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# Putting a face on prehistory: reconstructing Late-Mississippian faces

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# PUTTING A FACE ON PREHISTORY:

# RECONSTRUCTING LATE-MISSISSIPPIAN FACES

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## Abstract

This paper examines the results of artificial cranial deformation on the human skull in relation to the human face and the use of three-dimensional printing in the making of skull casts. Forensic facial reconstructions, following the American Method, were performed on three Native American skulls from the Late-Mississippian period, excavated from the Humber Site and on loan from the University of Southern Mississippi, in order to see whether or not the artificial deformation radically changed the faces of the individuals. Skull casts were made out of ABS plastic using rapid prototyping technology, as the original skulls were too fragile for traditional methods. The reconstructions were completed at the LSU FACES Lab under the direction of Ms. Mary Manhein, Ms. Eileen Barrow, and Ms. Nicole Harris. The majority of changes in the facial region caused by the artificial deformation were found in the formation of bones adjacent to the cranial vault. This is the area where the deformational pressures would be the greatest. The superior border of the eye orbit was found to be less projecting than normal, with the consequence that the placement of the eyes for the facial reconstruction was too shallow. The American Method relies upon both the superior and inferior edges of the orbit for the placement. Changing the placement of the eyes in the American Method using only the inferior border of the orbit compensated for the changes in the bone structure and allowed for the correct positioning of the eye and a better depiction of the individual. Rapid prototyping skull casting has tremendous potential for damaged modern and ancient skulls. However, higher resolution scans and casts are needed for this technique to be accepted in both the academic and law enforcement communities.

# Chapter 1: Introduction

Facial reconstructions, whether two-dimensional or three-dimensional, allow scientists to create approximations of faces that can be used to identify missing persons in a modern, forensic context or those in ancient and historical contexts. The present research specifically deals with putting a face on prehistory in this manner. Such work can bring the history to life for the many people for whom history is just a long succession of names and dates that one was required to memorize in grade school. This applies to anthropology as well, particularly archaeology, where a culture may be known only by subsistence and tool type. By giving people a face to go with a name, they can connect to the person and his or her story, bringing them to life in a way that a museum diorama or anatomical exhibit never could.

The human face is extremely variable and it is how we tell one another apart (Bates and Cleese 2001, Wilkinson 2004). No two faces are alike, not even those of identical twins (Bates and Cleese 2001). This individuality is found not only in the soft tissue of the face, the skin, fat and muscles, but also in the skeletal components (Helmer 1987, Wilkinson 2004). The expressions upon it, the way the nose is positioned in relation to the eyes and mouth, the general shape and symmetry of the skull, all contribute to the uniqueness of faces. The cranium and the mandible comprise the major skeletal elements of the skull. These elements are the ones that are preserved through time and are found by archaeologists, paleoanthropologists, and paleontologists (Helmer 1987, Wilkinson 2004).

This paper will address the possible complications of using facial reconstruction methods on skulls with culturally-modified crania. Three skulls, two male and one female, exhibiting fronto-occipital cranial deformation are used in this study. The skulls are from the Humber Site in Mississippi and belong to Native Americans of the Late-Mississippian period (roughly 1400 AD to 1500 AD) (Knight 1986). Most modern skulls retain their shape after death unless put under extraordinary pressures. However, this is not always the case with historic and prehistoric skulls. The weight of the earth pressing down over the years can cause some skulls to deform, sometimes mimicking the appearance of cultural deformation (Byers 2005). This study is only looking at skulls that were purposefully modified in infancy, altering the growth patterns of the cranial bones and reconfiguring the facial profile. These changes present a challenge to those wishing to reconstruct the faces and represent what the individual may have looked like in life. While prehistoric skulls with intentional deformation have been used in this study, there are implications for the use of facial reconstruction on skulls of missing persons that have been modified due to genetic syndromes and diseases (White 1996). This could also lead to further studies on the complications of using facial reconstruction in forensic cases where the skulls have post-depositional deformation.

This thesis briefly examines the histories of the Mississippian peoples, forensic facial reconstruction, and artificial cranial deformation. These three aspects form the basis for the current study, which looks at their interplay and results. The three skulls and subsequent reconstructions are based on this background research. The current thesis research seeks to extend the scholarship in ? for subsequent generations of students to be able to have greater understanding of this complex subject. Presented herein are the results of this research.

# Chapter 2: Late-Mississippian Native Americans

## *Mississippian Peoples*

Massive earthen monuments that rivaled the majesty of the pyramids of Egypt greeted American colonists as they moved into the interior along the major river valleys (Bailey 2004, Denevan 1992, Hudson 1976). Being prejudiced against the Native Americans of the times, scholars soon came to believe that a race of moundbuilders existed in the United States before the Native Americans (Hudson 1976, Thomas 2000). Everyone assumed that the Native Americans were incapable of building such massive monuments; so, they created myths about the origins of the mounds. They suggested that everyone from the ancient Atlanteans to the lost tribes of Israel to early Irish or Norse explorers had settled the land first but had later been slaughtered by the savage Indians (Hudson 1976, Thomas 2000). In fact, Mississippians were only the latest moundbuilders. Mounds have been found in the United States dating back as far as 7000 BC (Pauketat 2004).

## *Ceremonial Centers and Corn*

Mississippian influence sprawled along the eastern United States from the Mississippi and Ohio River valleys from Illinois to Louisiana and from eastern Texas to the Atlantic Ocean (Hudson 1976, Pauketat 2004), though it was centered in the Mississippi River bottomlands around St. Louis (Emerson 1997, Hudson 1976, Knight 1986) (See Figure 1). Mississippian Native Americans were not a part of a single nation or tribe, as we know them today (Hudson 1976, Pauketat 2004); rather, aspects of a generalized “Mississippian culture” were selectively adopted and modified by the different cultural groups as the influence expanded, much like Christians in Medieval Europe. Archaeologists have classified these diverse societies as Mississippian on the basis of the presence of several shared traits: monumental flat-topped mounds, shell tempered pottery, and maize (corn) agriculture (Cobb 2003, Cobb and Garrow 1996, Goldstein 1980, Hudson 1976, Pauketat 2004, Wesler 2001). The Mississippi period has been subdivided by archaeologists into Early, Middle, and Late periods. These periods are often defined by differences in cultural artifacts and are used to denote the different time periods in which the people lived (Knight 1986, Pauketat 2004, Shaffer 1992, Steadman 2008).


**Figure 1: Map of the United States showing Mississippian Area (darker area ) and the Area of Influence (lighter area). Image adapted from Cobb 2003 and Hudson 1976.**

The intensification of maize agriculture around 800 AD is believed by many researchers to have been the key to Mississippian cultural expansion (Hudson 1976, Pauketat 2004, Shaffer 1992). The Mississippians relied heavily upon maize and beans for the majority of their diet, though they continued to exploit local animal resources including deer and waterfowl (Hudson 1976, King 2003, Pauketat 2004). Without this intensification, the grandiose ceremonial complexes and spatially organized villages that arose later would not have been possible, if only due to a lack of food resources necessary for feeding the populace building the massive mounds and plazas and the accompanying population increase (Hudson 1976, Pauketat 2004, Powell 1992). Maize had been in the Southeast since around 200 BC, along with squash and gourds, but it was never a staple crop before the Mississippians (Hudson 1976). The relatively rapid growth of mound and plaza ceremonial centers in the archaeological record around 1050 AD leads researchers to conclude that this expansion reflects a sudden shift from relatively egalitarian foraging societies that practiced a little agriculture to a stratified agrarian society that relied upon levied labor to build massive ceremonial complexes (Pauketat 2004). Depending upon the scholar, the Mississippian period began around 900 AD and was in decline by 1400 AD, though some scholars maintain that some Native American nations in the Southeast, like the Natchez, were Late Mississippian and maintained Mississippian traditions until around 1700 AD (Emerson 1997, Hudson 1976, Pauketat 2004, Rayson 1992, Shaffer 1992).

Besides the impressive mound centers, the Mississippian period is known for the utilization and exploitation of massive trade networks that extended across the eastern United States (Cobb 2003, Cobb and Garrow 1996, Hudson 1976, Pauketat 2004, Pauketat and Emerson 1997, Peregrine 1992, Rayson 1992, Shaffer 1992). The Mississippians traded for raw materials and finished products from all across the North American continent (Hudson 1976, Hudson 1990, Pauketat 2004, Peregrine 1992). This trade network is believed to be largely responsible for the spread of Mississippian ideas throughout the American Southeast and the creation of the Mississippian Culture Area (Cobb and Garrow 1996, Pauketat 2004, Shaffer 1992). Many of these trade routes still existed at the contact period and were so well traversed and maintained that they continued to be used by colonists (Denevan 1992, Hudson 1976, Pauketat 2004, Rayson 1992). They were so well placed that, eventually, they were turned into highways and freeways (Pauketat 2004).

Some Mississippian chiefdoms have been described as “paramount” chiefdoms by researchers, which places them above simple and complex chiefdoms in the hierarchy of societies defined by anthropologists and historians (Beck 2003, Cobb 2003, Hudson 1976, Pauketat 2004, Pauketat and

Emerson 1997, Rayson 1992, Shaffer 1992). These polities had control over other complex and simple chiefdoms, either through threat of physical violence, treaties, alliances, or control of important ceremonial centers (Hudson 1976, Pauketat 2004, Pauketat and Emerson 1997, Rayson 1992, Shaffer 1992). These paramount chiefs quite probably extracted tribute from these lesser chiefdoms, or had a complex exchange system in place in which the paramount chiefs got the better end of the bargain (Hudson 1976, Pauketat 2004, Peregrine 1992, Shaffer 1992). The paramount chiefs would have lived at the large ceremonial centers, generally atop the larger flat-topped mounds, and it is likely that tribute was given during specific ceremonies where the lesser chiefs would have traveled to the centers to participate in the ceremonies (Emerson 1997, Hudson 1976, Pauketat 2004, Powell 1992, Shaffer 1992). The largest of all the ceremonial centers was Cahokia (located near St. Louis, MO), though there were several large centers containing multiple mounds and plazas, such as Etowah (in Georgia) and Moundville (in Alabama) (Denevan 1992, Hudson 1976, King 2003, Knight 1997, Rayson 1992, Shaffer 1992, Wesler 2001, Yerkes 2005).

### *Late-Mississippian*

The Late Mississippian period is dated from the fifteenth century, just before European contact, to the sixteenth century, though it possibly continued on until the eighteenth century, when the French destroyed the last major Natchez center in 1731 AD (Bailey 2004, Hudson 1976, Shaffer 1992, Shapiro 1984). Little historical documentation exists from the Late Mississippian, or contact period, when Hernando de Soto and other European explorers began to wander through North America in search of gold and other riches and encountered the different Native American nations (Bailey 2004, Hudson 1975, Hudson 1976, Hudson 1990, Rayson 1992). A fair number of the polities that are mentioned and described have been located, though some of the site identifications are quite controversial (Rayson 1992). Therefore, much of the ethnographic evidence compiled by scholars studying the Mississippian peoples has had to be taken from accounts from the later sixteenth and seventeenth century explorers

(Emerson 1997, Hudson 1976). These data are then corroborated against archaeological findings wherever possible in order to create the most complete picture possible of the lives of Mississippi peoples possible (Hudson 1976, Pauketat 2004).

The polities observed by explorers in the sixteenth century by and large were agricultural chiefdoms that had highly complex religious and inheritance systems (Bailey 2004, Denevan 1992, Hudson 1976, Rayson 1992, Shapiro 1984), though they do not appear as complex in the archaeological record (Hudson 1976, Pauketat 2004, Rayson 1992). The nations of Cofitachequi and Coosa were thriving paramount chiefdoms when Hernando de Soto and Juan Pardo passed through in the sixteenth century; yet, there is little archaeological evidence that indicates the complexity of their political or religious structures (Hudson 1990, Rayson 1992). The overwhelming quantity of material culture (statues, pipes, spear points, shells, and other exotic materials) found at archaeological sites from the earlier Mississippian periods has led many researchers to believe that the Early and Middle Mississippian periods had even richer cultures with more complex ceremonial systems and mortuary rituals in place than the Late Mississippian societies seen by de Soto and others (Emerson 1997, Hudson 1976, Knight 1986, Pauketat 2004, Steadman 2008). However, this lack of material deposition only may be an indication of the decreased importance in specialized pottery for each society or a shift in the type of material goods seen to be important enough to be traded for and interred with important leaders (Pauketat 2004).

### *Belief Systems*

Archaeological findings at Mississippian sites led to the identification of the Southeastern Ceremonial Complex, or the Southern Cult (Diaz-Granados 2004, Emerson 1997, Hudson 1976, Knight 1986, Knight 1997). This set of shared beliefs extended into all aspects of life, including art, physical appearance, and symbolic understandings (Diaz-Granados 2004, Hudson 1976, Knight 1986). A few of the symbols appear to be directly linked to Mesoamerican iconography. However, there is no clear explanation for how these symbols might have reached the Southeast (Hudson 1976). Hudson (1976) believed Mesoamerican influence could be seen in other aspects of the Mississippian world, including subsistence patterns and mound building and that some iconographic symbols were similar between the two societies. However, a few Mesoamerican symbols that were associated with agriculture and fertility appear to be linked to men, war, and conjury in the Southern Cult (Hudson 1976).

## ***Cranial Modification/Deformation***

### Prehistoric and Historic Periods

Peoples all around the world, including some Native American tribes of the United States, practiced cranial modification at different times (Aldred 1953, Blackwood and Danby 1955, Cheverud et al. 1992, Del Papa and Perez 2007, Field 1948, Hatt 1915, Kohn et al. 1993, Mason 1887, Murray 1954, Neumann 1942, Stewart 1937, Stewart 1943, Trinkaus 1982, von Bonin 1937). This practice can be traced back through human history all the way to the Neanderthals (Clark et al. 2007, Trinkaus 1982). As noted in Chapter 2, cranial modification is performed for a multitude of reasons including, but not limited to, a cultural perception of beauty, the use of modification as a status symbol, and keeping the infant strapped to a cradle board on the mother's back for ease of movement (Blackwood and Danby 1955, Cheverud et al. 1992, Clark et al. 2007, Hoshower et al. 1995, Kohn et al. 1993). It is started within hours or days of the birth and continues for one to three years (Blackwood and Danby 1955, Hoshower et al. 1995, Torres-Rouff 2002). At this point, the bones of the skull have been deformed long enough that, though some growth will continue, the skull will remain in the deformed shape for the rest of the individual's life (Blackwood and Danby 1955, Hoshower et al. 1995, Torres-Rouff 2002). These practices result in many forms of deformation in varying degrees of severity, according to the method used and the length of time it was applied.

### Mississippian Modification

Mississippian Native Americans also practiced fronto-occipital cranial modification/deformation (Hudson 1976, Mitchell 1977, Neumann 1942, Stewart 1943), which results in a shorter head (lengthwise) with a higher vault (vertically). The deformation is sometimes attributed to cradleboarding, though it appears that a more rigorous form is required for dramatic deformation. Cradleboards differed in styles and ornamentation, but the basic form was a flat plank of wood that the child would be strapped onto so the mother could carry the child more easily. Where cradleboarding was not used, boards, pads, or flat, circular stones were applied to achieve this affect (Figure 2) (Hudson 1976, Neumann 1942, Stewart 1943, Torres-Rouff 2002).

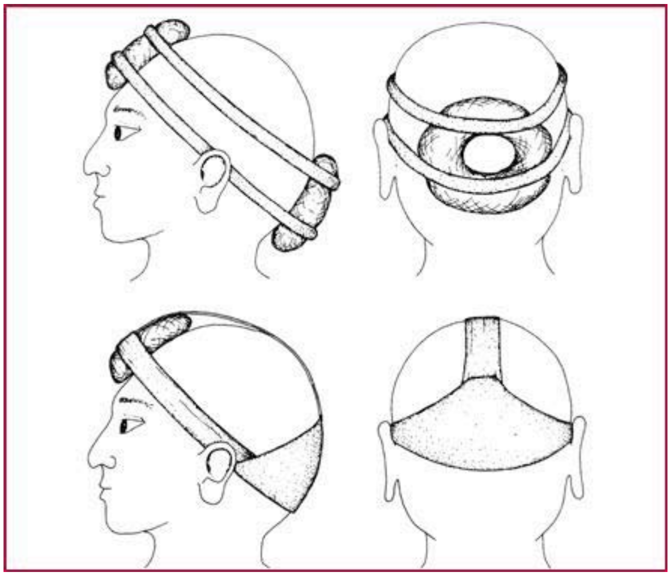

**Figure 2: Cranial Deformation Apparatus (Hoshower et al. 1995)**

In many Mississippian societies, pronounced cranial deformation was associated with high status; thus, while all children were cradleboarded, only the elites exhibited pronounced cranial deformation. The Mississippians believed that cradleboarding ensured that the child would grow up straight and strong and that the changes in head shape gave the individual superior eyesight (Hudson 1976). This belief most surely would have been acted upon as a strong, healthy person with superior eyesight who was extremely useful in a society where hunting was still crucial to survival and low-level warfare was almost always a possibility (Hudson 1976). In addition, many Native Americans, including those belonging to the Mississippian culture group, considered a specific head shape more attractive (rounder or longer typically) and this social preference would have placed amplified pressure upon the parents to make sure their child had such a head if he or she were to have a successful life (Cheverud et al. 1992, Hudson 1976, Torres-Rouff 2002). This detail of why cranial deformation was practiced is known because the Native Americans of the Southeast continued to practice cranial deformation into the colonial times. Cranial deformation was interesting to most adventurers and explorers because it was so different and alien from anything they had known (Hudson 1976, Neumann 1942, Stewart 1943).

Cranial deformation is also seen in many of the sculptures of the Mississippian era, both in males and females (Emerson 1997). Analysis of cranial deformation in some South American indigenous cultures has shown that when cranial deformation is prevalent in a society, it will likely show up to the same degree in the art of that society (Gill 1977). The cultural preference for a particular shape of head can attain perfection in art, where there are no physical processes to shift the bones back to a more normal configuration (Gill 1977).

The following chapter gives a brief history of forensic facial reconstruction and its development and applications. The methodologies described are used in this study to recreate the faces of the Late-Mississippian remains.

### Changes to the Skull

The practice of cranial deformation impacts the skull, and the brain encased within, in a multitude of ways that are not fully understood (Blackwood and Danby 1955, Hoshower et al. 1995, Kohn et al. 1993, Konigsberg et al. 1993). The early closure of sutures, in particular the sagittal suture, has the potential to impact the development of the brain, possibly affecting the cognitive skills of the individual (Cheverud et al. 1992, Hoshower et al. 1995). Cranial modification also affects several of the non-metric traits that physical anthropologists use in their determination of ancestry (Cheverud et al.

1992, Clark et al. 2007, Del Papa and Perez 2007, Konigsberg et al. 1993, White 1996). A prime example of this is the increase of Wormian bones in skulls with cranial deformation (see Figure 3) (Del Papa and Perez 2007, Konigsberg et al. 1993, White 1996).

There are two major types of cranial deformation, fronto-occipital, or anterior-posterior, and annual, or circumferential (Blackwood and Danby 1955, Clark et al. 2007, Hoshower et al. 1995, Kohn et al. 1993, Stewart 1943, Torres-Rouff 2002).

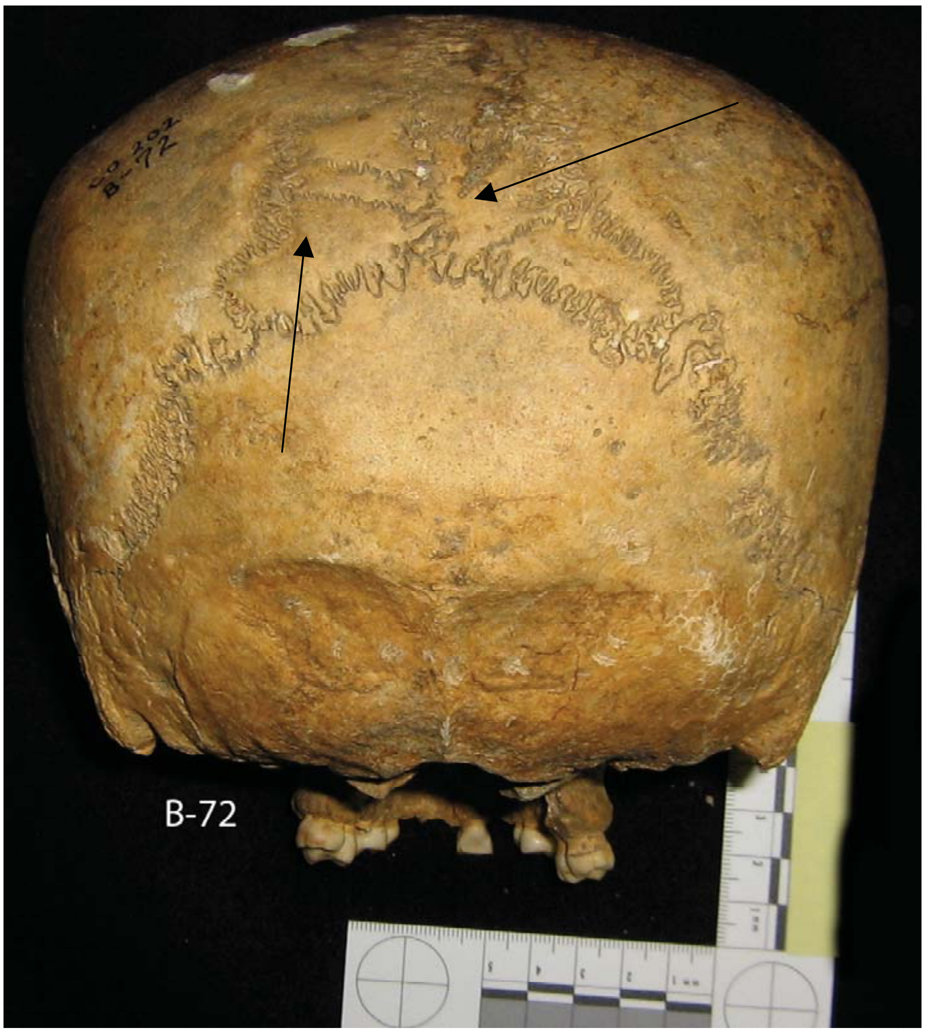


**Figure 3: Wormian Bones**

Fronto-occipital modification involves the flattening of the frontal and occipital bones, usually through cradleboarding (Cheverud and Midkiff 1992, Clark et al. 2007, Torres-Rouff 2002), while the circumferential method requires bands wrapped around the skull constricting it and forcing the skull to expand superiorly and posteriorly (Blackwood and Danby 1955, Clark et al. 2007, Hoshower et al. 1995, Torres-Rouff 2002). No one standardized system of classifying modified skulls has yet been compiled, rather each researcher has tended to create his or her own system based upon the sample studied (Cheverud et al. 1992, Clark et al. 2007, Hoshower et al. 1995 Stewart 1943).

### Fronto-Occipital Modification

The skulls in this study exhibit fronto-occipital deformation. In fronto-occipital deformation, the infant's head is strapped to boards, possibly with the addition of stones, or pads, and it is this restriction that causes the flattening of the frontal and occipital bones of the skull (Cheverud and Midkiff 1992, Cheverud et al. 1992, Hoshower et al. 1995, Kohn et al. 1995, Neumann 1942). This anterior-posterior restriction results in lateral expansion in the parietal bones, which gives the skull a shorter, rounded appearance in contrast to a normal, oblong skull (Cheverud and Midkiff 1992, Kohn et al. 1995, Hoshower et al. 1995). This widening of the parietals can cause changes in the mandible due to the articulation with the cranium at the temporomandibular joint, which can lead to a reshaping of the posterior aspect of the face (Anton 1989, Bastir and Rosas 2005, Cheverud and Midkiff 1992, Kohn et al. 1995). The flattening of the forehead can also warp the bones on the superior aspect of the eye orbit, flattening them backwards, causing the individual's eyes to protrude (Kohn et al. 1995).

Cradleboarding often produces a uniform deformation due to the hard, flat surface upon which the infant's head rests; however, it can produce unilateral deformation if the infant's chosen sleeping position is to one side or another, or if the pressure of the deformation apparatus is not applied equally (Gill 1977, Kohn et al. 1995). This can lead to a bi-lobed appearance with a depression along the sagittal suture giving the impression of two distinct halves, rather than a single rounded curve (Gill 1977, White 1996).

## Cultural Significance

The practice of cranial deformation can have long lasting social impacts upon the individual beyond the physical impacts upon the brain (Hoshower et al. 1995, Torres-Rouff 2002). The decision to perform cranial deformation upon one's child is fraught with deeper meaning and the right to make that decision may lie outside of the parental sphere (Blackwood and Danby 1955, Torres-Rouff 2002). A difference in physical appearance has often been the reason behind group identity, with the identifying feature being nose size/shape, skin color, head shape, body ornamentation, or even height (Torres-Rouff 2002). This does not have to be an outside definition, but can be a way of using the body to create a group identity (Blackwood and Danby 1955, Hoshower et al. 1995, Torres-Rouff 2002, White 1996).

Certain groups appear to have defined themselves through their head shapes, creating a clear indication of in-group and out-group membership that can be identified at first glance (Hoshower et al. 1995, Torres-Rouff 2002). Even within a group, status to particular levels of society (elite/non-elite, male/female) may be defined by the shaping of a child's head, or the prohibition against shaping the head (Blackwood and Danby 1955, Gill 1977, Hoshower et al. 1995, Torres-Rouff 2002, White 1996). Interactions between groups can lead to changes in cultural practices, including the strengthening or disappearance of cranial deformation (Hoshower et al. 1995, Hudson 1976, Torres-Rouff 2002). Many groups were discouraged from practicing cranial deformation by missionaries and colonial rulers because it was considered strange or barbaric by European standards; yet many continued to practice it in order to maintain their social or cultural distinction (Blackwood and Danby 1955, Hudson 1976, Neumann 1942, Stewart 1943).

# Chapter 3: History of Facial Imaging

## *Early Facial Reconstructions*

Facial reconstruction, or reproduction as some refer to it, has a long history and only recently has been applied to medico-legal issues. Artistic representations go back farther than the ancient Egyptians' death masks, as far back as 7000 B.C. in Jericho where clay was modeled over skulls in abstract representations of faces (Bonogofsky 2006, Phillips 2000, Prag and Neave 1997, Wilkinson 2004). These individuals subsequently were buried beneath the floors of their homes (Bonogofsky 2006, Phillips 2000, Prag and Neave 1997, Wilkinson 2004). These early representations were not accurate reproductions of their owner's faces (Croucher 2006, Prag and Neave 1997, Shishlina 2006, Vadetskaia 2006, Wilkinson 2004); however, they did provide the necessary beginning where people realized they could sculpt faces over skulls to provide a three-dimensional representation of what the person looked like.

It was during the Italian Renaissance that Western artists began to once again depict the human body and, more specifically, the face in more realistic studies (Poggesi 2006, Wilkinson 2004). Artists like Michelangelo, Leonardo da Vinci, and Andrea del Verrocchio conducted studies of the human body and captured their scientific studies in art, in drawings and wax models (Poggesi 2006, Wilkinson 2004). It was in the seventeenth century that "anatomica plastica" or anatomic wax modeling was developed in Italy (Poggesi 2006, Wilkinson 2004).

Giulio Gaetano Zumbo, a sculptor who lived from 1656-1701, revolutionized this field with his wax scenes (Poggesi 2006, Prag and Neave 1997, Wilkinson 2004). Zumbo was highly skilled and precise in his depiction of bodies in various stages of decomposition (Poggesi 2006, Wilkinson 2004). He even sculpted a wax face directly upon a skull (Figure 4), only partly covered with skin layer, so that the musculature and glands of the face could be seen clearly (Poggesi 2006, Wilkinson 2004). It is unknown if he accurately portrayed the subject's face, but considering the skill with which Zumbo modeled the glands and muscles, it can be assumed that the face is a truthful representation (Poggesi 2006, Wilkinson 2004). Artists like Ercole Lelli (1702-1766) and Joseph Towne (1808-1879) followed Zumbo and continued to develop the technique (Poggesi 2006, Prag and Neave 1997).

**Figure 4: Sculpture of the Human Face by Giulio Gaetano Zumbo (1656-1701)**
**Image courtesy of Kristin Monahan**

The earliest reconstructions that could be termed scientific were done in order to authenticate skulls of famous persons like Johann Sebastian Bach and Dante Alighieri (Prag and Neave 1997,Tiesler et al. 2004, Wilkinson 2004). These reconstructions were done by His and Kollman, respectively, and involved the taking of tissue depth measurements from cadavers and using that information to reconstruct the faces onto the skulls (Prag and Neave 1997, Tyrrell et al. 1997, Wilkinson 2004). His used a total of fifteen anatomical landmarks in his reconstruction, nine in the midline of the face and six in the lateral plane (Prag and Neave 1997).

The resulting reconstructions were then compared to portraits and busts of the artists and allowed the skeletal remains to be authenticated (Prag and Neave 1997, Wilkinson 2004). Neither His nor Kollman completed the reconstructions themselves; rather, they worked with talented sculptors, Sefner and Buchly, respectively, who were able to take the tissue depth data provided to them, scanty though they were, and create a face with them (Wilkinson 2004). Kollman and Buchly worked together on other reconstruction cases, and Sefner independently worked to verify Bach's identity by attempting to sculpt Handel's face upon Bach's skull (Wilkinson 2004). He found it possible, but only by ignoring all data provided by the tissue depth measurements and the skull itself (Wilkinson 2004).

This was the earliest test of the accuracy of facial reconstruction though it has by no means been the last. Another reconstruction by Kollman and Buchly was the face of a woman from the Neolithic era (Prag and Neave 1997, Wilkinson 2004). They used tissue depth data from hundreds of women from Auvenier, France, where the remains were found, to complete the reconstruction (Prag and Neave 1997, Wilkinson 2004). Various early reconstructions were also performed on archaeological specimens such as Neanderthals recovered from La Chapelle-aux-Saints and Le Moustier in France (Prag and Neave 1997, Wilkinson 2004).

It was not until the early twentieth century that other facial reconstructions were attempted (Taylor 2001, Wilkinson 2004). Dr. Wilton Krogman conducted a landmark study in three-dimensional clay reconstruction in 1946 (Iscan 1988, Taylor 2001, Tyrrell et al. 1997, Ubelaker and O'Donnell 1992, Wilkinson 2004). Krogman took a cadaver, photographed the face, removed the flesh, and then gave the skull to a sculptor, Mary Jane McCue, for her to perform the facial reconstruction (Taylor 2001, Ubelaker and O'Donnell 1992). Krogman provided McCue with information on the ancestry, sex, and age of the individual along with the appropriate tissue depth data (Taylor 2001). Krogman believed that this technique could be an aid in the identification of skeletal remains and he published his results in the *FBI Law Enforcement Bulletin* (Iscan 1988, Taylor 2001, Ubelaker and O'Donnell 1992).

These reconstructions were all completed by pairs, one member with great anatomical/anthropological knowledge and the other with great artistic skill. This combination is required for successful reconstructions, for both art and science, the latter in the form of physical anthropology, are needed for the reconstructions to be accurate and complete (Aulsebrook et al. 1995, Cesarani et al. 2004, Phillips 2000, Prag and Neave 1997, Taylor 2001). Before any reconstructions take place, the skulls have to be analyzed to determine the ancestry, stature/build, sex, and age of the individual (Cesarani et al. 2004, Kerley 1972, Phillips 2000, Prag and Neave 1997, Taylor 2001, Vanezis et al. 2000, Wilkinson 2004). Only once these are determined can the proper soft tissue depth measurements be given to the artist, and the reconstruction begun (Cesarani et al. 2004, Phillips 2000, Prag and Neave 1997, Taylor 2001, Vanezis et al. 2000, Wilkinson 2004).

### *Facial Reconstruction Techniques*

Facial reconstruction today is a combination of anthropological input incorporating tissue depth data collected in the last two hundred years and the skills of trained artists who are able to see imperfections and asymmetries in the skulls and translate these to the soft tissue (Aulsebrook et al. 1995, Prag and Neave 1997, Taylor 2001, Tiesler et al. 2004, Tyrrell et al. 1997, Wilkinson 2004). Facial reconstruction is an aid to law enforcement personnel who utilize it to identify missing persons from skeletal or badly decomposed remains (De Greef and Willems 2005, Prag and Neave 1997, Taylor 2001, Vanezis et al. 2000, Wilkinson 2004). Academics and museum personnel use the technology in historical cases where the faces of historical figures are desired for museum displays or identification purposes (Oeh 1996, Prag and Neave 1997, Taylor 2001, Tiesler et al. 2004, Vanezis et al. 2000, Wendrich 2004, Wilkinson 2004).

Three kinds of facial reconstruction are available: two-dimensional representation drawn over a picture of a skull, three-dimensional reconstruction using clay on the skull or a cast of the skull, and three-dimensional reconstruction using computers to sculpt the face over a scanned model of the skull

(Cesarani et al. 2004, De Greef and Willems 2005, Taylor 2001, Tyrrell et al. 1997, Vanezis et al. 2000, Wilkinson 2004). The most common practice today is the use of clay directly on the skull or cast (Phillips 2000, Prag and Neave 1997, Taylor 2001, Tyrrell et al. 1997, Wilkinson 2004). The computerized methods are still in the early stages of development and often require manual manipulation by a skilled technician, which does not remove the variability inherent in artistic reconstructions (Taylor 2001, Tyrrell et al. 1997, Wilkinson 2004). They often produce images that appear cartoonish due to the technology available (Taylor 2001, Wilkinson 2004). The two-dimensional method can be useful but may not aid in identification as much as three-dimensional methods due to the flat nature of the drawing and the necessary skill required of the artist to render the human face accurately on paper (Taylor 2001, Wilkinson 2004). Two-dimensional drawings also do not utilize the physical features of the skull that a sculptor can feel; some features may be overlooked (Taylor 2001, Wilkinson 2004).

Several different techniques for facial reconstruction have been developed in recent years. All of these techniques have been tested scientifically for accuracy and all have been found to be useful in both forensic and museum settings (Cesarani et al. 2004, d'Hollosy 2005, Lampe et al. 2005, Phillips 2000, Prag and Neave 1997, Snow et al. 1970, Stephan and Henneberg 2001, Stephan and Henneberg 2006, Taylor 2001, Wilkinson 2004). In any case, these methods are only employed when the bodies are badly decomposed, mutilated, or completely skeletonized (as in the case of archaeological and mummy reconstructions) (Oeh 1996, Stephan and Henneberg 2001, Vanezis et al. 2000). In forensic cases, facial reconstruction is considered a last resort when all other options have been exhausted (Haglund et al. 1987). The techniques have all been developed with close attention to anatomical detail, though some methods are more rigid in their adherence to sculpting each individual muscle and gland in Zumbo's fashion. The main three-dimensional clay reconstruction methods used today were developed separately by Mikhail Gerasimov, Betty Pat Gatliff, and Richard Neave (Cesarani et al. 2004, Prag and Neave

1997, Stephan and Henneberg 2001, Taylor 2001, Wilkinson 2004). These will be discussed in more detail below.

Two-dimensional and three-dimensional computer-aided reconstructions are also playing a greater role in the forensics field due to the amount of time required for three-dimensional clay reconstructions (Cattaneo 2007, Claes et al. 2006, Quatrehomme et al. 1997, Taylor 2001, Ubelaker and O'Donnell 1992, Vanezis et al. 2000, Wilkinson 2004). Some pioneers in these fields are Karen Taylor, who developed a two-dimensional method by drawing the face over a photograph of the skull with tissue depth markers, and Evison, Quatrehomme, and Ubelaker, who created three-dimensional computer methods, all of which are based on the three-dimensional American clay method developed by Betty Pat Gatliff and Clyde C. Snow (Claes et al. 2006, Davy et al. 2005, Evison 1996, Evison et al. 1998, Hirsch et al. 2005, Quatrehomme et al. 1997, Taylor 2001, Tyrrell et al. 1997, Ubelaker and O'Donnell 1992, Wilkinson 2004). All of the creators of the methods communicate the importance of sculpting the entire face so any asymmetries in the skeleton will be portrayed in the reconstruction (Taylor 2001, Wilkinson 2004).

## *Three-dimensional Clay Reconstructions*

### Anatomical or Russian Method

Mikhail Gerasimov was an anthropologist at Irkutsk University in Russia in the early twentieth century (Wilkinson 2004). He began working on facial reconstructions after studying forensic medicine (Wilkinson 2004). Gerasimov's reconstructions were built up layer by layer as he modeled all of the muscles, glands, and fat deposits onto the skull and then covered them with a skin layer which was, needless to say, the thickness of human skin (Cesarani et al. 2004, Prag and Neave 1997, Stephan and Henneberg 2001, Taylor 2001, Wilkinson 2004). Gerasimov performed over two hundred reconstructions during his career, both historical and forensic (Prag and Neave 1997). He reported great success with his method; however, one drawback to his method is the amount of time needed for the reconstruction, as each was incredibly detailed (Stephan and Henneberg 2001, Wilkinson 2004). Others have found Gerasimov's method to be time consuming to learn, requiring precise anatomical knowledge and detail in the reconstructions (Wilkinson 2004). Gerasimov believed the time investment was worth it as he felt it created a more accurate representation than the tissue depth method (Stephan and Henneberg 2001, Taylor 2001).

Gerasimov used the nasal bones, brow, and upper jaws to determine the shape of the nose (Wilkinson 2004), which is one of the hardest areas of the face to reconstruct accurately due to the abundance of soft tissue and the dearth of bone in that feature (Taylor 2001, Vanezis et al. 2000). Gerasimov's reconstructions were criticized by some researchers due to his lack of documentation on some cases (Wilkinson 2004). Critics suspected that Gerasimov performed his accuracy tests with prior knowledge of the persons' faces due to the high degree of accuracy that he attained and the far lower degree of accuracy that others have obtained using his method (Wilkinson 2004). However, these doubts seem unfounded as many of Gerasimov's accuracy tests were well documented and showed his high degree of accuracy to be real (Wilkinson 2004). Other reconstruction artists have also run into this criticism from outsiders who do not realize the individuality of the skulls and the fact that talented artists are able to take these differences and translate them into the soft tissue, in part due to the lack of scientific testing/replication defined by the scientific method and in part because of the low statistical success rate in positive identification (Phillips 2000, Prag and Neave 1997, Stephan and Arthur 2006). Facial reconstruction is a melding of science and art, and, while reconstructions may not be identical to the deceased, they provide enough information in forensic cases that relatives are able to see something in the face, which will lead to their contacting the police (Phillips 2000, Vanezis et al. 2000).

## Tissue Depth or American Method

Betty Pat Gatliff is a forensic artist, now based out of Oklahoma, who came to facial reconstructions through her association with forensic anthropologist Clyde Snow (Stephan and

Henneberg 2001, Taylor 2001, Wilkinson 2004). Gatliff and Snow worked from an earlier method developed by Krogman and McCue in 1946 (Prag and Neave 1997, Rhine 1990, Snow et al. 1970, Taylor 2001, Ubelaker and O'Donnell 1992, Wilkinson 2004). Tissue depth information was collected in many different studies from cadavers for various anthropological markers on the skull, like Nasion and Glabella (Cesarani et al. 2004, Prag and Neave 1997, Snow et al. 1970, Taylor 2001, Wilkinson 2004). Gatliff used these measurements to place markers on the skull to indicate the correct tissue depths for the different areas of the skull (Cesarani et al. 2004, Prag and Neave 1997, Snow et al. 1970, Taylor 2001, Wilkinson 2004). Clay was then laid down between these markers to build up the facial soft tissue, all the while paying attention to the individual bone morphology to see if any indications of injury or disease had left their mark upon the bones that would have translated to the facial soft tissue (Snow et al. 1970, Taylor 2001, Wilkinson 2004).

Anatomical knowledge is necessary for paying close attention to skeletal details, but this method does not model the muscles onto the skull; rather, clay is just laid down to the proper depths and can be adjusted for skeletal abnormalities (Snow et al. 1970, Stephan and Henneberg 2001, Taylor 2001, Wilkinson 2004). This method has come to be called the "American method" due to its prevalence among American forensic artists (Taylor 2001, Wilkinson 2004). It is also used heavily in law enforcement cases due to the relatively quick nature of the reconstructions and the accessibility of the tissue depth measurements, which are required for the reconstructions to be used in courts of law (Taylor 2001).

**Combination or Manchester Method**

Richard Neave is a medical artist and professor at Manchester University who has performed many facial reconstructions (Prag and Neave 1997, Taylor 2001, Wilkinson 2004). He first began performing reconstructions on Egyptian mummies as part of the Manchester Mummy Team, but has branched out into forensic work as well (Prag and Neave 1997). Neave's method is a melding of

Gerasimov and Gatliff, incorporating both tissue depth information and the meticulous sculpting of muscles onto the skull (Cesarani et al. 2004, Prag and Neave 1997, Stephan and Henneberg 2001, Taylor 2001, Wilkinson 2004). Neave always performs the reconstruction on casts of the skull rather than on the skull to avoid irreversible damage to the skull (Prag and Neave 1997, Taylor 2001). This method is often referred to as the "Manchester method" because of its development at Manchester University (Prag and Neave 1997, Taylor 2001, Wilkinson 2004).

Neave has performed several studies testing the accuracy of the Manchester method (Aulsebrook et al. 1995, Prag and Neave 1997, Neave and Prieels 2005, Wilkinson 2004). One study used four cadavers, whom he photographed fleshed and then reconstructed (Wilkinson 2004). Neave found that he could match the reconstructions to the faces and all of the reconstructions were distinct enough from each other that they could not represent the same person (Wilkinson 2004). Neave uses the same tissue depth measurements as the American method, but uses them more as guides while he lays down the muscles of the face like Gerasimov (Prag and Neave 1997, Wilkinson 2004). Neave has performed many historical reconstructions beyond the original mummies, including Lindow Man (a Bog Man from Cheshire, England), King Midas, and Philip II of Macedon (the father of Alexander the Great) (Bartsiokas 2000, Musgrave et al. 1984, Prag 1989, Prag 1990, Prag and Neave 1997, Wilkinson 2004).

The Manchester method requires more attention to the details of the muscular structure of the face and neck with greater anatomical knowledge on the part of the sculptor (Prag and Neave 1997, Stephan and Henneberg 2001, Wilkinson 2004). While it is always a good idea for the sculptors to have an awareness of anatomical structures, the methods developed by Gerasimov and Neave require a greater depth of knowledge in this area (Prag and Neave 1997, Wilkinson 2004). Neave also suggests an anthropological background for the sculptor, as that will allow him or her a greater chance of producing faces appropriate to the ethnicity of the skeletal remains (Prag and Neave 1997, Wilkinson 2004).

### *Soft Tissue Depth Measurements*

Average soft tissue depth measurements are used in facial reconstruction to sculpt the face onto the skull (Snow et al. 1970, Taylor 2001, Wilkinson 2004). These measurements have been compiled over the years through many different studies (De Greef and Willems 2005, De Greef et al. 2005, Niinimaki and Karttunen 2005, Stephan and Simpson 2008a, Stephan and Simpson 2008b, Taylor 2001, Wilkinson 2004). The original studies used needles on cadavers, measuring how deep the needle went in at different anthropometric points on the skull, while recent studies have utilized new technologies like radiographs, magnetic resonance imaging, and ultrasound to measure tissue thickness (De Greef et al. 2005, Garlie and Saunders 1999, Manhein et al. 2000, Prag and Neave 1997, Stephan and Simpson 2008a, Taylor 2001, Williamson et al. 2002, Wilkinson 2004). Measurements are taken with the head in the Frankfort Horizontal Plane to provide standardization and the best chances of identification (Prag and Neave 1997, Taylor 2001, Wilkinson 2004). These points are all standardized and are used by anthropologists and osteologists alike. Depending on the researcher, between fifteen and thirty-four points are measured (De Greef et al. 2005, Niinimaki and Karttunen 2005, Manhein et al. 2000, Williamson et al. 2002, Wilkinson 2004). Average tissue depth measurements taken for all of these points are then laid out in charts based on the person's sex, race, body type, and age (Wilkinson 2004). Since all of these factors affect the amount of fat deposits in the facial region, it is important to group them accordingly. An artist does not want to use information gathered from elderly, white men to reconstruct a 20-30 year old woman.

One of the major centers of facial reconstructions today is the Forensic Anthropology and Computer Enhancement Services (FACES) Lab at Louisiana State University. The FACES Lab has continued to refine the techniques utilized in facial reconstruction, using new technology like Adobe Photoshop® and portable ultrasound (Manhein et al. 2000). The team at the FACES Lab has also conducted studies in facial tissue depth that utilized ultrasound (Manhein et al. 2000), in addition to several other researchers (De Greef et al. 2005, Smith and Throckmorthon 2004, Stephan and Simpson 2008a, Stephan and Simpson 2008b). The use of ultrasound allowed the researchers to take the measurements on live subjects in an upright position, giving the data a greater accuracy in approximating living tissue (Manhein et al. 2000).

The older studies performed on cadavers with needles provided crucial information but have minor problems due to gravity acting upon an individual who is no longer living; however, comparisons of the measurements with the subject vertical versus horizontal do not reveal any significant differences in the measurements (Stephan and Simpson 2008a, Taylor 2001). The newer studies using ultrasound have the benefit of not harming the subject; therefore living people with faces vertical reduces changes for minor errors (Manhein et al. 2000, Smith and Buschang 2001, Stephan and Simpson 2008a, Taylor 2001). This provides a more natural tissue depth (Manhein et al. 2000, Taylor 2001).

A majority of studies have been completed on American blacks and whites (Manhein et al. 2000, Williamson et al. 2002), though many studies have occurred outside of the United States in order to depict their populations more accurately (Stephan and Simpson 2008a, Taylor 2001, Wilkinson 2002). Studies on Native American tissue depths are scarce, limited to Rhine's on Southwestern Native Americans (published in Taylor 2001 and Manhein 2009). Research is also being done on the differences between adults and juveniles (Manhein et al. 2000, Smith and Buschang 2001, Wilkinson 2002), and the differences between males and females in tissue thicknesses (Stephan and Simpson 2008a, Williamson et al. 2002). While major differences between adults and juveniles have led researchers to caution artists to only use juvenile data on juveniles (Manhein et al. 2000, Stephan and Simpson 2008b, Wilkinson 2002), some researchers report little distinction between males and females at certain anthropometric points (Stephan and Simpson 2008a, Stephan et al. 2005).

The following section looks at artificial cranial deformation and its effects upon the human skull. These changes possibly could impact the effectiveness of facial reconstruction. This potential effect is part of what is being considered in this research.

## Chapter 4: Materials and Methodology

The materials for this project consist of three Late Mississippian skulls exhibiting fronto-occipital cranial deformation, two males and one female, all between the ages of 25-35. The skulls were excavated from the Humber Site in Coahoma County, Mississippi, (Mitchell 1977, Tesar 1976, Tesar and Fichtner 1974). Louis Tesar and his wife, with the aid of several volunteers, excavated the Humber Site from 1974-1975 (Mitchell 1977, Tesar 1976, Tesar and Fichtner 1974). The Humber Site has been popular with pothunters and amateur archaeologists since its discovery in 1929 due to its rich collection of Late-Mississippian ceramics and trade goods (Mitchell 1977, Tesar 1976, Tesar and Fichtner 1974). The Cottonlandia Foundation out of Greenwood, Mississippi, funded the project in an attempt to prevent further loss of data (Tesar 1976, Tesar and Fichtner 1974).

After the initial excavation, all materials were transferred to the University of Mississippi where they were cleaned and prepared for study and curation (Mitchell 1977). The skeletal materials are now under the direction of Dr. Marie Danforth at the University of Southern Mississippi, who generously gave permission for the use of the skulls in this study. The skulls are extremely fragile and bits of bone flaked off even with the gentlest handling, prohibiting traditional methods of reconstruction (directly on the skull or on a plaster cast of the skull).

Cranial measurements of each skull were taken following the guidelines set out in Moore-Jansen et al. (1994). These measurements can be used to determine ancestry and sex (Bass 2005, Burns 1999, Byers 2005, Moore-Jansen et al. 1994, Stephens 1979, White 2000). That was not necessary for this study, as Dr. Danforth and her students previously had identified ancestry and sex for the three skulls. The cranial measurements were taken in order to compare the original skulls to the plastic copies in order to determine that a 1:1 ratio was maintained throughout and that errors in printing did not affect the results of the facial reconstruction. The complete list of cranial measurements taken by the author and Teresa Wilson, a research associate at the LSU FACES Lab, are from the original skulls and the skull casts (Appendix A).

Following the completion of the cranial measurements, the skulls were taken to the Engineering Communications Studio to be scanned. The author completed all scans with the assistance of Elizabeth Beard, a student worker in the Communications Studio (Figure 5). The NextEngine 3D Scanner, in concert with ScanStudio® software, was used for the scanning, trimming, and aligning of scans to create a three-dimensional model. The NextEngine Scanner uses laser stripe triangulation to measure distance from the scanner (Sansoni et al. 2009). This method of scanning has become much more accessible in recent years as less expensive scanners and software are made available (Sansoni et al. 2009).

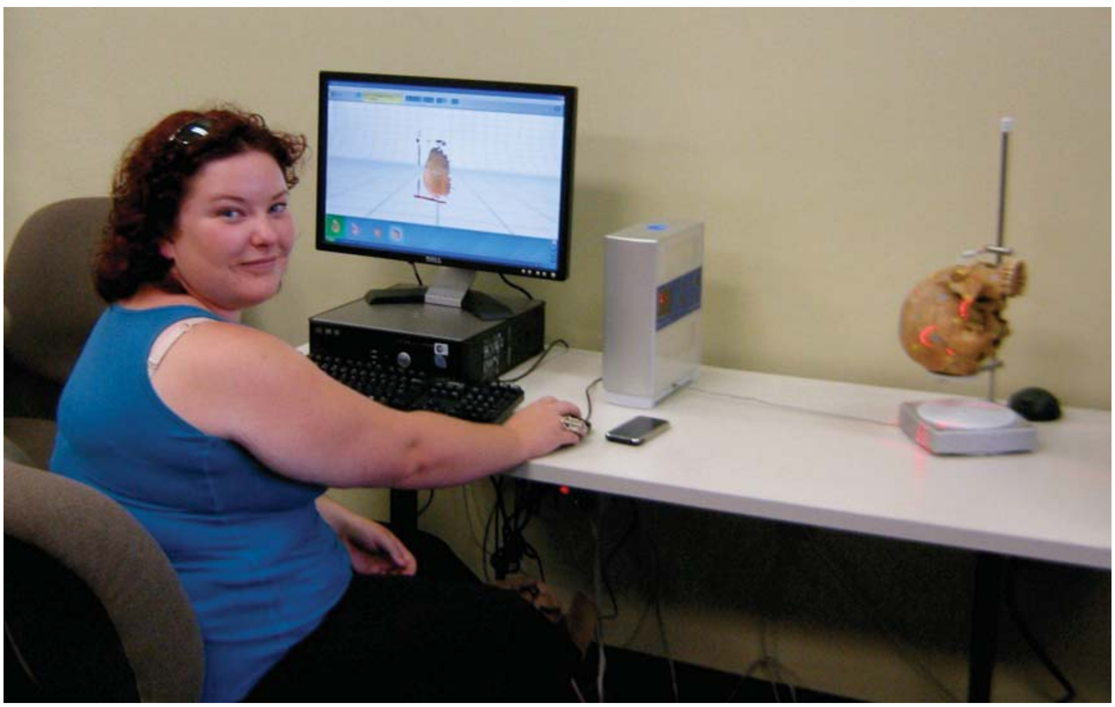

**Figure 5: Scanning of Skull by Alicia Canfield**

The files were then opened in Rhinoceros®, a software package that allows the manipulation of three-dimensional data in order to eliminate alignment errors (Sansoni et al. 2009), where the model was prepared for three-dimensional printing with the aid of Dr. Xin Li from LSU's Center for Computation & Technology. The models are then saved as .srt files, the format required for the three-dimensional printer. This technology was originally designed for reverse engineering of mechanical components, though recently it has expanded into such diverse fields as archaeology, paleontology, F-1 racing, criminal investigations, and art conservation (Joshi et al. 2006, Sansoni et al. 2009, Schramm et al. 2005, Seitz et al. 2005, Stokstad 2000).

Several different materials can be used to create three-dimensional models, including wax, paper, cornstarch and sugar, and acrylonitrile butadiene styrene (ABS) plastic (Joshi et al. 2006, Kalita and Ferguson 2006, Seitz et al. 2005, Stokstad 2000). The Communications Studio owns a 3-D printer that uses ABS plastic; so, that was the medium chosen for the skull casts (Figure 6). The female skull (B-72) was printed as a solid mass; due to cost and time constraints, it was the only one done in this method. The two male skulls (B-86-A and B-83-A) were printed using a honeycombing method where the internal structure of the skull, mainly the brain cavity, was filled with honeycombed plastic layers. This lightened the skulls considerably and halved the printing time (Figure 7).

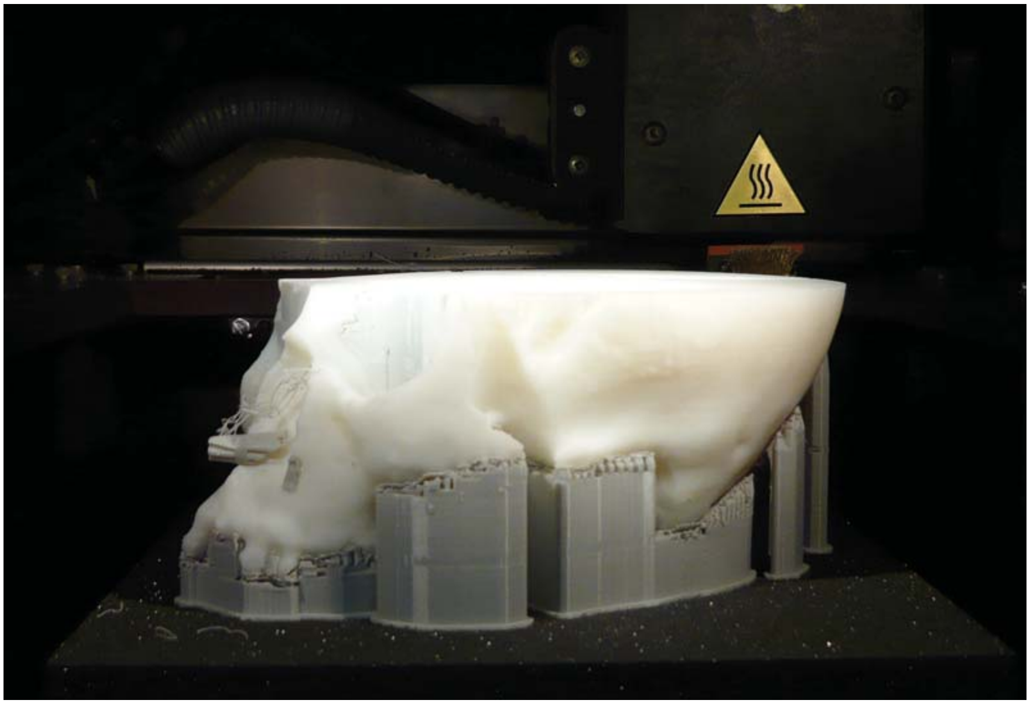

**Figure 6: Skull in the Process of Being Printed**
**Image courtesy of Warren Hull**

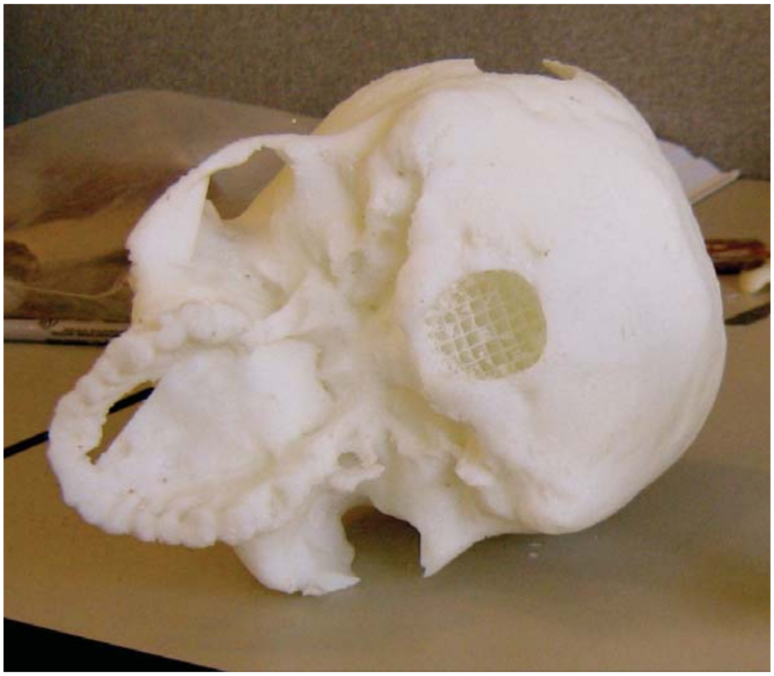

**Figure 7: Latticework Interior Seen Through the Foramen Magnum**

When the skulls came out of the three-dimensional printer, they were covered with support material. This material needed to be removed before the reconstruction could begin (Figure 8).

**Figure 8: Skull B-86-A with Support Material**

After the support material was removed, the author rescanned the completed skulls using the same method described above (Figure 9). This was done so that further analysis can be made from the scans themselves on the completeness of the reconstruction and the success of the algorithm designed by Dr. Li to close the open curves of the skull while still maintaining the necessary level of detail to keep this method viable for further, forensic reconstructions. The skull casts were remeasured before the reconstructions were begun to make sure that they were perfect 1:1 replicas. Some measurements were impossible to repeat due to holes that appeared in the replicas where none existed in the originals. Before the reconstructions could begin, these holes had to be filled with clay or covered over with masking tape. This ensured that the clay would not suddenly slump in these areas as the reconstructions progressed.

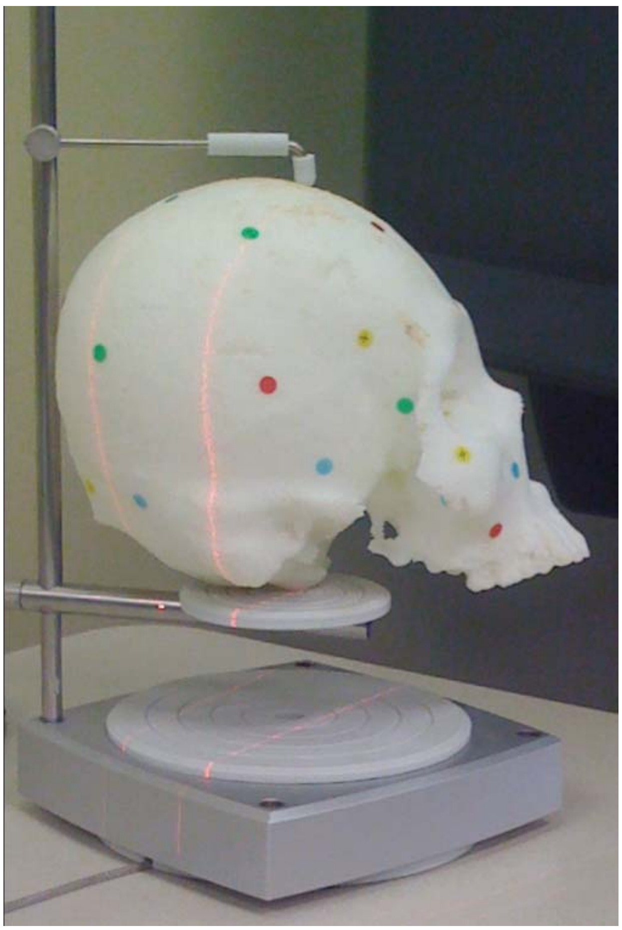

**Figure 9: Skull Cast of B-86-A Being Scanned**

Facial reconstructions were completed in the FACES Lab under the supervision of Eileen Barrow and Nicole Harris. The method of reconstruction used was the American Method developed by Betty Pat Gatliff. Reference materials included *Forensic Art and Illustration* by Karen Taylor, *Introduction to Clay Facial Reconstruction* by Mary Manhein, and several recent articles concerning the shaping of the nose and mouth (Rynn and Wilkinson 2006, Stephan and Murphy 2008, Wilkinson and Mautner 2003, Wilkinson et al. 2003). Tissue depth information on Native Americans can be found in both books courtesy of Stanley Rhine (See also Appendix E). "Normal" tissue depth markers were used as none of the bones exhibited signs of anemia or other pathologies indicating malnutrition. With the mixed diet of corn, beans, squash, deer, and any other seasonal foods (Hudson 1976, Pauketat 2004), it is likely that the individuals were of "normal" weights, neither obese nor emaciated. Photographs were taken at every step of the process. A photo of the completed clay reconstruction was used to create a photo composite reconstruction in Photoshop®.

# Chapter 5: Results

Figures 10-17 show the changes for each skull from start to finish. Each set begins with the original skull and goes through the finished reconstruction. In addition to the individual images, composite images have been made where possible, overlaying the original skull, the cast, and the reconstructions in different ways to illustrate the similarities and differences among them.


**Figure 10: Skull B-72: Original Skull, Skull Cast, Clay Reconstruction, Photoshop Reconstruction**

The major differences are found between the original skull and the skull casts.  Not only can one see the different holes from the original skull filled in, but changes in the size of the skulls, some general morphological changes, and even new holes created in the cast where the original bone was perfect before.


**Figure 11:   B-72: Original Skull with Cast Overlay**

**Figure 12:   B-72: Clay Reconstruction with Photo Reconstruction Overlay**

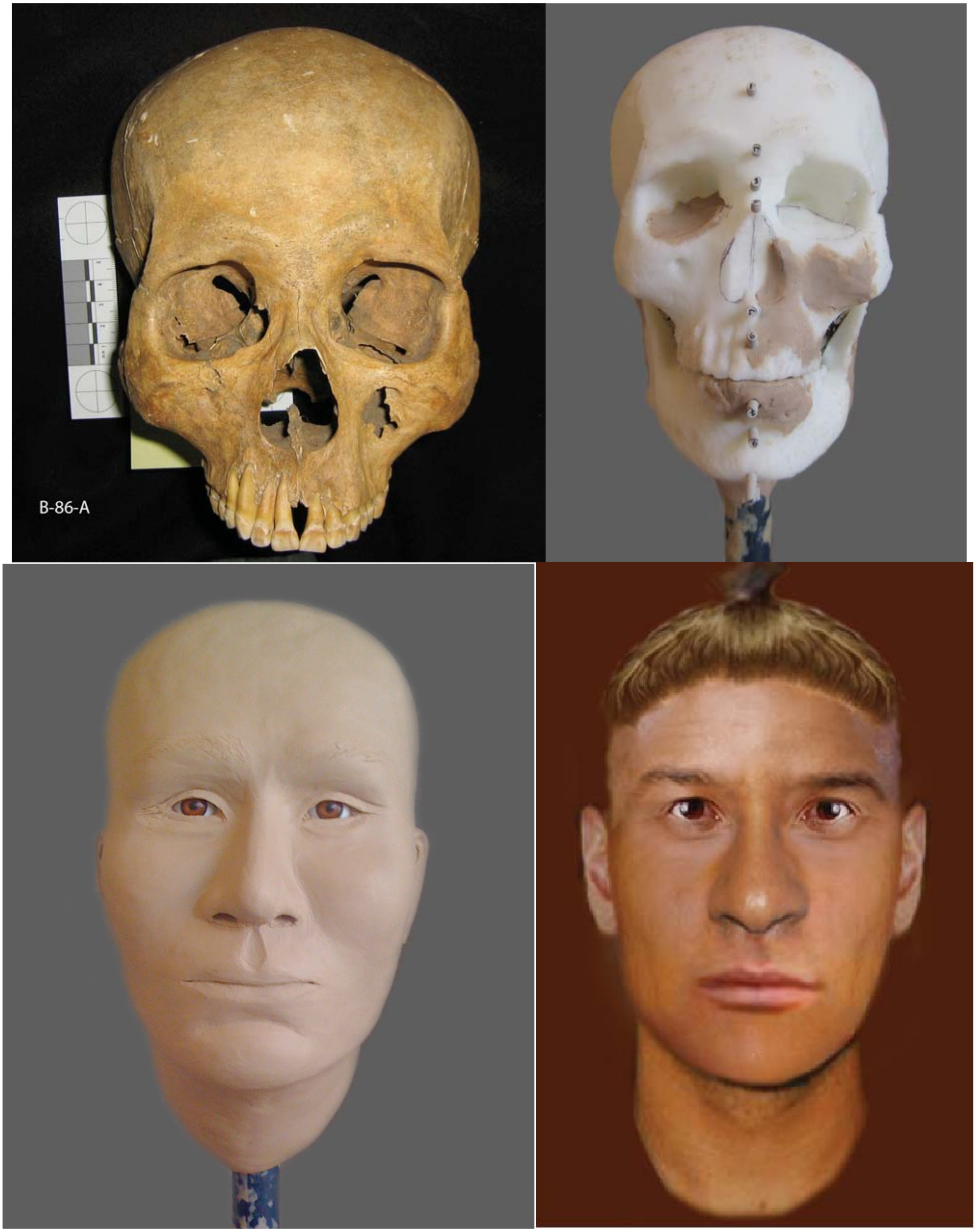


**Figure 13: B-86-A: Original Skull, Skull Cast, Clay Reconstruction, Photoshop Reconstruction**

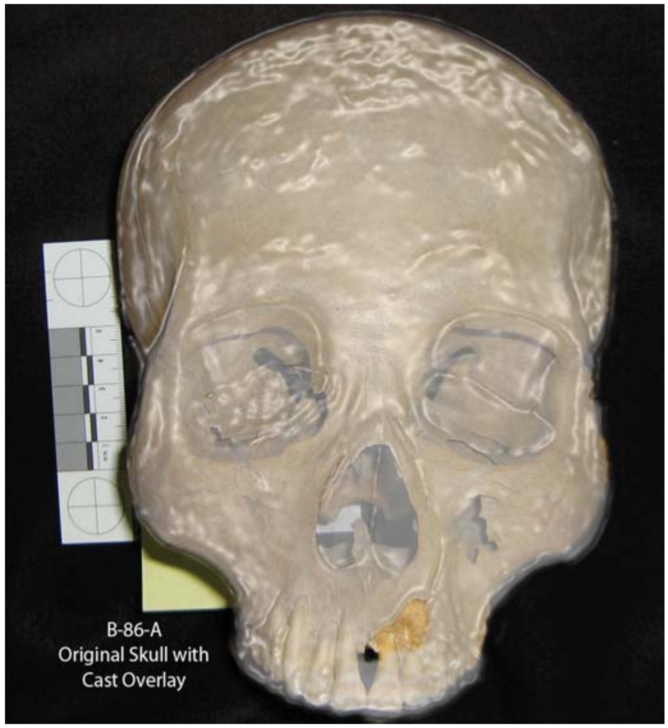


**Figure 14: B-86-A: Original Skull with Cast Overlay**

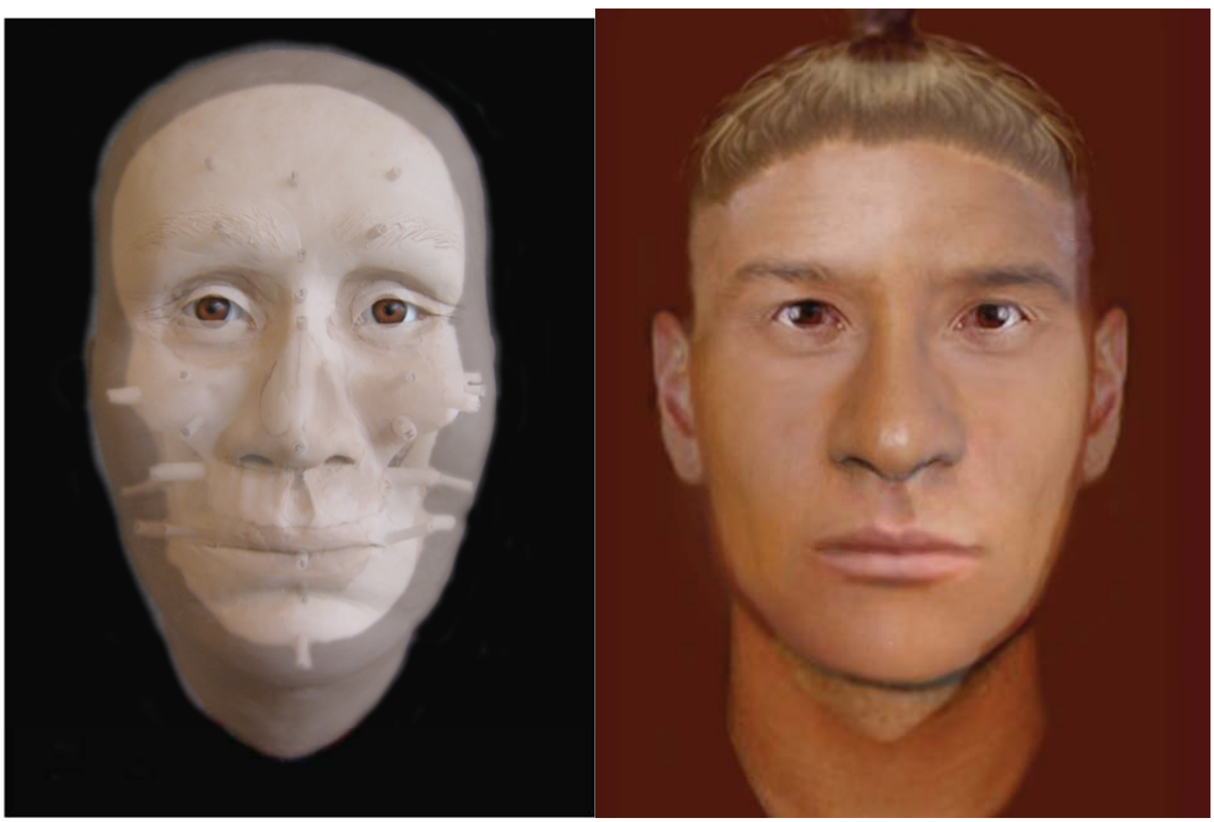

**Figure 15: B-86-A: Skull Cast with Clay Reconstruction Overlay and Clay Reconstruction with Photoshop Overlay**


**Figure 16: B-83-A: Original Skull, Skull Cast, Clay Reconstruction**


**Figure 17: Skull B-83-A Original Skull with Cast Overlay**

## *Skull Casts*

The three crania for this project were all printed differently in order to determine the best way to print skulls for later cases, while all three mandibles were printed the same, as solid pieces of ABS plastic. The first skull, B-72, was printed in anatomical position with the cranial base facing downwards as a solid mass of plastic (Figure 18). This ensures that the skull is protected against damage; however, it increases the cost of production and the printing time twofold. It also makes it difficult to drill the hole in the foramen magnum in order to place the skull on the stand for the reconstruction. This increase in time and money makes this method of printing impractical for many forensic and archaeological projects as budget concerns are often of the highest importance. On the other hand, the solid nature of the skull makes it ideal if the exhibit is going to be traveling often and there is a high risk of damage from repeated handling. The weight of the skull actually made it easier to complete the reconstruction

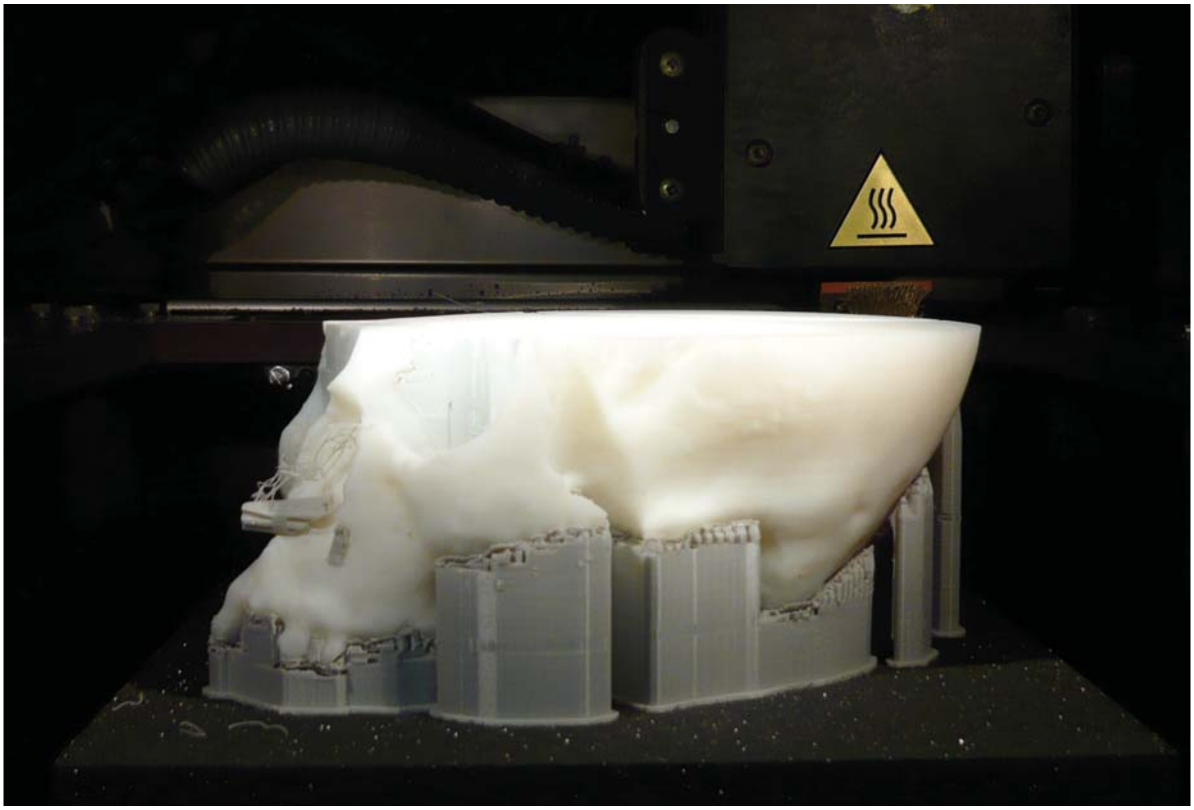

**Figure 18: Skull B-72: Partial Build**
**Image courtesy of Warren Hull**

because once it was in place, there was no dislodging it by accident while applying the clay layers. There were discrepancies between the original skull and the cast, though these were not major enough that they interfered with the facial reconstruction (See Appendix B for skull and cast photos). A comparison of the cranial measurements taken on the original skull and the cast led to the discovery of a 1-3 millimeters (mm) difference across the measurements. This is quite large, but as the difference was almost uniform it did not compromise the reconstruction; rather, it simply made the skull, and the resulting face, appear smaller than it should have been.

The second skull to be printed, B-86-A, was printed using a honeycombing, or latticework pattern on the interior structure, also in anatomical position. The interior latticework lightened the skull considerably while still maintaining the internal strength necessary to withstand outside pressures from the reconstruction and continued handling. The thinness of the outside layer made it easier to drill out the foramen magnum, but could make the cast more susceptible to damage from being dropped or shipped across the country. A partial printing of this skull was done in the solid plastic; so, some visual comparison can be made between the two methods. Some inconsistencies are present between the two casts, including damage to the zygomatic arch and the naso-maxillary region (Figure 19). Discrepancies between the original skull and the cast occurred in these areas and others (See Appendix C for more photographs of the skull and cast for comparison). A comparison of the cranial measurements revealed that the cast was an almost perfect 1:1 replica with no major differences observed.

**Figure 19: Comparison between Partial Cast (Solid) and Completed Cast (Latticework)**

The third skull, B-83-A (Appendix D), was printed using the latticework method, but with the occipital region rather than the cranial base facing downward. This allowed the machine to impart greater detail in the facial region, which is necessary for more accurate reconstructions. It lacked all of the facial imperfections of the second cast, leading to the conclusion that it was the orientation of the skull that contributed to the greater amount of imperfections seen in B-86-A. The cranium was also a near perfect 1:1 replica with only minor variations in the cranial measurements. However, the mandible for this skull experienced a variety of problems that are puzzling to say the least. The original mandible is perfect, with no holes and few missing teeth. On the other hand, the plastic replica has large gaping holes in several areas and is degraded in several others (For a comparison, see Figure 20).


**Figure 20: Comparison Between the Original Mandible and the Cast**

During the removal of the support material, several pieces of the mandible broke off. In the end, some of the support material was left on the mandible in order to maintain structural integrity so that it could be used for the facial reconstruction, flawed as it was. The author reconstructed the mandible with clay so that it could be used in the reconstruction, though it is recognized that it is no longer a true representation of the original mandible. The degraded nature makes the third reconstruction highly unreliable as almost half of the anatomical markers used for the facial reconstruction are on the mandible, and, thus, the reliability of the depths in the lower half of the face cannot be trusted.

## *Clay Reconstructions*

The test of the American Method of facial reconstruction is in whether it would have to change significantly for a skull showing cranial deformation, or if the general method would still apply with little to no provisos for the reconstruction artist. Researchers have documented changes in the cranial base and the face due to cranial deformation (Cheverud et al. 1992, Kohn et al. 1993). Therefore, it was believed that multiple changes would have to be made to the American Method to make it work with skulls exhibiting cranial deformation. However, this was not the case. Little overall change was observed and the original method worked extremely well. The only area where major changes to the American Method had to be made was in the placement of the eyes and the sculpting of the eyelids. Normally, the eyes are placed in the eye socket so that the most projecting point of the eye is flush with a line between the superior and inferior margins of the eye orbit (Manhein 2009). Younger individuals have larger fat pads behind the eyes, which cause the eye to be flush, or almost flush, to an imaginary line between the two borders (Taylor 2001, Wilkinson 2004, Wilkinson and Mautner 2003). This fat pad decreases with age, giving the individual a sunken, or deep-set appearance, as he or she grows older (Taylor 2001, Wilkinson 2004, Wilkinson and Mautner 2003).

Placement of the eyes in this manner caused them to be too deep-set, especially since all individuals were under the age of 40. This would have restricted peripheral vision. Interestingly, the process of cranial deformation altered the superior border of the eye orbit, causing it to appear almost receding. This was especially prominent in the female skull, B-72, though it is unknown exactly why this is. It is possible that the degree of cranial deformation was greater in B-72 than the others. A larger sample is needed to determine whether this is an isolated case or whether it is indicative of a cultural trend, women having a greater degree of deformation than men. The eyes were removed and re-placed in the skull with only the inferior border of the eye orbit being used to determine the protrusion of the eye. This resulted in a much more “normal” appearance and the ability to see out of the corner of the eye.

### *Photoshop® Reconstructions*

Photoshop® reconstructions were completed for the first two reconstructions, as those were the only reliable reconstructions available. Images from the Internet were used to piece together the faces in order to give a more realistic depiction. The LSU FACES Lab currently uses this technique and Eileen

Barrow and Nicole Harris gave assistance and advice when necessary. Clay reconstructions can be difficult to identify as they are missing the play of shadow and light upon skin tones that give the depth seemingly needed for people to recognize faces. The use of photographic composites gives the reconstructions a more life-like appearance, which is useful for archaeological exhibits as well. It is also easier to change eye and hair color, as well as hairstyles, in Photoshop® that in the clay. Many clay reconstructions have hair sculpted on, but some artists use wigs, which can give a more artificial appearance (Taylor 2001).

The only issue found in using this method with these skulls was the placement of the hair and the resulting foreshortening of the forehead on B-72. As seen in Figure 21, from the side, the forehead is quite large, sloping backwards sharply. However, in the original composite, it did not give this appearance. The hairline was pushed back in order to create a more appropriate depth to the forehead. Problems with the hair on B-86-A resulted more from the unusual style worn by Mississippian men, shaved on the sides and held up in a topknot or bun at the crown of the head. This is not a popular style nowadays, so it was difficult finding photographs to adapt for this head.

**Figure 21: B-86-A and B-72**

## Chapter 6: Discussion

The initial reason for casting the three skulls used in this study was because they were too fragile after more than five hundred years in the ground to survive a reconstruction directly upon the skull or the process of making a plaster cast. With the advances in three-dimensional scanning and rapid prototyping in recent years in terms of precision and cost reduction, the scanning/printing method created a viable alternative for archaeological and forensic reconstructions. This method of casting the skull is not currently used in forensic anthropology and this study is one of the first to examine the possibilities for the use of this technology in the anthropological field.

The program used for scanning the skulls, ScanStudio®, was easy to learn and easier to use. The first skull scanned, B-83-A, was used as the test skull for determining the best possible way to obtain the largest amount of skeletal detail with the fewest number of scans. The more scans completed, the larger the file had to be. Consequently, more RAM was required to process and align the scans to create the complete model. We determined that two 360$^o$ scans at different orientations (Figure 22), split into eight sections, caught the maximum amount of detail while keeping the file size to a minimum.

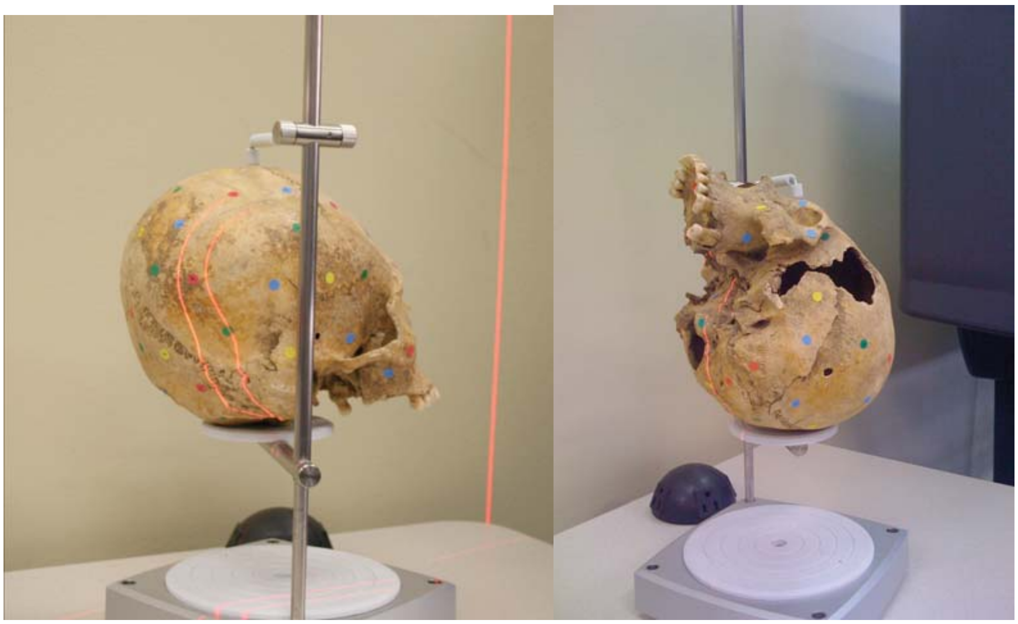

**Figure 22: Skull Orientations for 360$^o$ Scanning**

Additional scans were sometimes necessary to scan the oblique planes of the eye orbits and the dental arcade, but they could be done in single or bracket scans and did not add to the file size significantly. The scanning of the mandible was the most difficult due to the variety of planes and angles (Figure 23). Several additional scans were necessary to obtain the necessary detail, but there were still gaps in the scans that had to be corrected in Rhino. No issues with reflectivity were detected, but, most likely, there would be issues when scanning fresh, clean bones.

**Figure 23: Difficulties Scanning the Mandible**

The scanning stage was completed quickly, but the next stage, the closing of open curves in the aligned scans, experienced difficulties. The Engineering Communications Studio required a special program to close open curves in the scans in order to create a complete model that can be printed. Normally, ScanStudio® is able to close the curves in the scans and create a volumetric model; however, with the multitude of natural holes and post-depositional holes in the skull, ScanStudio® was unable to close all of the curves. This precipitated a need to create a specialized algorithm. Dr. Shane Li, from the

Center for Computation & Technology, was able to write an algorithm that closed the curves, but there were some unintended side effects.

Where the skeletal material had been complete, holes suddenly appeared. The original skeletal material and the initial files from ScanStudio® were double-checked by the author and Mr. Warren Hull for scanning errors or damaged areas that corresponded to damage in the casts. It appears that while the algorithm closed the open curves, it deteriorated several areas in each skull, though some had more damage than others. This phenomenon was first noticed in the printing of the second skull, B-86-A, where differences between the solid plastic and honeycombed plastic casts were unmistakable (Figure 24 and 25).

**Figure 24: B-86-A: Partial Cast, Honeycombed Cast, Original Skull**

**Figure 25: B-86-A: Original Skull and Skull Cast with New Hole**

The third skull, B-83-A, had the most errors caused by the closing of open curves. It brings up questions about the ability of the rapid prototyping method to produce a perfect 1:1 replica of a human skull. The gaping holes in the mandible were enough to ensure that the reconstruction could not be accurate, which makes identification less likely. Though accuracy is not demanded in reconstructions for display purposes, it should always be the goal of the reconstruction, whether it is intended for forensic or museum applications.

A large part of this research was determining out whether the American method of facial reconstruction would be able to adapt itself to a skull with cranial deformation as several studies have pointed out changes in facial morphology due to changes in the cranial vault. No major changes were required in this study to adapt the facial reconstruction method to the skull. This validates the use of the American method in both forensic and archival work. If little artistic input is required to change the method for each skull, then the results are more replicable and less variable. This makes facial reconstruction more applicable in the American legal system and may allow for greater use in the future. This study also shows that the skulls of modern individuals with cranial deformation due to medical reasons can be used in facial reconstructions for identification purposes. While the modification of the cranial vault does affect the growth and formation of the face, it is not enough to render the method of reconstruction useless.

The use of photographic reconstructions in this case was designed to impart a more life-like quality to the reconstructions.  As there are no reliable depictions of prehistoric Mississippian peoples to work from, a variety of images of Native Americans were used, both for the sculpting and the photographic reconstructions. Drawings and paintings exist that depict prehistoric Mississippians; however, the artists had limited access to their subjects and were constrained by the artistic ideals of their times.  They are not particularly useful when looking at facial differences.  Museum pieces are not often perfectly accurate, rather they are trying to get a particular message across to the visitor.

Problems with the hairstyles occurred due to their unusual nature in today's society. From depictions by the Spanish, we know that the women tended to wear their hair down or in twin braids, while the men wore their hair in a topknot with the sides cut short or shaved. In addition to being difficult to find, these styles were difficult to fit to the reconstructions. The shape of the foreheads and the elongated nature of the temples caused several problems with choosing a hairstyle. Having someone model the hairstyles may have solved some of these issues. Either the reconstructions looked like they had no forehead at all, or they began to resemble "coneheads". This was finally solved through blurring methods in Photoshop, but it does not necessarily look realistic, which was the purpose of performing this type of reconstruction. Perhaps having a digital catalog of hairstyles would help resolve this issue in the future.

# Chapter 7: Conclusion

The Mississippian period was a time of rapid change, where old ideas were being rediscovered and new ideas were spreading across the southeastern United States like wildfire. The increased dependence on corn and other agricultural products led to a change in diet that affected the very bone of a people. This led to higher rates of disease and degraded physical conditions in some cases due to poorer diets and an over reliance upon one substance, corn. This pattern has been seen all over the world during the switch to horticulture/agriculture from foraging/hunting subsistence patterns.

The process of cranial deformation marks not only one's body, but also one's social personae. Throughout the history of the world, people have identified with some and segregated themselves from others by means of body modification. The use of facial reconstruction methods in this case allowed a glimpse into how the Mississippian people might have seen themselves and identified themselves as a people separate from others. Further studies into other types of cranial deformation, such as that practiced by some Mayan peoples, and the effect of those types upon facial reconstruction methods, would not only make the science/art of facial reconstruction stronger in its ability to be applied to people with abnormal cranial formations, it would advance an understanding of the people themselves. How they looked, how they saw themselves, and how they saw others are important questions that can be answered in part through facial reconstruction.

The application of rapid prototyping skull casting has tremendous potential. The scanning and replicating of bones, which are extremely fragile, can be used in a variety of circumstances. Many situations arise where human bones can become fragile, such as fire victims, long exposure to the environment, archaeological burials, and paleoanthropological finds. These bones often have fractures and cortical flaking and researchers might do more damage than good in their handling of the remains. Through rapid prototyping, replicas could be made quickly with no further damage to the bones, while preserving a high resolution of detail. Then, the casts or computer files could be sent to multiple individuals and/or agencies for research and identification purposes.  However, higher resolution scans and casts are necessary for this type of casting to become accepted by the academic community.

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# Appendix A: Cranial Measurements

| Cranial Measurements* | | | | | | |
|---|---|---|---|---|---|---|
| **Skull ID #:** | **B-86-A** | | | | | |
| **Measurements Taken By:** | Original - Alicia Canfield | | Original - Teresa Wilson | | Cast - Alicia Canfield | |
| Side Where Appropriate | Left | Right | Left | Right | Left | Right |
| Maximum Length (g-op): | 160 | | 161 | | 160 | |
| Maximum Breadth (eu-eu): | 154 | | 156 | | – | |
| Bizygomatic Breadth (zy-zy): | 140 | | 143 | | – | |
| Basion-Bregma (ba-b): | 149 | | 152 | | 152 | |
| Cranial Base Length (ba-n): | 101 | | 105 | | 103 | |
| Basion-Prosthion L. (ba-pr): | 100 | | 102 | | 101 | |
| Maximum Alveolar Breadth (ecm-ecm): | 62 | | 70 | | 69 | |
| Maximum Alveolar Length (pr-alv): | 53 | | 59 | | 59 | |
| Biauricular Breadth: | 128 | | 131 | | 128 | |
| Upper Facial Height (n-pr): | 73 | | 74 | | 74 | |
| Minimum Frontal Breadth (ft-ft): | 100 | | 101 | | 101 | |
| Upper Facial Breadth (fmt-fmt): | 111 | | 112 | | 111 | |
| Nasal Height (n-ns): | 58 | | 57 | | – | |
| Nasal Breadth (al-al): | 27 | | 27 | | – | |
| Orbital Breadth (mf-ec): | 37 | 41 | 42 | 43 | 42 | 43 |
| Orbital Height: | 34 | 32 | 35 | 33 | 35 | 33 |
| Biorbital Breadth (ec-ec): | 102 | | 103 | | 103 | |
| Interorbital Breadth (mf-mf): | 24 | | 23 | | 21 | |
| Frontal Chord (n-b): | 115 | | 115 | | 115 | |
| Parietal Chord (b-l): | 130 | | 135 | | 131 | |
| Occipital Chord (l-o): | 60 | | 57 | | 58 | |
| Foramen Magnum | 33 | | 33 | | 34 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Length (ba-o): | | | | | | |
| Foramen Magum Breadth: | 30 | | 30 | | 30 | |
| Mastoid Length: | 25 | 25 | 25 | 25 | 26 | 26 |
| **Mandibular Measurements** | | | | | | |
| Chin Height (gn-id): | 38 | | 38 | | 38 | |
| Body Height at Mental Foramen: | 37 | 37 | 37 | 37 | 37 | 37 |
| Body Thickness at Mental Foramen: | 14 | 13 | 14 | 14 | 14 | 13 |
| Bigonial Diameter (go-go): | 107 | | – | | 107 | |
| Bicondylar Breadth (cdl-cdl): | 127 | | – | | 126 | |
| Minimum Ramus Breadth: | 39 | 38 | – | 38 | – | 36 |
| Maximum Ramus Breadth: | 46 | 45 | – | 42 | – | – |
| Maximum Ramus Height: | 64 | – | – | – | – | – |
| Mandibular Length: | 90 | | – | | – | |
| Mandibular Angle (in Degrees): | 116 | | – | | – | |
| *A (–) indicates that the measurement was unable to be taken. | | | | | | |
| **Cranial Measurements** | | | | | | |
| **Skull ID #:** | **B-83-A** | | | | | |
| **Measurements Taken By:** | Original - Alicia Canfield | | Original - Teresa Wilson | | Cast - Alicia Canfield | |
| Side Where Appropriate | Left | Right | Left | Right | Left | Right |
| Maximum Length (g-op): | 163 | | 165 | | 164 | |
| Maximum Breadth (eu-eu): | 146 | | 146 | | 146 | |
| Bizygomatic Breadth (zy-zy): | – | | – | | – | |
| Basion-Bregma (ba-b): | 151 | | 151 | | 15 | |
| Cranial Base Length (ba-n): | 106 | | 114 | | 106 | |
| Basion-Prosthion L. (ba-pr): | 100 | | 102 | | 102 | |
| Maximum Alveolar Breadth (ecm-ecm): | 66 | | – | | 65 | |
| Maximum Alveolar Length (pr-alv): | 54 | | 59 | | 56 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Biauricular Breadth: | – | | – | | – | |
| Upper Facial Height (n-pr): | 76 | | 76 | | 76 | |
| Minimum Frontal Breadth (ft-ft): | 87 | | 89 | | 88 | |
| Upper Facial Breadth (fmt-fmt): | 103 | | 103 | | 101 | |
| Nasal Height (n-ns): | 54 | | 56 | | 56 | |
| Nasal Breadth (al-al): | 27 | | 28 | | 28 | |
| Orbital Breadth (mf-ec): | 41 | 41 | 38 | 38 | 39 | 40 |
| Orbital Height: | 35 | 36 | 35 | 34 | 35 | 34 |
| Biorbital Breadth (ec-ec): | 93 | | 94 | | 94 | |
| Interorbital Breadth (mf-mf): | 22 | | 22 | | 22 | |
| Frontal Chord (n-b): | 116 | | 116 | | 116 | |
| Parietal Chord (b-l): | 135 | | 141 | | 125 | |
| Occipital Chord (l-o): | 99 | | 51 | | 98 | |
| Foramen Magnum Length (ba-o): | 39 | | 39 | | 39 | |
| Foramen Magum Breadth: | 32 | | 32 | | 32 | |
| Mastoid Length: | 21 | 24 | 27 | 27 | 27 | 27 |
| **Mandibular Measurements**** | | | | | | |
| Chin Height (gn-id): | – | | 33 | | | |
| Body Height at Mental Foramen: | 31 | 33 | 33 | 33 | | |
| Body Thickness at Mental Foramen: | 14 | 15 | 14 | 15 | | |
| Bigonial Diameter (go-go): | 109 | | 108 | | | |
| Bicondylar Breadth (cdl-cdl): | 123 | | – | | | |
| Minimum Ramus Breadth: | 38 | 38 | 38 | 38 | | |
| Maximum Ramus Breadth: | 44 | 45 | 47 | 46 | | |
| Maximum Ramus Height: | 66 | – | 67 | – | | |
| Mandibular Length: | 81 | | 84 | | | |
| Mandibular Angle (in Degrees): | 119 | | 113 | | | |
| **No Measurements on the Mandible were able to be taken due to its degraded state. | | | | | | |
| | | | | | | |

| Cranial Measurements | | | | | | |
|---|---|---|---|---|---|---|
| **Skull ID #:** | **B-72** | | | | | |
| **Measurements Taken By:** | Original - Alicia Canfield | | Original - Teresa Wilson | | Cast - Alicia Canfield | |
| Side Where Appropriate | Left | Right | Left | Right | Left | Right |
| Maximum Length (g-op): | 157 | | 158 | | 155 | |
| Maximum Breadth (eu-eu): | 153 | | 155 | | 151 | |
| Bizygomatic Breadth (zy-zy): | – | | – | | – | |
| Basion-Bregma (ba-b): | 136 | | 136 | | 133 | |
| Cranial Base Length (ba-n): | 95 | | 95 | | 93 | |
| Basion-Prosthion L. (ba-pr): | 100 | | 99 | | 96 | |
| Maximum Alveolar Breadth (ecm-ecm): | 69 | | 67 | | 65 | |
| Maximum Alveolar Length (pr-alv): | – | | 56 | | – | |
| Biauricular Breadth: | 121 | | 121 | | 118 | |
| Upper Facial Height (n-pr): | 75 | | 75 | | 72 | |
| Minimum Frontal Breadth (ft-ft): | 91 | | 91 | | 90 | |
| Upper Facial Breadth (fmt-fmt): | 99 | | 99 | | 96 | |
| Nasal Height (n-ns): | 56 | | 54 | | 54 | |
| Nasal Breadth (al-al): | 23 | | 26 | | 23 | |
| Orbital Breadth (mf-ec): | 40 | 40 | 36 | 36 | 37 | 37 |
| Orbital Height: | 35 | 35 | 33 | 34 | 37 | 34 |
| Biorbital Breadth (ec-ec): | 92 | | 94 | | 93 | |
| Interorbital Breadth (mf-mf): | 22 | | 23 | | 22 | |
| Frontal Chord (n-b): | 105 | | 109 | | 103 | |
| Parietal Chord (b-l): | 100 | | 128 | | 101 | |
| Occipital Chord (l-o): | 89 | | 57 | | 85 | |
| Foramen Magnum Length (ba-o): | 33 | | 34 | | 33 | |
| Foramen Magum Breadth: | 30 | | 30 | | 30 | |
| Mastoid Length: | 17 | 22 | 19 | 26 | 19 | 24 |

| Mandibular Measurements | | | | | | |
|---|---|---|---|---|---|---|
| Chin Height (gn-id): | 34 | | 35 | | 32 | |
| Body Height at Mental Foramen: | 33 | 32 | 33 | 32 | 32 | 32 |
| Body Thickness at Mental Foramen: | 12 | 12 | 11 | 11 | – | |
| Bigonial Diameter (go-go): | – | | – | | – | |
| Bicondylar Breadth (cdl-cdl): | – | | – | | – | |
| Minimum Ramus Breadth: | 34 | 33 | 35 | 34 | 33 | 31 |
| Maximum Ramus Breadth: | 45 | 44 | 46 | 46 | 46 | 45 |
| Maximum Ramus Height: | – | – | – | – | – | – |
| Mandibular Length: | – | | – | | – | |
| Mandibular Angle (in Degrees): | – | | – | | – | |

# Appendix B: B-72 Photos


CO-202
B-72
B-72
Posterior View


B-72 Right
Lateral View

B-72 Left Lateral View

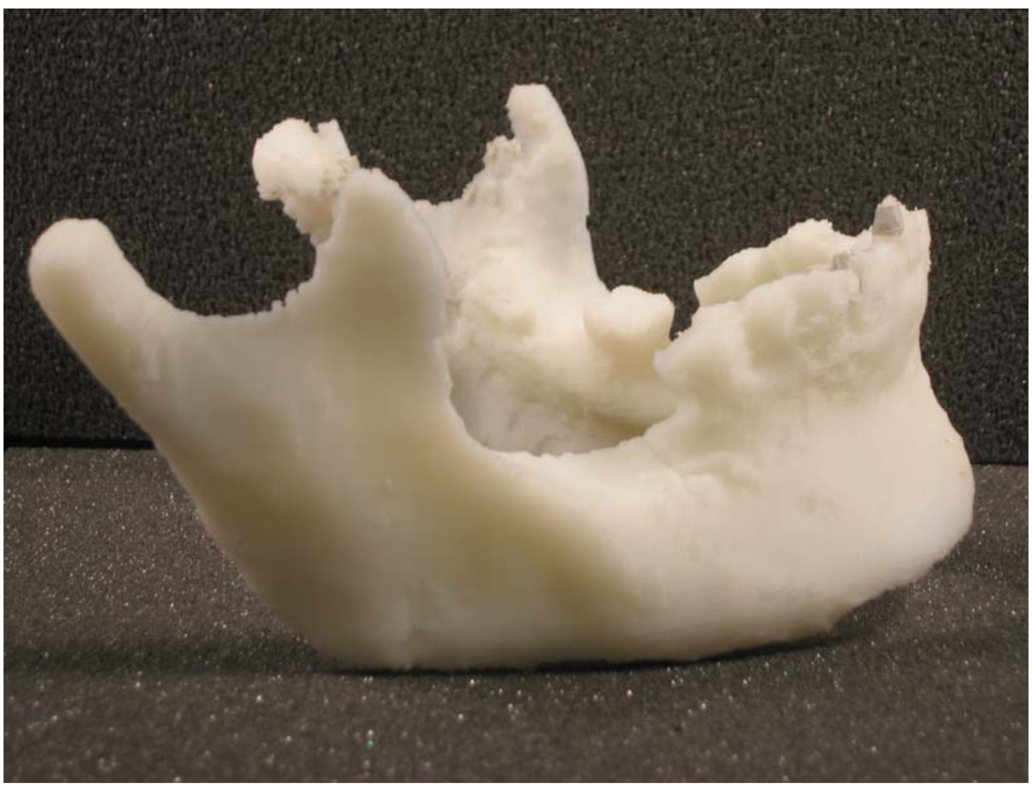
B-72 Inferior View

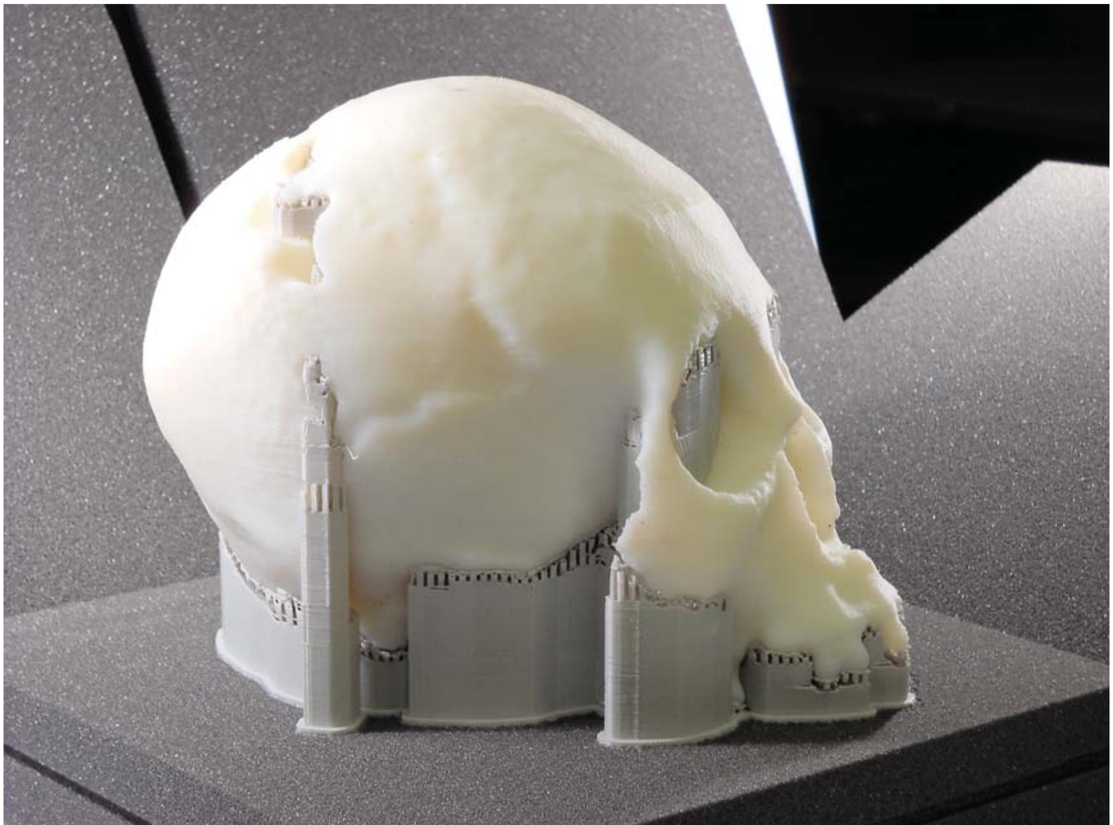

B-72
Mandible Superior
View

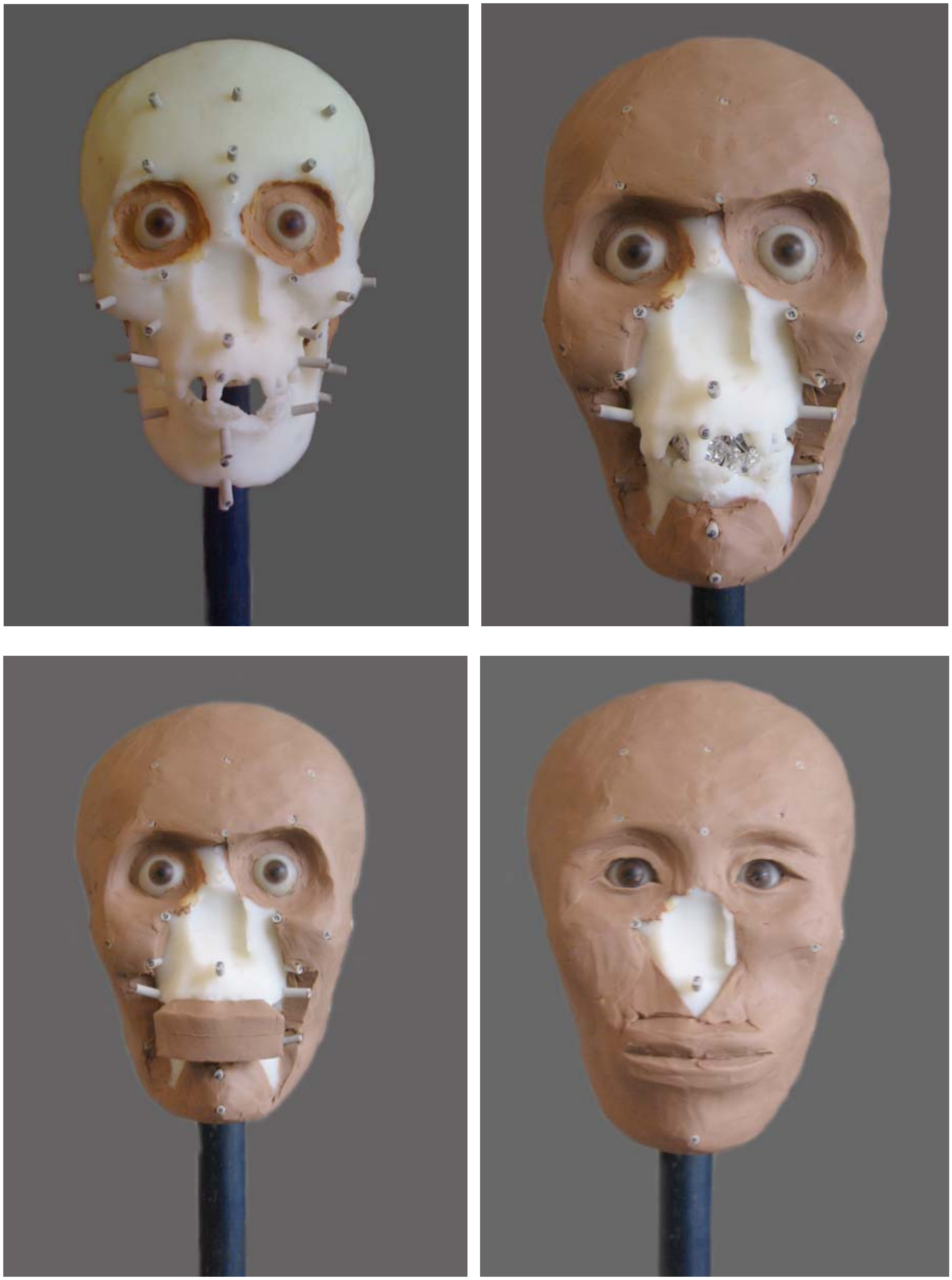

B-72
Mandible in Separate
Pieces


B-72 Mandible
External View
Left Lateral Portion


B-72 Mandible
Exterior View
Right Lateral Portion

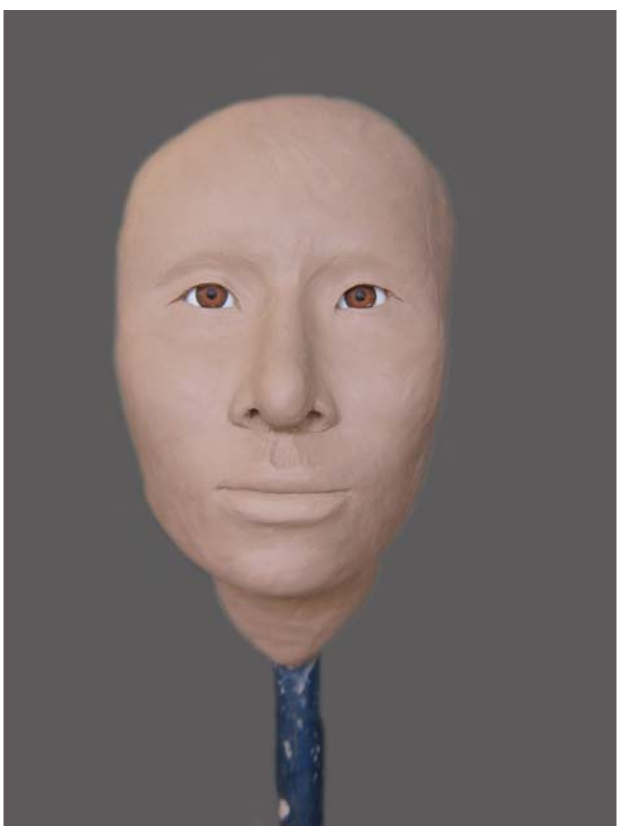
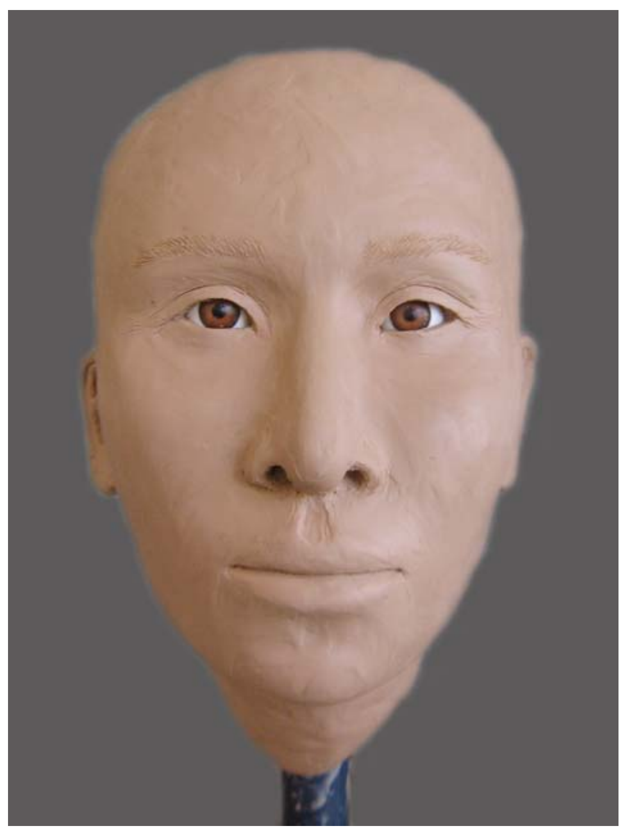








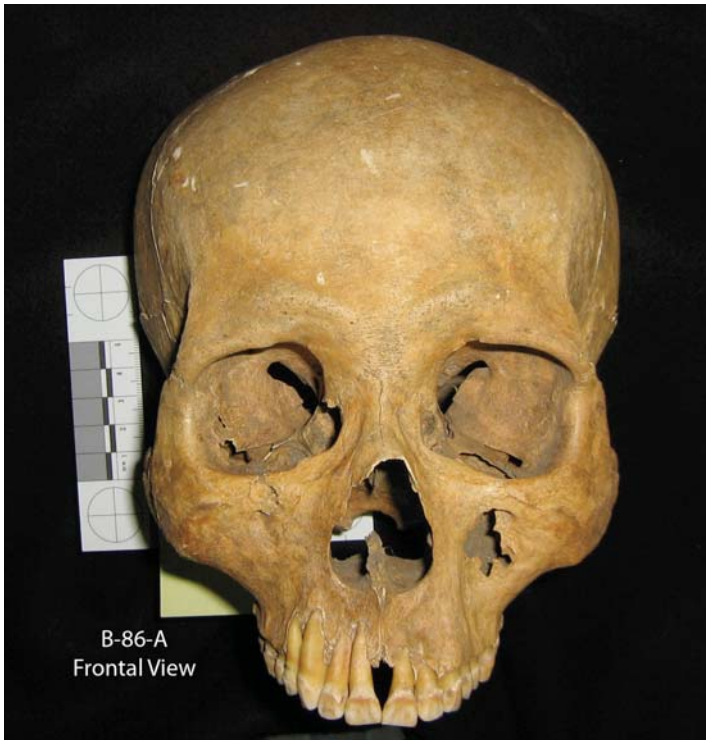



B-72
Original Skull with Cast
Overlay

**Photoshop Reconstruction and Photoshop Reconstruction Overlaying Clay Reconstruction**

# Appendix C: B-86-A Photos

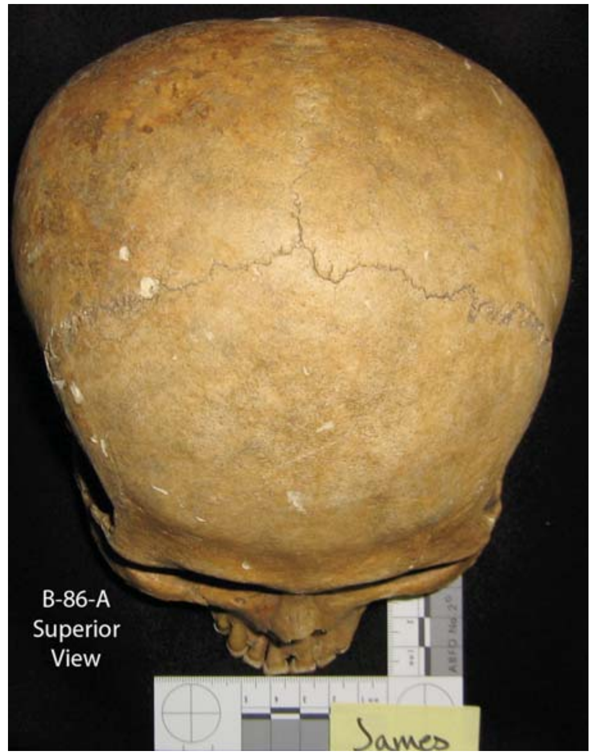




B-86-A
Right Lateral
View


B-86-A
Left Lateral View


B-86-A
Inferior View


B-86-A
Superior
View
James


B-86-A
Mandible
Anterior View


B-86-A
Mandible
Interior View

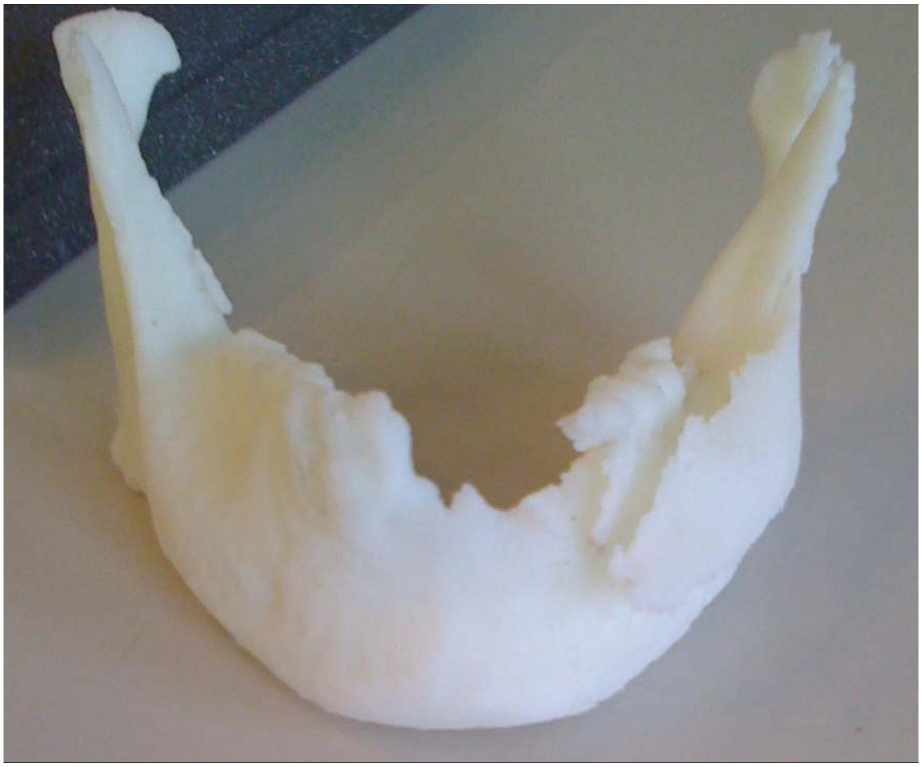
B-86-A Mandible
Superior View

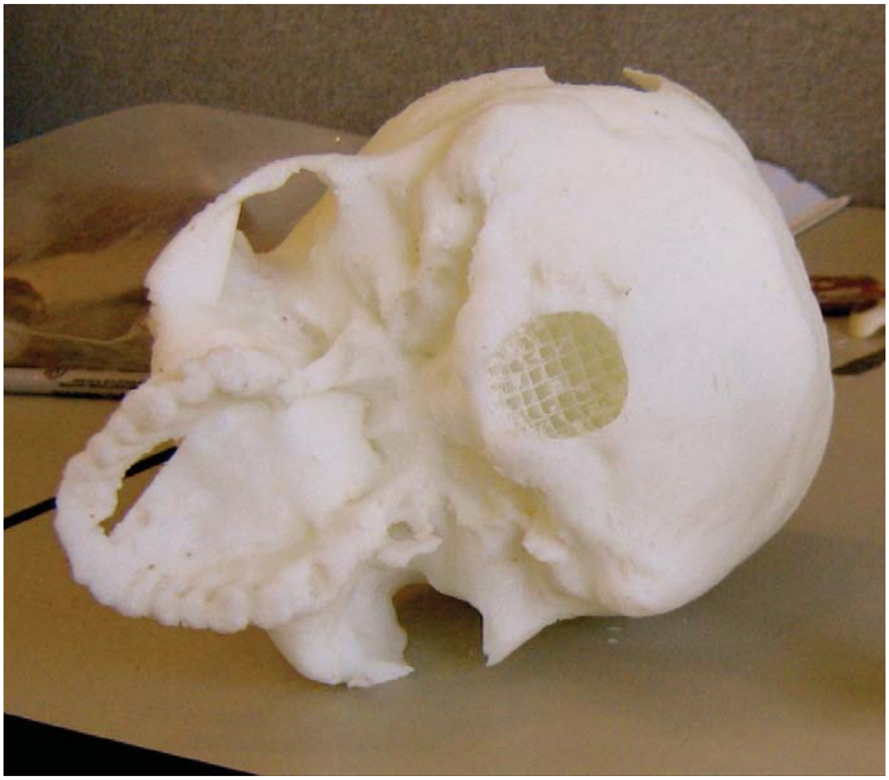

B-86-A Mandible
Right Lateral View

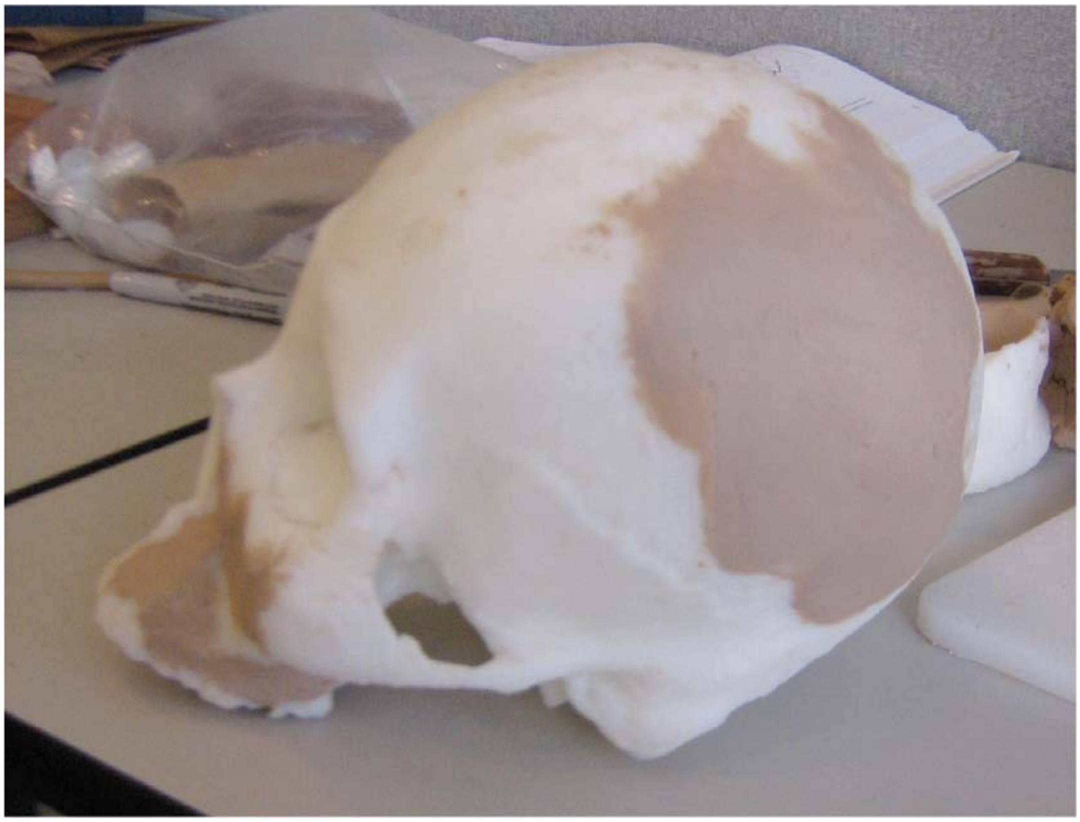

B-86-A
Mandible
Left Lateral
View

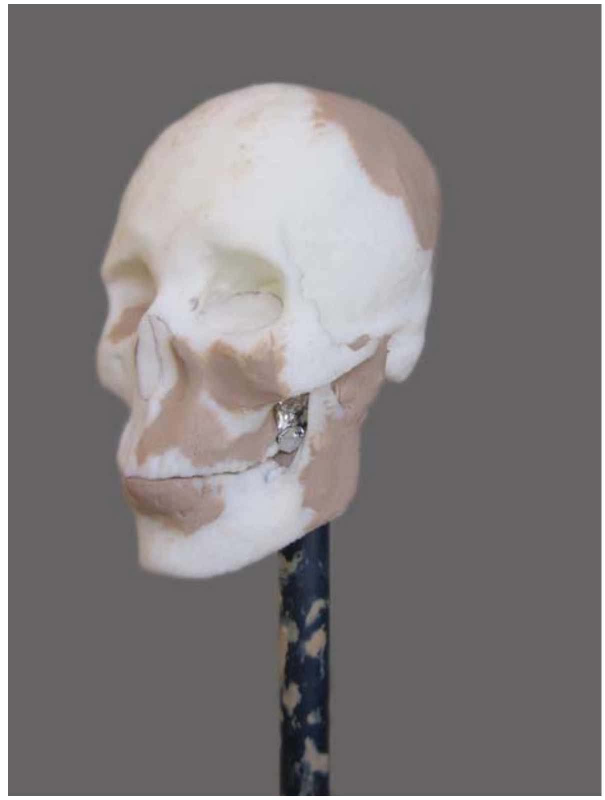

IAMON


DIAMOND





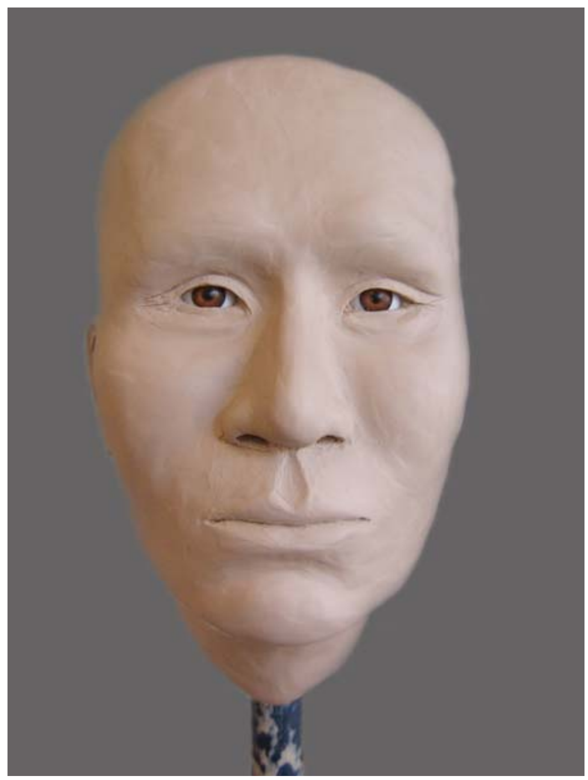


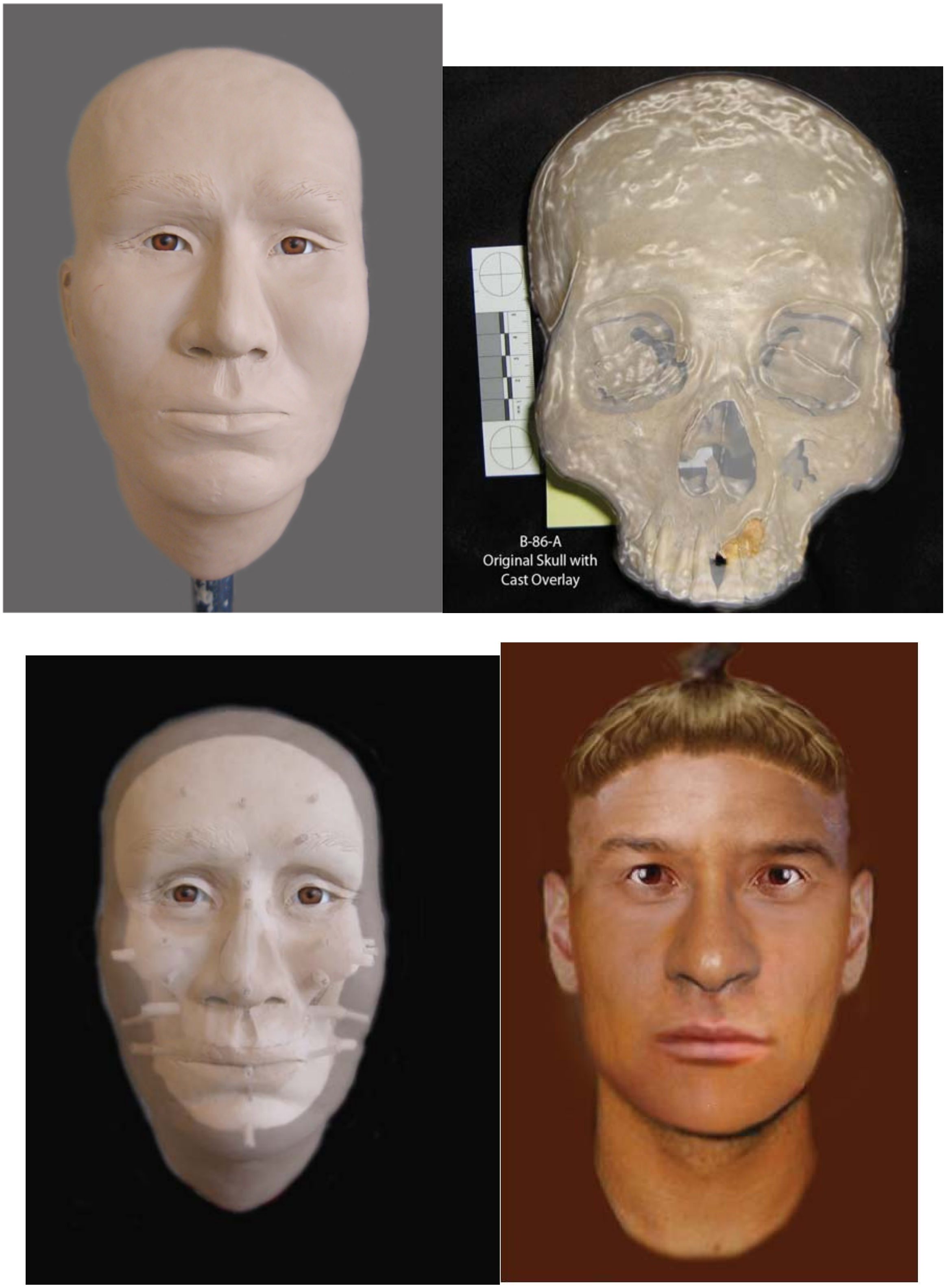














**Clay Reconstruction Over Cast with Marker and Photoshop Reconstruction**

# Appendix D: B-83-A Photos



[redacted]
B-83-A
Right Lateral
View


[redacted]
B-83-A
Left Lateral View


B-83-A Inferior View


B-83-A
Superior View

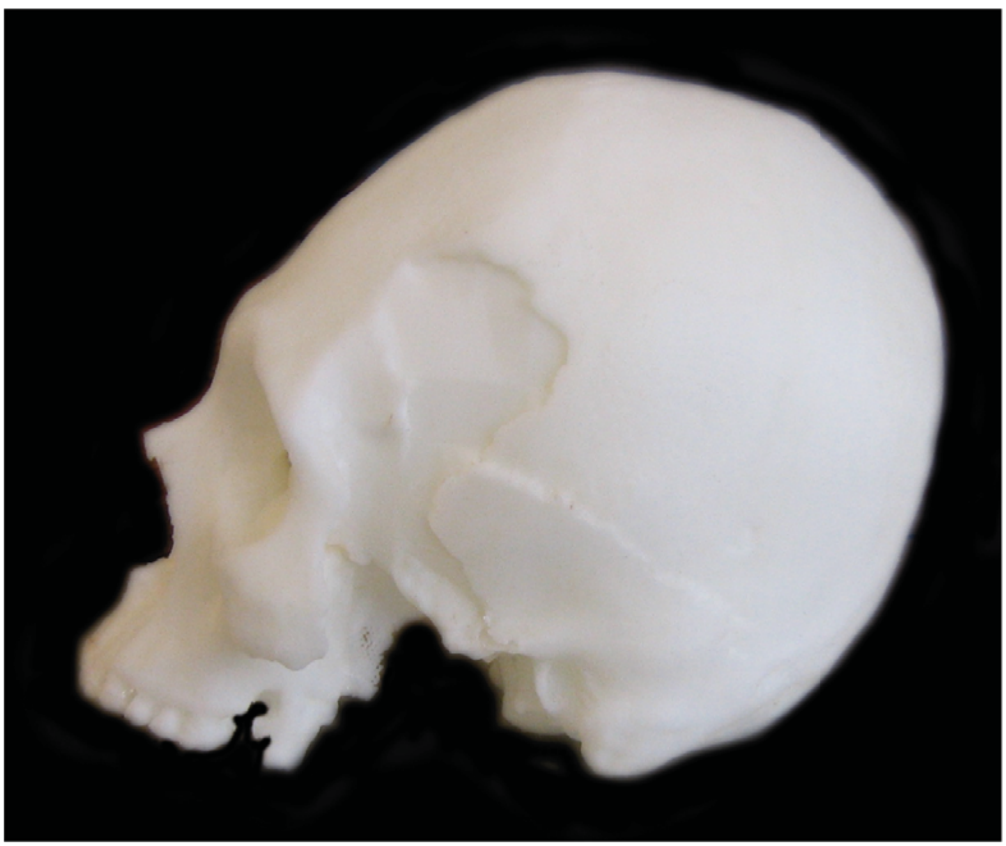

B-83-A
Mandible

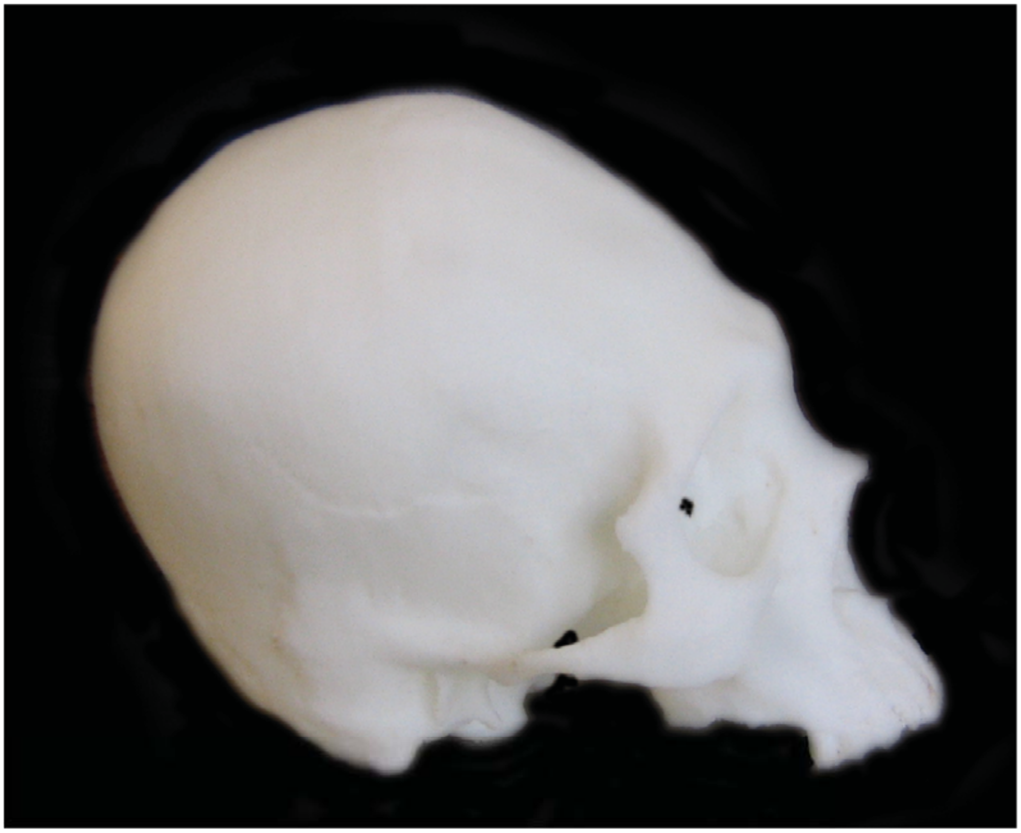

B-83-A
Mandible
Interior View
CQ 202
B-83-A

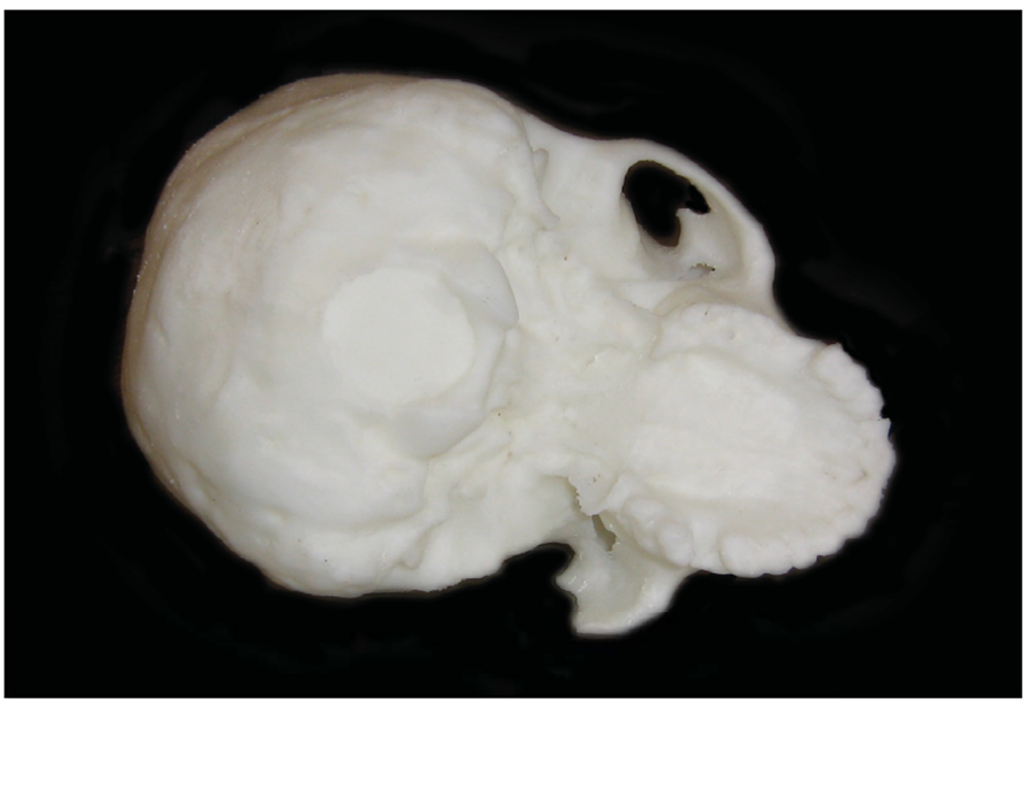

B-83-A
Mandible
Superior View

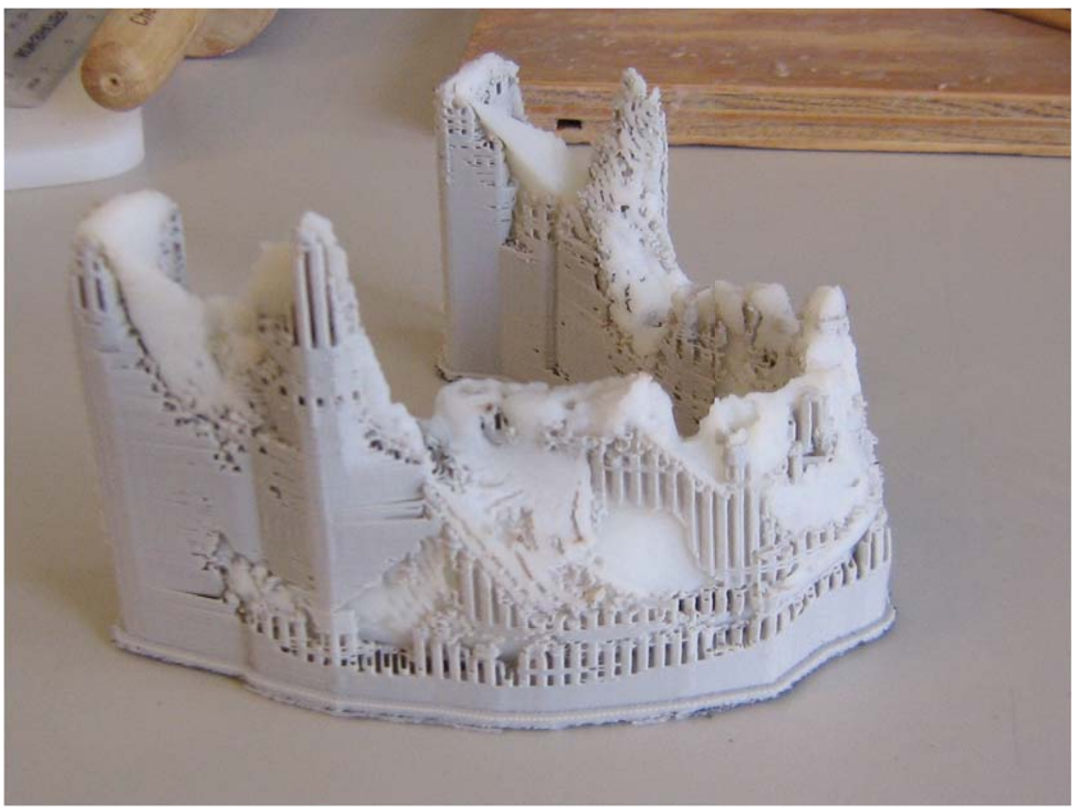

B-83-A
Mandible
Right Lateral View

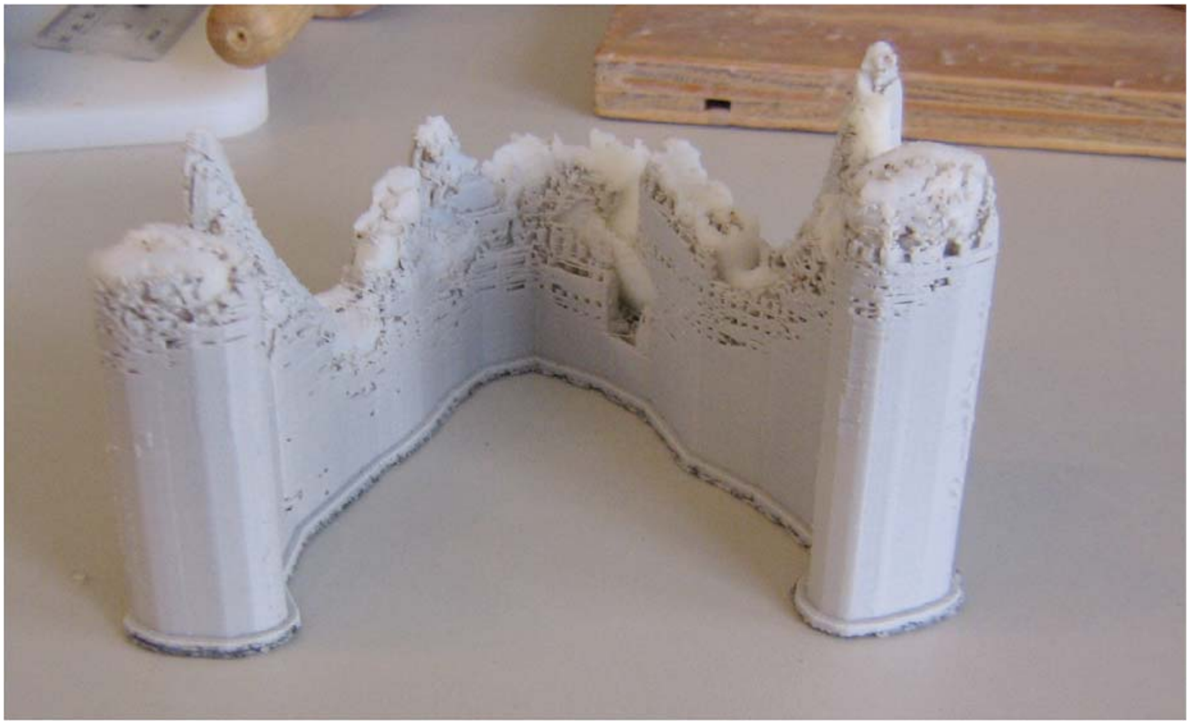


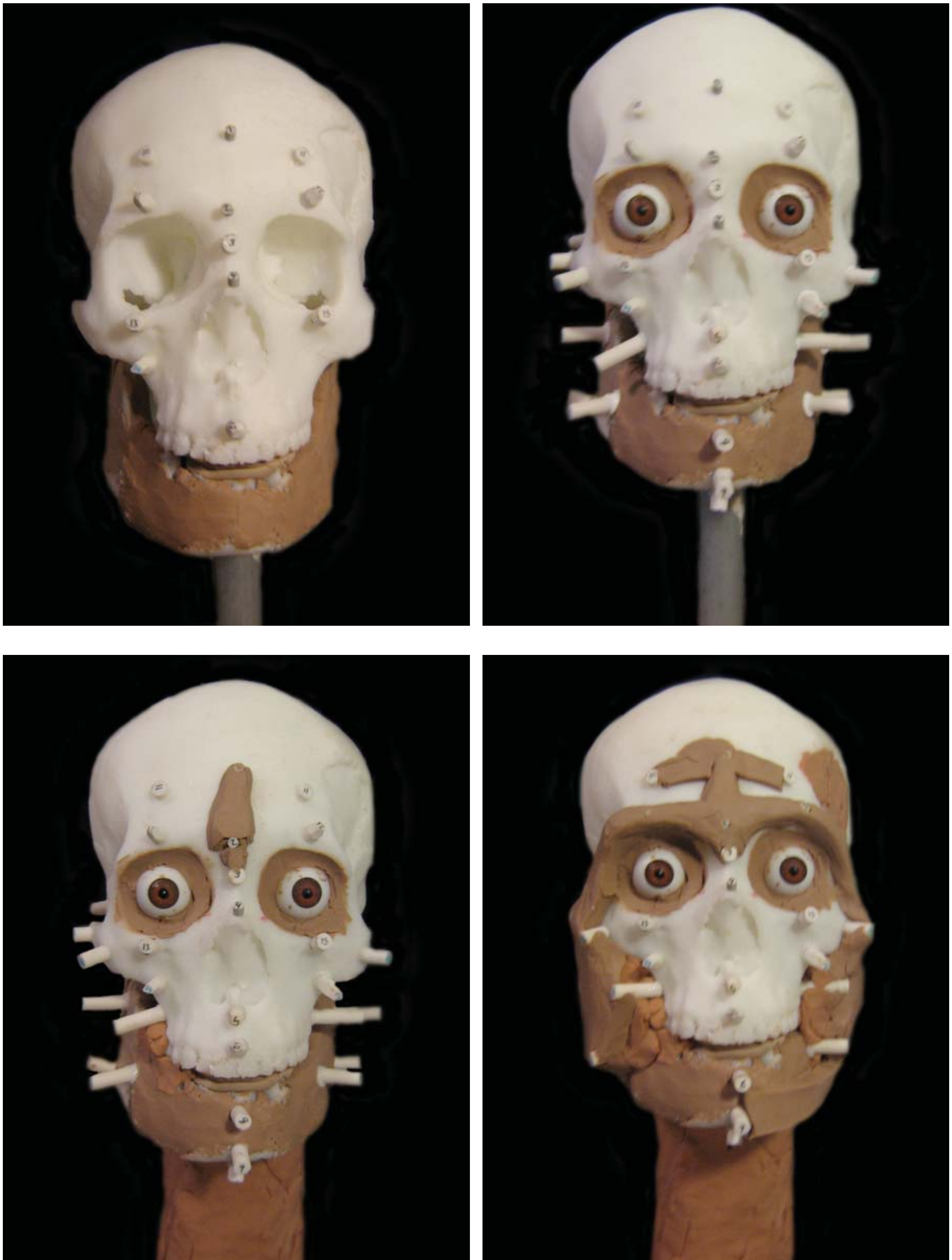


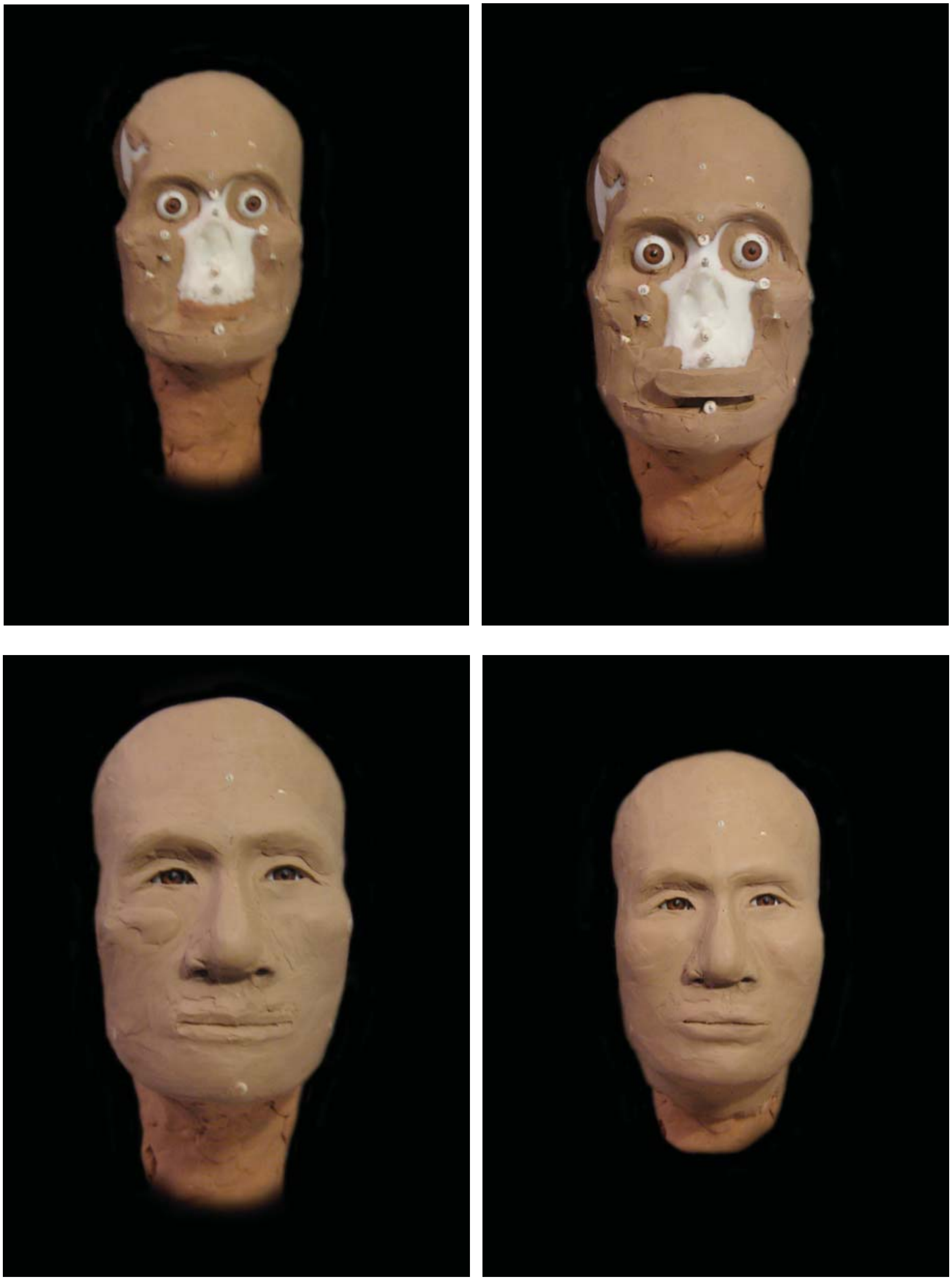


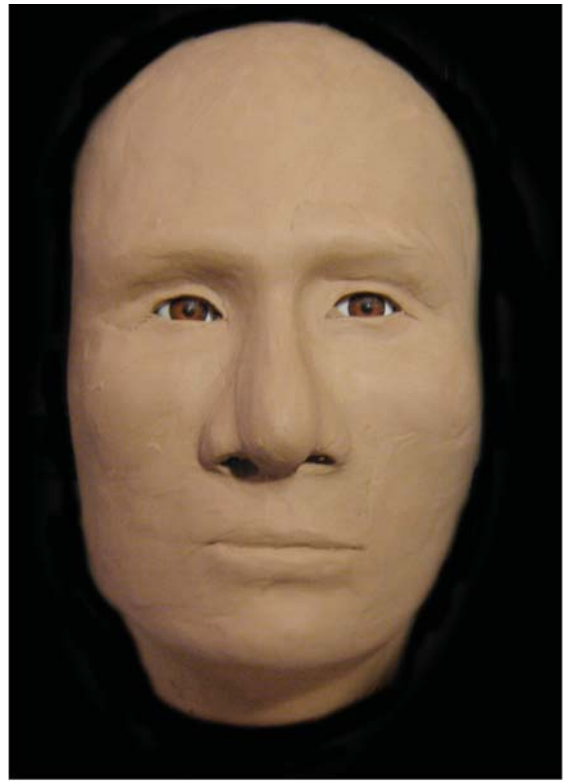








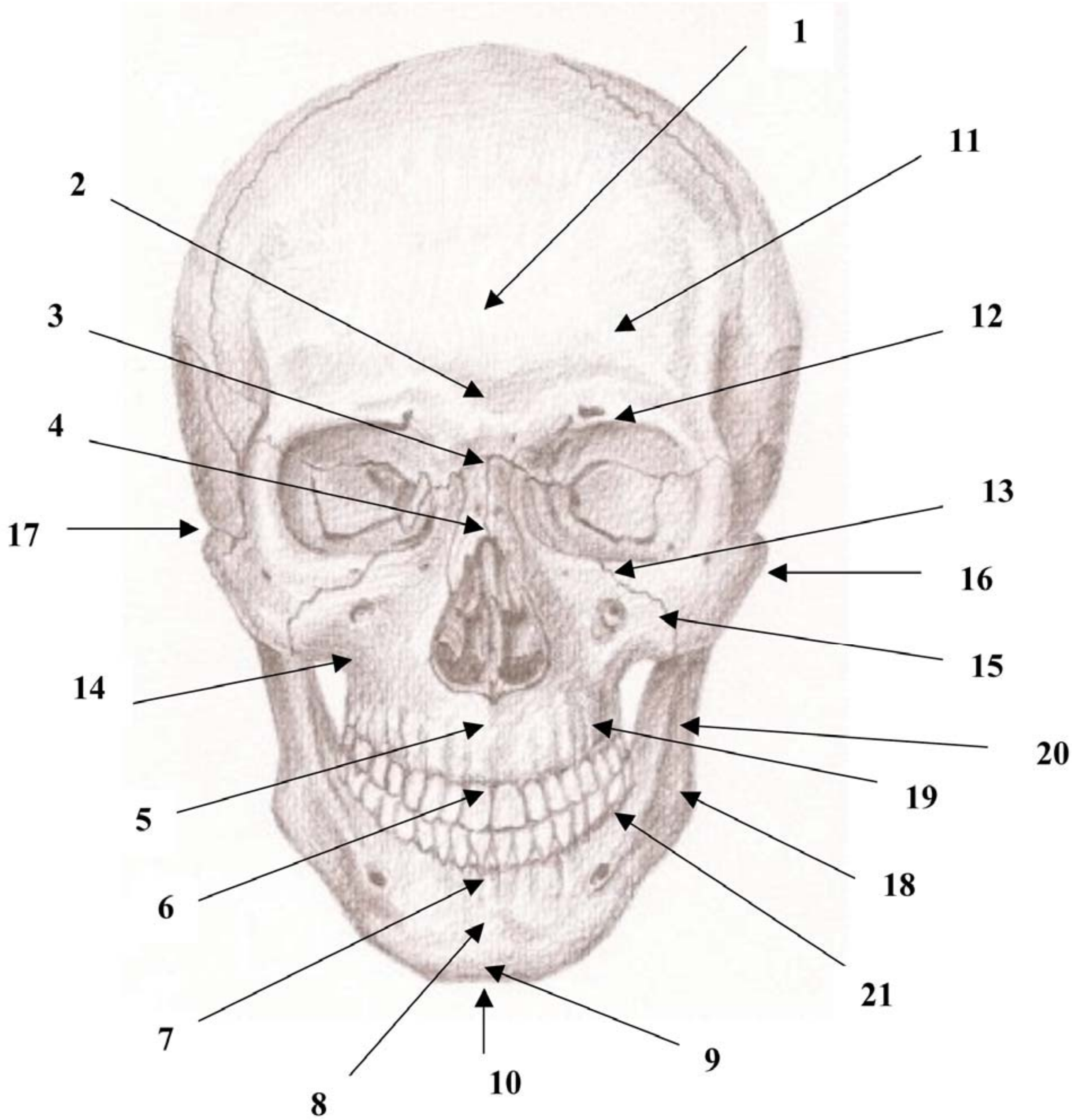


# Appendix E: Native American Tissue Depth Data and Anatomical Marker Placement

| | Slender | | Normal | | Obese | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| Measurement | [4] | [1] | [9] | [2] | [5] | [3] |
| | | | **Midline** | | | |
| 1. Supraglabella | 5.75 | 4.00 | 5.00 | 4.50 | 4.50 | 4.25 |
| 2. Glabella | 5.75 | 4.75 | 5.75 | 4.50 | 6.00 | 4.50 |
| 3. Nasion | 5.75 | 6.50 | 6.86 | 7.00 | 6.50 | 5.00 |
| 4. End of nasals | 2.75 | 2.50 | 3.50 | 2.50 | 3.25 | 3.25 |
| 5. Mid-philtrum | 7.50 | 10.00 | 9.75 | 10.00 | 9.25 | 8.51 |
| 6. Upper lip margin | 8.25 | 9.50 | 9.75 | 11.00 | 9.25 | 10.00 |
| 7. Lower lip margin | 9.25 | 12.00 | 11.00 | 12.25 | 8.75 | 11.25 |
| 8. Chin-lip fold | 8.50 | 9.00 | 11.50 | 10.00 | 9.75 | 11.00 |
| 9. Mental eminence | 8.00 | 11.00 | 12.00 | 13.00 | 12.50 | 13.25 |
| 10. Beneath Chin | 5.25 | 8.00 | 8.00 | 8.00 | 8.00 | |
| | | | **Bilateral** | | | |
| 11. Frontal eminence | 4.75 | 4.75 | 4.25 | 4.00 | 4.50 | 4.20 |
| 12. Supraorbital | 6.75 | 5.00 | 9.00 | 8.50 | 8.50 | 8.25 |
| 13. Suborbital | 3.75 | 3.25 | 7.50 | 6.25 | 7.75 | 6.75 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 14. Inferior malar | 10.00 | 9.00 | 14.00 | 12.00 | 15.75 | 15.00 |
| 15. Lateral orbit | 8.00 | 8.25 | 12.50 | 11.50 | 11.75 | 13.75 |
| 16. Zygomatic arch, midway | 6.00 | 5.75 | 7.50 | 7.00 | 8.75 | 9.00 |
| 17. Supraglenoid | 5.75 | 4.50 | 8.50 | 6.25 | 9.75 | 7.75 |
| 18. Gonion | 7.75 | 6.25 | 13.25 | 10.50 | 15.40 | 12.75 |
| 19. Supra $M^2$ | 14.25 | 11.75 | 21.50 | 18.00 | 23.50 | 19.00 |
| 20. Occlusal Line | 15.50 | 12.25 | 20.75 | 17.50 | 22.75 | 19.25 |
| 21. Sub $M_2$ | 12.50 | 10.50 | 19.25 | 17.00 | 18.50 | 15.75 |


1
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# VITA

Alicia Joy Canfield was born in October 1984, in Minneapolis, Minnesota. She graduated from the University of Minnesota Morris in May 2007, with a Bachelor of Arts in anthropology and a minor in history. Alicia began her graduate education in August 2007 in the Department of Geography and Anthropology at Louisiana State University. Upon completion of a Master of Arts degree in anthropology, she plans to teach and travel the world before seeking a doctoral degree.