed all female (N=19) measurements to be smaller or equal to those of males with the exception of the lateral orbit area (Figure 1, point 15).

These findings reflect the degree of sexual dimorphism in humans which is less than that in chimpanzees, as confirmed by Cramer and Zhilman's 1978 study of *Pan paniscus* (ibid.:489): male/female index, 78% versus 84-89% for common chimpanzees and 89% for humans.

Findings similar to weight and age correlations in chimpanzees have been noted in humans; Stoudt, Damon and McFarland (1965) found weight was correlated with age in human females up to the age of 60, and in human males, up to the age of 50. Thereafter, there is a slow decline in weight.

Humans and chimpanzees appear to undergo similar changes in the face as a process of aging. Loss of tissue thickness around the mouth and cheeks in chimpanzee males and around the mouth in chimpanzee females may be due to the same factors as in humans - dental attrition, tooth loss, alveolar resorption and diminution in size of mandible (Brown, 1973). The increase in tissue thickness in female chimpanzees as a factor of age in the sub-orbital and chin-lip fold and frontal eminence areas is also associated with aging in human females: Lower eyelids cover a fatty tissue layer and the skin under the chin can double if the person is fat (ibid.:173)

The results of the oestrus cycle analysis in female chimpanzees is inconclusive. This may be due to the small sample size (N=4) and the difficulty in recording the cycles accurately. Changes in facial tissue thicknesses related to oestrus/menstruation could be tested on larger samples of non-human primates or humans now that tissue thickness can be measured with ultrasound. A comparison should be made on the same individuals before and after oestrus/menstruation and during oestrus/menstruation to give accurate results.

9.5 SUMMARY

It is evident from this experiment that chimpanzee tissue thickness is greater overall and less variable than that of humans. This fact emphasizes the need to have standards available for facial reconstruction that are more relevant to the individual being reconstructed, such as in the case of fossil hominids that have both human and primate features. These standards will now be used in an experiment in facial reconstruction to see if the results are different from those using human facial tissue thickness standards.

TABLE 3

Chimpanzee Weights and Ages

Weights and ages of male and female chimpanzees measured in the experiment.

PRC NO.	MALES (N = 14)	WEIGHT (KG.)	AGE (MOS.)
32	PALEFACE	96.4	321
713	CHINO	65.2	173
714	TACO	60.8	173
806	TED	59.6	138
674	CLIFF	58.4	230
748	J.D.	57.6	159
752	DAVE	57.2	262
673	EMORY	57.2	225
478	LOU	56.0	230
234	GROMEK	55.4	250
853	LEONARD	54.6	142
756	PATRICK	53.8	153
923	LEO	50.2	82
1063	DALTON	49.0	84
	MEAN	55.3	187
	FEMALES (N = 15)		
549	ARLENE	57.2	211
621	CONNIE	53.0	229
978	TRACY	52.0	213
258	VIOLET	51.6	256
649	KATE	49.6	259
774	KITTY	49.2	256
973	JAMIE	49.0	142
640	CLAIR	47.6	229
679	SUSIE	46.2	(220)
985	DENISE	45.8	191
631	LOLITA	44.8	327
932	LUPE	43.2	101
819	MONICA	42.6	166
1137	CRYSTAL	41.8	133
778	SHERRIL	41.6	130
	MEAN	47.7	204

TABLE 4

Male Chimpanzee vs. Human Tissue Thicknesses

Averages of tissue thicknesses of 14 male chimpanzees compared to Rhine, Moore and Weston's 1982 normal male human standards.

		MOORE (1981) *	PRESENT STUDY **	
		MEAN (MM.)	MEAN (MM.)	RANGE
1.	SUPRAGLABELLA	4.36 ± .13	10.10 ± 1.89	7.44 - 12.89
2.	GLABELLA	5.26 ± .14	9.77 ± 2.35	5.87 - 13.30
3.	NASION	6.45 ± .16	9.28 ± 1.67	6.17 - 11.07
4.	END OF NASALS	3.01 ± .10	9.19 ± 2.12	5.50 - 11.64
5.	MID-PHILTRUM	10.01 ± .27	9.08 ± 1.89	6.35 - 11.36
6.	UPPER LIP MARGIN	9.72 ± .34	9.90 ± 1.61	7.07 - 11.94
7.	LOWER LIP MARGIN	10.91 ± .37	9.75 ± 2.10	6.30 - 13.03
8.	CHIN-LIP FOLD	10.85 ± .25	9.09 ± 2.56	5.20 - 12.03
9.	MENTAL EMINENCE	11.26 ± .29	9.55 ± 2.02	6.33 - 12.40
10.	BENEATH CHIN	7.25 ± .22	9.57 ± 2.05	6.06 - 11.65
	LEFT SIDE MEASUREMENTS			
11.	FRONTAL EMINENCE	4.35 ± .12	9.95 ± 2.25	6.09 - 12.78
12.	SUPRAORBITAL	8.26 ± .18	9.83 ± 2.18	6.00 - 12.03
13.	SUBORBITAL	5.79 ± .22	9.07 ± 2.56	4.59 - 13.24
14.	INFERIOR MALAR	13.34 ± .38	9.59 ± 1.98	6.22 - 12.21
15.	LATERAL ORBIT	9.75 ± .36	10.16 ± 2.16	6.62 - 13.13
16.	ZYGOMATIC ARCH, MIDWAY	7.04 ± .26	9.12 ± 2.18	4.62 - 11.65
17.	SUPRAGLENOID	7.94 ± .40	9.67 ± 1.74	6.21 - 11.42
18.	GONION	10.69 ± .47	9.55 ± 1.84	6.20 - 11.71
19.	SUPRA-M^2	18.78 ± .71	9.62 ± 1.66	6.59 - 13.23
20.	OCCLUSAL LINE	17.54 ± .56	9.90 ± 1.76	6.12 - 11.87
21.	SUB-M^2	15.03 ± .56	10.10 ± 1.79	6.85 - 12.72

* N = 67
** N = 14, except in measurements 4, 10, & 21, where N = 13

TABLE 5

Female Chimpanzee vs. Human Tissue Thicknesses

Averages of tissue thicknesses of 15 female chimpanzees compared to Rhine, Moore and Weston's 1982 normal female human standards.

		MOORE (1981) *	PRESENT STUDY **	
		MEAN (MM.)	MEAN (MM.)	RANGE
1.	SUPRAGLABELLA	3.47 ± .26	10.97 ± 1.94	5.84 - 13.42
2.	GLABELLA	4.82 ± .27	11.05 ± 1.75	6.07 - 12.81
3.	NASION	5.44 ± .31	10.58 ± 1.41	7.62 - 12.39
4.	END OF NASALS	2.68 ± .19	9.92 ± 1.56	5.24 - 12.24
5.	MID-PHILTRUM	8.42 ± .51	10.47 ± 1.92	4.48 - 13.19
6.	UPPER LIP MARGIN	8.92 ± .64	10.08 ± 1.76	5.98 - 14.02
7.	LOWER LIP MARGIN	10.09 ± .70	10.40 ± 1.17	8.19 - 12.67
8.	CHIN-LIP FOLD	9.55 ± .48	11.24 ± 1.78	5.93 - 13.85
9.	MENTAL EMINENCE	9.89 ± .54	10.40 ± 1.48	6.84 - 12.09
10.	BENEATH CHIN	5.69 ± .49	10.92 ± 1.62	7.14 - 13.45
	LEFT SIDE			
11.	FRONTAL EMINENCE	3.61 ± .23	10.56 ± 1.59	5.50 - 2.88
12.	SUPRAORBITAL	7.07 ± .34	10.44 ± 2.55	4.21 - 13.43
13.	SUBORBITAL	5.93 ± .41	9.69 ± 2.05	5.35 - 12.82
14.	INFERIOR MALAR	12.28 ± .72	9.89 ± 1.30	7.07 - 11.93
15.	LATERAL ORBIT	10.53 ± .67	10.46 ± 1.66	6.65 - 12.78
16.	ZYGOMATIC ARCH	7.13 ± .49	10.51 ± 1.57	7.13 - 12.48
17.	SUPRAGLENOID	7.93 ± .76	10.79 ± 1.49	7.24 - 13.66
18.	GONION	9.41 ± .88	10.52 ± 2.14	5.55 - 13.69
19.	SUPRA-M^2	17.82 ± 1.34	10.47 ± 1.14	8.28 - 11.94
20.	OCCLUSAL LINE	16.97 ± 1.05	10.58 ± 1.59	6.46 - 13.09
21.	SUB-M^2	15.18 ± 1.05	10.21 ± 1.63	6.89 - 12.37

*N = 19

**N = 15 (Except in measurements 6,7,19 and 20 where N = 14 and measurement 21 where N = 3.)

TABLE 6

Spearman's Rank-order Correlation Coefficients, Females

Weight and age correlated with tissue thickness in chimpanzee females using Spearman's r test.

		x WEIGHT	x AGE	N
	AGE	+.523 **		15
1.	SUPRAGLABELLA	-.146	+.123	15
2.	GLABELLA	-.011	+.155	15
3.	NASION	+.011	-.430	15
4.	END OF NASALS	+.225	-.084	15
5.	MID-PHILTRUM	.000	+.132	15
6.	UPPER LIP MARGIN	-.459	-.743 ***	14
7.	LOWER LIP MARGIN	+.196	+.009	14
8.	CHIN-LIP FOLD	+.711 ***	-.077	15
9.	MENTAL EMINENCE	+.011	-.268	15
10.	BENEATH CHIN	+.125	-.248	15
	LEFT SIDE MEASUREMENTS			
11.	FRONTAL EMINENCE	+.725 ***	-.095	15
12.	SUPRAORBITAL	-.229	-.388	15
13.	SUBORBITAL	+.461 *	+.054	15
14.	INFERIOR MALAR	+.025	-.359	15
15.	LATERAL ORBIT	-.154	-.238	15
16.	ZYGOMATIC ARCH, MIDWAY	-.075	-.205	15
17.	SUPRAGLENOID	+.102	-.089	15
18.	GONION	-.154	-.423	15
19.	SUPRA-M^2	-.152	-.552 **	14
20.	OCCLUSAL LINE	-.125	-.363	14
21.	SUB-M_2	-.170	-.298	13

* $P < .05$
** $P < .025$
*** $P < .0025$

TABLE 7

Spearman's Rank-order Correlation Coefficients, Males

Weight and age correlated with tissue thickness in chimpanzee males using Spearman's r test.

		x WEIGHT	x AGE	N
	AGE	+.501 *		14
1.	SUPRAGLABELLA	-.433	-.215	14
2.	GLABELLA	-.007	-.171	14
3.	NASION	-.042	-.125	14
4.	END OF NASALS	-.225	-.304	13
5.	MID-PHILTRUM	-.284	-.314	14
6.	UPPER LIP MARGIN	-.301	-.022	14
7.	LOWER LIP MARGIN	-.490 *	-.237	14
8.	CHIN-LIP FOLD	-.305	-.242	14
9.	MENTAL EMINENCE	-.314	-.391	14
10.	BENEATH CHIN	-.132	-.284	13
	LEFT SIDE MEASUREMENTS			
11.	FRONTAL EMINENCE	-.345	-.378	14
12.	SUPRAORBITAL	-.446	-.026	14
13.	SUBORBITAL	-.333	-.510 *	14
14.	INFERIOR MALAR	-.530 *	-.422	14
15.	LATERAL ORBIT	-.451	-.347	14
16.	ZYGOMATIC ARCH, MIDWAY	-.481 *	-.396	14
17.	SUPRAGLENOID	-.319	-.385	14
18.	GONION	-.007	+.099	14
19.	SUPRA-M^2	-.138	-.376	14
20.	OCCLUSAL LINE	-.452	-.460 *	14
21.	SUB-M^2	-.319	-.459	13

* $p < .05$

TABLE 8

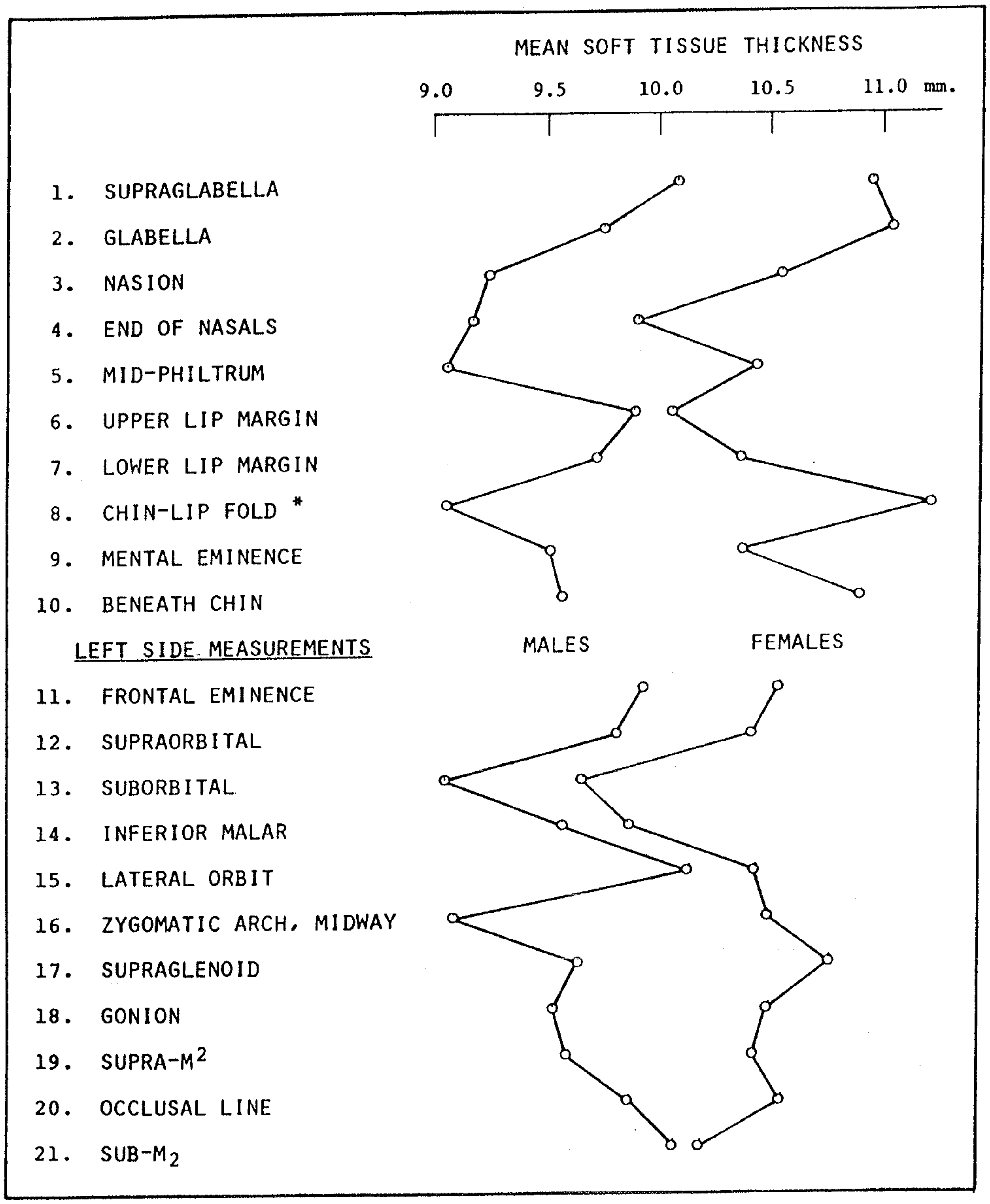
American Indian Standards

Facial tissue thickness measurements from American Indians (Mongoloids) (Moore, 1981).

Measurements	Slender MALE N = 4	Slender FEMALE N = 1	Normal MALE N = 9	Normal FEMALE N = 2	Stout MALE N = 5	Stout FEMALE N = 3
Glabella	5.87 ± .59	4.75 ± 1.19	5.83 ± .40	4.50 ± .84	6.00 ± .53	4.58 ± .68
Supraglabella	5.81 ± .56	4.00 ± 1.13	4.86 ± .37	4.50 ± .80	4.60 ± .50	4.33 ± .65
Nasion	5.75 ± .68	6.50 ± 1.36	6.86 ± .45	7.00 ± .96	6.50 ± .61	5.16 ± .79
End of Nasal	2.75 ± .43	8.50 ± .86	3.61 ± .28	2.50 ± .61	3.30 ± .38	3.16 ± .49
Mid Philtrum	7.62 ± 1.11	10.00 ± 2.23	9.63 ± .74	10.00 ± 1.58	9.20 ± 1.00	8.41 ± 1.28
Upper Lip Margin	8.37 ± 1.40	9.50 ± 2.80	9.83 ± .93	11.00 ± 1.98	9.20 ± 1.25	10.08 ± 1.62
Lower Lip Margin	9.25 ± 1.54	12.00 ± 3.08	11.02 ± 1.02	12.25 ± 2.18	8.85 ± 1.38	11.16 ± 1.78
Chin Lip Fold	8.50 ± 1.05	9.00 ± 2.11	11.50 ± .70	10.00 ± 1.50	9.70 ± .95	11.00 ± 1.22
Beneath the Chin	5.18 ± .90	8.00 ± 1.81	8.00 ± .60	4.50 ± 1.29	7.90 ± .81	7.66 ± 1.05
Mental Eminence	7.87 ± 1.18	11.00 ± 2.37	12.11 ± .79	10.00 ± 1.68	12.40 ± 1.06	13.33 ± 1.37
Left Supraorbital	7.18 ± .74	5.25 ± 1.48	9.13 ± .49	6.50 ± 1.05	8.30 ± .66	8.41 ± .85
Right Supraorbital	6.50 ± .71	5.00 ± 1.43	8.94 ± .47	5.62 ± 1.02	8.60 ± .64	8.00 ± .83
Left Suborbital	3.87 ± .90	7.75 ± 1.80	7.55 ± .60	7.00 ± 1.28	7.75 ± .81	7.08 ± 1.04
Right Suborbital	3.81 ± .93	6.25 ± 1.87	7.77 ± .62	5.62 ± 1.32	7.60 ± .83	6.33 ± 1.08
Left Lateral Orbit Inferior Zygomatic	7.87 ± 1.47	9.25 ± 2.95	12.80 ± .98	11.75 ± 2.09	11.35 ± 1.32	13.58 ± 1.71
Right Lateral Orbit Inferior Zygomatic	8.31 ± 1.58	7.25 ± 3.17	12.55 ± 1.05	11.50 ± 2.24	12.25 ± 1.42	14.08 ± 1.83
Left Zygomatic Arch Halfway	6.18 ± 1.06	6.00 ± 2.13	7.83 ± .71	7.25 ± 1.51	8.95 ± .95	9.08 ± 1.23
Right Zygomatic Arch Halfway	5.81 ± 1.19	5.75 ± 2.39	7.27 ± .79	6.75 ± 1.69	8.50 ± 1.07	8.75 ± 1.38
Left Gonion	7.68 ± 1.52	8.00 ± 3.84	13.16 ± 1.28	10.50 ± 2.72	12.30 ± 1.72	12.33 ± 2.22
Right Gonion	7.62 ± 1.96	10.00 ± 3.92	13.19 ± 1.30	10.50 ± 2.78	12.35 ± 1.76	13.00 ± 2.26
Left Supra Molar 2	14.06 ± 2.92	---- ± ----	21.94 ± 1.94	18.00 ± 4.17	19.30 ± 2.61	19.00 ± 3.37
Right Supra Molar 2	14.50 ± 2.80	---- ± ----	21.38 ± 1.88	18.12 ± 3.98	18.40 ± 2.51	19.08 ± 3.24
Left Frontal Eminence	4.75 ± .51	5.00 ± 1.02	4.22 ± .34	4.00 ± .72	4.80 ± .45	4.16 ± .59
Right Frontal Eminence	5.00 ± .55	4.75 ± 1.12	4.05 ± .37	4.00 ± .79	4.50 ± .50	4.25 ± .64
Left Interior Malar	10.31 ± 1.58	11.25 ± 3.16	13.86 ± 1.05	12.00 ± 2.24	15.35 ± 1.42	14.75 ± 1.88
Right Inferior Malar	9.68 ± 1.81	16.25 ± 3.63	13.94 ± 1.21	11.75 ± 2.58	16.30 ± 1.63	15.08 ± 2.10
Left Supraglenoid	5.93 ± 1.67	7.50 ± 3.34	8.44 ± 1.11	6.50 ± 2.37	7.95 ± 1.50	7.58 ± 1.93
Right Supraglenoid	5.81 ± 1.84	7.00 ± 3.69	8.38 ± 1.23	6.00 ± 2.62	7.70 ± 1.65	7.66 ± 2.13
Left Occlusal Line of Ascending Ramus	15.00 ± 2.30	13.50 ± 4.60	20.72 ± 1.53	17.62 ± 1.53	17.95 ± 2.06	19.16 ± 2.66
Right Occlusal Line of Ascending Ramus	15.87 ± 2.16	11.00 ± 4.32	20.80 ± 1.44	17.50 ± 3.07	18.50 ± 1.94	19.33 ± 2.50
Left Sub Molar 2	12.43 ± 2.30	---- ± ----	19.18 ± 1.53	16.50 ± 3.25	14.20 ± 2.06	15.33 ± 2.66
Right Sub Molar 2	12.50 ± 2.23	---- ± ----	19.41 ± 1.48	17.50 ± 3.16	15.15 ± 2.00	16.00 ± 2.58

Sexual dimorphism in facial soft tissue thicknesses in chimpanzees.

Figure 8: Chimpanzee Sexual Dimorphism



PART FIVE: APPLYING FORENSIC TECHNIQUES TO PALEONTOLOGICAL PROBLEMS

Chapter X

FACIAL RECONSTRUCTIONS OF HUMAN FOREBEARS

Almost since the begining of the development of facial reconstruction in the late nineteenth century, researchers have applied their knowledge to revealing the facial features of our human forebears.

In 1898 Kollmann and Buchly reconstructed the face of a neolithic woman whose skull was found at the Auvernier Station in Switzerland. Kollmann measured the tissue thicknesses of 100 women from the Auvernier region in France and used the average of these measurements as the basis for the facial reconstruction. In 1910 the anatomist Solger reconstructed the head of an adult Neanderthal based on skull of a juvenile Neanderthal from Le Moustier, France. The face of the Neanderthal from La Chapelle was modelled by the anatomist Eggeling with advice from the anthropologist Martin. Sculptor Louis Masquet worked with anthropologist Rutot to produce a series of portraits of early humans. The French anthropologist Marcellin Boule reconstructed the musculature of the La Chapelle Neanderthal which formed the basis for later reconstructions of this individual (Gerasimov, 1971:XVII).

One of these later reconstructions was carried out in 1910 by J.H. McGregor who also created likenesses of Cro-Magnon, Piltdown man, "Pithecanthropus" and others for the American Museum of Natural History. McGregor used the tissue thickness standards available at the time, which he deemed, "...invaluable in the present (Neanderthal) restoration" (McGregor, 1926).

The Russian sculptor and anatomist Gerasimov spent most of his life recreating the facial features of "The People of the Stone Age" (Gerasimov, 1964). He reconstructed Sterkfontein 5, Pekin man, the Taung child, the Steinheim woman, the youth from Le Moustier and Rhodesian man. While it appears that Gerasimov concentrated more on muscle markings and the shape of the skull to determine facial features, he did use tissue thickness measurements in some cases, especially to establish the profile. For the Taung child reconstruction, (see Figure 2) he used soft tissue thickness measurements taken from a three to five year old chimpanzee and from human children aged from three to four years (Gerasimov, 1971:69).

Much later, Shapiro tried reconstructing Olduvai hominid 5, "Pithecanthropus erectus" and "Sinanthropus pekinensis." A much smoother reconstruction of "Sinanthropus pekinensis" was carried out by Weidenreich. There is no mention of either researcher using available tissue thickness standards in their reconstructions (Shapiro, 1974).

Most recently, American artist Jay Matternes has created a new face for the Neanderthals and one-dimensional reconstructions of new fossil hominid finds. These "graphic restorations" take facial tissue thickness measurements into consideration on a minimal basis (Rensberger, 1981). Matternes incorporated non-human primate facial features into his reconstruction of Australopithecus africanus which was based on a composite chimpanzee-hominid skull (Johanson and Edey, 1981:377).

Rhine applied modern human tissue thicknesses to a chimpanzee facial skeleton and reported the result resembled a chimpanzee (personal communication; conversation of August, 1983). This suggests how some researchers have tackled the problem of relating fossil hominid facial reconstructions to their non-human primate forebears. The previous discussion of the difference in tissue thickness between Caucasoids and Mongoloids demonstrates the importance of using facial tissue thickness standards that are closely related to the reconstruction. This is the basis of the following experiment.

Chapter XI

AN EXPERIMENT IN FORENSIC PALEONTOLOGY

11.1 INTRODUCTION

Thus far, it has been assumed that some difference exists between human and chimpanzee facial tissue thickness measurements, but up until this time, no systematic assessment of the difference has been attempted.

Once the facial tissue thicknesses of the 29 chimpanzees were obtained, two sets of standards were developed based on the average tissue thicknesses of both males and females. No attempt was made to divide either group into emaciated, obese and normal subjects because of the small size of the groups and the difficulty in categorizing chimpanzee morphology on a level similar to that of humans. The largest chimpanzee in the male sample, for instance (Paleface, weight 96.4 kg.), did not have the thickest facial tissue, yet in humans there is a known correlation between body weight and facial tissue thickness (Moore, 1981).

In order to test whether the use of chimpanzee standards in reconstructing the faces of fossil hominids would make any discernible difference in their appearance, it was decided to conduct the following experiment. Two fossil hominid specimens, one robust (SK 48) and one hyper-robust (two versions of OH 5; one restored by Tobias, one by Williams) were selected for facial reconstruction. Each of the three specimens was reconstructed twice; once using modern human standards and once using chimpanzee standards. Normal male human standards were used even though the specimens were classified as being robust and hyper-robust species, and SK 48 is probably female (Day, 1977:247). Our chimpanzee standards were not divided into obese, normal and emaciated categories because of our small sample size, therefore we arbitrarily classified them as "normal". It was felt that by using male normal standards we would have the best basis for a visual comparison of all the facial reconstructions. Caucasoid, rather than Black or Japanese standards were used because they were the average of the three sets of measurements (Moore, 1981; Rhine and Campbell, 1980).

The specimens selected for this experiment were chosen because of the controversy surrounding their classification into two different species: A. robustus and A. boisei. It was thought that facial reconstructions of individuals representing these two species might illuminate some facet of the arguments presented. Furthermore, since the cranial parts composing the A. boisei specimen (OH 5) had been assembled by several researchers, including matching the cranium with different mandibles, it was hoped that facial reconstructions of this specimen might yield information concerning the accuracy of the various restorations.

Although Robinson (1960,1961) restored SK 48, a facial reconstruction has never been done, to my knowledge. In this experiment, the SK 48 cranium was restored and matched up with a restored mandible - SK 23. The completed facial reconstruction was then compared to facial reconstructions based on two OH 5 restorations; one by Tobias and another by Williams, and similarities and differences were assessed.

11.2 SWARTKRANS I RECONSTRUCTION

11.2.1 Description of Original Specimens

The Swartkrans I and II reconstructions are based on Wenner-Gren cast W-GF No. F-SK16 of SK 48 found in Transvaal, South Africa by Broom et al. (Broom and Robinson, 1952). The Swartkrans remains were found in cave breccia and have been dated to as early as 2.3 million B.P. (Grine, 1981).

SK 48 is considered to represent an adult female, based on an almost complete dentition. The cranium is crushed and incomplete and shows warpage, although some parts of the sagittal crest are still present (Day, 1977:245). The cranium was matched up with the contemporaneous SK 23 mandible. It is virtually complete and has been assessed as fully adult female. The assessment is based on its size in relation to other finds (Day, 1977:248).

11.2.2 Method and Materials

To restore the remains of SK 48 to what may approximate its original state, the Wenner-Gren cast was re-cast in plaster. From this replica, parts were removed and other parts built up: The compressed nasals, right orbital ridge and zygomatic arch were re-built and a balance achieved between the compressed left malar and the warped right malar. The maxilla was re-aligned and missing teeth, modelled on the basis of the existing ones, inserted. The posterior part of the cranium was built up to approximate its original position and missing parts of the sagittal crest put in place (see Robinson, 1961). A satisfactory, although still slightly asymmetrical, result was achieved (see Figure 9).

The restored cranium was matched up to the SK 23 mandible. Unfortunately, the mandible has been badly warped and crushed which made its restoration difficult. The cast I used was from the University of Pennsylvania Museum.

To restore SK 23, the cast was cut through at the midline and also at an angle through both sides of the body just behind the third molars. The four parts were then supported in plasticine and re-aligned into a position that took the compression of the incisors into consideration. Plaster was poured into the spaces and into the centre of the mandible to secure it. Once dry, the excess plaster was shaved away. The result is shown in Figure 10. The resultant restoration fit the restored SK 48 cranium very well, even though no attempt had been made to assure a good match.

This mandible and cranium combination is quite different from the composite individual described by Day (1977:254) formed by matching the SK 847 cranium up to the SK 15 mandible. The latter has a very heavy supraorbital ridge, and more prominent and angulated nasal bones. According to Day, the ramus of the mandible "...must have been quite squat and quite different in morphology from the tall A. robustus mandible (SK 23)" (ibid.).

The SK 48 cranium and the SK 23 mandible were plastered together to form a firm unit that could withstand drilling. The whole was then oriented in the Frankfurt plane before being mounted on a stand. Holes were drilled into the plaster at the 21 points on the face as illustrated in Figure 1. Wooden dowels marked with measurements corresponding to facial tissue thicknesses of normal human males were inserted into the holes and glued in place (see Figure 11). The teeth and gums were painted to give a life-like appearance to the model. 2.2 mm diameter plastic eyes (based on size determined from volume of orbits - see chapter on facial reconstruction methods) were placed in position and held with plasticine. Bear eyes were used since no plastic chimpanzee eyes were available; comparison of photos of chimpanzee eyes with other animals showed bear eyes to be the best substitute.

Nasal cartilages were modelled, based on both human and chimpanzee facial anatomy, and inserted in the nasal cavity. Portions of the facial musculature were reproduced and applied. Reconstructing the facial musculature is considered to be a superfluous step in facial reconstruction by some practitioners (especially Gatliffe, 1979), but thought to be a worthwhile step by others (Neave, 1979) and is relied upon solely by still others (i.e. Gerasimov, 1971; Matternes in Johanson and Edey, 1981:379). Considering the age and condition of the specimens upon which I was working, I thought every possible step should be taken to assure as accurate a reproduction as possible. Therefore I assumed that the addition of the musculature would be a positive contribution to this outcome.

The muscles applied to the reconstructions in this experiment were the masseters, orbicularis oculi, orbicularis oris, levator anguli oris, levator labii superioris, sternomastoid and trapezius. The facial "muscles of expression" were applied to provide natural facial contours. The masseters helped define the massive chewing muscles that characterize the australopithecine face. The trapezius muscles gave an impression of the size and positioning of the neck and the temporalis fleshed out the sagittal crest. The shape and form of these muscles were derived primarily from Raven's Anatomy of the Gorilla (1950), with reference to human anatomy textbooks (see Basmajian, 1981; Greischeimer and Wiedeman 1972) whenever necessary (see Figure 12).

After the muscles were set in place, the remaining facial tissue was applied up to the tops of the thickness markers as indicated. The "skin" was a 2 brown: 1 black plasticine mixture kneaded together. The result was a racially intermediate skin tone, since the colour of these individuals is unknown. The "skin" was applied in patches to the tops of the wooden pegs or markers and the patches joined smoothly, much as described by Wilder and Wentworth (1918:104). Another technique of distributing the "skin" is shown in Gatliffe and Snow's 1979 article on facial reconstruction; this is a "latticework" arrangement, bridging the gap from one marker to another.

At this stage in the facial reconstruction, the face is covered but almost featureless. This illustrates the difficulty posed for non-artist practitioners in producing a life-like visage from what is, at this point, a blob of amorphous tissue.

As outlined in the chapter on "Facial Reconstruction Guidelines", there are few, if any, markers on the skull that allow for the exact interpretation of size and location of the soft features- eyes, nose, ears and lips - on the face. It is even more difficult to extrapolate location when working with non-humans for whom there is no living correlate. It was decided, therefore, in instances where the features were almost completely hypothetical, that both human and chimpanzee features would be taken into consideration. Thus, the ears of the Swartkrans individuals are human in form but chimpanzee in size. The nose is also half chimpanzee, half human; chimpanzee in size but half-human in shape. The form follows that on individuals with broad, flat malars, i.e., Old or New World Mongoloids. Guidelines for human noses exist and are described in the appendix. Nose size and shape is, in general, dependent upon size and shape of nasals, nasal spine and size of nasal aperture. The nasal apertures in both OH 5 and SK 48 are approximately the same size. Tobias (1967:113) has suggested OH 5 has nasal characteristics in common with both <u>Pan</u> and <u>Homo</u>. The mouth is more human than typically chimpanzee in form, basically following the dictates of the guidelines concerning reconstruction of this feature.

11.3 SWARTKRANS II RECONSTRUCTION

The facial reconstruction process using chimpanzee standards did not differ markedly from that using modern human measurements, with the exception of the following:

When the chimpanzees measurements were being taken with ultrasound, it was difficult to pinpoint the location of the second molar, so M1 measurements were used. The nasal cartilages, in all the facial reconstructions were modelled on chimpanzee cartilages; i.e., barrel-shaped (Schultz, 1956), because this seemed most appropriate for the flat nasal bones. The length of the nose, however, was calculated to be twice the length of the nasal bones, instead of three times, as in modern humans. If the latter measurement had been used, the nostrils would end up just above the lips! Nasal width was the same used for modern humans. The ears were reconstructed to be somewhat larger than human: the size and shape of the skulls seemed to justify this.

No attempt was made to increase the tissue thickness measurements at points 19, 20 and 21, as suggested in the ultrasound facial reconstruction experiment. The solution to the problem in this area has yet to be solved by CAT scans.

All the reconstructions included sagittal skin pads, a feature said to be co-incident with the occurrence of the sagittal crest (Montagna and Yun, 1963; Straus, 1942). Sakka (1978) proposed that KNM ER-406 had a sagittal skin pad which, "..enlarges at the end to cover the parieto-occipital trigone." Without this pad, the reconstruction is left with a large "cleft" in the centre of the cranium, caused by the two large temporalis muscles meeting at the crest. These muscles, a typical primate feature, do not appear to have ever been taken into consideration before in a facial reconstruction of a fossil hominid (see Figures 13 and 14 for completed reconstructions).

11.4 ZINJ I RECONSTRUCTION

11.4.1 Description of Original Specimen

The reconstructions of Zinj I and Zinj II were based on Carolina Biological Supply Company cast number 28-1175, *A. boisei*. The company's description reads:

> "The frontal and cranial portions were cast from remains found at Olduvai Gorge...the lower jaw was cast from a specimen found at Peninj...(the lower jaw used in the reconstruction has since been shown to be too apelike)."

The model upon which the lower jaw was based remains obscure, since the jaw does not appear to be similar to any of the ones created by either Leakey (see Day, 1977:136) or Tobias (1967:Pl.42) and the measurements do not match those of the Peninj (also called the Natron) mandible.

The A. boisei specimen used in this experiment is OH 5 because it is one of the most complete specimens and casts of it are readily available. The original cranium was found eroding out of a slope in site FLK by Mary Leakey at Olduvai Gorge in Tanganyika, East Africa. The find excited the scientific community for several reasons: It represented a relatively large and almost complete cranium and it was found in a context which suggested a great deal about hominid behaviour:

> "The very great difference between the condition of the hominid skull and that of the animal bones on the same living floor (all of which had been deliberately broken up) seems to indicate clearly that this skull represents one of the hominids who occupied the living site, who made and used the tools and who ate the animals" (L.S.B. Leakey, 1959).

The latter comment is still hotly debated, as is L.S.B. Leakey's assignment of the specimen to a new species. According to Leakey,

> "...the new skull from Olduvai, while clearly a member of the Australopithecinae clearly differs from both Australopithecus and "Paranthropus" much more than these two genera differ from each other" (ibid.).

Despite their physical differences, Tobias (1976:407) has lumped A. robustus and A. boisei into one superspecies. Rak (1983) used cranial data for phylogenetic assessment of the African hominids. He concluded that A. boisei is a more derived sister taxon of A. robustus:

> "A. boisei is the manifestation of the end of an evolutionary series in which A. robustus represents one stage - the placement of these two species in the genus Australopithecus seems to incorporate best the notion of the morphological distance between them" (1983:121).

These latter concerns will be addressed more fully in the conclusions to this chapter.

11.4.2 Method and Materials

The plastic Carolina Biological Supply Company cast was re-cast in our laboratory. The result was a hard plaster model into which holes could be drilled. Wooden pegs marked with depths according to the same normal male human standards used previously were inserted. Musculature, eyes and tissue were then added. Essentially the same method was followed in this reconstruction as that used to reconstruct the Swartkrans I individual. The only exception to the procedure was that there were no modifications made to the cast and the jaw and cranium were cast as one unit. The result is shown in Figure 15.

11.5 ZINJ II RECONSTRUCTION

The facial reconstruction on the Carolina Biological Supply Company cast of OH 5 using male chimpanzee standards was carried out using the same method as for Swartkrans I. A comparison of Zinj I (human standards) and Zinj II (chimpanzee standards) is shown in Figure 16.

11.6 ZINJ III RECONSTRUCTION

11.6.1 Description of Original Specimens

Mary Leakey was the first to assemble OH 5 from several hundred fragments. The specimen is considered to represent a young adult male (Tobias, 1967:77). Tobias (ibid.:8) produced a later restoration which included the additional parts recovered subsequent to the 1959 Mary Leakey restoration.

More than one researcher has wondered how faithful Tobias' restoration of OH 5 is to the original. Certain features of the restoration, i.e., the cranial capacity and facial height, have made OH 5 an anomaly, even among *A. boisei* specimens (see Tobias, 1967:79 and Rak, 1983:54).

L. Williams of the Department of Anthropology, Lakehead University, has re-assembled the face of OH 5 from the pieces of the Wenner-Gren cast (W-GF No.s F-OL15-F-0L19). The new restoration has included shortening the face by re-assembling the pieces forming the right sub-orbital region and the left and right malars. The left lateral orbital rim was moved up, allowing the pieces forming the malars to also be moved up. Williams felt the teeth of OH 5 protruded too far from their sockets: The incisors were repositioned, thus shortening their height and producing a Curve of Spee absent in the original restoration.

The result (see Figure 11) is a much more prognathous individual than that restored by L.S.B. Leakey (1959). The lack of prognathism in OH 5, according to Tobias, "contrasts rather sharply with that of other Australopithecines" (Tobias, 1967:117). This recent realignment of the face of OH 5 by Williams decreases the superior facial height (nasion-alveolare) to 91.23 mm from Tobias' estimated 111.5 mm (1967:107). The facial height is now much closer to that of my restored SK 48; that is, 85.2 mm. According to Tobias, the facial height of the unrestored SK 48 is 80.0 mm (ibid.).

11.6.2 <u>Method and Materials</u>

The Williams restoration was cast in dental stone in preparation for drilling. Since no mandibular remains of OH 5 have ever been found, I decided to use the Peninj specimen (Wenner-Gren cast W-GF no. F-NAI). In 1964 this almost complete mandible with teeth was found at Peninj near Lake Natron in Tanzania, 50 miles from Olduvai Gorge by a member of the G. Isaac expedition (Leakey, L.S.B. and Leakey, M.D., 1964). Defined by L.S.B. Leakey as an <u>A</u>. <u>boisei</u> specimen, it has been dated at about 1.5 m.y. B.P. and is considered to be contemporaneous with OH 5 (Tobias, 1976:404). As mentioned previously, the Peninj mandible was L.S.B. Leakey's latter choice in his reconstruction of OH 5. The mandible is an excellent match, with the exception that the fossae. The mandible was affixed to the cranium and the composite skull oriented in the Frankfurt plane and mounted on a stand. Facial reconstruction, using normal male human standards, followed the procedure outlined previously. The result is Zinj III.

11.7 ZINJ IV RECONSTRUCTION

A second set of casts of the Williams reconstruction and the restored Peninj mandible were made. These were similarly oriented and mounted and musculature and facial tissue thickness based on male chimpanzees applied. This reconstruction is called Zinj IV and is shown in Figure 16 alongside Zinj III.

11.8 RESULTS

11.8.1 Reconstructions Based on Human Standards

The facial reconstructions based on modern human male tissue thickness standards were compared. These were Zinj I, (Carolina Biological Supply Company cast); Zinj III (Williams restoration) and Swartkrans I (Wenner-Gren cast)(see Figure 18).

It was theorized that facial reconstructions of these individuals might shed some light on the accuracy of the original restorations, and may contribute to some understanding of their species allocation by various authors.

understanding of their species allocation by various authors.

The description of the Carolina Biological Supply Company cast of OH 5 noted that the mandible used in this restoration had been disregarded because it was "too apelike". The failure of this "apelike" mandible in their restoration is readily apparent in my facial reconstruction of Zinj I: The face slopes dramatically inwards from the broad shelf of the malars, giving the face a very triangular shape. On the facial reconstruction from the Williams restoration (Zinj III), the proportions of the face are much more well-balanced, although the mandible appears to be set too far forward, giving a "lantern-jaw" appearance. The mandible does, however, fill out the lower part of the face to a much greater degree than the one created by the Carolina Biological Supply Company for their cast.

On both facial reconstructions, the cranium, with the muscles of the sagittal crest rebuilt, appears somewhat cap-like, almost pointed. It does not visually integrate well with the rest of the cranium.

The eyes in all three reconstructions are close-set, like those of gorillas and chimpanzees. The mouths are based on modern human facial reconstruction guidelines, and as such, are perhaps too human. This feature should be remodelled to form some intermediate between human and primate. With few bony markers from which to extrapolate, the mouth must remain hypothetical.

The most satisfactory facial reconstruction, from the point of view of well-balanced features, is Swartkrans I. This result indicates that the SK 23 mandible, as suggested by my restoration, is a very good match for the cranium, and may, in fact, be quite close to the original in structure and appearance. The masseter area, however, is still quite hollow, suggesting either inaccurate restoration of the mandible or tissue thickness standards that are too small for this area. R. Neave (personal communication, August 4, 1984) has noted that his facial reconstructions still have a "cadaverous" appearance in the masseter area, even when he is using the most up-to-date measurements available. This may be due to the sampling problem described in an earlier chapter, or it may indicate that human tissue thickness measurements are inappropriate on these subjects. In each of the three reconstructions based on human standards, I did not model masseters that exceeded the tissue thickness depths in that area (points 18 and 19, Figure 1) even though the facial anatomy may have dictated otherwise. To have done so would have biased the results.

11.8.1.1 Reconstructions Based on Chimpanzee Standards

In general, the facial reconstructions using chimpanzee tissue thickness measurements (Figure 19). resemble chimpanzees more than those using modern human measurements. This is the result of the thicker measurements in the forehead and orbital regions. This thicker tissue makes the glabella appear to be more prominent and insets the eyes to a greater degree than the former standards. It also makes the nose less prominent. This is especially evident in the reconstruction of Swartkrans II. The Swartkrans and Williams (Zinj IV, Swartkrans II) reconstructions based on these standards are more successful than that of Zinj II reconstructed on the Carolina Biological Supply Company cast. The reason for this is the same as in the case of the human standards: The mandible is not suited to the restoration. In the chimpanzee-based reconstruction, the face has an even more triangular appearance than the human-based one, due to the heavier tissue thickness in the upper facial region.

These results emphasize the importance of using the correct standards for the facial reconstruction, since appearance can vary considerably depending upon the variation and size of these figures. This also suggests some difficulty in obtaining an accurate reconstruction using only muscle markings to estimate facial features.

On the original, the teeth have been oriented almost vertically in their sockets even though this is not suggested by the formation of the alveolus nor by the Tobias restoration. The mandible must have been modelled on that of a gorilla or a chimpanzee because the body similarly curves inward. The lower ramus lacks the typically primate everted gonial angle; therefore this area must have been copied from the Peninj mandible which lacks such a pronounced feature. On SK 23 there is an actual inversion of the gonial angle, although this is probably due to post-mortem compression.

This evidence suggests that the mandible built by Tobias and Clarke for OH 5 and shown in plates 41 and 42 of Volume II of Olduvai Gorge was indeed based on gorilla features:

> "The degree of development of the masseteric impressions of OH 5 far exceeds that in other australopithecines and is more comparable with conditions in the gorilla" (Tobias, 1967:210).

It is the construction of this "gorilla" mandible which has in part contributed to the triangular shape of Zinj I's face. The other contributing factor is discussed further on in this section. The Zinj II facial reconstruction fails for much the same reasons as that of Zinj I, although the Peninj mandible is much more suited to this reconstruction than the one articulated with the Carolina Biological Supply Company cranium.

face. The other contributing factor is discussed further on in this section. The Zinj II facial reconstruction fails for much the same reasons as that of Zinj I, although the Peninj mandible is much more suited to this reconstruction than the one articulated with the Carolina Biological Supply Company cranium.

By several indications, it appears that the cranium of OH 5 was inaccurately restored. In 1960, shortly after the discovery of OH 5 by Mary Leakey, L.S.B. Leakey and J.T. Robinson debated whether OH 5 should be classified as *A. robustus* on the basis of, for one fact, the position of the sagittal crest. L.S.B. Leakey positioned it further back on the cranium in his restoration than was typical for *A. robustus* (Robinson, 1960: L.S.B. Leakey, 1960). This is a clue to the problem inherent in the Leakey/Tobias restorations; the posterior part of the cranium of OH 5 has been fitted to the anterior portion leaving a large gap in between. The result is a cranial capacity calculated to be similar to that of the largest estimated for the australopithecines, with the exception of an hypothetical Taung adult (ibid.:79). When the supra-orbital height index is taken, however...

> ".... OH 5 falls to the top of the pongid range. It differs appreciably from *australopithecus* and the *Hominidae* in possessing a calvaria which rises but little above the upper margin of the orbits. This is a feature which OH 5 shares with *Paranthropus*" (Tobias, 1967:17).

The Leakey and Tobias restorations of OH 5 have been based on joining the facial to the cranial portion at the pterygoid plate (ibid.:8). The reader must bear in mind, however, that this fit occurs only because of the way all the other parts have been joined by Leakey and Tobias. I believe that the anterior and posterior portions of the OH 5 cranium should be assembled so that they are closer together. Based on my Swartkrans restoration, I estimate the sagittal crest should be moved approximately 16 millimeters further forward. The result would be a more "rounded" cranial vault similar to that suggested by Robinson (1960) for this specimen. This rearrangement would, in effect, shorten the area of attachment on the zygomatic arch and thus infer a smaller mandible by association. The projected mandibular height for a Peninj mandible adjusted to fit the Williams restoration is approximately 101.00 mm as opposed to 106.2 mm for Tobias' restoration (op. cit., Pl. 42). It is still puzzling, however, that this contemporaneous A. boisei mandible in its original state falls so short of this measurement.

It was mentioned previously that SK 48 had been assessed as female, even though it had a typical male feature, the sagittal crest. This Swartkrans specimen was reconstructed using male standards so that an unbiased comparison could be made with the two other specimens.

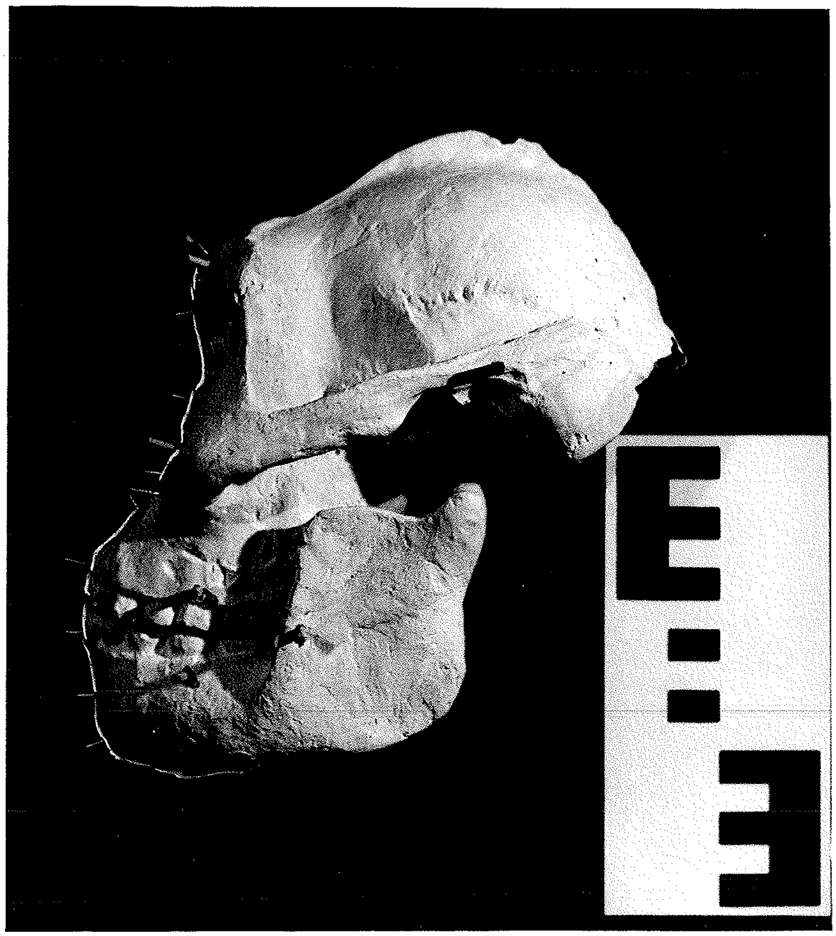
identifying sexual dimorphism in hominids deserves more than a cursory comment, however, and will be discussed in more detail in the next chapter.

(l) Cast of original Swartkrans find (SK 48) and (r) author's restoration.

Figure 9: Comparison of SK 48 Restorations

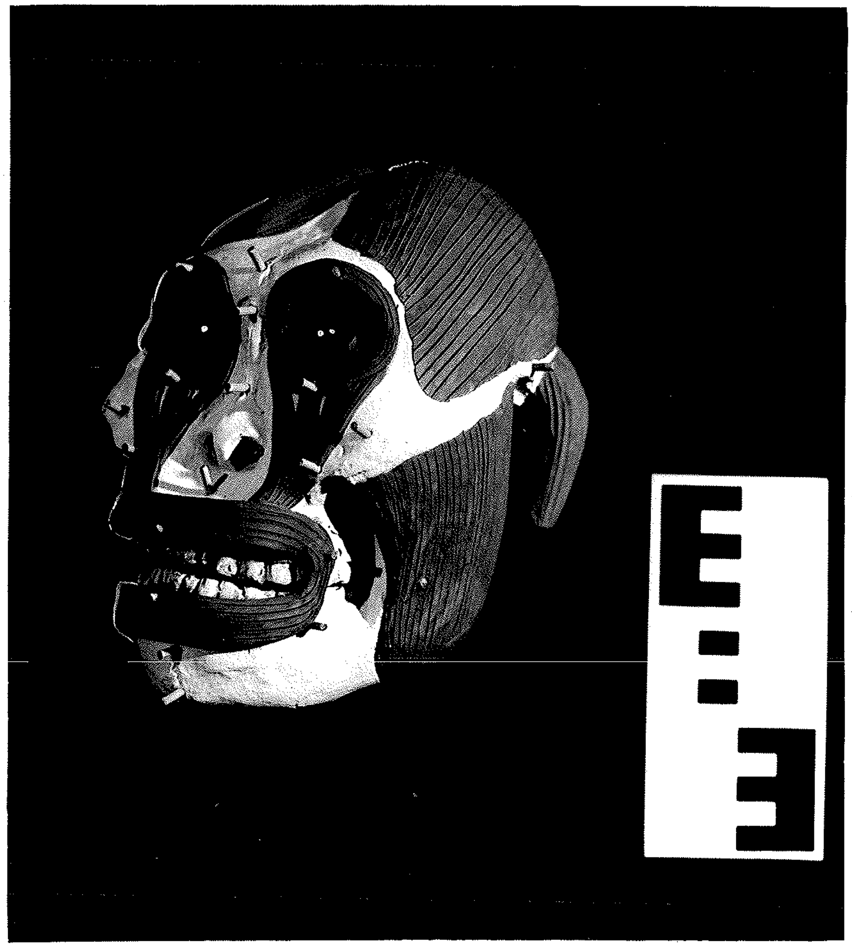
A comparison of the mandibles used in the facial reconstructions. (l) to (r) Wenner-Gren's Natron mandible; Carolina Biological Supply Company's mandible for Olduvai hominid 5; University of Pennsylvania SK 23 mandible; author's restoration of SK 23.

Figure 10: Comparison of Mandibles Used in the Reconstructions



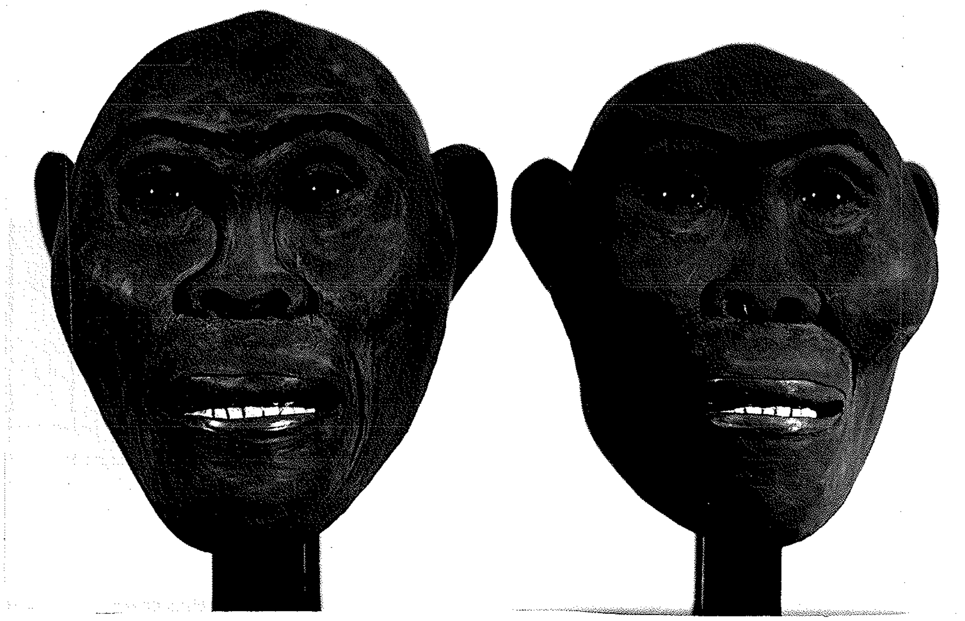
Zinj IV with pegs in place to mark tissue depths. Shortfall in mandibular height of the Natron mandible is visible.

Figure 11: Cast of Williams Restoration of OH 5



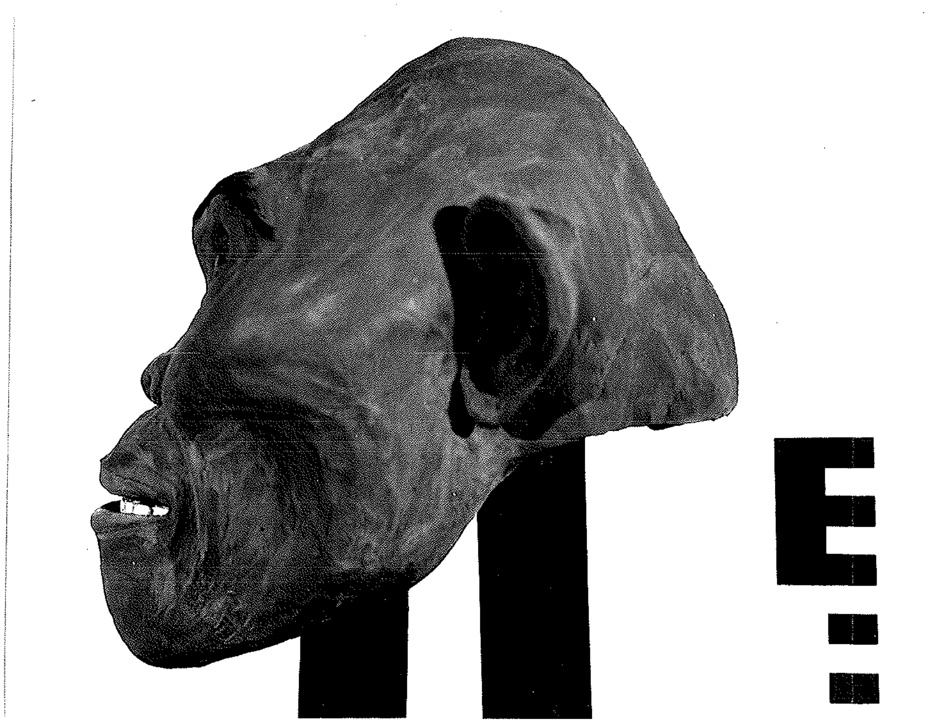
Zinj IV showing musculature used in the facial reconstructions.

Figure 12: Reconstruction of Facial Muscles



Swartkrans I and II based on reconstructed cranium and mandible. (r) is based on chimpanzee standards, (l) on human.

Figure 13: Frontal View of Swartkrans I and II



Side view of completed reconstruction of Swartkrans I.

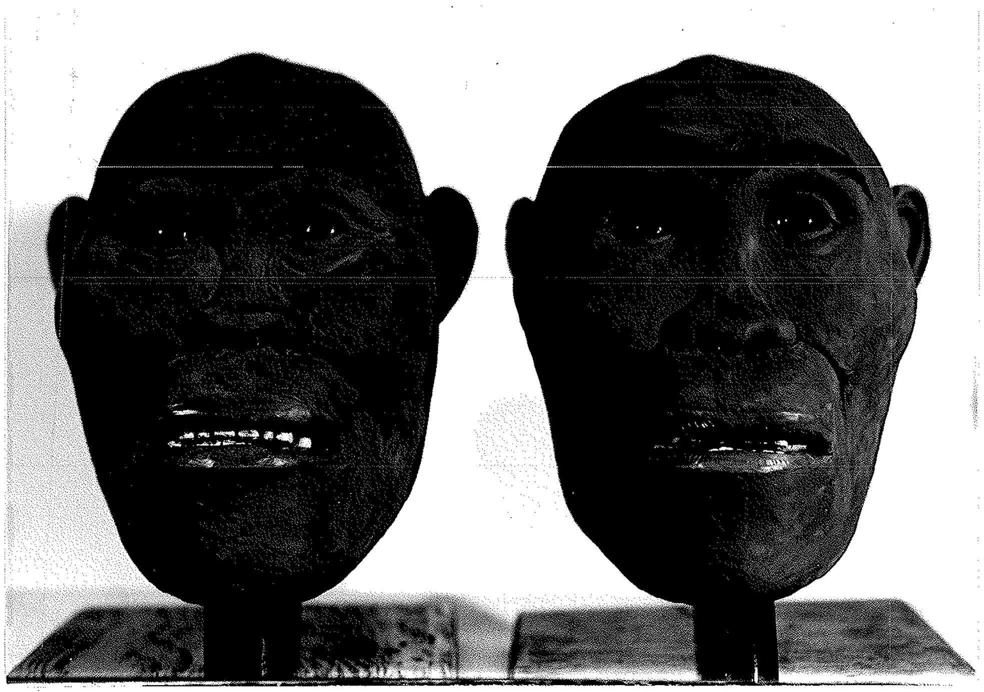
Figure 14: Side View of Swartkrans I

Carolina Biological Supply Company Cast of Olduvai hominid 5 derived from L.S.B. Leakey and P. Tobias restorations.

Figure 15: Carolina Biological Supply Company Restoration of OH 5

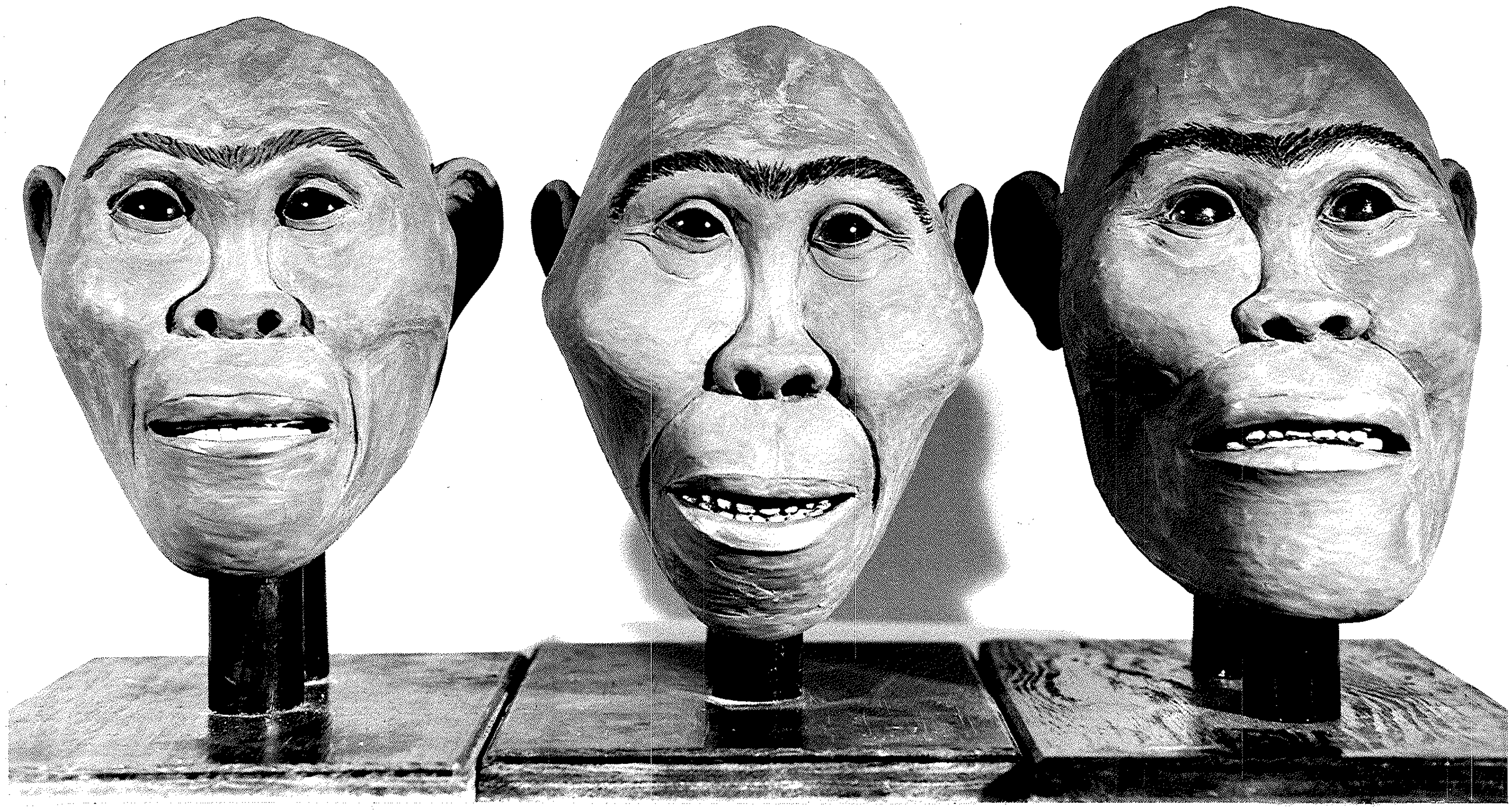
Zinj I and II, reconstructed on the Carolina Biological Supply Company cast. (r) is based on chimpanzee standards, (l) on human standards.

Figure 16: Comparisons of Zinj I and II



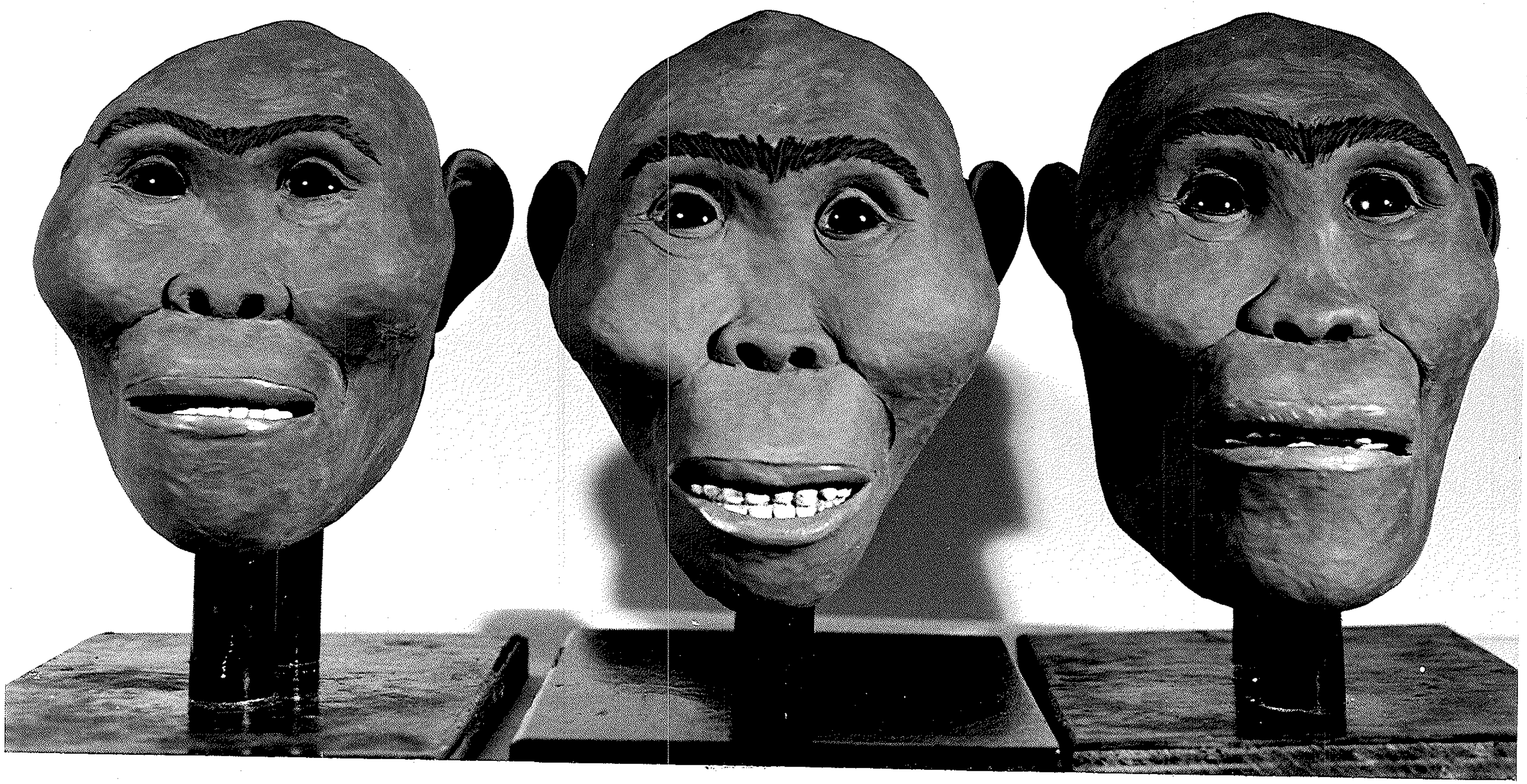
Zinj III and IV, reconstructed on the Williams/Wenner-Gren cast. (r) is based on chimpanzee standards, (l) on human standards.

Figure 17: Comparisons of Zinj II and IV



Comparisons of reconstructions based on normal human male (Caucasoid) standards (l) to (r): Swartkrans I, Zinj I and III.

Figure 18: Reconstructions Using Human Standards



Comparisons of reconstructions based on chimpanzee standards; (l) to (r) Swartkrans II, Zinj II and IV.

Figure 19: Reconstructions Based on Chimpanzee Standards

Chapter XII

IDENTIFICATION OF SEXUAL DIMORPHISM IN HOMINIDS

In the chapter "Obtaining Chimpanzee Facial Tissue Thickness Standards" the degree of sexual dimorphism in chimpanzees and humans was cited. In relating these two primates to their possible intermediate relative - Australopithecus - the question of sexual dimorphism arises: Could SK 48 have been the female counterpart of OH 5 if OH 5 is really, as Robinson suggested, a robust, rather than an hyper-robust specimen...? "No grounds appear to exist for regarding this form as anything other than a typical Paranthropus" (Robinson, 1961).

In 1919, Bonnet asserted, with little skeletal evidence to back him, that sexual dimorphism in hominids becomes, "...ever more pronounced the more primitive the form" (ibid.:23). Studies of non-human primates have demonstrated the marked sexual dimorphism in terrestrial animals; male gorillas, for example, can be double the size of females (Wood, 1976). According to Brace (1972) humans do not conform to this degree of dimorphism, presumably because of the intervention of culture in altering selective forces that shape the human form: Thus, "...it should also follow that the earlier the hominid, the less effective was the cultural solution to obstacles to survival imposed by the environment."

Brace's basic contention is that sexual dimorphism may account for most of the differences evident in the Swartkrans sample, and between samples such as Sterkfontein as well. Therefore it is wrong to split these individuals into different species:

> "The range of variation among fossil hominid remains at Swartkrans (the richest australopithecine site of them all) is greater than the average difference between the fossil hominids of Swartkrans and of Sterkfontein or of any other site that has produced enough specimens so that a range of variation can be estimated. It appears to me that the within population variation at Swartkrans was greater than that found at any subsequent stage of hominid evolution. This probably reflects an adaptive sexual dimorphism comparable to that of the non-human primates. Perhaps all the extremes of variation between as well as within the populations of early hominids can be accounted for by sexual dimorphism" (ibid.).

Pilbeam and Zwell (1972), from a study of *Gorilla gorilla* found that canine and P3 measurements yielded data useful in determining sexual dimorphism in hominids. As expected, their results showed little sexual dimorphism in modern humans and considerable sexual dimorphism in *Australopithecus*.

After dividing their sample of australopithecines into distinct time bands, the authors found that the coefficients of variation increased up to where, in the 1.5 - 2.0 m.y. time band, they doubled those of *Homo* sapiens and tripled those of Gorilla gorilla. They concluded; "...the variability within the 1.5 - 2.0 million year hominid sample is considerably greater than that of any living hominoid species and thus should be considered as representing more than one species."

Whether this analysis is conclusive is open to question. The authors emphasize that the South African faunal materials are not reliably dated. Brace (1972) points out some problems with sampling these sites:

> "The three complete and one almost complete mandibular dentitions from the Transvaal differ more than do the means of populations to which they belong. This reinforces the view that the difference between a robust and a gracile population is largely due to chance, the chance of which specimen is preserved. As it happens, the three Swartkrans mandibles are larger on the average than the rest of the Swartkrans material while the one complete Sterkfontein mandible is decidedly smaller than the average for that site. The range of variation present among specimens from a single site, as found in the contrast between SK 12 and SK 74, finds no parallels in more recent hominids. The persistence of both large and small individuals at Omo and in the East Rudolf area supports our view that sexual dimorphism characterized australopithecine populations for a long time."

Wolpoff found that, based on gorilla studies, canine breadth was the most accurate measure of non-human primate sexual dimorphism:

> "The frequency distributions of canine breadth in gorillas and baboons are bimodal. There is virtually no overlap between the male and female distributions, and an attempt to use canine breadth to sex individual specimens would be extremely accurate" (Wolpoff, 1976a).

Applying this factor to the South African australopithecine sample, he found...

> "...the frequency distribution of canine breadths appears strongly bimodal, with virtually no overlap between the modes. The bimodality occurs whether the South African samples are broken into gracile and robust groups, or considered all together."

Wolpoff then used his results to divide his sample into male and female to ascertain whether he could find any more dental characteristics that were sex-related. He found that posterior tooth dimensions, beginning with P4, were greater in males:

> "I believe that the pattern suggests a great difference in female and male australopithecine body size, with the significant amount of posterior dimorphism resulting from the fact that the much larger males must masticate many more calories."

Wolpoff's analysis also demonstrated that tooth size variation in specimens of the same sex revealed, "...far too much variation to conceivably run in one biological population." This led him to believe that australopithecine populations were probably polytypic (Wolpoff, 1976a).

In another study, Wolpoff analyzed specimens previously sexed by others to see if combining canine breadth with estimated sexing-error step-function gave results that agreed with their conclusions:

SK 48 had originally been assessed as female by Broom and Robinson (1952:10), noted Wolpoff;

> "...in spite of the low sagittal crest found on SK 48. While sagittal crests are commonly found with males in primates such as gorillas, females with crests are not unknown. That cresting is somewhat indicative of sex is due to the fact that crests result from the relation of the jaw musculature and cranial size" (Wolpoff, 1976b).

Wolpoff's new analysis also sexed SK 48 as female:

> "SK 46 and SK 48 came out as different sexes, although neither determination is absolutely certain. This seems unusual in view of the similarities between the crania. They were both sexed initially as females in view of comparisons with the much larger SK 12. That they might be different sexes is suggested by the extremely larger parietal dimensions of SK 46...I believe it possible that they are both the same sex, and I take this result to indicate the presence of some overlap between male and female distributions" (ibid.).

In 1980, Brace and Ryan considered the possibility that male/female tooth differences "...are specifically adaptive in and of themselves. Since the dentition is primarily a food-processing device, it is worth considering whether male/female differences in size are related to male and female dietary differences."

According to the authors, males' growth is apparently more affected by dietary deprivation than that of females. In addition, a high degree of dimorphism could be the result of maximization of genetic potential through effective resource exploitation. Could this account for the "polytypic" character of the australopithecines suggested by Wolpoff?

> "Another direct body of evidence suggesting polytypism is in the indications of dietary variation shown by the different tooth wear patterns. These differences crosscut particular sites, and seem to have nothing to do with any of the proposed taxonomic schemes. The different wear patterns strongly suggest different dietary preferences which might be among the causes of population differences (Wolpoff, 1976a)."

Brace and Ryan (op. cit.) argue that sexually dimorphic physical effects are much more likely to appear in a group where the subsistence base is single-crop agriculture rather than hunting and gathering.

In contrast, Wolpoff (1980:96) has stated that, "...hominid adaptability argues against a single dietary specialization in the early hominids." He provides a striking example of the effect of different diets on dentition in omnivorous bears and the bamboo - eating giant panda. The panda molars show transverse expansion and the pre-molars have undergone addition and size expansion.

If differing diets produce different dentitions and males and females have different dentitions, then, according to Brace and Ryan's picture of life in the middle and upper Pleistocene, males would exhibit the pattern of wear typical in omnivores or carnivores and females exhibit that of herbivores or omnivores. This is, in effect, the opposite of what is found (Frayer, 1980).

Brace and Ryan, (op. cit.) emphasize that it is the selection for a large male physique adaptive to big-game pursuits which maintained sexual dimorphism in a population for as long as it was practised. This view has been expanded by Frayer to include sex-role specialization as the basis for sexual dimorphism. He found that, in the Mesolithic, as both sexes began to share labor, sexual dimorphism decreased.

12.1 CONCLUSIONS

The problem of sexing the hominid remains found in many of the African sites has been tackled only recently. The problem was raised by the controversy surrounding the sexing of the remains at Swartkrans and Sterkfontein - one site was said to have yielded females only, and the other males (see Brace, 1972).

The lack of any substantial sample of the usual reliable indicators such as pelves, has daunted many researchers. There is an abundance of dental remains, however. Many crania exist, but most are crushed and broken. Some, like SK 48, exhibit both male and female traits.

Wolpoff (1976a, 1976b, 1980), has attempted to devise a method of sexing hominid skeletal material on the basis of a single morphological trait - width of the canine. Using this technique, Wolpoff assigned the same sex to SK 48 as in the original analysis by Broom and Robinson, despite the presence of a typically male trait - a sagittal crest.

Wolpoff (1976b) noted, however, that SK 48 was at the top of the range for female canine breadth. While sagittal crests are found almost exclusively in modern male primates, the same feature in hominids could be due to differences in body size or diet. According to Wolpoff (1975) sagittal cresting occurs in both gracile and robust South African samples, and is related to body size and diet. There is a general concurrence among the authors mentioned that both of these factors probably contributed to the high degree of sexual dimorphism that existed at this time in the populations sampled.

It appears unlikely that Sterkfontein and Swartkrans were single-sex populations. Current research suggests that the australopithecines were probably polytypic. The degree of sexual dimorphism present probably exceeded that of the gorilla. This degree of dimorphism, which is far greater than that of modern humans, may have been the reason for erroneously assigning individuals to several species. On this basis, Brace (1972) suggests; "A male from one site compared to a female from another site may be taken to represent a generic or a specific distinction if the range of variation in Homo sapiens is used as the standard of reference." This may be exactly what has happened with the assessment of OH 5 and SK 48. Further research on sexual dimorphism may confirm that they are both just male and female specimens of the same species, as suggested by their facial reconstructions.

PART SIX: FUTURE DIRECTIONS IN FACIAL RECONSTRUCTION

Chapter XIII

GENERAL CONCLUSIONS

In this thesis, I set out to try and improve current practices in facial reconstruction, particularly as they pertain to the three-dimensional method. In the process I found that, even though, according to Rhine, "...there remains a reservoir of reluctance to accept the method as fully validated" (Rhine and Campbell, 1980) some very good results were being achieved even when technical precision was less than optimal. By the latter I refer to the use of rubbers, rather than pegs, to indicate tissue thickness depths; the employment of casting techniques that do not always produce perfect copies of the original; the use of outdated tissue thickness measurements; the creation of skulls from x-rays. A good example of the "success" of practitioners using the aforementioned techniques is the high percentage (60%) of identification achieved by Betty Gatliffe in her facial reconstructions of homicide victims (Rensberger, 1984).

I believe that my tests of facial reconstruction of fossil hominids have demonstrated the importance of using the most appropriate set of standards for the individual being reconstructed, and that the introduction of a new technique for measuring facial tissue thicknesses will allow more populations to be measured and consequently, more standards based on larger samples to be produced. Ultrasound seems to offer the best technical capabilities at this moment, and I hope to publish a set of facial tissue thickness standards based on this technique in the near future. CAT scans will also be investigated for the development of facial tissue thickness standards, but the equipment is not suitable for field use for the reasons outlined previously.

I hope that my thesis has indicated some of the problems that exist in facial reconstruction and suggested how they may be be overcome. I emphasize that the best results are bound to be achieved by close attention to detail; and I therefore offer the cumulative comments on reproducing anatomical details of the face in the two Appendices. I believe that further research in facial reconstruction will firmly remove facial reconstruction from the realm of "scientific parlor tricks" (Rhine and Campbell, 1980) to become a highly-respected and valued investigative technique.

Appendix A

FACIAL RECONSTRUCTION GUIDELINES

Facial reconstruction has been accomplished by several methods; matching skull to portrait or photograph, creating a face from X-rays of the skull, building a face through superimposing facial features on illustrations of skulls, and by construction of a three-dimensional model. These methods are adequately explained by Stewart (1979:244-274).

The three-dimensional model was chosen for my experimental work because it allows the greatest degree of scientific accuracy and includes the greatest number of variables for consideration in the reconstruction. The following steps are normally taken to produce a facial reconstruction using this method.

A.0.1 Preliminary Assessment of Sex, Age and Race

The age, sex and race of the specimen should be assessed by a qualified physical anthropologist, and facial tissue thickness standards corresponding to the latter two attributes used in the reconstruction. Krogman (1971:18-207) gives reliable indicators of sex and race from landmarks on the skull which may be used in an assessment. Gerasimov (1971:52-53) and Brown (1953) give good outlines of changes in the face that accompany the aging process. Gatliffe and Snow (1979) and Neave (1979) demonstrate how aging the facial reconstruction should proceed.

A.0.2 Step 1: Casting the Original Specimen

The original specimens are cast in plaster, plastic or dental stone. A sturdy replica that can withstand drilling must be obtained. Neave, Barson and Percy (1976) give a full description of a useful technique for casting human remains in plaster using Algenate.

A.0.3 Step 2: Assembling the Cast

If the skull has been cast in several parts, or if the cranium and mandible have been cast separately, they must be glued or plastered together before being mounted on a stand.

A.0.4 Step 3: Painting the Cast

Teeth and gums are painted to approximate natural colours.

A.0.5 Step 4: Applying Measurement Guidelines

The twenty-one points on the face are located on the cast. The most accurate way of marking tissue thickness depths is by transferring these dimensions to wooden pegs and setting these pegs into holes drilled into the skull at the points marked. Gatliffe and Snow eschew the peg method for a simpler one using pencil rubbers glued to the surface of the skull (Gatliffe and Snow, 1979). Wilder and Wentworth (1918:105) settled for using pieces of paper shored up by plasticine as markers.

After application of tissue, depths may be checked by inserting a small metric ruler into the tissue at various points. Some practitioners use this method as the whole basis for reconstruction, completely disregarding the use of markers.

A.0.6 Step 5: Setting of the Eyes

Eyes are set in place. The size of the human eyeball is said to vary little in size from individual to individual, being almost round in shape and 1" (2.5 cm) in diameter (Basmajian, 1981:353). According to Greischeimer and Wiedeman (1972:277), the eyeball occupies the anterior one-fifth of the orbital cavity. By filling the eye socket with plasticine, weighing it and dividing the weight by 5, the approximate size of the orbit may be obtained.

There is general agreement that the eye is placed with the centre of the pupil slightly above and towards the outer border of the socket, inset so that a ruler held against the sub and supra-orbital rims should come in contact with the pupil (McGregor, 1926; Wilder and Wentworth, 1918:104; Krogman, 1973:266).

A.0.7 Step 6: Applying the Musculature

Facial and neck musculature is applied. This is an optional step, used by some practitioners and not others (see reconstruction of Swartkrans I for details on reconstruction of muscles). Most apply only masseters and temporalis (see McGregor, 1926; Gerasimov, 1971:117), presumably to fill in the "terra incognita" of the cheek region (Rhine and Campbell, 1980) not supplied with standards in Kollmann and Buchly's 1898 list of facial tissue thickness measurements.

A.0.8 Step 7: Applying the Skin

Skin colour is chosen to match the race of the individual being reconstructed, and is usually made of some pliable material such as clay or plasticine. How it is applied depends upon whether the application of musculature has preceded this step. Wilder and Wentworth (1912:104) affixed clay to the height of each marker and then joined it; Gatliffe (Gatliffe and Snow, 1979) favoured a "latticework" bridging the markers which was thereafter filled in. In order to make sure that skin depths are not exceeded, it is recommended that the tops of the markers be left exposed up until the last stages of reconstruction, then lightly smoothed over.

A.0.9 Step 8: Formation of the Nose

Most methods of estimating the size of the finished nose have been cast into doubt (see Suk, 1935, for particularly scathing comments). Krogman (1973) suggested the completed nose should be based on the nasal aperture forming three-fifths of its size. Gatliffe and Snow (1979) estimated nose length to be three times the length of the nasal spine. Neave (1979) found the shape of the nose could be determined by...

> "The anterior nasal spine and the nasal bone, if present, are key points, for although they do not show us exactly what the shape was, they can give us a good indication of the direction and form that the nose must have taken. This, combined with a knowledge of ethnic group, age and sex, gives enough information for speculation with a fair degree of accuracy. It does not, of course, allow for the unusual or the bizarre."

It appears that the form of the nose may at least be somewhat reliably estimated by following a line formed by the nasals to where it intersects with one drawn following the line of the akanthion (Harrison, 1966; McGregor, 1926). Gerasimov (1971:55) suggests that the "...roof of the nose is determined by the lateral margin of the piriform opening." He concludes, as does Neave, that as many criteria as possible be taken into consideration as the basis of the reconstruction. McGregor (ibid.) found moulding the nasal cartilages in plastic helpful as a preliminary step in reconstructing the nose.

A.0.10 Step 9: Formation of the Ears

Although the shape of the ear has no bony correlate on the skull, the size and placement of the ear can be estimated. Gerasimov, although he gives no specific guidelines, notes that attention should be paid to the "...construction of the temporal bone, direction, size and shape of the auditory meatus, form and relief of the mastoid process and direction of the ascending ramus of the lower jaw" (ibid.:61). Welcker (1883) noted that the ear lies approximately 5.33 mm. posterior and superior to, the external auditory meatus. Guidelines for ear size have long been known to artists; it is approximately equal to nose length (see illustration in Gatliffe and Snow, 1979).

A.0.11 Step 10: Formation of the Lips

This is doubtless one of the most difficult features to reproduce. Gerasimov (1971:55-60) gives the most detailed description of mouth forms corresponding to sex, race and dental characteristics. Wilder and Wentworth (1918:107) observed, "...the oral slit, when the mouth is in repose, seems to coincide with the line formed by the edges of the upper teeth and to extend upon each side to about the middle of the second premolar (bicuspid) tooth." The authors further proposed that the lips over the incisor region should be made to be as wide as the teeth. Stewart (1979:267) contests this; "Lips in particular seem to me to vary much more than the underlying bone structures. For this reason, all one can hope to achieve is a mouth that is consistent with the indicated sex, age and race." The latter seems to be the most prudent course to follow in reconstruction of the lips.

A.0.12 Step 11: Reconstruction of the Hair

Colour, amount and placement of hair can only be hypothesized unless there is some actual evidence available. Age and sex can contribute to an estimate. Practitioners often base this feature on photos of the deceased (see Gerasimov, 1971 for case histories).

In the reconstruction of my fossil hominids, scalp hair was not modelled because colour, covering and form are entirely hypothetical for these individuals. Eyebrow shape can generally be estimated from the contour of the supra-orbital torus, although the location of the eyebrow, above or below this bony marker, can vary as a factor of age (Brown, 1953).

Appendix B

A NOTE ON CASTING

In the hope that this thesis may be referred to by individuals who wish to try their hand at facial reconstruction, I am including herewith some information on casting procedures.

Neave, Barson and Percy (1976) developed a method for casting models for medical teaching which has been used to cast skulls for facial reconstruction (Neave, 1979). This method is based on using Algenate impression material for the mould and dental stone for the cast. Both of these materials are readily available in various quantities from dental supply houses.

While the authors of this article make the method sound easy, the novice may find satisfactory results hard to come by for the following reasons:

A large piece of Algenate, such as that needed to cast a skull, is quite slippery and unwieldy, and small pieces tend to sag or break off easily. These should be held in place during pouring by fixing them with toothpicks. I also found that it is not always possible to fit the two halves of the mould back together again with 100% accuracy. The likelihood of this happening is enhanced when many more lugs are used than recommended, especially when they are placed close to the edge of the impression. The sturdiest Algenate moulds, I have found, are made with a very thick mixture of Algenate. Some preliminary experimentation with the material will give the best results.

One of the most disappointing results of casting is retrieving a cast that has important spots "missed" from it. This can be avoided, for the most part, by first "basting" the inside of the mould with the casting material before pouring in the whole quantity. Once the latter is achieved, it is important to invert the mould after about five minutes of setting. This eliminates the possibility of a "lop-sided" cast being formed. Inverting the mould means that the Algenate must reach the top of the container, and that the pouring hole must be plugged.

All of the above illustrates the need for careful planning. Most errors will be avoided if some experimentation with materials precedes the actual casting of the skull. Other casting methods can of course be used, but the Algenate method is relatively inexpensive and useful when only one cast of the original is required.

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ADDENDUM

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