**The author(s) shown below used Federal funds provided by the U.S. Department of Justice and prepared the following final report:**

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|---|---|
| **Document Title:** | **Estimation of Biological Parameters for Human Identification in Cases of Missing Persons, Mass Disasters, and Human Rights Violations** |
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| **Document No.:** | **240687** |
| **Date Received:** | **January 2013** |
| **Award Number:** | **2008-DN-BX-K163** |

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# ESTIMATION OF BIOLOGICAL PARAMETERS FOR HUMAN IDENTIFICATION IN CASES OF MISSING PERSONS, MASS DISASTERS, AND HUMAN RIGHTS VIOLATIONS

## FINAL REPORT

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Date: July 11, 2012

Award Number: 2008-DN-BX-K163

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**ABSTRACT**

The problem of missing, endangered, and unidentified persons is increasingly approached through a human rights model with successful outcomes. However, a clear framework for varied contexts and clarification is needed on the degree to which populations vary and the potential causes for observed variation. For example, do populations age at different rates? If so, is that measurable difference an artifact of the statistical modeling used or sampling? If not, does the variation occur because of inherent genetic variation or environmental conditions? What are the implications of using standard calibrations across populations in criminal trials?

To help answer questions about skeletal variation in human identification, a large dataset was developed, titled, *International Databank of Skeletal Biomarkers for Human Identification (DHI)*. This research effort was designed to be a multi-year study involving data collection from autopsies at the Department of Pathology and Forensic Medicine, Lagos State University College of Medicine (LASUCOM), Lagos, Nigeria and numerous museum skeletal collections with African populations. The objectives of this research project were to:

1) collect osteometric, morphological, and elemental and isotope data on skeletal and dental traits for contemporary African populations in Nigeria and other contemporary American populations and Diaspora;
2) test the degree of population variation among diverse populations to assess the applicability of methods used across populations;
3) recalibrate biological parameters for identification methodology using a Bayesian statistical approach and hazard analysis where needed; and
4) develop internationally relevant data protocols and a framework for research in human identification (RHI).

Morgue work at LASUCOM resulted in the collection of demographic data (n=2,887), skeletal age biomarkers for sternal ribs and pubic symphyses (n=474), and photographs of skeletal variation (n=270). Data includes age, sex, ethnicity, stature, weight, presence of nutritional or metabolic disease, chemical and elemental data, cause and manner of death, drug use, and location/time since death. Initial fieldwork was also undertaken in Asaba, Nigeria where the 1967 massacre of more than 500 Igbos over several days resulted in the creation of several large mass burials. As a result of this effort, the grave sites were mapped and protocols were developed for collecting missing person data and conducting witness interviews.

In addition to Nigeria, data collection from skeletal samples housed at museums in South Africa; France; New York; Washington, D.C.; Florida, and New Mexico with African and Diaspora populations were also completed. In total the DHI includes skeletal data from 21 countries, representing approximately 97 ethnic groups, for the following biomarkers: demographic data for autopsy cases (n=2,907) and skeletal cases (n=1,750), dental development (n=978), sternal rib ends (n=571), pubic symphyses (n=576), hyoids (n=362), chemical isotopes (n=330), cadaver stature (n=760), cadaver weight (n=309), 3D craniometrics (n=840), and long bone metrics (n=875). Additionally, photographs and 3D images of skeletal variation in these collections were created as a reference guide for researchers and practitioners.

As a result, numerous presentations and publications have resulted on human identification, methods for estimating the biological profile, population specific calibrations of specific methods, and chemical and elemental data for identification. The outcomes of this

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research include unique osteometric, morphological, and isotopic parameters for human identification, insight into human skeletal variation with implications for human identification, the development of internationally relevant data protocols and resources, and quantified estimation parameters for morphological and metric based data.

The craniometric variation among broad African regions and Diaspora populations is demonstrated and population specific parameters needed for sex estimation are provided for diverse African groups. More accurate age parameters for juveniles are found using traditional standards, than population specific measures, though the need to make informed Bayesian priors explicit is demonstrated. Population specific age parameters are provided for Nigerian and East European populations. Finally, chemical isotopic and elemental analyses of hair, bone and teeth demonstrate that while ethnic variation within Nigeria is not differentiated; Nigerian, "Foreign-born", and Americans can be significantly identified and has potential as a useful identification parameter. Moreover, isotopic analysis shows that environmental contamination due to lead exposure in gasoline differentiates African populations and that secular trends for exposure can be measured within the Nigerian population. Overall, the significance of research in Nigeria and the applicability of this research throughout Africa and the United States are further discussed in this report and demonstrate the timeliness of this project.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AM | American Populations |
| Ca | Calcium |
| COFFA | International Consortium for Forensic Anthropology Programs |
| DHI | International Database of Skeletal Biomarkers for Human Identification |
| EE | East European Populations |
| GM | Geometric Mean |
| HHRR | Human Rights |
| ICC | International Criminal Court |
| ICFAHR | International Consortium for Forensics, Anthropology, and Human Rights |
| ICRC | International Committee for the Red Cross |
| ICTR | International Criminal Tribunal for the Rwanda |
| ICTY | International Criminal Tribunal for the Former Yugoslavia |
| IHL | International Humanitarian Law |
| IHRL | International Human Rights Law |
| ILD | Inter-landmark Distance |
| LASUCOM | Lagos State University, College of Medicine, Nigeria |
| MP | Missing Person |
| NCIC | National Crime Information Center |
| NCMEC | National Center for Missing and Exploited Children |
| NIJ | National Institute of Justice |
| OTP | Office of the Prosecutor, ICTY, United Nations |
| Pb | Lead |
| PMI | Postmortem Interval |
| PDF | Probability Density Function |
| RHI | Research in Human Identification |
| Sr | Strontium |
| Th | Thorium |
| U | Uranium |
| UID | Unidentified Decedent |
| UT | University of Tennessee |

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**ACKNOWLEDGEMENTS**

We would like to acknowledge and thank program manager, Danielle McLeod-Henning and the National Institute of Justice for making this research possible. We would like to thank the many individuals who worked with us in Lagos and Asaba, Nigeria. In particular we thank the Asabi community and the many medical residents and forensic science students at LASUCOM. The latter group include Dr. Sunday Soyemi, Dr. Olajide Lawal, Dr. Ayodele Sanni, Dr. Olugbenga Oyewole, Dr. Valentine Okeke, Dr. Festus Emiogun, Dr. Oluwaseun Williams and Dr. Oluwayemisi Kila. We acknowledge the special aid of the following: Hon. Emma Okocha; Prof. Chike Edozien, Asagba of Asaba and His Royal Palace; Chief Philip C. Asiodu former Nigerian Petroleum Minister; The Iyase Of Asaba, Chief Onyeobi; Archbishop of Enugu, Emmanuel Chukwuma; Prof. Chimalum Nwankwo; and The Traditional Chiefs and the Youths of Ogbeosuwa. In Nigeria, thank Chris Onyemenam, Barrister Chuck Nduka Eze, Superintendent Akaraiwe, Ify Uraih and Alban Okonkwo for their support and assistance. Further, we thank the Asaba Commitee in the U.S.A. Lawrence Okolo, Dr. Chizea, Fabian Onwuasim, Ngozi Okocha, Emma Obi, Richie Omo, Veronika Dike, Prof. Louis Okonkwo, and Secretary Obianya.

We also thank our American colleagues who contributed to the research: Dr. Greg Berg, Dr. Tony Falsetti, Dr. Richard Estabrook, Dr. Rob Tykot, and Dr. Tom Bennett. Furthermore, we want to thank graduate students who contributed greatly throughout this project, from the Department of Anthropology, University of South Florida: Meredith Tise, Melissa Pope, John W. Powell III, Ashley Humphries, Liotta Noche-Dowdy, Keara Dotson, Charles Dionne, Casey Anderson; and student volunteers Jared Tur and Katherine Page. We also thank the National Center for Missing and Exploited Children (Glenn Miller, Supervisor of the Forensic Imaging Unit and Samantha Peters, Call Center Analyst).

Finally, we would like to acknowledge the following museums and people for permitting access for data collection: the American Museum of Natural History, New York (Gisselle Garcia-Pack, Curatorial Associate); Maxwell Museum of Anthropology, University of New Mexico, Albuquerque, New Mexico (Dr. Heather Edgar, Curator of Human Osteology, and Carmen Mosley, Graduate Assistant); Muséum national d'Histoire naturelle, Paris, France (Dr. Philippe Mennecier, Responsible for Conservation of Biological Anthropology Collections; Véronique LaBorde, Collections Manager); Raymond A. Dart Collection, University of Witwatersrand, Johannesburg, South Africa (Brendon Billings, Curator); National Museum of Natural History, Smithsonian Institution, Washington, D.C. (Dr. David Hunt, Physical Anthropology Collections Manager, and Rhonda Coolidge, Repatriation Osteology Laboratory).

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## SECTION I: EXECUTIVE SUMMARY

The task of identifying the vast number of unidentified (UID) human remains is an on-going and increasingly difficult problem due to the high number of missing children and adults. Various reporting systems and protocols, a lack of inter-agency communication, cross-jurisdictional boundaries, and differential access to resources make the process more tenuous. The International Committee for the Red Cross (ICRC) has undertaken a major initiative to address the problem of *the Missing* as a global Human Rights (HHRR) issue to raise awareness, provide tools to families of missing persons (MP), and to ensure accountability for responsible parties in criminal cases. The latter is accomplished by providing accurate data on patterns of injuries and the causes and manners of death to positively or contextually identified persons. National initiatives such as NamUs.org increasingly help resolve cases locally by linking MP and UID data in a public forum.

It has been estimated that there are approximately 13,500 unidentified individual cases in the U.S.A. and on average 1,000 new unidentified cases annually, according to the FBI's National Crime Information Center (NCIC), *Missing Person and Unidentified Person Files* (2007). Anthropologists play a prominent role in the process of human identification, particularly in decomposing and skeletonized cases as the parameters they provide about age, sex, and ancestry point investigators in a specific direction. Upon reviewing open, unsolved cases ("cold cases"), it is often these fundamental parameters that are modified to bring new light to a case. It should be noted that typically "cold case" refers to an unsolved homicide. Many of the challenges in UID cases are similar, whether the manner of death is homicide or not and are therefore discussed together in this report, regardless of the manner of death.

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In the U.S.A., the pool of persons who go missing and subsequently become part of the UID population is predominately adult, male, under-represented minorities, foreign-born individuals, and people from at-risk groups. In particular, a growing obstacle to the identification of UIDs is the increase of foreign-born immigrants, including migrant workers and undocumented persons in the United States. Individuals of foreign born nationality are an important component in UID cases as there may not be access to information about who is missing, personal data about the decedent, nor family members available to aid the identification process. In addition to domestic homicides, mass disasters, armed conflicts and human trafficking increase the number of missing, endangered, and unidentified persons across many borders. Therefore, methods and protocols for diverse populations and settings are required in both domestic and international cases.

Terms such as *mass disaster, critical incident,* or *mass fatalityincident* have been used to describe the context in which unexpected, large scale destruction and death have resulted from neither natural or man-made causes (Kimmerle and Doying 2009). The context of critical incidents is highly variable but typically these events are isolated in time and place. They tend to be single incidents and are public as generally the situation is known immediately. Woven throughout the framework of disaster response in the United States, collaboration and cooperation act to ensure that victims are served by a network of responders. The role of anthropology in these situations is focused on the recovery and identification of human remains. These processes are similar to mass fatalities resulting from armed conflict, warfare, and genocide though the characteristics and extent of such incidents vary considerably and tend to fall under the auspice of human rights (HHRR).

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Increasingly, HHRR enforcement is upheld through criminal and forensic investigations into violations against International Humanitarian and Human Rights Laws (IHL or IHRL). Forensic investigations into HHRR abuses and war crimes are generally characterized by a high number of victims, an even higher number of missing persons, conflicts that occurred over long periods of time (sometimes many years) and over large geographical areas such as the entire country or region of the world. In contrast to many mass disasters falling under the purview of natural events, in HHRR cases the context is criminal though the recovery and identification efforts may be considered humanitarian, meaning that the identification effort and repatriation of remains is for families rather than criminal prosecution. Investigations may also be conducted over many years and under changing legal authority, therefore the crime scenes are complex and often clandestine, the cultural and biological parameters are highly variable, and the entire judicial process may be in transition (Table 1). In spite of this complexity and the significant challenges international investigations imposes, perpetrators of war crimes, crimes against humanity, genocide, and violations to the Geneva Conventions are successfully prosecuted (for examples, refer to Skinner 1987; Snow *et. al*. 1984; Kirschner and Hannibal 1994; Burns 1998; Ferllini 1999; Campobasso *et. al.* 2003; Haglund 2001; Cordner and McKelvie 2002; Scott and Connor 1997; Fondebrider 2002; Okoye et al. 2006; Kimmerle and Baraybar 2008). Forensic and anthropological evidence has been critical to many cases of prosecution for violations of IHL and homicide.

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Table 1. Characteristics of mass disasters with regard to human remains in contrast to homicides and violations to IHL.

- The contexts of critical incidents are highly variable, including natural and man-made disasters and mass fatalities.
- Critical incidents may or may not involve a crime scene and tend to be a single incident, in contrast to cases of IHL.
- Limited in time and geographical location, in contrast to cases of IHL.
- The pool of missing persons is generally known, at least in the United States, in contrast to cases of IHL where people are killed but also displaced as refugees.
- Missing person cases in the U.S.A. vary as to type and frequency that are reported.
- Critical incidents tend to be highly destructive with generally poor recovery of human remains.
- Critical incidents tend to be highly public events, that are immediately known. In contrast, IHL cases and cold case homicides are investigated years following the death.
- Critical incidents compared to IHL cases may have more people wounded and displaced than killed, depending on the cause of the incident.

## OSTEOLOGICAL METHODS FOR IDENTIFICATION

The fundamental **Osteological Protocol** asks a series of questions that lead to the identity of an unknown person, the circumstances surrounding death, and a reconstruction of injuries that may have contributed to the individual's death (Table 2). The initial parameters of an individual's identity are their age, sex, height, weight, ancestry and facial shape and form. Individual traits unique to each person include skeletal pathology, congenital anomalies, unique boney architecture of particular structures, cranio-facial form, and chemical isotopes. In combination, these factors help establish a **Biological Profile** of an individual. Furthermore, attention to the scene and field recovery is important for distinguishing trauma from animal scavenging, postmortem dismemberment, or other alternations to the body. Specifically, anthropologists are in the position to contribute to human identification in a number of ways:

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1) establish a biological profile as the initial parameters in the identification process;

2) a biological profile may contextualize the decedent within a social framework (i.e., more victims of critical incidents tend to be the elderly, under-represented minorities, or in poor health) which provides a greater understanding of social-level vulnerabilities to disasters or victims of HHRR abuses;

3) conduct interviews for witnesses or missing person information;

4) estimate age for the identification of living persons (a more common issue needed for individuals who are in police custody); and

5) provide skills specific to human remains repatriation and cemetery re-internment operations.

Table 2. General osteological checklist for human identification.

- Crime Scene / Burial Factors
- Taphonomy / PMI
- Skeletal and Dental Inventory
- Age-at-Death Estimation
- Cranial and Post-cranial Metric Analyses
- Ancestry Estimation
- Sex Assessment
- Facial and Clothing Approximations
- Perimortem Injuries or Skeletal Trauma
- Unique Skeletal Markers or Congenital Anomalies
- Skeletal Pathology
- Trabecular Bone or Skeletal Morphology for Radiographic Comparisons
- Odontograms: Inventory, Pathology, Modification, or Anomaly
- Imaging: Radiography, Photography, 3D Laser Scanning
- Bone Sampling for Chemical and Elemental Data and DNA Analysis

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## SCOPE OF THE PROBLEM: CHALLENGES TO IDENTIFICATION

There are a number of challenges to the identification process including access to antemortem data, witness memory, and variation across populations. Human identification is based on a variety of methods to estimate parameters about individuals and consists of a process that gathers information, interprets data to estimate information about a person, and excludes cases thereby limiting the pool of potential matches.

### *ACCESS TO ANTEMORTEM DATA, INTERVIEWING WITNESSES AND DATA STORAGE*

Determining who is missing, obtaining access to *antemortem* records, and managing large amounts of data are primary tasks for operating identification processes on any scale. Lorton and Langley (1986) warned about biological traits used in the identification process that may change over time such as weight, hair color or style, and clothing. This raises a very important point about data reliability, and also about how a person's biological description may be viewed by the witness giving the description. Moreover, as an investigation is managed over many years such as in cold case investigations, different personnel continuously add updates or supplements as new information or tools for analysis are made available. For example, Kimmerle and Doying (2009) wrote about the effects of Hurricane Katrina (August 2005) in the U.S. Gulf Coast region. In New Orleans, the DMORT teams worked with the Louisiana Family Assistance Center (LFAC) whose mission was to reunite families and assist in the identification of the missing. Finding information to match physical traits present on the human remains was extremely difficult as most dental and doctor offices were flooded or severely wind damaged and therefore most patient records were destroyed. Katrina's unique challenges were also a condition

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of the unprecedented and massive population displacement in the United States that occurred as a result of the event.

In homicide investigations in the U.S.A., the role of anthropologists is separate from that of investigators who are charged with the tasks of interviewing families and witnesses. However, in many international contexts of critical incidents or violations to IHL, anthropologists and human rights workers are charged with these tasks and may be responsible for collecting information about missing persons, creating missing person databases, and interviewing witnesses to aid with locating graves. Investigators who are developing a forensic interview strategy must account for a variety of factors before they consider the validity of episodic memory, such as the elapsed amount of time between the event and the interview, the psychological effects of trauma, the potential of outside influence upon the memory, cultural perspectives of the interviewees, the age of the interviewee at the time of the event and the time of the interview, and any other hidden agendas brought to the interview process (Massucci et al. 2011).

### *INDIVIDUAL AND POPULATION ESTIMATION*

Methods for biological profiling applied across populations are often noted to be inaccurate and then new parameters for estimating age, stature or sex are provided. Numerous investigators have pointed out that apparent population differences may be due to sampling or the type of statistical modeling used thereby leaving questions about the biological differences among populations unresolved (Bocquet-Appel and Masset 1982, 1996; Ferillini 1999; Konigsberg and Frankenberg 2002; Kimmerle et al. 2008; Hoppa 2000; Hoppa and Vaupel 2002). The question is to what extent do populations vary such that methods need to be uniquely

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calibrated for each population? What are the acceptable ranges or levels error? Can investigators apply one set of identification parameters (i.e. a stature regression equation) to diverse populations, accurately? The answers to these questions have not always been clear. For the purpose of creating the initial parameters of identification (i.e. broad age categories or stature estimates), the application of methods across populations, even with a greater error rate may be sufficient as the goal in that stage of identification process is to create more inclusive categories. However, when investigators are attempting to make a presumptive or positive identification or to present demographic information in criminal trials, the level of accuracy may need to be higher and also quantified.

### *GEO-REFERENCING MOBILITY*

Mobility patterns have been shown useful to case solvability. Spatial analysis is a tool that can be used to predict victim vulnerability, closure for clandestine grave searches, and increase case solvability. The purpose of chemical and isotopic analyses is to create a geographical reference that can be used in the process of identification. Specifically, the traditional concept of ancestry or race in anthropology is challenged by new tools and ways to look at identity and is essential to human identification. Craniometric analyses through linear and 3D modeling were compared with chemical isotope data to estimate contextual identification (Kimmerle and Kamenov n.d.). In particular, the utilization of strontium and lead isotope data from teeth and bone material to identify potential place of origin of unidentified decedents was explored. Collectively, these methods do not provide information on a presumptive or positive identification, rather they point towards a contextual identity such as possible geographical place of origin and/or the degree of mobility that serve to point investigators in a particular direction. Ancestry or "race" has been an initial parameter that anthropologists have provided to the

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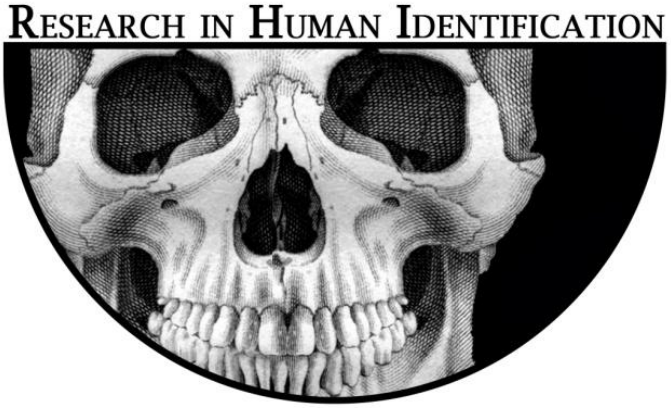
medicolegal community for nearly a century, but now there is the ability to use new and more discriminating methods. The constructed biological profile along with contextual identification parameters are also used for the basis for forensic facial approximations.

## SECTION II: INTRODUCTION

In 2004, Kimmerle and Jantz organized a symposium and special anthropology section of the *Journal of Forensic Sciences (vol. 53(3);2008)* in which eleven papers were published together following an initiative by The Office of the Prosecutor (OTP), ICTY, United Nations. During the trial of General Radislav Krstic (*Prosecutor of the Tribunal against Radislav Krstić*, Case No. IT-98-33), questions about anthropological methods used for identification and demographic reconstruction from mass graves became an important issue because it showed who the victims were and whether a crime was committed (i.e. civilian populations or soldiers). As a result, the OTP authorized an internal research initiative to help address the issues of 1) methods developed for American forensic casework and applied internationally and 2) variation in aging among American and Balkan populations. The purpose of this initiative was to address these questions about population variation in human identification so that in subsequent trials such topics would not jeopardize the anthropological evidence of the case. Since these were war crime trials involving mass graves, the anthropological evidence was central to showing the cause of death and pattern of crimes committed. This body of work addressed many issues in human identification specific to cases of genocide and created new population specific calibrated methods for East European populations where necessary. The current research initiative into human identification (RHI) builds on this model with a primary focus on African, American, and

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Diaspora populations although previously unanalyzed data, such as the sternal rib method for aging for East Europeans, was also investigated and compared to Nigerian populations.




The purpose of this research project was to investigate methods of identification relevant to African and diverse populations, building largely on the framework of the earlier ICTY-UT initiative. Specifically, the purpose of this research project was to collect data on contemporary African and American populations to investigate individual and population variation and to develop and recalibrate existing methods to diverse demographic structures or populations when necessary, specifically to:

1) test for population variation among Nigerian, African-American, Euro-American, and East European populations;

2) investigate the presence or influence of diseases, drug use, and nutritional stress on skeletal variation for human identification;

3) re-calibrate (when necessary) aging, sexing, and metric formulae through Bayesian statistical and maximum likelihood analyses; and

4) develop a theoretical framework for RHI and appropriate protocols, reference materials, and atlases for research and applied forensic cases.

To achieve these objectives, a framework for RHI was developed that resulted in body of work on human skeletal variation for contemporary populations; original analyses of data and research on skeletal variation in Africa, Europe and the United States (Figure 1); a large databank, titled, *International Databank of Skeletal Biomarkers for Human Identification*; two data collection protocols; and photographic and 3D imaging reference guides. The protocols,

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best practices recommendations, and reference materials consist of the following and can be downloaded at www.icfahr.usf.edu/rhi/:

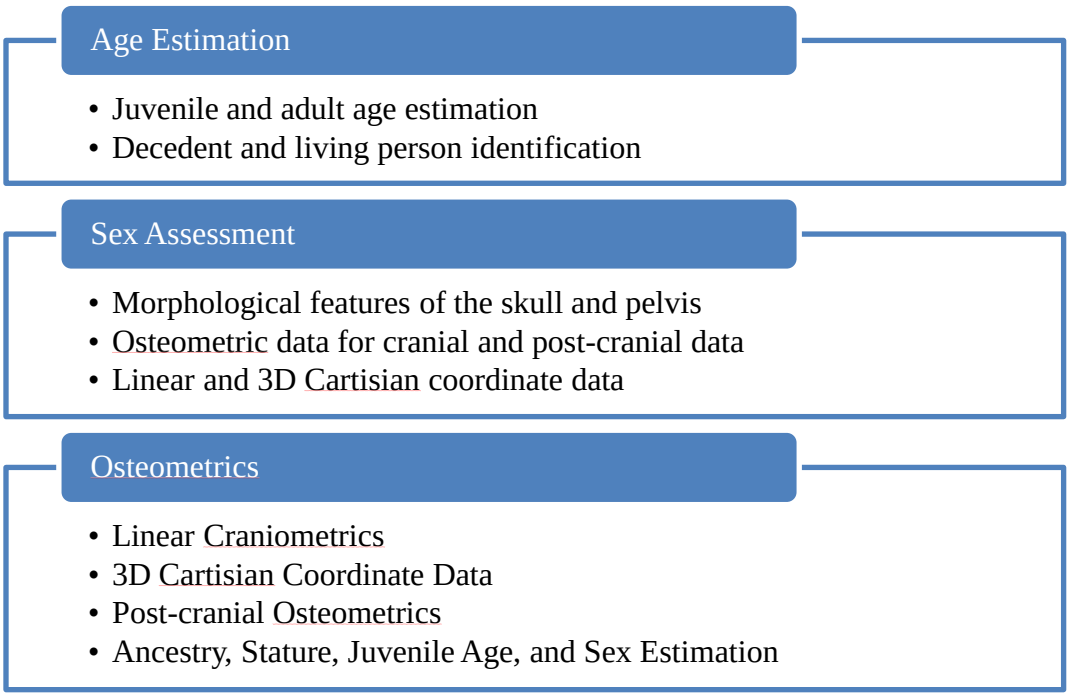
1) Kimmerle EH, Powell JW. 2012. 3D Digital Reference Guide for Research in Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

2) Kimmerle EH, Tise ML, Humphries AL. 2012. Data Collection Protocol for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

3) Kimmerle EH, Pope MA, Tise ML. 2012. Atlas for Biometric Variation Among African Populations for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

4) Kimmerle EH, Massucci CJ, Tise ML. 2012. Interview Protocol for Missing, Endangered, and Unidentified Persons. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

Figure 1. Methods for biological profiling.



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## CATEGORIES OF HUMAN IDENTIFICATION

Osteological methods for the purpose of individual identification are used to construct a biological profile. Depending on whether the decedent is immediately identified or not, the biological parameters for identity (i.e., age at death, sex, stature, ancestry, etc.) may be made available to the public and entered into a number of local, state and federal databases. Some of these databases are for law enforcement use only (i.e., NCIC), while others are available to the public (NamUs.org). Depending on the goals of particular investigators, those parameters can be narrowed or widened to be more or less inclusive. At various stages in the identification process, it may be advantageous to be more or less inclusive. Therefore, investigators must decide what information or level of details to provide the medico-legal community and to the public. In other words, investigators should keep in mind that data collected for individual identification is particular to the type of identification being sought (Table 3). There are varying levels of human identification, which require different types of analyses and have corresponding levels of relevancy when presented (or not presented) in criminal trials. Therefore, investigators should consider the objective or stage within the identification process when selecting which methods to use and what levels of errors to accept.

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Table 3. Classification of varying types of decedent identification.

**Presumptive Identification**

- The possible identity of an individual based on information that is consistent with individuality but that is not mutually exclusive to only one person. All of the initial parameters for identification are used here, such as age, sex, ancestry, stature, unique skeletal markers, skeletal pathology, and antemortem trauma.

**Positive Identification**

- The positive identification of an individual is established through information that is exclusive to only that individual (i.e., DNA, fingerprints, unique skeletal or dental morphology, or sinus patterns) and is derived by comparisons of ante- and postmortem information that are unique to a particular individual.

**Collective Identification**

- The identification of an individual into a particular cultural, demographic, religious or ethnic group may estimate a collective identity. General descriptive characteristics about the individual place him/her within a particular group. For example, the age, sex, or ethnicity of the individual may demonstrate group membership derived from biological factors or other physical evidence associated with the decedent (i.e., particular clothing or jewelry depicting religious affiliations).

**Contextual Identification**

- For an individual or group of individuals, contextual identification is similar to collective identity but can be applied at the individual or group level. This form of identification serves to inform about the status and context of the individual, such as “foreign-born individuals”, “migrant workers”, or “homeless”.

- The characteristics about an individual are consistent with certain population characteristics, but limited to strict “group” membership. Increasingly this category is useful along Border states in the U.S.A. where many unknown, unidentified decedents fall to categories such as “migrant workers”, “transients”, or “victims of human trafficking”.

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## LITERATURE REVIEW

A review of literature on population variation and biometric methods for identification in Africa indicates a limited number of studies have been done. Osteological methods investigating human variation, that are specifically calibrated using contemporary African populations have been primarily developed using data from South Africa. Several studies have investigated sexual dimorphism using different anatomical structures (Asala 2001, Asala et al. 2004, Bidmos and Dayal 2003). Two recent studies specifically tested methods for sex and age estimation for juveniles using South African populations and coordinate data (Franklin et al. 2007, Franklin and Cardini 2007). In the mid-twentieth century, two initial studies investigated age estimation for West and East African juveniles (Billewicz and McGregor 1982, Chagula 1960). A more recent study by Olze and coworkers provides insight into the effect of population variation in forensic age estimation among juveniles (Olze et al. 2004). A limited body of research has investigated ancestral variation using osteometric data. One study of particular interest is Bruner and Manzi (2004) which compared North and East Africans. Other works have also investigated population variation and ancestry such as by Delgado-Burbano (2007) and a number of stature methods have been developed for East and South African populations (broadly construed) such as Allbrook (1961), Asala (2001), Asala et al. (2004), Tobias (1975), Bidmos (2005 and 2008), and Bidmos et al. (2004).

Tobias (1975) studied the secular trends of both body size and stature for South Africans. His findings were consistent with American trends for significant secular changes and illustrate that the use of data from contemporary groups are appropriate for forensic identification. However, what is consistently lacking in the published literature are studies which directly test population variation between modern African-Americans and various African populations.

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The specific application of methods derived from one human population and applied to another may appear inaccurate (Bocquet-Appel and Masset 1982, 1996; Ferillini 1999, Konigsberg and Frankenberg 2002) and the interpretation that populations differ significantly in the timing of age related changes or degree of sexual dimorphism. The limited skeletal samples of known individuals have also affected method development. Numerous investigators have pointed out that apparent population differences may be an artifact due to sampling or inaccurate data (such as estimated age structures) rather than biological or environmental differences (Hoppa 2000, Hoppa and Vaupel 2002). For example, Kemkes-Grottenthaler (2002) points out that apparent population differences may be the result of extrinsic factors such as material culture (i.e. health care access, nutrition, or cultural behaviors) that affect bone density or degeneration, particularly among older aged individuals. Research into this question for this project shows that the apparent advanced aging of skeletal remains for females may appear older in some populations due to a loss of bone mineral density.

Kemkes-Grottenthaler (2002;64) provides a brief review of various studies that have found significant population variation in "biologically induced differences in the aging mechanisms." These biological differences are believed to affect the metabolic rate, which in turn influences the aging process (Kemkes-Grottenthaler 2002). In this example, access to adequate nutrition or health care affects the presence and significance of metabolic and nutritional disorders. When the aging processes of American and Bosnian males and females are directly compared in this research, no differences among adult males are found. However, significant differences among older aged females are noted and are attributed to Bosnian females suffering from more severe osteoporosis and other nutritional inadequacies (Kimmerle et al. 2008). Understanding the differences observed in these two populations through a biocultural

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lens enables meaningful interpretations to be drawn about the nature of aging among diverse groups.

## SECTION III: MATERIALS AND METHODS

The primary goal of this research initiative was to investigate the ways in which diverse international and domestic settings can shape the identification process and to produce reliable methods and a framework for identification in varied settings. Due to the legal, cultural, and biological variation across populations, not only do specific calibrations have to be considered in osteological analyses, but so do the ways in which that information is used in criminal proceedings across diverse legal settings and the ways in which antemortem information about missing persons is collected, stored, and shared.

The data for RHI come from autopsies of 'fresh' cases, as well as, forensic skeletal cases and osteological collections housed in museum collections. The standard data manuals in forensic anthropology do not typically include morgue cases, therefore, the resulting protocols through this project are meant to provide a basic framework for some of these diverse settings. The RHI project is built on the Standard Operating Manual of the Forensic Anthropology Laboratory at the University of South Florida (2006 v. 1.2). Additional osteological methods, laboratory SOPs, best practice guidelines, and data collection standards were consulted from SWGANTH, numerous laboratory manuals, and published studies (i.e., Adams and Lothridge 2000; Bass 2005; Buikstra and Ubelaker 1994; Burns 2007; Moore-Jansen et al. 1994; Byers 2007; Schaefer et al. 2009; and White et al. 2011).

Further, the photographs and 3D scans illustrating variation in biomarkers for population variation in age, sex, pathology, and trauma are provided in two atlases. Refer to the appendixes

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for more details on the samples and methods used for their development (www.icfahr.usf.edu/rhi; Kimmerle et al. 2012; Kimmerle and Powell 2012).

Table 4. Data collection for RHI.

| "FRESH" AUTOPSY | SKELETONIZED CASES |
|---|---|
| Demography & Birth Year | Demography & Birth Year |
| Cause and Manner of Death | Presence of Nutritional or Metabolic Disorders |
| Location Body Recovered | Osteological Protocol for Morphological and Metric Traits for Sex, Age, Stature and Ancestry |
| Stage of Decomposition | 3D Craniometrics |
| Presence Nutritional or Metabolic Disorders | Post-cranial Metrics |
| Rib and Pubic Symphysis Phases | Elemental and Isotope Data |
| Weight and Stature | |
| Hyoid Fusion | |
| Elemental and Isotope Data | |

The DHI and related protocols for data collection includes a variety of contexts such as fresh autopsied cases, as well as skeletonized and decomposing cases that may be known but unclaimed (Table 4). Great care was taken to note when biometric parameters are *known* and when they are *estimated*. Both types of information and data from a variety of cases help to answer different questions about variation, disease, demography, and population parameters. Therefore, it is important to include a systematic protocol to all cases, whether individuals are identified or not, as they may later become known. Also, because this project researched questions about variation, as well as defined individual estimation parameters, data was needed for known/identified individuals. To calculate estimation parameters for age or sex, data from only known individuals is used. It should be noted that the age at death information for the Nigerian sample comes from death certificates. Therefore, it is not necessary that only identified individuals be studied; rather larger data sets are important for a variety of research questions

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and can yield different types of information. As new parameters are defined, they can also be applied retrospectively to prior cases that may aid in their solvability.

## AFRICAN RESEARCH: FOCUS IN NIGERIA

There has been ongoing transitional justice reform in Nigeria with the improvement of coroner laws in Lagos State. This is a trend throughout many regions of Africa, particularly as the ICC is increasingly investigating cases throughout the region. Advanced training for medico-legal death investigations and forensic science, pathology, and anthropology has resulted. Nigeria is the optimal place for research on skeletal variation among African populations because of its population size, diversity, and geographic location. Nigeria is Africa's most populated nation with more than 150 million people and is home to 1 in 4 Africans (Figure 2). It is centrally located in West Africa and is in the center of recent and on-going conflict areas. Furthermore, Nigeria is ethnically diverse with more than 200 ethnic groups, although the most populous and politically influential groups include the Hausa and Fulani, Yoruba, Igbo, and Ijaw representing 78% of the population. These groups cross national boundaries and extend beyond Nigerian borders. Nigeria has a global population with a large number of international workers, refugees from neighboring countries, and migrant workers further adding to the diversity and complexity of the region. Additionally, in the past several years, there have been over 10,000 extrajudicial killings of suspects, innocent civilians, multi-national oil workers, and politicians by the police, the military forces, vigilante groups, and armed militants in various parts of Nigeria. More recent sectarian violence and major airline crashes have claimed several thousand lives in the past couple years.

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Figure 2. Map of Nigeria and ethnic groups within the country.

In 2007, coroner laws were reinstated though debate has followed the ruling. The medical examiner's office at LASUCOM completes an average of 8 autopsies per day. During this time, morgue work at LASUCOM resulted in training local medical students and forensic pathologists on data collection and the collection of demographic data (n=2,887), skeletal age biomarkers (n=474), and photographs (n=270). Demographic data includes cause and manner of death, the presence of nutritional or metabolic diseases, drug use, location/time since death, weight and stature, ethnicity, age, and sex. Some of the main opposition to medico-legal death investigations has been from the medical community, fearing allegations of malpractice or

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criminal liability (Odebode 2008). The data presented here reflect the first reported, autopsied cases systematically investigated in Nigeria and reflect the morbidity and mortality patterns of an underserved population. Overall, the utility and power of these investigations for documenting human health insecurities is demonstrated, the implications of which for human identification methods are yet to be determined. The relevance of morbidity data and substance use is shown to be a significant factor for age related variation among individuals.

## NIGERIAN DEMOGRAPHIC SAMPLE FOR AGE ESTIMATION

Demographic data from Nigeria for age estimation consists of total of n=2,887 cases autopsied at the Office of the Chief Medical Examiner at LASUCOM from 2006-2010. These cases represent some of the only autopsies systematically performed in Nigeria. The differences between mean age of death for males and females were tested with the *Students t-test*: The t-score is $t=4.960$, $df=1542.589$, $p \leq 0.000$, demonstrating that the age distributions between the groups are significantly different. Young females are over-represented, whereas male deaths are more consistent throughout older age cohorts. Younger females are predominately dying as a result of pregnancy related deaths, as well as a higher frequency of metabolic, nutritional, and infectious diseases.

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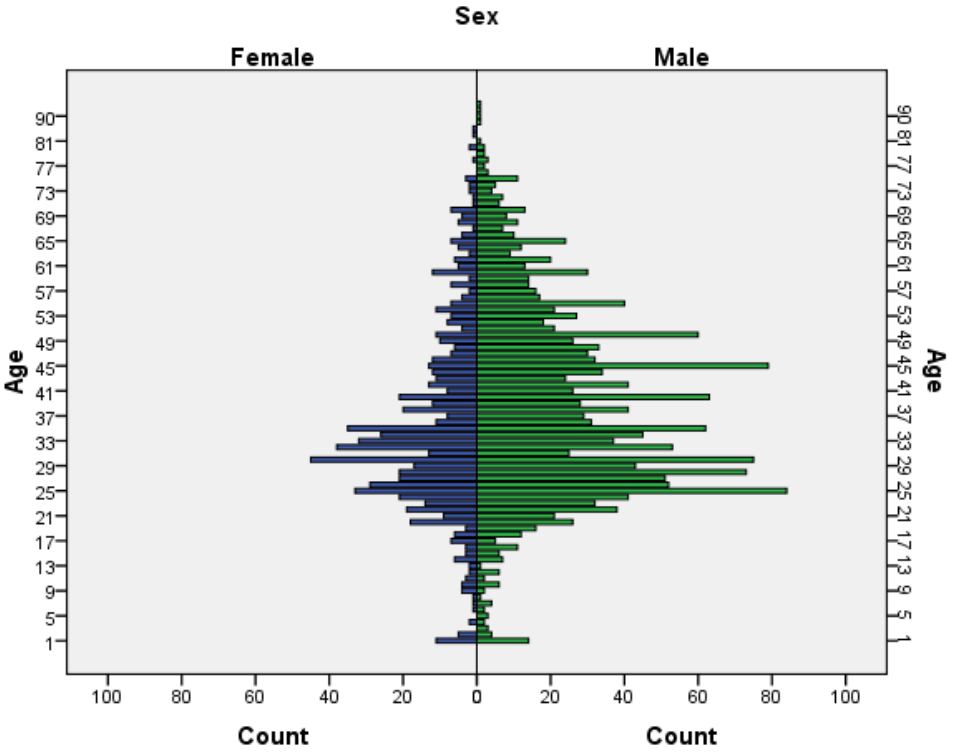



Figure 3. Age distributions for autopsied males and females at LASUCOM, Nigeria.

Figure 3 above appears to show classic signs of "age heaping," particularly for the males where there are spikes at about every 5 years. To further examine this problem the data were combined by sex but limited to only those cases where "manner of death" was listed as "accident" ( N = 1,168), "homicide" (N = 192), or "natural" (N = 1,268). The age-at-death distribution for this total sample of 2,628 individuals is plotted in Figure 4 below.

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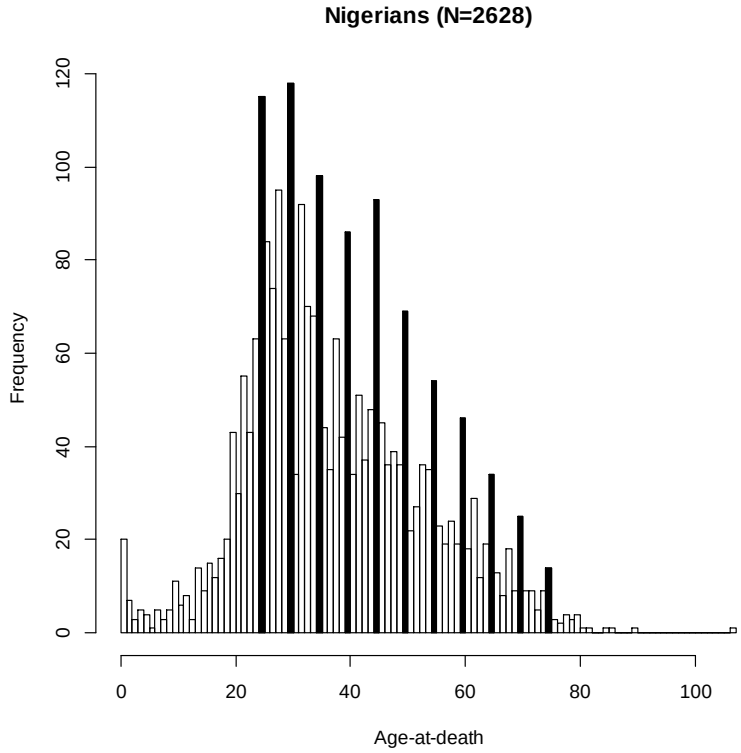



Figure 4. Age distribution for 2,628 LASUCOM, Nigeria deaths.

In Figure 4 ages-at-death of 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, and 75 years are marked in black. It is clear from this plot that across the fifty year age span from 25 to 75 there is "age heaping" on ages that end in a zero or a five. Such patterns of age heaping are commonly known from reported age data where ages are not verified against a birth certificate (Stockwell 1966). Myers' (1940, 1954) "blended method" is often used to represent digit preference in reported data. Nagi et al. (1973) give a specific example for Senegal, 1960 in an article on age heaping in African censuses. We follow their example in calculating an "index of preference" for digits based on the 2,451 deaths between ages 20 and 79 years of age (inclusive) out of the 2,628 Nigerian deaths. Terminal digits of zero and five make up 15.85% and 16.48% of ages in the "blended" population, respectively, while we would expect them to each make up 10% of the

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ages if there were no digit preference. The "index of preference" (half of the sum of absolute deviations) at 13.18 is well above the cut-off of 3.0 that is generally considered as the dividing line below which there is no digit preference.

The data can also be used to calculate "Whipple's Index" which in this context is the total number of deaths at ages 25, 30, 35, 40, 45, 50, 55, 60, and 65 divided by one-fifth the number of deaths between 23 and 62 years, inclusive, and multiplied by 100 to bring this to a percent. Whipple's index does not adjust for mortality. Myers' "blending" method does adjust for mortality by accounting for the fact that within, for example, ages of 20-29 years one would ordinarily expect more deaths at, say, 20 years than at 29 years because the cohort size has been decreased by prior deaths at 20, 21, …, 27, and 28 years of ages. Whipple's index for the Nigerian data is 168, which places the Nigerian data at the upper end of the "rough" category and near the "very rough" category (Jowett and Li 1992) defined at 175. An index of 100 represents no digit preference, while an index of 0 indicates complete avoidance of ages ending in zeroes and fives and an index of 500 indicates that only ages ending in zeroes and fives are used. Reported age data from Africa in general, and Nigeria in specific, are well known to generally be unreliable (Caldwell and Igun 1971; Byerle and Terera 1981; Cleveland 1989; Palamuleni 1995). In the absence of data on date of birth, reported ages such as are available for the current study must always be treated as suspect. The evidence for strong digit preference in the current data demonstrates that ages are not "known" for at least a portion of the sample.

## RESEARCH IN MISSING PERSON PROTOCOLS: FIELDWORK IN ASABA, NIGERIA

Human identification is a two pronged problem. Both robust methods for the estimation of biological profiles about decedents, and accurate and accessible data about

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missing persons are required for comparison. Initial fieldwork was undertaken in Asaba, Nigeria where the 1967 massacre of more than 500 Igbos over several days resulted in the creation of several large mass burials. As a result, alleged mass graves were located and mapped and protocols were developed for missing person and grave location data collection. Due to on-going political instability and increased violence in Nigeria during our research period with massacres of 400+ persons in single incidents, we were not able to conclude grave excavations. We submitted a change of scope to NIJ and were able to add several important components to this research including elemental and isotope analysis of Nigerian and American samples (n=330), hyoid ossification for Nigerian and American samples (n=362), and additional data collection at museums in South Africa; France; New York; Washington, D.C.; and New Mexico with African and Diaspora samples.

The data collected for this research project come from a variety of locations and sources and are summarized by location in Table 5. Skeletal and dental data for African and Diaspora samples come from LASUCOM (Lagos State University, College of Medicine, Nigeria); the Museum national d'historie naturelle in Paris, France; the Raymond A. Dart Collection in Johannesburg, South Africa; the Maxwell Museum of Anthropology in Albuquerque, NM; the Smithsonian Institution in Washington, D.C., and the American Museum of Natural History in New York City, NY. The following populations are represented in these samples: Nigeria, Cameroon, Benin, Chad, Sudan, Mali, Nigeria, Ghana, Malawi, Zimbabwe, Botswana, Mozambique, Zambia, Ghana, Congo, Kenya, Rwanda, South Africa, Tanzania, and Americans with European, African, and Mexican ancestry. The data for comparative samples in the United States and Europe are summarized in Tables 6-9.

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As a result, the DHI includes data from 21 countries, representing approximately 97 ethnic groups, and the following skeletal biomarkers: demographic data (n=2,887), dental development (n=28), sternal rib ends (n=571), pubic symphyses (n=576), hyoids (n=362), chemical isotopes (n=330), stature (n=760), weight (n=309), 3D craniometrics (n=840), and long bone metrics (n=875).

Data was collected by Kimmerle or graduate students (Meredith Tise, Ashley Humphries, and Melissa Pope) and medical residents in Nigeria trained by Kimmerle. In the effort to control for observer variation in data collection, the number of investigators per type of data was limited and random checks for observer variation was completed. Additionally, photographs were taken of the elements used for aging data (sternal rib and pubic symphysis) so that they could also be additionally scored or cross-checked by Kimmerle.

All of the data collected and presented here comes from direct observation of skeletal tissue. In the majority of the cases, the collections were already skeletonized for direct observation. In the samples from LASUCOM, soft tissues were processed through non-chemical means so that the bone could be directly observed, recorded, and photographed.

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Table 5. Sample locations by museum or collection.

| Source | Acronym | Location |
|---|---|---|
| American Museum of Natural History | AMNH | New York, New York |
| Lagos State University College of Medicine | LASUCOM | Lagos, Nigeria |
| Maxwell Museum of Anthropology | UNM | University of New Mexico, Albuquerque, New Mexico |
| Muséum national d'Histoire naturelle | MNHN | Paris, France |
| National Museum of Natural History | NMNH | Smithsonian Institution, Washington, DC |
| Raymond A. Dart Collection of Human Skeletons | Dart | University of the Witwatersrand, Johannesburg, South Africa |
| Forensic Anthropology Laboratory Osteological Collection | USF | Department of Anthropology, University of South Florida, Tampa Florida |

*Note that skeletal collections will be referenced according to their acronyms.

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Table 6. African samples by location with age cohort and country of origin.

| Museum | Population | Sample Size | Age Cohort* |
|---|---|---|---|
| AMNH | Cameroon | 19 | J/A |
| | Congo | 2 | J |
| | Ghana | 64 | J/A |
| | Kenya | 2 | J |
| | Nigeria | 31 | J/A |
| | Rwanda | 1 | J |
| | South Africa | 2 | J |
| | Tanzania | 2 | J |
| Dart | Botswana | 63 | J/A |
| | Malawi | 36 | A |
| | Mozambique | 48 | J/A |
| | Zimbabwe | 13 | J/A |
| LASUCOM | Nigeria | 655 | J/A |
| MNHN | Afro-Cuban | 4 | A |
| | Benin | 40 | J/A |
| | Cameroon | 6 | A |
| | Chad | 30 | J/A |
| | Congo | 40 | J/A |
| | Ghana | 2 | A |
| | Kenya | 25 | J/A |
| | Mali | 27 | A |
| | Sudan | 26 | J/A |
| NMNH | African American | 183 | J/A |
| | Cameroon | 2 | A |
| | Congo | 2 | A |
| | Gabon | 14 | J/A |
| | Ghana | 4 | A |
| | Kenya | 37 | J/A |
| | Liberia | 1 | A |
| | Senegal | 1 | A |
| | South Africa | 5 | J/A |
| UNM | New Mexico | 121 | J/A |

* "J" = juvenile; "A" = adult.

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Table 7. Comparative American and East European samples for pubic symphysis research (Kimmerle et al. 2008).

| **Collection** | **Males (*n*)** | **Females (*n*)** | **Total (*n*)** |
|---|---|---|---|
| Balkan Reference Sample | | | |
| Kosovo | 592 | 97 | 689 |
| BiH | 55 | 1 | 56 |
| Croatia | 116 | 0 | 116 |
| Total (*n*) | 763 | 98 | 861 |
| | | | |
| Balkan Skeletal Sample | | | |
| Kosovo | 106 | 83 | 189 |
| BiH | 55 | 1 | 56 |
| Croatia | 51 | 0 | 51 |
| Total (*n*) | 212 | 84 | 296 |
| | | | |
| American Skeletal Sample | | | |
| FDB | 41 | 43 | 84 |
| Gilbert-McKern | 0 | 147 | 147 |
| Korean War Dead | 258 | 0 | 358 |
| Los Angeles Medical Examiner | 739 | 0 | 739 |
| Robert J. Terry Anatomical Collection | 422 | 328 | 750 |
| | | | |
| Total (*n*) | 1,560 | 518 | 2,078 |

Table 8. East European (EE) and American (AM) samples for sternal ribs and single rooted teeth.

| **Skeletal Element** | **Male *(n)*** | **Female *(n)*** | **Total *(n)*** |
|---|---|---|---|
| Sternal Rib End (EE) | 540 | 82 | 622 |
| Tooth (EE) | 364 | 48 | 412 |
| Sternal Rib End (AM) | 250 | 102 | 148 |

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Table 9. American and East European osteometric data.

***Cranial Coordinate Data – U.S.A.***

- 3D Coordinate Cranial Data: UT Forensic Databank, William M. Bass Donated Collection, and Robert J. Terry Anatomical collection (n=526, including 226 females and 300 males of European and African-American ancestry).

***Post-cranial Data - U.S.A.***

- Robert J. Terry Anatomical Collection, Post-Cranial Data (n=745, including 381 males and 355 females of European and African-American ancestry)

***Post-cranial Data - Balkans***

- Post-Cranial Data Kosovo (n=70)
- Post-Cranial Data Croatia (n=85)

## STATISTICAL METHODS

Through the course of this project, different types of data were used to test population variation and create population relevant parameters for craniometric distance, discriminant function analysis for sex estimation for Botswana, recalibrated age parameters for Nigeria, and chemical and elemental analysis of Nigerian and American populations. Specifically, research investigated concepts and methods for human identification; estimating the biological profile and population specific calibrations for age and sex estimation (Table 10).

A variety of statistical methods were used including descriptive statistics, linear and logistic regression, principal component analysis, and Bayesian statistics to establish accurate parameters through the use of maximum likelihood estimates. Descriptive statistics and general data management were run in SPSS 17.1 (Systat 1998) and SAS 9.2 (2001). Statistical procedures specific to Bayesian analyses are run in the statistical program "R" Version 1.7.1 (http://www.r_project.org). Other statistical programs or methods used are listed in the specific examples.

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Table 10. List of methods and samples tested.

| Research Area | Statistical Methods | Samples |
|---|---|---|
| Human Identification | Descriptive trends and witness interviews for locating graves and missing person data | Unidentified decedents U.S.A. and Nigeria |
| Recalibrated Age Parameters | Bayesian Statistics | U.S.A., East Europe, and Nigeria |
| Craniometric Bio-distance | ANOVA, canonical principal component analysis, Pearson product moment correlation coefficients | African Samples and American Diaspora |
| Sex Estimation | ANOVA, canonical principal component analysis, and sectioning points | Botswana and American Diaspora |
| Chemical and Elemental Data | N/A | U.S.A. and Nigeria |

## METHODS FOR TESTING CRANIOMETRIC VARIATION AMONG POPULATIONS

Seventeen groups totaling 794 crania were used to examine the craniometric variation among the 17 African and Diaspora populations (Humphries et al. n.d.). Only adult crania were included in this study (Table 11). Males and females were pooled to incorporate all of the observed biological variation within the populations and increase sample sizes. According to Sardi et al. (2005), sex variation is negligible within each population in among-population comparisons. The twelve traditional craniometric measurements, or interlandmark distances (ILDs), that were used in this study are listed in Table 12. Data were collected using traditional spreading and sliding calipers and a MircroScribe G2X digitizer, using ThreeSkull (Ousley 2004).

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Table 11. Sample sizes.

| Population | (n) |
|---|---|
| Benin | 38 |
| Botswana | 59 |
| Cameroon | 17 |
| Chad | 28 |
| Congo | 37 |
| Gabon | 13 |
| Ghana | 36 |
| Hispanic | 8 |
| Kenya | 51 |
| Malawi | 36 |
| Mali | 27 |
| Mozambique | 46 |
| Nigeria | 27 |
| African-American (Blacks) | 134 |
| European-American (Whites) | 198 |
| Sudan | 25 |
| Zimbabwe | 13 |

Table 12. Craniometric Measurements.

| Interlandmark Distances (ILDs) |
|---|
| 1. Maximum Cranial Length (GOL) |
| 2. Maximum Cranial Breadth (XCB) |
| 3. Cranial Height (BBH) |
| 4. Nasal Height (NLH) |
| 5. Nasal Breadth (NLB) |
| 6. Left Orbital Breadth (OBB) |
| 7. Left Orbital Height (OBH) |
| 8. Biorbital Breadth (EKB) |
| 9. Interorbital Breadth (DKB) |
| 10. Frontal Cord (FRC) |
| 11. Parietal Cord (PAC) |
| 12. Occipital Cord (OCC) |

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While directly accounting for size effects, size and shape variables were computed using the raw inter-landmark distance (ILD) measurements (Mosimann and James 1979; Darroch and Mosimann 1985). Size is defined as the geometric mean (GM). Size is the product of all variables divided by the number of variables. The GM for the 12 cranial measurements used is calculated as:

$$Size = \left( \prod_{i=1,n} X_i \right)^{1/n}$$

Once the new size variable was computed, each raw cranial variable was then divided by the GM to create shape variables (Y = X/SIZE). The shape variables are simple ratios of the GM, measuring the size of a particular region relative to the overall size of the cranium (Roseman and Weaver 2004). These variables do not necessarily remove absolute size from the analyses and provides an indication of the "geometric similarity" among the populations being examined. A one-way analysis of variance or ANOVA was performed on the size variable (GM) to test the null hypothesis ($H_0$) that the mean size is not significantly different among the groups. The alternative hypothesis ($H_1$) states that the means are significantly different for any two of the 17 populations. Additionally, to test whether group centroids are significantly different, the degree of differentiation among the groups was measured using Mahalanobis Generalized Squared Distances ($D^{2)}$. Mahalanobis $D^2$ is a function of the group means and the pooled variances and covariance's that measures the degree of differentiation observed among the considered populations.

A canonical discriminant analysis was performed and canonical variates were derived from the newly transformed shape variables to examine between-group differences relative to within-group variation. The canonical variates are linear combinations of predictor variables that

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summarize between-population variation. The canonical discriminant analysis procedure reports significant canonical axes and the total canonical structure, which allow for the graphical comparison of the populations relative to the significant shape variables. Also included are the eigenvalues, which indicate the percentage of total variation that each canonical component provides. Eigenvalues are the ratio of between-class variation to within-class variation for the canonical variable. The first canonical component has the highest correlation among the groups, followed by the remaining in descending order. Finally, a Pearson Product Moment Correlation Coefficient was used to measure the strength of the relationship between the size variable and canonical axes.

## POPULATION PARAMETERS FOR SEX ESTIMATION

Craniometric data from 331 individuals were used to assess the regional variation of sexual dimorphism within six West and South African populations and American Diaspora (Kimmerle et al. n.d. and Tise et al. n.d.). Sixteen inter-landmark distance (ILD) measurements were used. Based on the observed craniometric relationships among populations, the objectives of this research were to examine patterns of sexual dimorphism in cranio-facial features among West and South African groups and the American Diaspora.

The degree of sexual dimorphism was assessed for each group. Individual variable indexes of sexual dimorphisms (ISD) were calculated, and then the mean ISD was calculated to compare the average level of sexual dimorphism between all groups. Size and shape variables were calculated using the raw ILD measurements to directly account for size effects (Mosimann and James 1979; Darroch and Mosimann 1985). Population specific formulae for sex estimation were calculated for any group with a significant level of sexual dimorphism.

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## AGE ESTIMATION: JUVENILE TOOTH DEVELOPMENT

Kimmerle and Konigsberg (2011) researched the issue of population specific age parameters for tooth development in assessing living person ages. Kasper et al. (2009) presented data on third molar development for 950 individuals ranging in age (at the last birthday) from 12 to 22 years including the mean and standard deviation for age within seven stages of third molar formation ("B" through "H" from Demirjian et al.'s 1973 scoring system). As Konigsberg et al. (2008:542) noted "a final problem with any method that conditions on stage to estimate age is that all of these methods contain an implicit prior distribution for age." This is seen in the present study particularly for teeth where the root apex is complete (stage "H"). Kasper et al. assume that age within stage is normally distributed, but because their sample's age distribution is truncated at 12 and 22 years, the mean age within stage "H" must be less than 22 years. It is also difficult to justify the assumption that the age distributions within stages are normal, as these distributions depend on: 1) the age distributions for when individuals move to the next higher stage and 2) the overall age distribution of the sample. By Bayes' Theorem:

$$f\left(a\middle|i\right)=\frac{p\left(i\middle|a\right)\,f\left(a\right)}{\int_{a=0}^{\varpi}p\left(i\middle|a\right)\,f\left(a\right)},$$

where p(i|a) is the probability that someone at exact age "a" is in stage "i," f(a) is the probability density function for age, and f(a|i) is the probability density function that someone is exact age "a" given that they are in stage "i," and ω is the upper limit of integration (i.e., the maximum possible age). Kasper et al. use the assumption of a normal distribution of age within stage to present probabilities (given stage) that an individual is 18 years old or older. This issue can instead be treated by using a parametric model for p(i|a). More specifically a cumulative probit model on the log scale ages can be used to model p(i|a). This is precisely the model that was

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used by Moorees, Fanning, and Hunt (1963*a and b*) in their classic studies of dental development. Kasper et al.'s summary data tables were used to estimate the "transition parameters" in log cumulative probit models. This analysis assumes that the age at which individuals move from a stage to the next higher stage follows a lognormal distribution with a common within-tooth variance. As an example, the estimated mean ages-to-transition for female maxillary third molars between stages B through H were 9.89, 11.15, 13.46, 14.86, 16.56, and 18.66 years, while the log-scale standard deviation was 0.1758. To find the probability that someone was 18 years old or older based on tooth stage (and under an uninformative prior) equation (2) can be integrated:

$$f\left(a\middle|i\right) = 1 - \int_{a=0}^{18} \frac{p\left(i\middle|a\right)}{\int_{a=0}^{\varpi} p\left(i\middle|a\right)}.$$

NIGERIAN AGE RIBS AND PUBIC SYMPHYSES

To simplify the analysis it is assumed that the rib and pubic symphysis data are conditionally (on age) independent. This is a commonly made assumption (Boldsen et al. 2002:86-87; Lucy et al. 2002) which may be difficult to justify for traits within a single bony region, but which may be logically posited between the rib and pubic symphysis. Under conditional independence the probabilities from the rib stage and from the pubic symphysis stage are multiplied to jointly estimate age. This is done using a variant of "lrage.viewer" ("lrage.viewer.biv" available at https://netfiles.uiuc.edu/lylek/www/KK2013.htm). For the 321 individuals having both rib and pubic symphysis data "lrage.viewer.biv" applies single trait models for the rib and pubic symphysis stages and combines these with the total Nigerian age-at-death distribution.

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The single trait models were fit using cumulative probit analysis with age measured on a logarithmic (base "e") scale (Konigsberg et al. 2008). The website https://netfiles.uiuc.edu/lylek/www/TransAna/TransAna.htm describes this model as well a number of alternative "transition analysis" models.

To represent the total sample age-at-death distribution for adults, 167 deaths that were recorded at ages less than 20 years were removed leaving 2,461 individuals. A Gompertz-Makeham mortality model was fit to these recorded ages at death after subtracting 20 years from all ages. This hazard model specifies the hazard of death at exact age *t* as:

$$h(t) = a_2 + a_3 \times \exp(b_3 \times t),$$

where *t* is the age (minus 20 years), $a_2$ represents a "baseline" hazard that does not depend on age, and $a_3$ and $b_3$ represent "senescent" mortality. The subscript numbering for the hazard parameters follows that from the Siler model (Siler 1979; Gage and Dyke 1986) which also includes a juvenile component represented by a negative Gompertz model ($a_1$ and $b_1$). The survivorship to age *t* is:

$$S(t) = \exp\left(-a_2 + \frac{a_3}{b_3}\left(1 - \exp(b_3 \times t)\right)\right),$$

and the probability density for death at exact age *t* is the product of the hazard with the survivorship. The three parameters in the Gompertz-Makeham model were estimated using the method of maximum likelihood, where each parameter was converted to a log scale (and then exponentiated within the likelihood) in order to remove the constraint that parameter values cannot be negative.

In fitting the Gompertz-Makeham model to the total sample and comparing this to the mortality for the osteological sample it became clear that the age-at-death distributions differed

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between these two samples. Because the Gompertz-Makeham is supposed to represent the actual prior distribution for age-at-death, it was necessary to create a new osteological sample in order to assess the 50% highest posterior densities produced by "lrage.viewer.biv." This was done by picking 296 ages-at-death, where there were nine deaths at each age from 20 to 27 (inclusive), so there were nine deaths at age 20, 21, 22, 23, 24, 25, 26, and 27. Similarly, there were eight deaths at from 28-37, seven from 38-43, six from 44-48, five from 49-53, four from 54-57, three from 58-62, two from 63-68, and one from 69-72. The rib and Suchey-Brooks stages for the 296 individuals in this new test sample were formed by bootstrap sampling on the stages within the actual yearly age interval. So for example, at age 20 years nine individual stages were drawn (with replacement) from the four individuals in the original sample who were at 20 years of age.

## HYOID AGE ESTIMATION AND IMPLICATIONS FOR INFLICTED TRAUMA PATTERNS

The fusion of primary and secondary ossification centers is one of the commonly used methods by forensic anthropologists to age adolescents and young adults due to the specific age ranges at which elements of long bones and vertebrae fuse together. However, few studies have looked at the fusion process in the hyoid bone, particularly since it has significant applications for fracture patterns and interpretations on the mechanism of injury related to cases of strangulation. Data collection was performed in collaboration with the Hillsborough County Medical Examiner's Office in Tampa, Florida and LASUCOM in Nigeria (Dionne *et al.* 2011; Seasons *et al.* 2011). For each hyoid bone, variables on demographic information, cause and manner of death, and past or present abuse of alcohol and drugs were recorded.

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ELEMENTAL AND ISOTOPE ANALYSIS

Sr and Pb isotopes are measured with either Multi-Collector Inductively-Coupled Plasma Mass-Spectrometry (MC-ICP-MS) and/or Thermal Ionization Mass-Spectrometry (TIMS). Recent works (Ellam 2010; Kamenov 2008) concluded that the MC-ICP-MS is the method of choice for high-precision Pb isotope analyses, as utilized in this work. Typically very small amount (0.05g or less) of bone/tooth material is required for precise isotope analyses and the sample preparation is done under clean lab environment. The bone/tooth sample is dissolved with 50% $HNO_3$ (high-purity, "Optima-grade") and purified through 2-stage ion-chromatographic extraction to isolate Sr and Pb for subsequent isotope analyses (Kamenov et al. 2009). For this work Sr and Pb isotope analyses were performed in the Department of Geological Sciences at the University of Florida on a Nu-Plasma MC-ICP-MS. Detailed description of the analytical protocol is given in Kamenov (2008) and Kamenov et al. (2009). Sr isotope data are relative to NBS 987 = 0.71024 (+/-0.00004) and Pb isotope data are relative to following NBS 981 values: $^{206}Pb/^{204}Pb$=16.937 (+/-0.004), $^{207}Pb/^{204}Pb$=15.490 (+/-0.003), and $^{208}Pb/^{204}Pb$=36.695 (+/-0.009).

## SECTION IV: RESULTS

HUMAN IDENTIFICATION: MORBIDITY AND MORTALITY IN NIGERIA

Much of the observed variation among populations may be the result of epigenetic factors. Teasing out the environmental, nutritional, pathological and genetic influences in shaping bone morphology is not often possible, at least at the macroscopic level. However, understanding the variation in basic factors acting upon individuals in diverse populations provides a framework for interpreting observed differences. Approximately 65% of Nigerians included in this analysis died of natural causes, most frequently hypertensive heart disease,

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congestive cardiac failure, and pneumonia. The majority of these cases involved individuals less than 30 years of age, with low average ages at death for males (44.69 years) and females (42.05 years). The low ages of death, particularly due to natural rather than accidental or violent causes, speaks to possible health disparities and has implications for other transitional justice initiatives centered around human health securities. These ages are consistent with published life expectancy data for Nigeria. For example, among males the ages at death ranged from 7 to 81 years old. Approximately 59% died of natural causes, 18% from motor vehicle accidents, 18% from trauma related accidents, and 5% due to homicide. In comparison, the ages at death among females ranged from 20 to 75 years. Approximately 82% died of natural causes, 5% of motor vehicle accidents, 10% trauma related accidents, and 3% due to homicide. Among the female sample, the natural causes of death included most frequently hypertensive heart disease, septicemia, ventricular failure, and eclampsia. A higher number of female deaths occur at younger ages as a result from deaths related to pregnancy.

Interestingly, among males the manner and cause of death were frequently reported as: "penetrating gunshot wound to head, chest or thorax" or "charred body" and were attributed to accidents. In published case studies from Nigeria, it has been noted that sharp trauma and interpersonal violence has been underreported. The cases investigated here included machete injuries and 96% of those cases were assaults resulting from homicides. The frequency of skeletal lesions and causes of death are listed in Tables 13 and 14. The frequency of natural deaths for women is almost double that of men and the mean age at death is lower among females. In comparison, the frequency for accidental or violent trauma related deaths for men is nearly doubled which is expected for most forensic samples.

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Table 13. Frequency of skeletal lesions related to nutritional deficiencies.

| Location | Female (n) | Male (n) | Total (n) |
|---|---|---|---|
| Cribra orbitalia | 26.2% (37/141) | 21.7% (96/442) | 22.8% (133/583) |
| Porotic hyperostosis | 8.4% (13/154) | 6.4% (26/403) | 14.3% (39/557) |

Table 14. General causes of death.

| Category of Death* | Males (n=1955) | Females (n=786) |
|---|---|---|
| Pregnancy/Labor | 0 | 18.2% |
| Cardiac/Hypertension | 19.4% | 21.9% |
| Metabolic/Nutritional | 1.8 | 4.2% |
| Infectious | 8.5% | 15.9% |
| Neoplams | 1.4% | 3.2% |
| Trauma | 66.5% | 32.4% |

*Less than 1.0% of cases included Stillbirth/Congenital Defects (n=26), dehydration (n=18), drugs related deaths (n=9), and medical error (n=4)

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## HUMAN IDENTIFICATION: NIGERIAN FIELDWORK

During the initial research visit to the alleged grave sites in Nigeria, community leaders explained what events unfolded in 1967. Among the participants was one elderly man who helped bury the dead, stated:

> "… men and women were rounded out from their houses and told to come to the center for a celebration to welcome federal troops. Once people gathered, they were shot and about 200 people were ultimately buried in a mass grave… only men dug the grave [including himself] … and it was about 6 feet deep …very deep."

Figure 5 is the map of the Ogbeosowa mass burials, based on field visits and multiple field interviews at the site in 2008. Figure 6 also shows the reported Ogbeosowa mass burials and pictures of the site as it was developed and changed from 2008-2010. Protocols for forensic field interviews to locate graves and collect antemortem information about missing persons ranging from international HHRR to American 'cold cases' was developed. The Cardinal consideration for methods to be put into practice in the context of forensic investigations is the *issue of relevancy*. In a criminal case, the facts in issue are those facts which must be proved or disproved to substantiate the charge or to establish any exception or exemption from or qualification to the operation of the law creating the offense charged. In the U.S.A., the Laws of Evidence require that a piece of evidence can only be admissible at trial if it is relevant to the fact in issue. So if the evidence is relevant it is admissible, if not, it is not admissible. In foreign countries, the specific rules of evidence also must be followed (i.e., Law of the Federation of Nigeria Section 6, Evidence Act, Cap.112, Vol. VIII).

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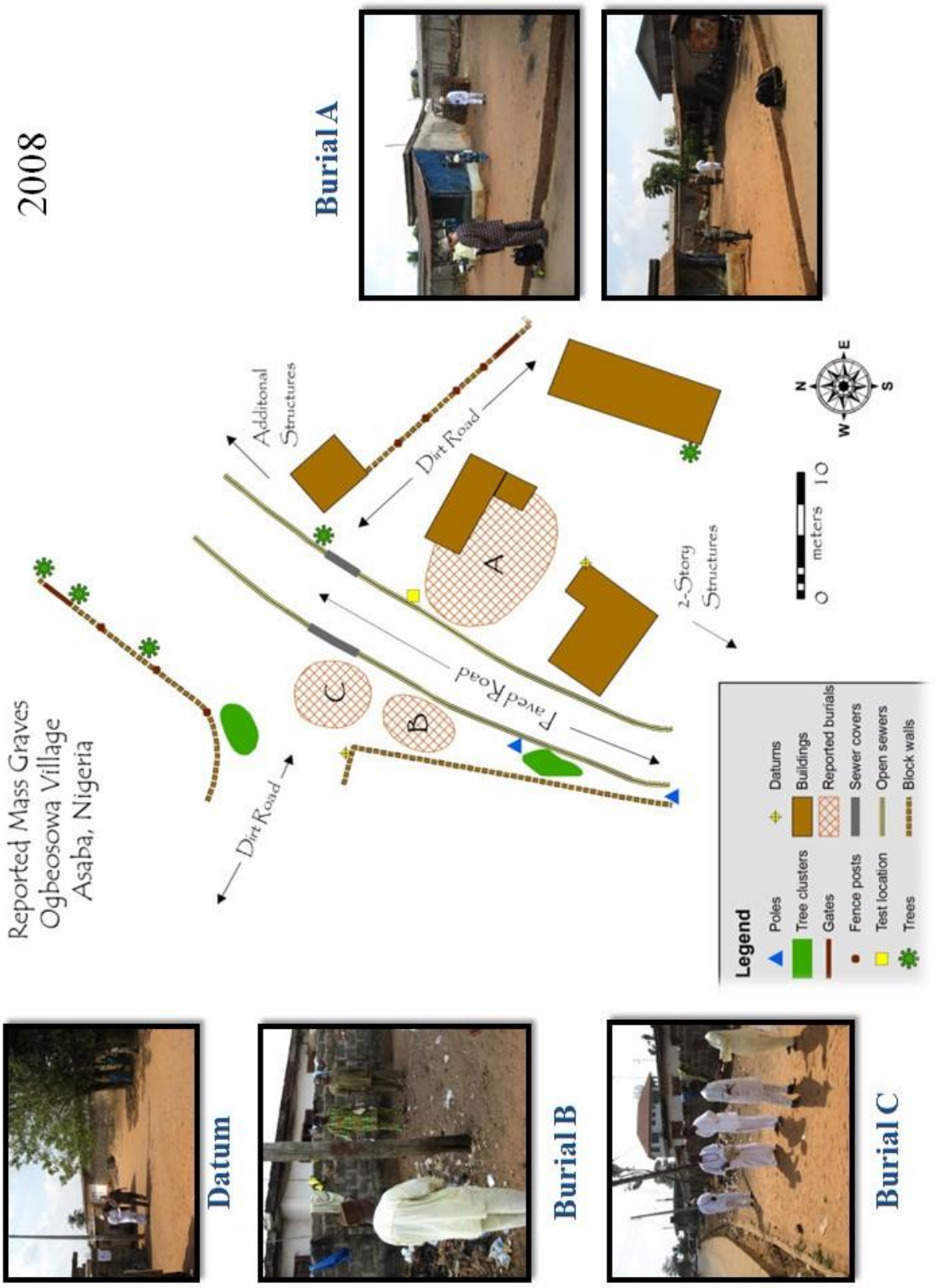



Figure 5. Map of reported mass graves in Ogbeosowa village and images of the site in 2008.

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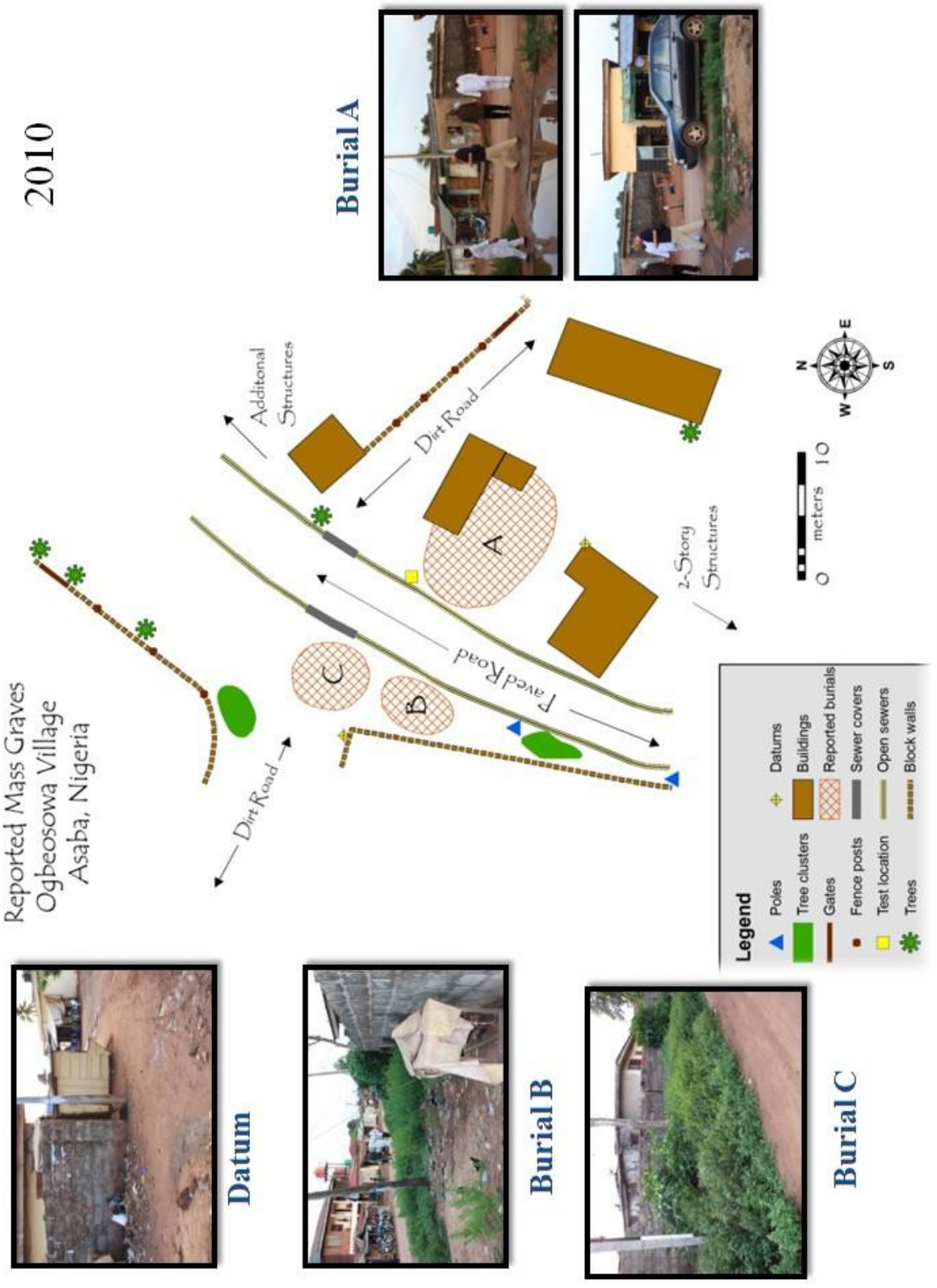



Figure 6. Map of reported mass graves in Ogbeosowa village and images of the site as it changed due to development in the area in 2010.

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## CRANIOMETRIC VARIATION AMONG AFRICAN AND DIASPORA POPULATIONS

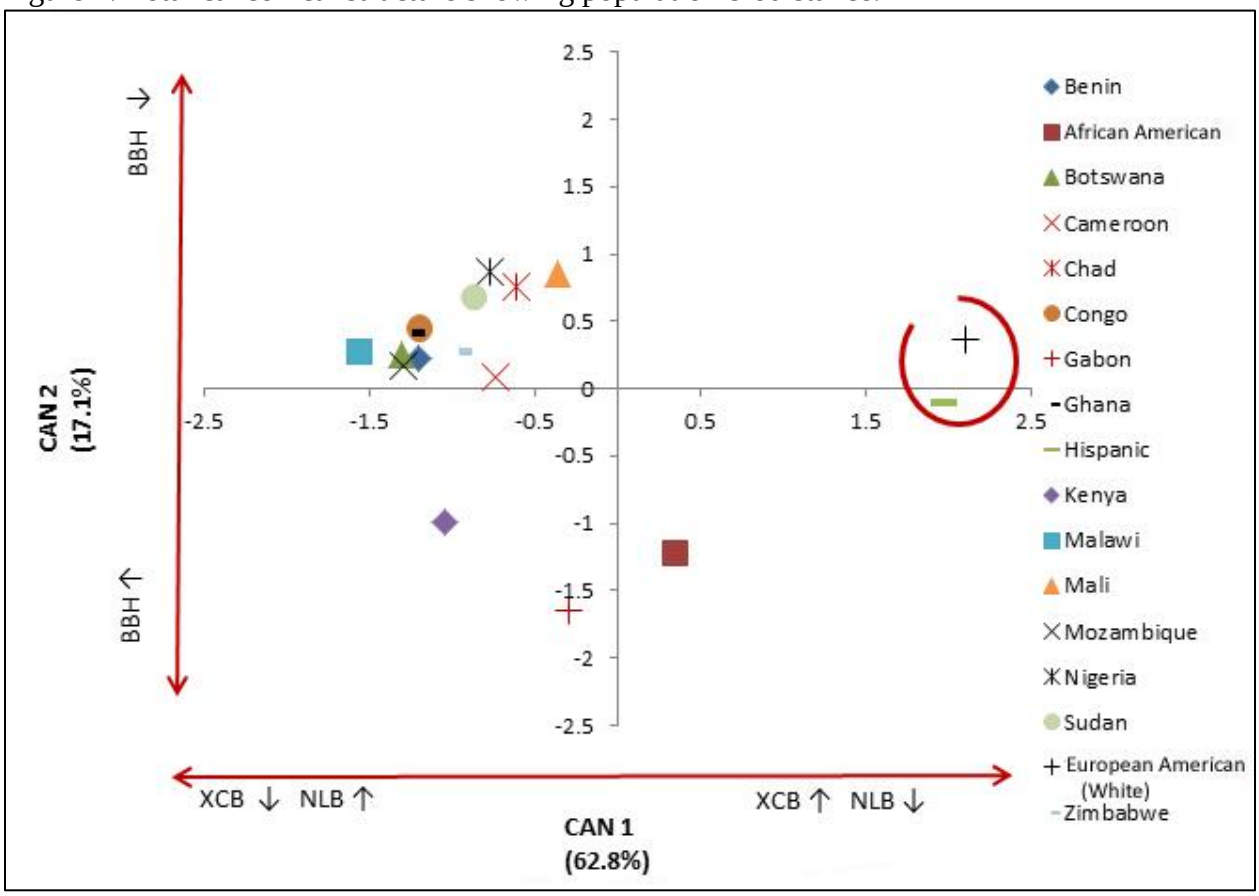
The biological similarity of seventeen groups (n=794) was tested. Groups are significantly different when their corresponding p-value is <0.05. As expected, groups that are geographically closer to one another are shown to be more similar in craniofacial form. The four samples representing southern Africa (Malawi, Mozambique, Zimbabwe, and Botswana) are not significantly different from one another. Several of the samples representing Western Africa are not significantly different from one another (Nigeria and Cameroon, Congo and Cameroon, Ghana and Benin, Ghana and Congo, Mali and Chad). Within the Western region, a difference is observed between the coastal populations (who are more similar to one another) and the land locked populations (Mali and Chad) who are similar to one another but statistically different from the coastal populations. The Mahalanobis distances also show that one of the populations representing Eastern Africa (Kenya) is significantly different from all other groups in this analysis. The sample representing Sudan, while considered an East African country, is not significantly different from the sample representing the adjacent country of Chad. As expected, the samples representing the Americas, European-Americans, African-Americans, and Hispanics, are significantly different from all of the African groups tested.

Figure 7 is a graphical representation of the first two significant canonical axes accounting for roughly 80% of the total among-group shape variation. The total canonical structure, the correlation between the original variables and the canonical variates, reveals that for CAN1 and CAN2 the variation on the first canonical axis separates the groups with respect cranial breadth (XCB) and nasal breadth (NLB), while the second axis isolates the groups on cranial height (BBH). Figure 6 illustrates that most of the African groups cluster more closely and that they have narrower, shorter vaults and broader nasal apertures than the American groups. The African samples that did not cluster with the other African groups were Gabon and

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Kenya. These two groups have higher vaults. African-Americans fall intermediate to the African groups and the European and Hispanic American groups with regard to nasal breadth and also have higher cranial vaults.

Figure 7. Total canconical structure showing population biodistance.

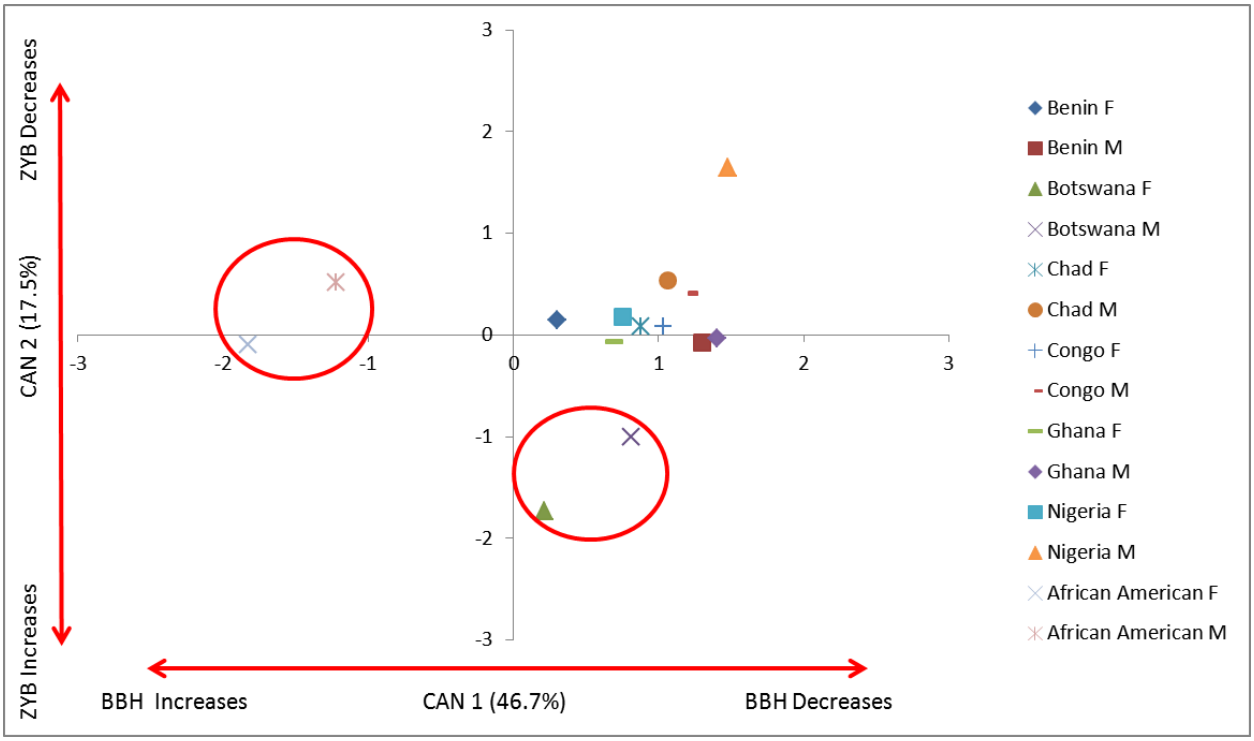


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## POPULATION PARAMETERS FOR SEX ESTIMATION

Craniometric data from 331 individuals was used to assess the regional variation of sexual dimorphism in six West and South African populations and American Diaspora (Kimmerle et al. n.d.; Tise et al. n.d.). Interestingly, the Botswana males and females appear to be the most differentiated of all the groups with the mean value for males being 5.76% larger than that for females (Figure 8). Therefore, population specific parameters for sex estimation were developed for American and Botswanan populations (Tables 15-17) and are reported in the data collection protocol (Kimmerle et al. 2012).

Figure 8. Total canonical structure illustrating population variation in sexual dimorphism.



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Table 15. Botswana sex estimation classification functions.

| Element | Classification Function |
|---|---|
| Cranium | (0.38309*GOL)+(0.38309*XCB)+(0.67821*ZYB)+(0.21559*BBH)+ (-0.53515*AUB) +(0.41511*NLH)+(-0.8825*NLB)+(-0.89632*OBH)+(-137) |
| Humerus | (0.05902*HUMXLN)+(0.45757*BUE)+(0.53245*HUMEBR)+(-68.20684) |
| Femur | (0.73072*FEMHDD)+(0.21374*FEMEBR)+(-46.22531) |
| Tibia | (0.67289*TIBPEB)+(-47.75888) |

Table 16. Botswana sex estimation cross-validation.

| Element | Male Cross-Validation Rate | Female Cross-Validation Rate | Total Cross-Validation Rate |
|---|---|---|---|
| Cranium | 90.32% | 90.32% | 90.32% |
| Humerus | 85.19% | 92.59% | 88.89% |
| Femur | 88.46% | 92.59% | 90.53% |
| Tibia | 78.57% | 86.67% | 82.62% |

Table 17. Botswana sex estimation: Postcranial sectioning points and cross-validated classification rates.

| Measurement | Abbrev. | Male (n) | Female (n) | Sectioning Point (mm) | Classification Rate |
|---|---|---|---|---|---|
| Humeral Head Diameter | HUMHDD | 27 | 27 | 40 | 88.89% |
| Humerus Epicondylar Breadth | HUMEBR | 27 | 29 | 57 | 87.29% |
| Humerus Prox. Epiphyseal Breadth | BUE | 27 | 27 | 44 | 87.04% |
| Femoral Head Diameter | FEMHDD | 26 | 27 | 42 | 86.83% |
| Radius A-P Diameter at Midshaft | RADAPD | 26 | 30 | 12 | 85.65% |
| Radius Maximum Length | RADXLN | 25 | 29 | 240 | 85.38% |
| Ulna Maximum Length | ULNXLN | 25 | 29 | 256 | 85.38% |
| Ulna Dorso-Volar Diameter | ULNDVD | 26 | 30 | 15 | 84.23% |
| Radius Max. Diameter of Head | RDH | 26 | 30 | 21 | 83.72% |
| Tibia Prox. Epiphyseal Breadth | TIBPEB | 28 | 28 | 71 | 82.62% |

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## POPULATION PARAMETERS FOR AGE ESTIMATION

Age parameters for adults and juveniles were tested for population variation between Balkan, American and Nigerian populations based on the juvenile dental development among Hispanic, European, and African Americans (Kimmerle and Konigsberg 2011; Dotson *et al.* 2011 and 2012); adult methods of aging using the fourth sternal rib (Kimmerle and Konigsberg 2009); and hyoid ossification for American and Nigerian populations (Dionne *et al.* 2011, Seasons *et al*. 2011). This body of work demonstrates the following: 1) Moorees et al. 1963a and b is highly reliable and preferred over other methods for aging the development of teeth; 2) the value of probably density functions for providing aging parameters; 3) the need to make informed priors explicit in Bayesian analyses and the importance of the issue of "coverage" when making forensic estimations; 4) population specific calibrations for the fourth rib and pubic symphysis; and 5) the timing and significance of fusion of the hyoid for age variation and its role in assessing fracture patterns.

## JUVENILE TOOTH DEVELOPMENT – POPULATION VARIATION IN AGING

Kimmerle and Konigsberg (2011) researched the issue of population specific age parameters for tooth development in assessing living person ages. Kasper et al. (2009) presented data on third molar development for 950 individuals ranging in age (at the last birthday) from 12 to 22 years including the mean and standard deviation for age within seven stages of third molar formation ("B" through "H" from Demirjian et al.'s 1973 scoring system). To find the probability that someone was 18 years old or older based on tooth stage (and under an uninformative prior) equation (2) can be integrated:

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$$f\left(a\left|i\right.\right) = 1 - \int_{a=0}^{18} \frac{p\left(i\left|a\right.\right)}{\int_{a=0}^{\varpi} p\left(i\left|a\right.\right)}.$$

Using this method, the probabilities that individuals in stage "G" were 18 years old or older were 0.5183, 0.6718, 0.3457, and 0.5164 for female maxillary third molar, female mandibular third molars, male maxillary third molars, and male mandibular third molars, respectively. This finding is substantially different than the reported accuracy by Kasper et al. and demonstrates the need for clear discussions about the biases implicit in demographic data as well as the possible evidentiary biases that result from such assumptions about the data.

## ADULT AGE ESTIMATION - ISSUES OF "COVERAGE" AND "PROBABILITY DENSITY FUNCTIONS"

To estimate age, probability density functions (PDF) for the posterior distributions of age at each symphyseal and rib phase are calculated (Kimmerle and Konigsberg 2009). Although the pubic symphyses were studied for European populations in prior research (Kimmerle et al. 2008), the rib phases were not analyzed nor were diverse African and American populations. The age estimates are based on the calculated age distribution from the Gompertz-Makeham hazard analysis and the ages-of-transition. Population variation in aging is tested. To estimate the age-at-death for an individual, the *highest posterior density region* for each phase is calculated. Statistical summaries of the Bayesian estimates for the probability of age are provided for different regions (95%, 90%, 75%, and 50%) for and are reported in the supplemental Data Collection Protocol (Kimmerle et al. 2012). An analysis of deviance shows that the mean ages-to-transition do differ between the two samples ($p<0.0001$).

Age estimation in the identification process is in part an issue of "coverage", that is the proportion of cases that fall within nominal confidence limits. Exactly 50% of cases (126/252)

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are within the limits. For the comparable analysis using Iscan et al.'s stated 95% limits, 145 of 252 cases (57.5%) are within the limits. So, what does this mean? It shows that even though the Balkan and U.S. samples' aging patterns for the fourth rib are demonstrably different, a Balkan "standard" applied with an appropriate prior to the U.S. sample has the correct "coverage." This is in direct distinction to the original method which gives confidence limits that are too narrow to include the stated percentage of cases.

The Nigerian data was then compared to the American and Balkan data. Demographic data for n=2,590 cases and biometric scores (n=356) for the pubic symphysis and fourth ribs, scored in the manners of Suchey-Brooks and Iscan and co-workers, were collected for identified individuals autopsied at LASUCOM, Nigeria. The Nigerian rib phase data is presented with the age distribution of the reference sample. Overall the average ages and general age ranges for each phase are lower than that of the original methods. The descriptive age statistics for each of the samples are compared. The Nigerian samples have a lower mean age at death, though the overall range is consistent, whereas the American sample tends to be slightly older.

Comparing the distributions of the three samples through independent sample t-tests, reveals they are significantly different, for both male and female groups, well below the 0.05 level. Interestingly, the mean difference is far less between Nigerians and Americans, 4.35 years, than it is among Nigerian and Balkan samples, 13.6 years. To calculate age-at-death parameters that can be used by investigators in the field – a Bayesian statistical approach is used based on Kimmerle and Konigsberg (2009) and the age parameters are presented in the Data Collection Protocol (Kimmerle et al. 2012).

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## TESTING FOR POPULATION VARIATION

A *proportional odds probit regression* analysis and an *improvement chi-square test* were used to test for variation among two populations in the morphological aging process of the fourth rib (Kimmerle and Konigsberg 2009). Kimmerle and Konigsberg found that proportional odds probit regression analysis was used to measure the association between the proportion of cases that exhibited a particular rib phase and age for each population (Fox 2002). The population (American or Balkan sample) was used as a dichotomous dummy variable (0=American population, 1=Balkan population) and the rib phase was regressed onto the log-age, population, and the interaction between the log-age and population. The model was run twice, once with the interaction term and once without the interaction term, for the total sample, males, and females. An analysis of deviance was used to test the adequacy of the model which was calculated using an improvement chi-square based on the two models (Fox 2002), thereby comparing the observed frequencies of rib phases from both samples to ascertain whether they contained the same proportion of phases conditional on age.

It is demonstrated that there is not a significant association between the aging process of fourth sternal rib and population when testing the two populations (*df = 1, chi-square likelihood ratio = 3.209, p = 0.10*). However, when males *(df = 1, chi-square likelihood ratio = 0.7428, p = 0.10)* and females are treated separately, there is a significant association among females *(df = 1, chi-square likelihood ratio = 15.071, p = 0.001)*. This finding is consistent with prior research of pubic symphyses investigating population variation among these populations (Kimmerle et al. 2008).

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## NIGERIAN PARAMETERS FOR AGE ESTIMATION

The mean values on the logarithmic scale for the rib transitions in the Nigerian osteological sample were 2.70, 3.10, 3.31, 3.70, 3.89, 4.25, and 4.44 with a common standard deviation of 0.4785. These values translate into modal transition ages of about 11.83, 17.66, 21.78, 32.17, 38.90, 55.76, and 67.43 years on the straight scale, median transition ages of 14.88, 22.20, 27.39, 40.45, 48.91, 70.11, and 84.77 years, and mean transition ages of 16.68, 24.89, 30.71, 45.35, 54.84, 78.61, and 95.06 years. Note that because the transitions were modeled with log-normal distributions the modes are less than the medians which are less than the means on the straight scale. The mean values on the logarithmic scale for the pubic symphysis transitions in the Nigerian osteological sample were 2.74, 3.09, 3.48, 3.77, and 4.29 with a common standard deviation of 0.4284. These values translate into modal transition ages of about 12.89, 18.29, 27.02, 36.11, and 60.73 years on the straight scale, median transition ages of 15.49, 21.98, 32.46, 43.38, and 72.97 years, and mean transition ages of 16.98, 24.09, 35.58, 47.55, and 79.98 years.

The estimated parameter values for mortality in the Gompertz-Makeham model (beginning at age 20 years) were $a_2 = 1.16\times10^{-5}$ , $a_3 = .0286$, and $b_3 = 0.0312$. These were combined with the above transition analysis parameters to obtain the 2.5%, 25%, 50%, 75%, and 97.5% values of age at each combination of rib stage and pubic symphyseal stage (Table 18).

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Table 18. Age table for combined 4th rib and pubic symphyseal phases.

| Rib Stage | PS Stage | 2.5% | 25% | 50% | 75% | 97.5% |
|---|---|---|---|---|---|---|
| 1 | 1 | 20.00 | 20.00 | 20.00 | 22.44 | 30.30 |
| 1 | 2 | 20.00 | 20.00 | 20.00 | 23.46 | 33.48 |
| 1 | 3 | 20.00 | 20.00 | 20.00 | 24.91 | 37.38 |
| 1 | 4 | 20.00 | 20.00 | 21.82 | 27.03 | 41.89 |
| 1 | 5 | 20.00 | 21.85 | 26.52 | 32.03 | 47.98 |
| 1 | 6 | 20.00 | 28.28 | 34.65 | 42.08 | 57.53 |
| 2 | 1 | 20.00 | 20.00 | 20.00 | 23.34 | 33.13 |
| 2 | 2 | 20.00 | 20.00 | 20.00 | 24.98 | 37.35 |
| 2 | 3 | 20.00 | 20.00 | 22.50 | 27.31 | 42.31 |
| 2 | 4 | 20.00 | 22.28 | 26.90 | 32.36 | 47.55 |
| 2 | 5 | 20.00 | 26.31 | 32.14 | 39.01 | 54.20 |
| 2 | 6 | 23.08 | 33.57 | 40.63 | 48.65 | 65.34 |
| 3 | 1 | 20.00 | 20.00 | 20.00 | 24.16 | 35.40 |
| 3 | 2 | 20.00 | 20.00 | 21.12 | 26.37 | 40.32 |
| 3 | 3 | 20.00 | 21.29 | 25.55 | 30.57 | 45.88 |
| 3 | 4 | 20.00 | 24.86 | 30.22 | 36.54 | 51.39 |
| 3 | 5 | 20.45 | 29.42 | 35.82 | 43.23 | 58.53 |
| 3 | 6 | 25.65 | 37.03 | 44.41 | 52.61 | 69.44 |
| 4 | 1 | 20.00 | 20.00 | 20.00 | 25.29 | 38.28 |
| 4 | 2 | 20.00 | 20.13 | 23.92 | 28.37 | 43.98 |
| 4 | 3 | 20.00 | 23.75 | 28.88 | 34.95 | 50.12 |
| 4 | 4 | 20.00 | 27.85 | 33.91 | 40.98 | 55.79 |
| 4 | 5 | 22.72 | 33.01 | 39.95 | 47.82 | 64.17 |
| 4 | 6 | 28.67 | 40.98 | 48.68 | 57.02 | 73.71 |
| 5 | 1 | 20.00 | 20.00 | 21.53 | 26.87 | 41.56 |
| 5 | 2 | 20.00 | 22.49 | 27.17 | 32.70 | 47.78 |
| 5 | 3 | 20.00 | 26.65 | 32.46 | 39.28 | 54.13 |
| 5 | 4 | 21.57 | 31.06 | 37.61 | 45.11 | 60.81 |
| 5 | 5 | 25.30 | 36.51 | 43.76 | 51.81 | 68.36 |
| 5 | 6 | 31.57 | 44.43 | 52.25 | 60.57 | 76.89 |
| 6 | 1 | 20.00 | 20.21 | 24.19 | 28.83 | 44.87 |
| 6 | 2 | 20.00 | 24.74 | 30.11 | 36.46 | 51.48 |
| 6 | 3 | 20.46 | 29.41 | 35.78 | 43.14 | 58.35 |
| 6 | 4 | 23.61 | 34.11 | 41.06 | 48.89 | 65.21 |
| 6 | 5 | 27.82 | 39.81 | 47.34 | 55.53 | 72.03 |

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*Table 18 continued…*

| Rib Stage | PS Stage | 2.5% | 25% | 50% | 75% | 97.5% |
|---|---|---|---|---|---|---|
| 6 | 6 | 34.33 | 47.70 | 55.64 | 63.94 | 79.91 |
| 7 | 1 | 20.00 | 22.82 | 27.74 | 33.52 | 48.90 |
| 7 | 2 | 20.00 | 27.78 | 33.80 | 40.83 | 55.58 |
| 7 | 3 | 22.71 | 32.83 | 39.64 | 47.37 | 63.51 |
| 7 | 4 | 26.27 | 37.60 | 44.84 | 52.84 | 69.24 |
| 7 | 5 | 30.74 | 43.32 | 50.99 | 59.19 | 75.38 |
| 7 | 6 | 37.28 | 50.94 | 58.88 | 67.07 | 82.59 |
| 8 | 1 | 20.00 | 25.53 | 31.30 | 38.09 | 53.63 |
| 8 | 2 | 21.44 | 31.08 | 37.77 | 45.48 | 61.53 |
| 8 | 3 | 25.32 | 36.64 | 43.99 | 52.15 | 68.91 |
| 8 | 4 | 29.27 | 41.61 | 49.27 | 57.54 | 74.03 |
| 8 | 5 | 34.11 | 47.51 | 55.46 | 63.76 | 79.72 |
| 8 | 6 | 40.89 | 55.08 | 63.12 | 71.27 | 86.38 |

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Table 18 can be used to state highest posterior density regions for age-at-death or point estimates of age-at-death (though generally the use of point estimates for age-at-death is very ill-advised). Point estimates can be given using the $50^{th}$ percentile value ("50%"). Note that there are seven of the 48 combinations (eight rib stages by six pubic symphysis stages) for which the point estimate of age-at-death is on the lower boundary of 20.0 years. This occurs for a Suchey-Brooks pubic symphysis stage of "one" combined with rib stages of 1 – 4, a Suchey-Brooks stage of "two" combined with rib stages of "one" or "two," and a Suchey-Brooks stage of "three" combined with a rib stage of "one." The $25^{th}$ and $75^{th}$ percentiles ("25%" and "75%") can be used to construct a 50% highest posterior density. For example, the 50% highest posterior density for an individual with both scores recorded as "five" would be 51.81 – 36.51 years. Similarly, the $2.5^{th}$ and $97.5^{th}$ percentiles can be used for a 95% highest posterior density region, so that this same individual (with both scores equal to "five") would have a 95% highest posterior density region of 25.30 – 68.36 years.

Of the 296 individuals in the bootstrap sample, 141 (47.63%) had ages that fell within their stated 50% HPD. This is not significantly different from the 50% expected ($p=0.4158$). It is important to understand that this bootstrap sample ages in the same way as the original osteological sample (the bootstrap sample is selected from the original osteological sample) and follows the same age-at-death distribution as the total sample Gompertz-Makeham model. Thus, some would argue that these results are circular, and certainly if the table above was applied to a sample that differed in its prior age-at-death distribution and/or its pattern of aging, the stated highest posterior densities could be misleading.

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## HYOID AGE ESTIMATION AND IMPLICATIONS FOR INFLICTED TRAUMA PATTERNS

Dionne and co-workers (2011) found that a wide variation exists in the unilateral and bilateral fusion patterns of the hyoid bone (Figure 9). Unilateral fusion was observed as early as at 8 years of age while bilateral fusion was first visible at age 23 years. As a previous study demonstrated, the majority of hyoid bones are fully fused in the elderly but in some cases the hyoid may remain only partially fused. Two males from our sample, one in his 70s and one is his 80s, still exhibited a unilaterally fused hyoid at the time of death. Overall, the number of individuals displaying unilateral fusion increased steadily until the 40-49 age bracket and decreased afterwards. Conversely, the percentage of individuals with bilateral fusion constantly increased from 65.0% in the 20-29 age bracket to over 90.0% in the 70-79 and 80+ age ranges. In both ancestral groups the mean age for bilateral fusion occurred approximately five years earlier in men while in both sexes, African American individuals exhibited bilateral fusion two years earlier. The regression formula demonstrated that 30% of the variation in age is explained by greater cornua fusion patterns. Through our understanding of the pattern in which the greater cornua fuse to the hyoid bone, anthropologists can better understand estimate the risk of fractures to neck structures according to the ossification of the hyoid bone. Further conclusions are presented in the Data Collection Protocol (Kimmerle et al. 2012).

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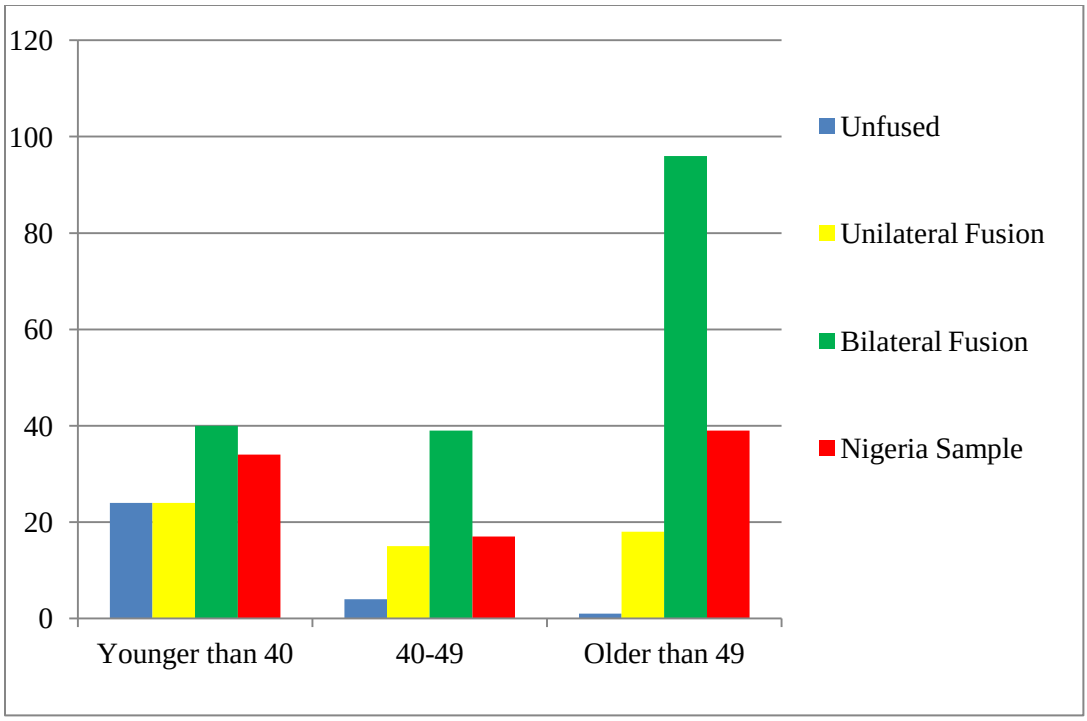



Figure 9. Age distribution of hyoid fusion and mobility among American and Nigerian samples.

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## ELEMENTAL AND ISOTOPE ANALYSIS

Kimmerle and co-workers (2009) found significant trends in the demographic patterns of unidentified decedents as affecting case solvability, such as a 2:1 ratio for female to male identification. Reanalysis of ancestry classification for UID shows that modern methods (i.e. 3D-ID) results in new classifications in some cases. Figure 10 demonstrates that among male UID in the sample (Kimmerle and Kamenov, n.d.), the majority had been classified as "White" (53/57), whereas the majority of females were classified as "Black" (6/9). The category "White" includes traditional "Hispanic", MesoAmerican, Indigenous, and European-American ethnicities and nationalities. The statistical programs Fordisc 2.0 (Ousley and Jantz 1996), Fordisc 3.1 (Ousley and Jantz 2005), and 3D-ID (Slice and Ross 2009) were used to re-evaluate the sex and ancestry for each individual. Additionally, hair, bone and tooth samples were collected for isotope and elemental analyses for each individual and were compared to craniometric estimations of ancestry.

As reported in Kimmerle and Kamenov (n.d.), of the four strontium isotopes ($^{84,86,87,88}Sr$), only $^{87}Sr$ is a product of rubidium 87 radioactive decay. Because $^{87}Rb$ slowly decays into $^{87}Sr$ over time, geological formations in different parts of the world will have varying amounts of $^{87}Sr$, depending on the Rb/Sr ratio. Sr in soils, plants, and waters in a given region is typically controlled by the geology of the underlying bedrock. Sr substitutes for Ca in the mineral matrix of skeletal material and the pathway of Sr from bedrock to humans is primarily through food webs with little, if any, fractionation from the bedrock to the human skeleton (Price 1989). Therefore, Sr isotopes can help us identify the geographical place of origin of a given individual. A complication in using Sr isotopes for modern forensic investigations is the consumption of "imported" vs. "local" foods, especially in large metropolitan areas. In such cases, the Sr isotopic

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composition of a given individual can be a mixed signature of local Sr (local water and food) and imported Sr (imported food, drinks). This complication is likely to be less important for rural areas and older cold cases. More important, this complication is not present in the Pb isotope system. Lead also has four isotopes, three of which are the results of radioactive decay: $^{204}$Pb, $^{206}$Pb (parent $^{238}$U), $^{207}$Pb (parent $^{235}$U), and $^{208}$Pb (parent $^{232}$Th). Similarly to Sr isotopes, different rock formations will have different Pb isotopes depending on time and U/Th/Pb ratios. Pb also substitutes for Ca in the mineral matrix of skeletal material and several recent works indicate that the local dust/soil is what controls the Pb isotopic compositions of human blood and teeth (Laidlaw et al. 2005; Kamenov 2008). Therefore, isotope analysis of human teeth/bones can be used to pinpoint the geographic origin of an individual. A complication with the Pb isotope technique is the wide-spread contamination of the local soil/dust by Pb released from anthropogenic sources, mainly the wide-spread U.S.A.ge of leaded gasoline in the near past. Therefore, the skeletal material will be recording a Pb isotope signal representing a mix between natural Pb, controlled by the local bedrock geology, and anthropogenic Pb, added by recent human activities (Kamenov 2008).

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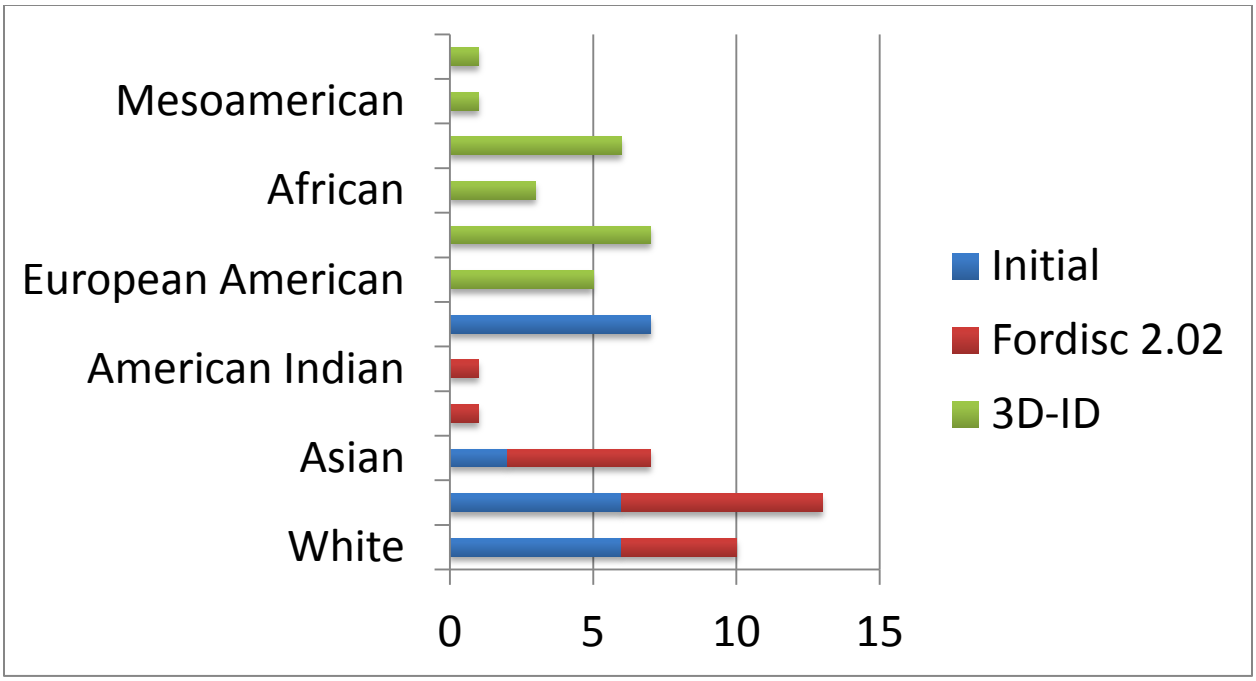



Figure 10. Comparisons of ancestry classifications based on different methods of craniometric analyses.

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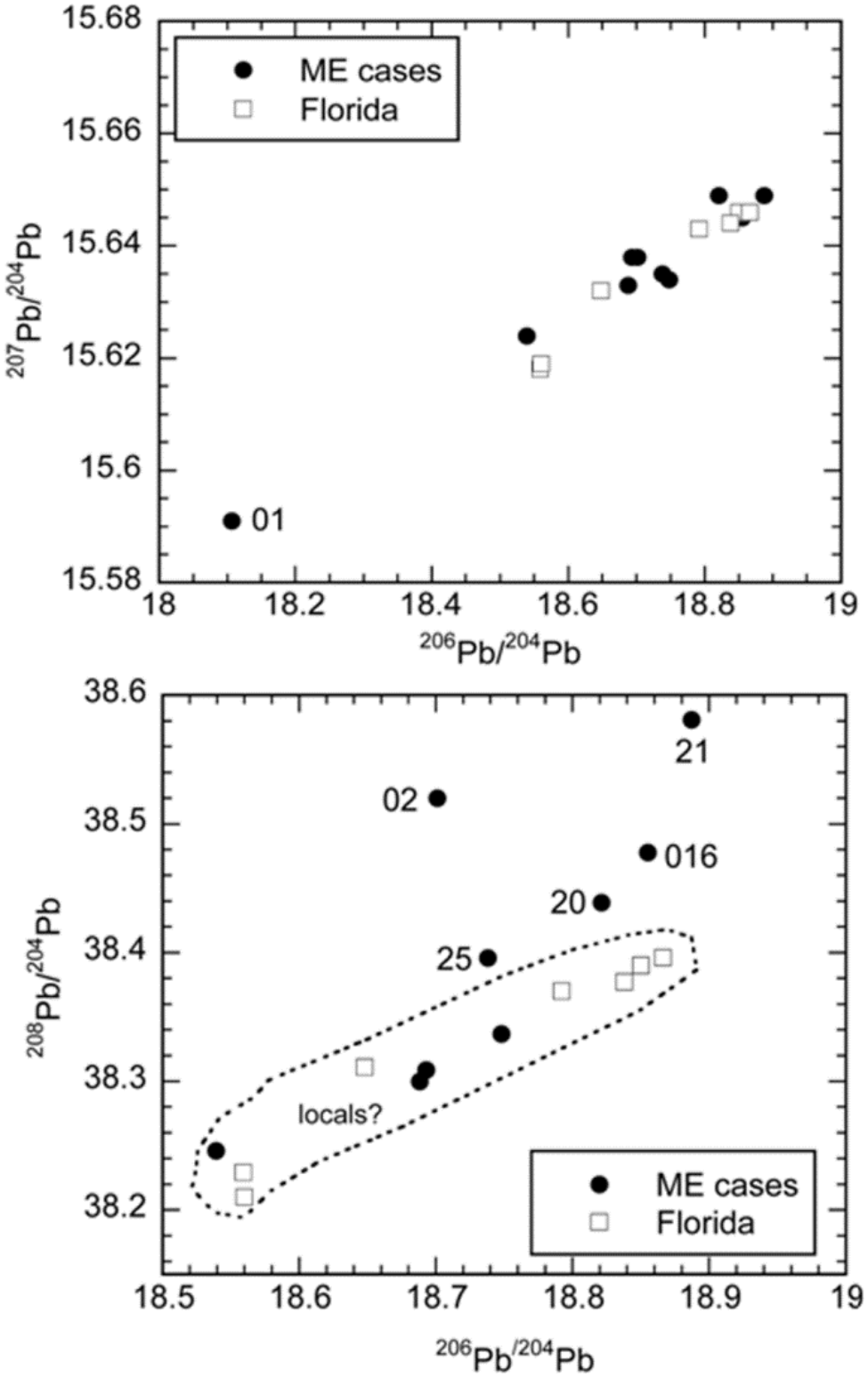



Figure 11. Pb isotope values demonstrating “local” vs. “foreign” born individuals.

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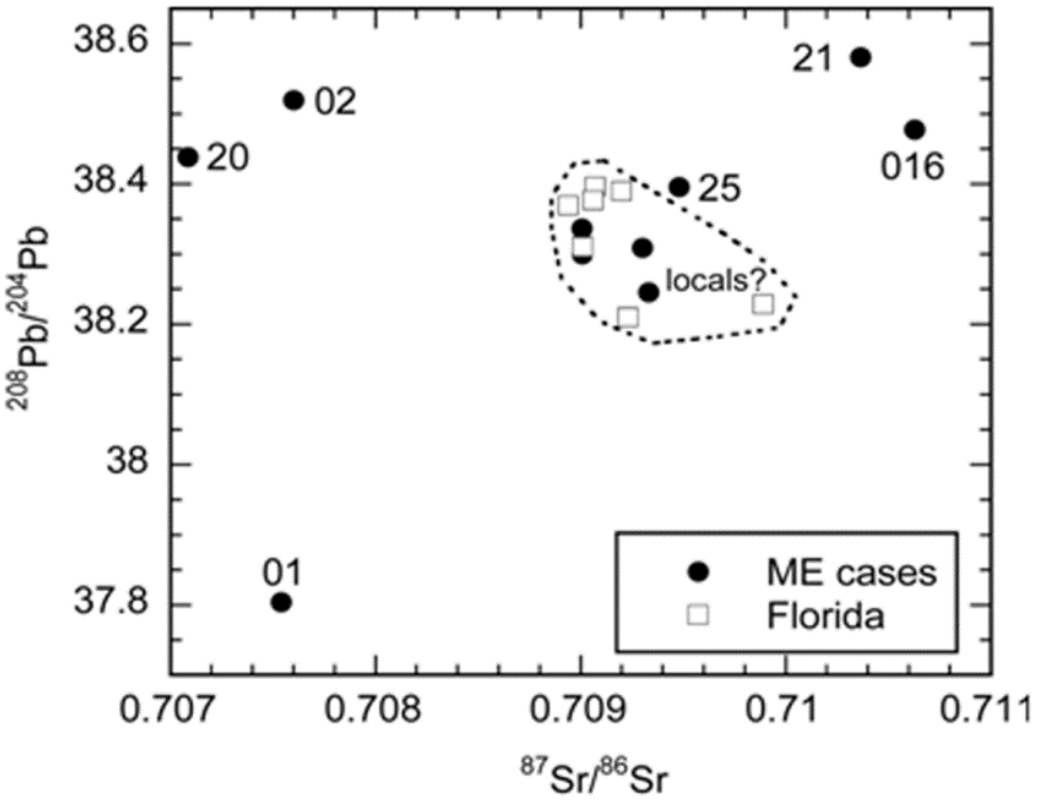



Figure 12. Pb/Sr isotope values demonstrating "local" vs. "foreign" born individuals.

Ancestry estimation through craniometric methods is linked with the Sr-Pb isotopic information to identify the likely place of origin for UID, i.e. was this individual born in the U.S.A. or foreign-born? In Figure 11, Sr and Pb isotope data for tooth enamel from ten UID (Table 19) are compared to Floridian tooth enamel. The data show relatively large variations that allow us to distinguish several groups. The UID case enamel samples that show similar isotopic range to the isotope data for Floridian tooth enamels and can be regarded as "locals". In this case we assume that the Floridian enamel data are representative of individuals that were born and spent the early years of their lives (during the formation of the given tooth enamel) in Florida. Whereas, sample USF 01 is an individual that can be clearly identified as "foreigner" when compared to Florida data (Figures 11 and 12). Very little is known about this individual, except that he was likely from an African ancestry based on craniometric analyses. The low-

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radiogenic Pb isotope data observed in USF 01 indicates the individual was neither born nor spent his childhood in the U.S.A. This conclusion stems from the fact that during the last several decades the anthropogenic Pb in the U.S.A. was sourced from "Mississippi Valley Type" ores characterized with highly elevated $^{206}Pb/^{204}Pb$ ratios, very distinct from the ratios observed in sample 01. It is well known that in the U.S.A., as well as other places in the world, the Pb isotope signal in the environment is expected to be a mixture of natural and anthropogenic sources. The "Mississippi Valley Pb" anthropogenic addition is clearly observed in the Pb isotope record in the U.S.A., including Florida (Kamenov et al. 2009). Furthermore, relatively high-radiogenic $^{206}Pb/^{204}Pb$, around 18.5 and above, was measured in teeth from US-born USAFA cadets (Regan 2006). Therefore, the low-radiogenic Pb isotopic composition of USF 01 indicates that this individual was born and grew up outside of continental U.S.A. As the individual was identified as African American (Figure 11), this can be indicative of an African origin. Africa, however, is characterized with relatively older rock formations expected to yield overall more radiogenic than 0.7075 Sr isotopic ratios. The Sr isotope information allowed us to discard Africa as a possible place of origin for USF 01. The relatively low $^{87}Sr/^{86}Sr$ combined with the African ancestry places the most likely place of origin of this individual in the Caribbean, possibly Cuba, Haiti, or Jamaica. We excluded Jamaica as about 2/3 of its territory is covered by Tertiary limestones expected to have higher than 07075 $^{87}Sr/^{86}Sr$ ratio. Cuba has more diverse geology, however, majority of the population is not from African ancestry. Haiti, on the other hand, has the right geological settings (volcanic terranes characterized with relatively lower $^{87}Sr/^{86}Sr$) and 95% of the population is African descent. Taking into account the significant presence of Haitian immigrants in Florida, the African ancestry, and the Sr-Pb isotopic data, the most likely place of origin for USF 01 is Haiti. Through the investigation, the

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police have presumptively identified this individual from Haiti and are currently waiting DNA results for possible identification.

Table 19. Lead and strontium isotope data for Floridian Cold Cases (ME cases) and tooth enamel from Florida individuals.

| | $^{206}Pb/^{204}Pb$ | $^{207}Pb/^{204}Pb$ | $^{208}Pb/^{204}Pb$ | $^{87}Sr/^{86}Sr$ |
|---|---|---|---|---|
| ***tooth enamel from ME cases at Hillsborough, FL*** | | | | |
| USF 01 | 18.106 | 15.591 | 37.804 | 0.707539 |
| USF 02 | 18.701 | 15.638 | 38.520 | 0.707600 |
| USF 16 | 18.855 | 15.645 | 38.478 | 0.710628 |
| USF 17 | 18.539 | 15.624 | 38.246 | 0.709330 |
| USF 18 | 18.688 | 15.633 | 38.300 | 0.709007 |
| USF 19 | 18.693 | 15.638 | 38.309 | 0.709300 |
| USF 20 | 18.821 | 15.649 | 38.439 | 0.707085 |
| USF 21 | 18.887 | 15.649 | 38.581 | 0.710363 |
| USF 23 | 18.748 | 15.634 | 38.337 | 0.709005 |
| USF 25 | 18.738 | 15.635 | 38.396 | 0.709479 |
| ***tooth enamel from Florida individuals*** | | | | |
| Maxillary molar, Juvenile | 18.850 | 15.646 | 38.390 | 0.70920 |
| Maxillary molar, Juvenile | 18.866 | 15.646 | 38.396 | 0.70907 |
| Maxillary molar, Juvenile | 18.838 | 15.644 | 38.377 | 0.70906 |
| Mandibular molar, Adult | 18.559 | 15.618 | 38.229 | 0.70989 |
| Mandibular molar, Juvenile | 18.560 | 15.619 | 38.210 | 0.70923 |
| AFA-176* | 18.792 | 15.643 | 38.370 | 0.70894 |
| AFA-089* | 18.648 | 15.632 | 38.311 | 0.70901 |
| **USAFA cadets, data from Regan (2006)* | | | | |

## CHEMICAL METHODS FOR IDENTIFICATION OF AFRICAN POPULATIONS AND SECULAR TRENDS

The primary Nigerian ethnic groups were tested using Sr and Pb isotopes and show similar variations in their Pb isotopic compositions (Figure 13). Each group shows relatively large span in the Pb isotopic compositions recorded in their rib samples, however, there is more

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or less complete overlap in the ranges observed in the different groups. This indicates some common, most likely anthropogenic, Pb source available everywhere in the country. It is well-known that Nigeria has been using leaded gasoline with very high Pb content until very recently, most likely until the mid-2000s or even later (Rankin et al. 2005). Therefore, the observed Pb isotopic composition in the rib samples is a record of environmental exposure to Pb released during the era of leaded gasoline usage. As can be seen on Figure 14, there is an overall negative correlation between age and $^{206}Pb/^{204}Pb$ observed in the Nigerian bone samples. The only outlier is sample 75, which is the oldest individual (77 years old at the time of death) from the whole group (Figure 15). This negative correlation indicates that younger people were exposed to Pb with different Pb isotopic composition compared to older people. This most likely is due to U.S.A.ge of different Pb ore for the leaded gasoline additives. The low $^{206}Pb/^{204}Pb$ is consistent with Australian Pb used for manufacturing of the lead additive. The elevated $^{206}Pb/^{204}Pb$ can be either due to relatively lower amount of lead contributed to the environment in the last few years or can be due to a switch in the Pb ore used in the gasoline additive. Values around 18.2 for $^{206}Pb/^{204}Pb$ are consistent with Pb ore mined in Canada and it is likely that such ore is used for the leaded gasoline additive sold in Nigeria (www.lead.org.au/lmcos.html). Environmental contamination with Pb released from gasoline is consistent with the Pb isotopes observed in the Nigerian soils. Pb released during gasoline combustion is expected to concentrate in the labile fraction of local soils. Therefore, the soil leachates will be representative of the anthropogenic lead mostly derived from the leaded gasoline usage in Nigeria.

Sr isotopes also do not allow distinction between the five ethnic groups utilized in this study (Figure 16). As can be seen on the Figure 16, most of the individuals cluster at values around 0.712 for $^{87}Sr/^{86}Sr$, which is expected based on the known geology of Nigeria. Few

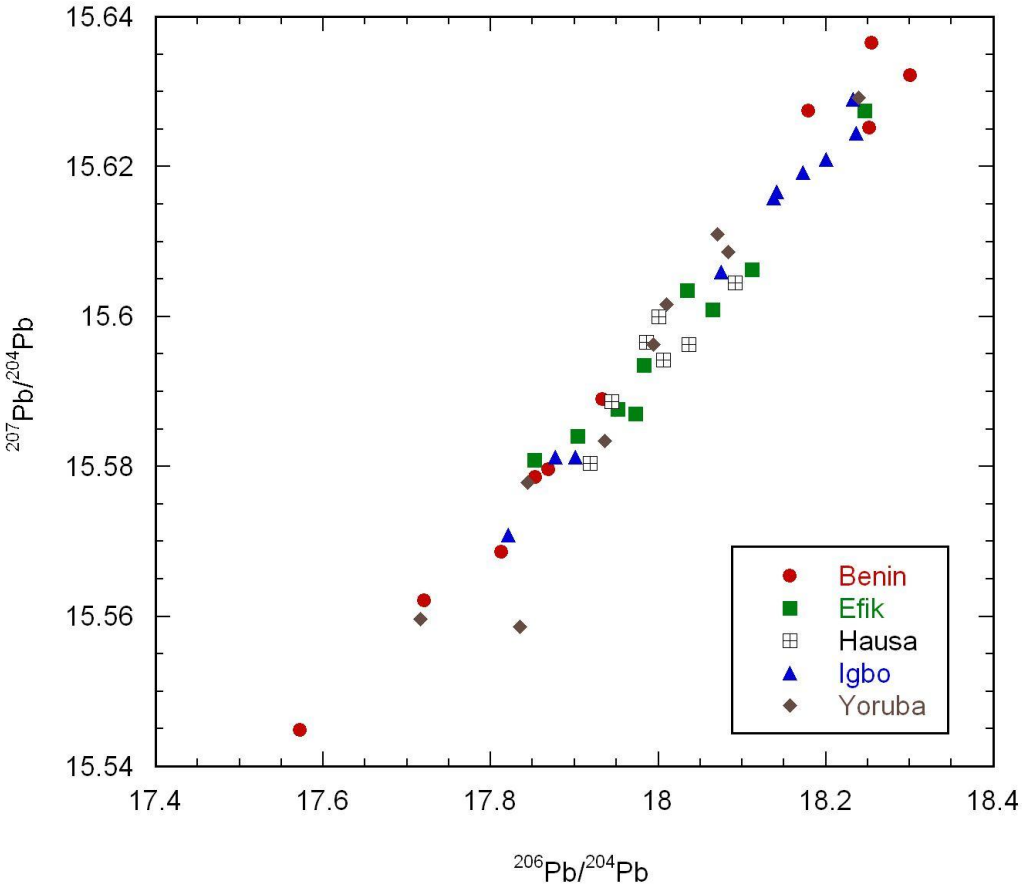
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individuals plot to slightly higher Sr isotopic values (0.713-0.715), which is also expected, especially for East and Northwest Nigeria due to the exposure of old metamorphic rocks. This indicates that there may be some distinctions based on the particular place of origin and/or dietary habits as Sr is not likely to be affected as much as Pb by anthropogenic activities.

Regardless that the isotope data appears to be of no immediate use for distinguishing different ethnic groups in Nigeria, when the Nigerian data are compared to our Florida cold cases data a unique trend is observed. As can be seen on Figure 16, the Nigerian data form a distinct trend towards Floridian sample 37 (samples 37-1 and 37-3). These two samples are from a skull of African origin and based on the isotope composition we suggested that this is likely an archeological artifact. The new Nigerian data confirm this suggestion as sample 37 is in Pb-Pb space where we expect to plot the possible pre-anthropogenic end-member for the African Pb (before the introduction of leaded gasoline). In addition, the distinct field formed by Nigerian samples when compared to Florida samples show that these data will be useful for distinguishing remains from recent immigrants from the African region from U.S.A. and E.U. individuals (Figure 17).

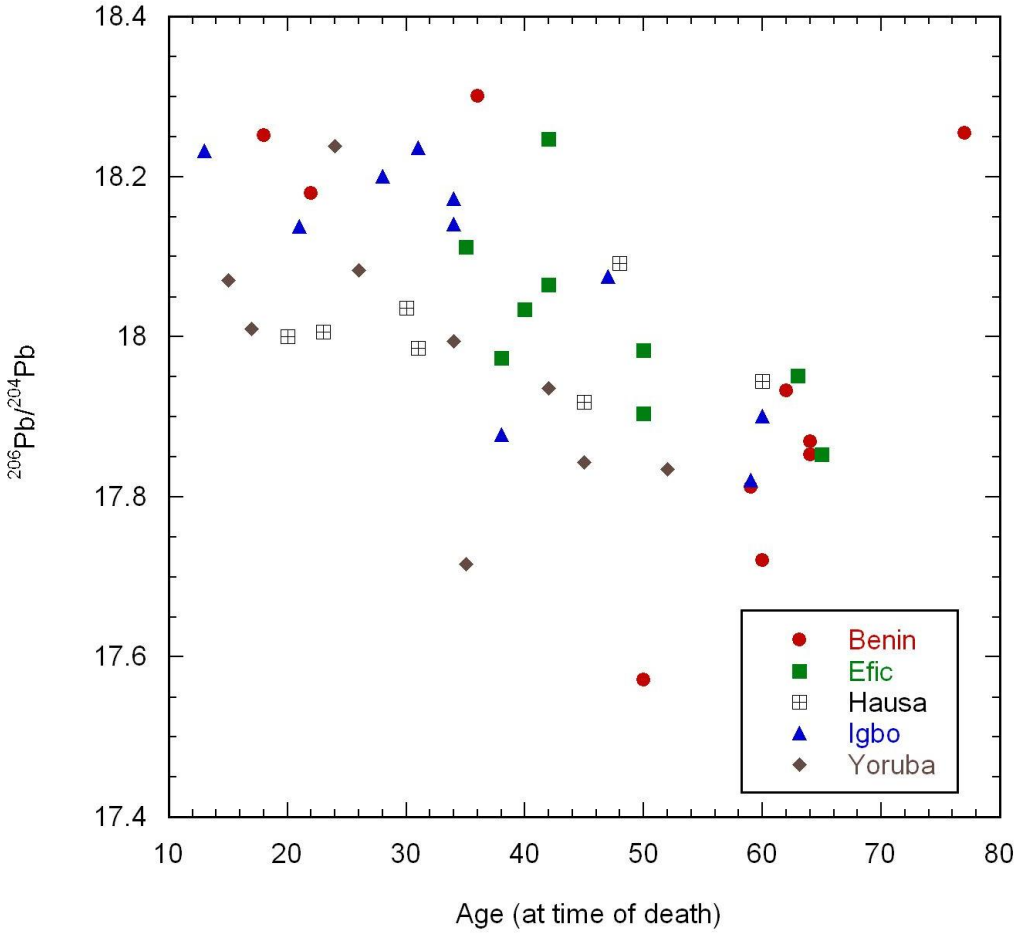
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Figure 13. Pb isotope data for the different ethnic groups from Nigeria.



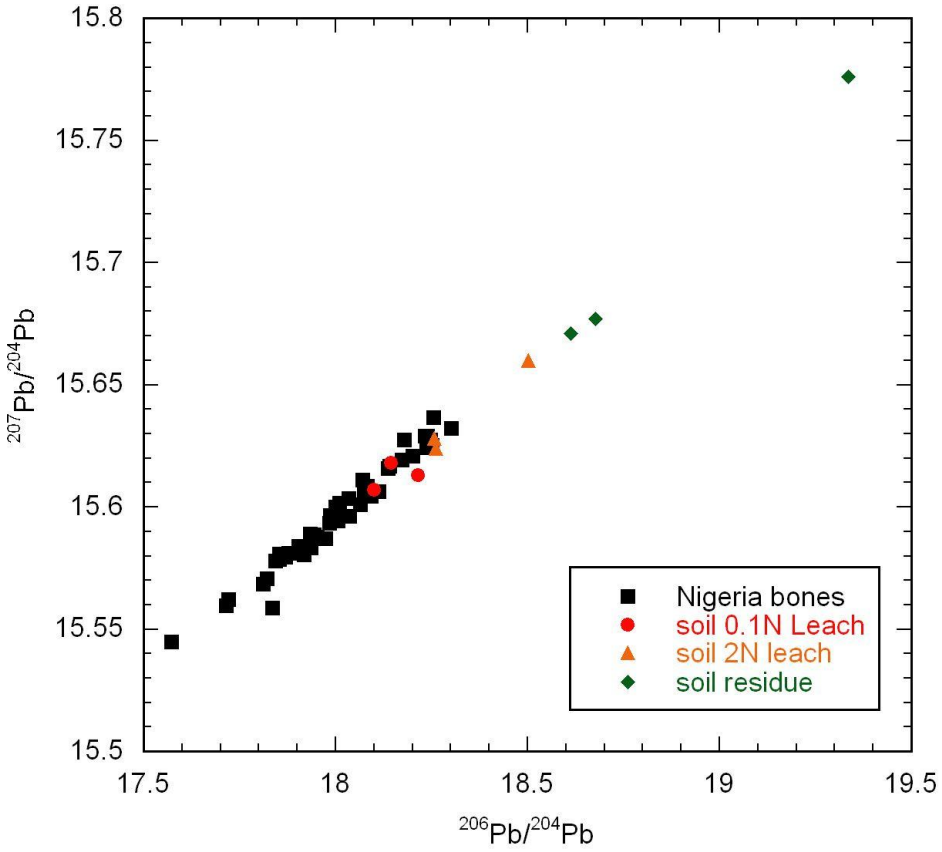
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Figure 14. Age vs. 206Pb/204Pb observed in Nigerian bone samples.



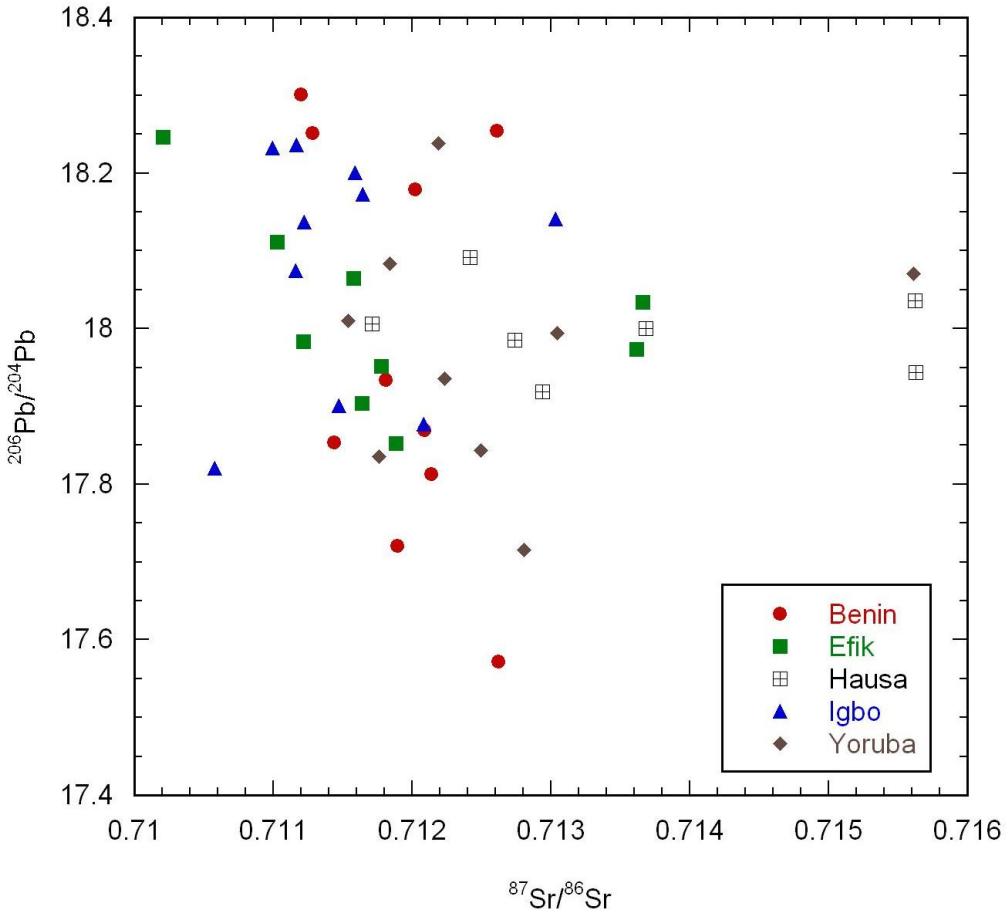
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Figure 15. Pb isotopic compositions for Nigerian bones compared to Nigerian soil and leachates.



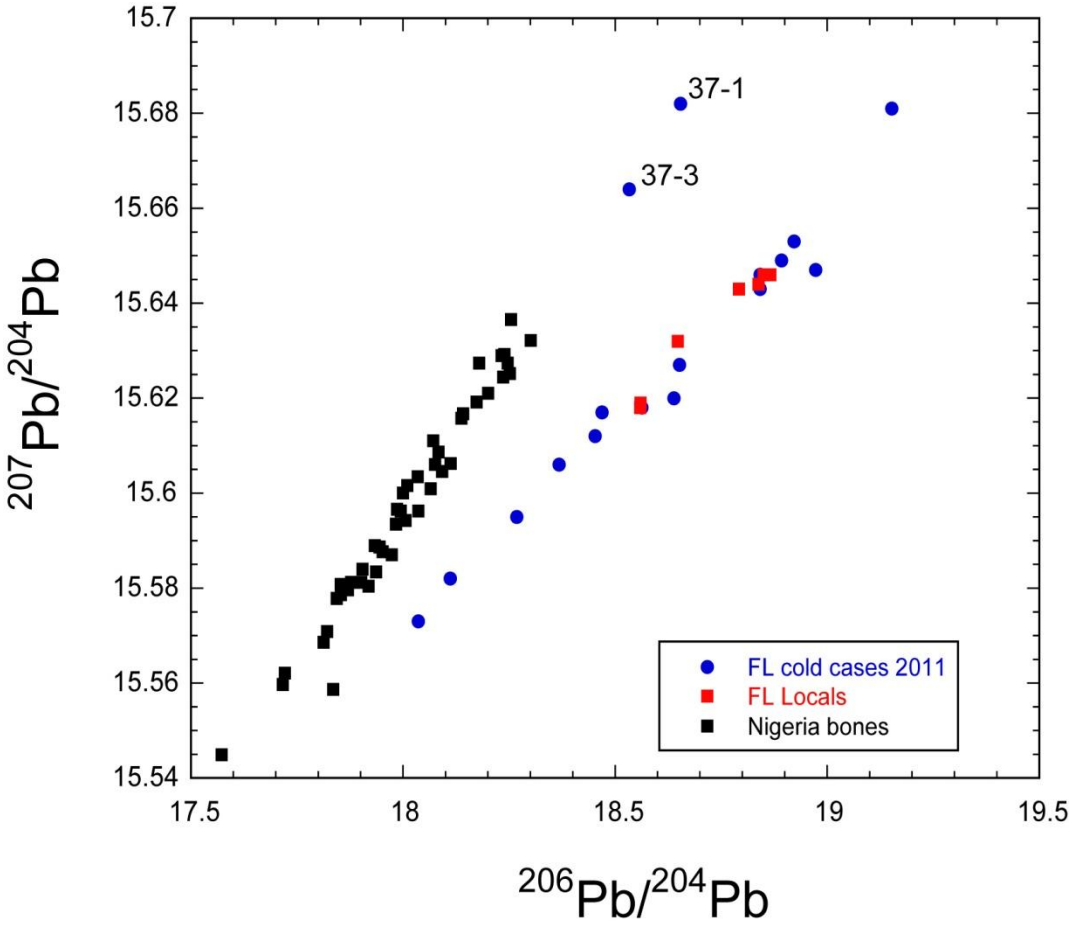
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Figure 16. Sr vs. Pb isotopes for Nigeria bone samples.



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Figure 17. Nigeria bone Pb isotopes compared to Florida cold cases.



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## SECTION V: CONCLUSIONS

### DISCUSSION OF FINDINGS

The outcomes of this research include unique osteometric, morphological, and isotopic parameters for human identification, a large database of unique skeletal biomarkers for human identification, population specific methods for biological profiling, and photographic and 3D reference materials. Research into human identification through this initiative investigates the significance of several methods applied across populations and provides a framework that may be applied to a variety of contexts including craniometric biodistance, age and sex estimation, and chemical and elemental isotopes (Table 20). For example, some of the main questions investigated include:

1) analyses of craniometric variation among African and Diaspora populations;
2) population specific parameters for sex estimation for Botswana;
3) evaluation of accurate age parameters for juveniles;
4) tests for population variation among adult aging methods; and
5) isotopic and elemental analyses of hair, bone and teeth.

Numerous presentations and publications have resulted from this research on **human identification** (Kimmerle et al. 2008; Kimmerle 2009; Kimmerle et al. 2009; Kimmerle 2010; Cunha et al 2011; Noche-Dowdy et al. 2011; Noche-Dowdy and Kimmerle 2012); **methods for estimating the biological profile** and **population specific calibrations** of specific methods (Noche-Dowdy et al. 2010; Kimmerle and Obafunwa 2010; Kimmerle and Konigsberg 2011; Dionne et al. 2011, Seasons et al. 2011, Tur et al. 2011, Dotson et al. 2011, ; Tise et al. 2012; Pope et al. 2012; Dotson et al. 2012) and **chemical and elemental analysis** of hair, bone and teeth. Some of these results have been published and several other book chapters and papers are in press, under review, or about to be submitted to journals (refer to the section on research outcomes for a complete list).

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Table 20. List of major outcomes.

| Research Area | Results |
|---|---|
| Human Identification | • Observable patterns among cases of MP and UID likely to remain open.<br>• Protocols for interviewing witnesses for MP data and clandestine grave searches |
| Recalibrated Age Parameters | • Population specific age parameters for 4th rib (East European populations), pubic symphysis and 4th rib (Nigeria), and hyoid (U.S.A. and Nigeria) |
| Craniometric Bio-distance | • Regional characteristics for West, East, South African and American Diaspora |
| Sex Estimation | • New estimation parameters for Botswana and American Diaspora |
| Chemical and Elemental Data | • Differentiation of American and Nigerian born persons, secular trends in chemical values for Nigerians |

This report summarizes the research in human identification that was undertaken as a collaborative effort among researchers in the U.S.A. and Nigeria to address problems of the missing, endangered and unidentified persons from a variety of contexts. The outcomes of this research includes unique osteometric and morphological parameters for human identification relevant to international populations, insight into human skeletal variation with broad implications for human identification outside of Africa, and quantified estimation parameters for morphological and metric based data. The significance of research in Nigeria and the applicability of this research throughout West Africa and the United States will be demonstrated as transitional justice initiatives through many regions of Africa include identification and medico-legal death investigations.

The specific project outcomes include an international biomarker databank for human identification created from this research project and subsequent analyses incorporates several lines of evidence critical for human identification and is relevant to American cold cases, as well

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as international cases. This is the largest databank of contemporary populations with this diverse data set currently in the field of forensic anthropology including skeletal, demographic, autopsy, and isotopic data. While several areas were researched to address some of the initial parameters, much of the data has yet to be analyzed and research will continue into many aspects of human identification. Specifically, several data protocols were developed which may be useful reference materials for researchers and investigators working in Africa and beyond in diverse settings including:

1) Kimmerle EH, Powell JW. 2012. 3D Digital Reference Guide for Research in Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

2) Kimmerle EH, Tise ML, Humphries AL. 2012. Data Collection Protocol for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

3) Kimmerle EH, Pope MA, Tise ML. 2012. Atlas for Biometric Variation Among African Populations for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

4) Kimmerle EH, Massucci CJ, Tise ML. 2012. Interview Protocol for Missing, Endangered, and Unidentified Persons. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

In addition, several projects have stemmed from the RHI initiative and will continue beyond the scope of this grant including the creation of the *International Consortium for Forensics, Anthropology, and Human Rights* (ICFAHR)( www.icfahr.usf.edu); the *Tampa Bay Cold Case Project;* and the *Asaba Memorial Project* (www.asabamemorial.org).

This project has several positive outcomes that could not have been anticipated such as in October 2009 when witnesses, survivors, and Asaba Diaspora came to USF for a two day symposium on Memory, Memorials, and Mass Graves, titled the *Inaugural Asaba Symposium*. The USF Libraries Holocaust and Genocide Studies Center worked with us to videotape more

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than 30 hours of witness testimony through formal interviews, which is the beginning of an online oral history archive about the massacre. By recording survivor testimony, this project documented a massacre of Igbo civilians that took place in Asaba, Nigeria, in October 1967.

The research outcomes to date include unique osteometric, morphological, and isotopic parameters for human identification, insight into human skeletal variation with broad implications for human identification, and quantified estimation parameters for morphological and metric based data. Examples of the primary findings are discussed:

1) Analyses of craniometric variation among African and Diaspora populations. As expected, summary findings included clustering among Central and West Africa, with differentiation among Coastal populations, and further differentiation from Kenya, South Africa, and American populations. The photographic reference created through this project illustrates craniometric variation among populations, sexual dimorphism, age, and nutritional pathologies.

2) Based on the high degree of sexual dimorphism found among the Botswana population, compared to other groups, population specific parameters for sex estimation were developed for several cranial and long bone elements.

3) Tests for population variation among adult aging methods and the age evaluation of accurate parameters for juvenile dental development suggests any observed variation in age among populations can be overcome with appropriate informed priors, however they must be made explicit. The use of probability density functions offer biological and statistically appropriate age parameters for adult biomarkers and offer investigators flexibility in constructing age intervals.

4) Chemical and isotopic analyses of hair, bone, and teeth demonstrate the value of such methods for distinguishing American "local" from "foreign-born" individuals, assigning geographic areas of birth location or human mobility, secular trends in environmental contamination and exposure to lead.

## IMPLICATIONS FOR POLICY AND PRACTICE

With the development of professional standards and educational initiatives in the forensic sciences globally, there is an increasing need for research in human identification in varied settings. The professionalization of forensic science is an increasingly global issue as people

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travel and large scale critical incidents involve multi-national victims. There are many examples of international incidents involving victims across several countries, such as Hurricane Katrina or the Asian Tsunami that resulted in a high number of victims, many of whom, came from regions outside the affected areas. Nigeria has had four major airplane crashes killing victims from Nigeria as well as the United States and Europe. Such mass fatality victims regardless of nationality were often buried in mass graves without a system and protocol for individual identification. The problem of missing persons and unidentified human remains in the U.S.A. with an estimated 1000 new "cold cases" each year is a constant challenge. All of these examples highlight the need to identify victims from a population approach and for international collaboration. Human variation is a product of both genetics and environmental and cultural factors that affect morbidity and the demographic structure. Therefore, data collection protocols should be adaptable to diverse cultural, biological and legal settings. The outcomes of this research have the potential to impact the criminal justice system by providing: 1) quantitative statistics on biometric indicators of a victim's identity for age, sex, stature, and ancestry among African, American and European populations; 2) quantified analysis of population variation among these groups; 3) a model for biometric indicators of identification based on traits through Bayesian statistical parameters that meet the basic requirements for the presentation of scientific evidence as required in American Federal Courts (*Daubert v. Merrell Dow Pharmaceuticals, Inc. 509 US 579, 1993*); and 4) protocols and reference materials that aid with systematic data collection for UID and MP.

Since our initial visit, the Asaba community started to create a permanent memorial and annual events to commemorate victims. For the first time in more than forty years, victims have come forward to talk about the events that occurred and the family members that were killed.

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While forensic investigators often have a focus on criminal prosecution and legal truths, the humanitarian outcomes may be substantial as in this example (Figure 18).



Figure 18. The first public event to commemorate the massacre and lay a foundation for a permanent memorial at the location of the reported graves occurred in Asaba (photograph courtesy of Richie Omo).

A substantial outcome from this project has been the inclusion of isotopic analysis with ancestry estimation and refined parameters for the biological profile for unsolved UID cases in Florida. A service oriented research initiative in human identification, the *Tampa Bay Cold Case Project*, has brought the USF Forensic Anthropology Laboratory together with the Department of Geological Sciences and the University of Florida, local Medical Examiner Departments and law enforcement agencies throughout the region. The methods, protocols, and reference

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materials described in this report are being applied all of unsolved cases, dating from 1950 to present throughout central Florida and resulted in the creation of a network and website for collaborators, called ICFAHR, the *International Consortium for Forensics, Anthropology, and Human Rights* (www.icfahr.usf.edu). This partnership has been formalized between USF and the Hillsborough County Sheriff's Office and the National Center for Missing and Exploited Children to provide training and technical assistance to all current and past cases. The goals for this initiative are to:

1) aid with human identification;
2) systematically apply a comprehensive set of methods and tools to all unsolved cases;
3) investigate regional homicide patterns; and
4) document osteological, chemical, burial, and post-mortem factors about each case to develop a baseline of data relevant to the local population and natural environment in the region to aid case solvability.

This consortium focuses on problems of missing, endangered and unidentified persons through training and technical assistance. Many of the unsolved cases in Border states such as Florida, represent individuals who were foreign-born, migrant workers, homeless or other at-risk or marginalized groups. Therefore, a consortium such as ICFAHR works to bridge members of the medico-legal community with academics, international associations, and local consulates in hopes of finding resolution for local and international cases.

## IMPLICATIONS FOR FUTURE RESEARCH

The outcome of this research effort has been a large international databank for human identification. Many aspects of this data have been analyzed and presented or published, however this body of work is only a fraction of the information collected. Two areas of planned future research include more in-depth biodistance studies of central African populations and the

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degrees of sexual dimorphism within these groups and refined age parameters for African groups using different mortality distributions.

## SECTION VI: DISSEMINATION OF RESEARCH FINDINGS

The results of RHI have been presented at numerous local, national, and international conferences and have been published in the following venues:

1) Website
    a. International Consortium for Forensics, Anthropology, and Human Rights (ICFAHR), Research in Human Identification: www.icfahr.usf.edu/rhi
    b. Resource focused website with listservs that foster a professional network of investigators dedicated to RHI and online publications.

2) Publications (Refer to attached list)

3) Presentations at professional scientific meetings and other conferences including:
    a. American Academy of Forensic Sciences (AAFS)
    b. American Association of Physical Anthropologists (AAPA)
    c. Society for Applied Anthropology (SAA)
    d. Forensic Anthropology Society of Europe (FASE) Annual Meeting
    e. Annual Meeting of the American Association of Behavioral and Social Sciences
    f. USF Symposium, "Memory, Memorials, and Mass Graves"
    g. Lagos State University (LASUCOM), College of Medicine, Nigeria

4) Professional Networking Groups
    a. International Consortium for Forensic Anthropology Programming (COFFA), www.coffa.usf.edu

PUBLISHED PROTOCOLS RESULTING FROM GRANT RESEARCH:

1) Kimmerle EH, Powell JW. 2012. 3D Digital Reference Guide for Research in Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

2) Kimmerle EH, Tise ML, Humphries AL. 2012. Data Collection Protocol for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

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3) Kimmerle EH, Pope MA, Tise ML. 2012. Atlas for Biometric Variation Among African Populations for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

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## SECTION VIII:
## APPENDIX A. EXTENDED BIBLIOGRAPHY FOR RESEARCH IN HUMAN IDENTIFICATION

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**APPENDIX B.** Kimmerle EH, Tise ML, Humphries A. 2012. Data Collection Protocol for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

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**APPENDIX C.** Kimmerle EH, Massucci CJ, Tise ML. 2012. Interview Protocol for Missing, Endangered, and Unidentified Persons. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

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**APPENDIX E.** Kimmerle EH, Pope MA, Tise ML. 2012. Atlas for Biometric Variation Among African Populations for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

- See Attached

# Data Collection Protocol for Human Identification





Research in Human Identification



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Version 1.0.2012

Research funded by:

This project was supported by Award No. NIJ 2008-DN-BX-KI63 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

The opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect those of the Department of Justice.

To Cite:
Kimmerle EH, Tise ML, Humphries AL. 2012. Data Collection Protocol for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

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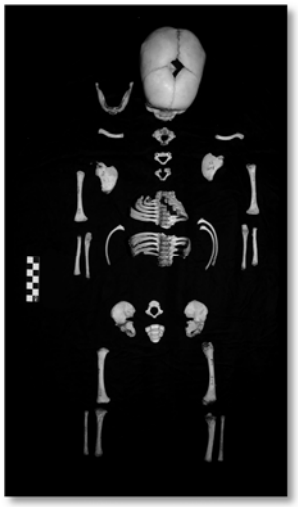
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# EXECUTIVE SUMMARY

The increasing number of investigations into the problem of missing, endangered, and unidentified persons, particularly in the context of homicide investigations, cold cases, armed conflict, terrorism, natural disasters and other critical incidents require the development of new methods and recalibration of existing methods to reflect diverse populations and settings for recovery and analysis. The estimation of biological parameters for human identification is a cornerstone of forensic anthropology and the multitude of methods available must be accurate and reliable for successful identifications to be made. Associated artifacts, evidence, and information about the scene also provides critical information about the context, informing investigators about human identification, the post-mortem interval (PMI), and whether or not a crime was committed.

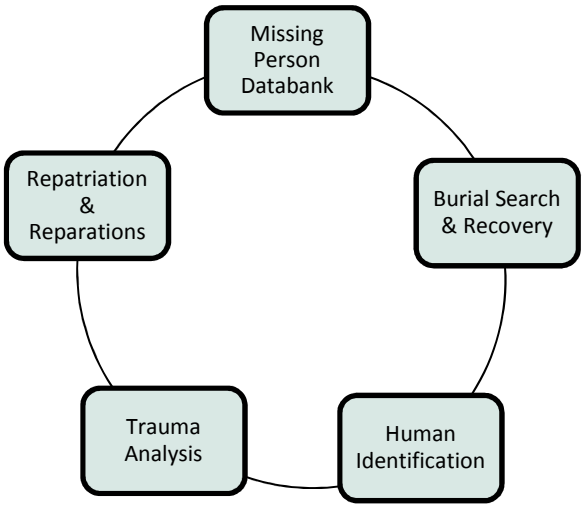


This data collection protocol is a product of a research initiative into human identification (NIJ-2008-DN-BX-K163). The intent of this research initiative was to investigate the ways in which diverse international and domestic settings can shape the identification process and to produce reliable methods that work in varied settings. Due to the legal, cultural and biological variation across populations, not only do specific calibrations have to be considered in osteological analyses, but so do the ways in which that information is used in criminal proceedings across diverse legal settings and the ways in which antemortem information about missing persons is collected, stored, and shared. Therefore, the objectives of the research initiative were to collect osteometric and morphological data on skeletal and dental traits for contemporary populations and test the degree of population variation among African, American, and European populations to assess the applicability of methods used across groups. The outcome of this project has led to a body of research and allowed for the creation of an *International Databank of Osteological Biomarkers for Human Identification,* as well as the creation of reference atlases. These atlases include the *Photographic Atlas for Human Skeletal Variation* and the *3D Digital Reference Guide for Research in Human Identification.* The following protocol was developed for the creation of the databank and expanded to include a full protocol for human identification in forensic anthropology.

# EXECUTIVE SUMMARY

Data for research in human identification come from autopsies of 'fresh' cases, as well as, forensic 'skeletal' cases and osteological collections. Increasingly, forensic anthropologists work with decomposing and 'fresh' remains in autopsy settings, as well as human rights and mass disaster incidents. The standard data protocols in forensic anthropology do not often reflect this modern range of contexts, therefore, this Protocol is meant to provide a basic framework for some of these diverse settings.

The purpose of this Protocol is to provide a resource for data collection in research and casework in human identification. This Protocol presents the primary instruments for implementing the procedures and protocols for human identification in forensic anthropology and helps to establish uniformity and standardization of data collection and analysis from a variety of autopsy and research settings. Therefore, the spirit and intent of this Protocol is that all data will be accurately and systematically collected and analyzed, and that physical evidence will be documented, collected and analyzed to ensure accurate testing and interpretations. This Protocol outlines the methods corresponding to the *International Databank of Osteological Biomarkers for Human Identification.* However, this Protocol does not include every method available in forensic anthropology. While it is meant to be a useful tool for practitioners, the intention is that it is adaptable to a number of contexts and should be modified to meet the particular needs of varying cases internationally and domestically.




This Protocol is built on the Standard Operating Manual of the Forensic Anthropology Laboratory at the University of South Florida (2006 v. 1.2). Additional data protocols, best practice recommendations, and

studies in method calibration for world populations were consulted and added, resulting from a body of research into methods for human identification (NIJ-2008-DN-BX-K163). Further examples of international skeletal variation in biomarkers for population variation in age, sex, and pathology, as well as trauma are provided in two atlases that were created under the same Research in Human Identification initiative (www.icfahr.usf.edu/rhi; Kimmerle et al. 2012; Kimmerle and Powell 2012). The images in these atlases come from the *International DataBank of Skeletal Biomarkers for Human Identification* (NIJ-2008-DN-BX-K163). In addition, standard osteological methods, laboratory SOPs, best practice guidelines, and data collection standards were consulted from SWGANTH, numerous laboratory manuals, and published studies (i.e., Adams and Lothridge 2000; Bass 2005; Buikstra and Ubelaker 1994; Burns 2007; Moore-Jansen et al. 1994; Byers 2007; Schaefer et al. 2009; and White et al. 2011).

Depending on the research questions, design, and availability of data for diverse populations, sources of data may come from museum collections, forensic casework, fresh autopsies, published data, and retrospective analysis of various reports. The data available from a "fresh" autopsy is different than for skeletonized cases. Therefore, to accommodate multiple forms of possible data sources, a number of protocols for both "fresh" and "skeletonized" cases are provided. Some general best practices for data collection represented in this manual include:

- Investigators should always indicate whether data comes from known/documented sources or is estimated.
- Investigators should record when information is "absent" rather than "missing" or "unknown".
- Data collection should always include basic demographic information about the case or individual.
- Statistical analyses should be carefully selected with a well-developed research design.
- The data collection protocol should be modified to fit the selection criteria for the research design. Assuming the methods of a particular published study are applicable to all research questions on a given topic is not accurate and may result in conflicting or irrelevant conclusions.

# EXECUTIVE SUMMARY

- Investigators should keep in mind that data collected for individual identification is particular to the **TYPE OF IDENTIFICATION** being sought. There are varying levels of human identification, which require different types of analyses and have corresponding levels of relevancy when presented (or not presented) in criminal trials. Therefore, investigators should consider the objective or stage within the identification process when selecting which methods to use and what levels of errors to accept.

Osteological methods for the purpose of individual identification are used to construct a biological profile. Depending on whether the decedent is immediately identified or not, the biological parameters for identity (i.e., age at death, sex, stature, ancestry, etc.) may be made available to the public and entered into a number of local, state and federal databases. Some of these databases are for law enforcement use only (i.e., NCIC), while others are available to the public (NamUs.org). Depending on the goals of particular investigators, many biological parameters can be narrowed or widened to be more or less inclusive. At various stages in the identification process, it may be advantageous to be more or less inclusive. Therefore, investigators must decide what information or level of details to provide the medico-legal community and to the public.

# EXECUTIVE SUMMARY

## CLASSIFICATION TYPES OF IDENTIFICATION

**PRESUMPTIVE IDENTIFICATION**

- The possible identity of an individual based on information that is consistent with individuality but that is not mutually exclusive to only one person. All of the initial parameters for identification are used here, such as age, sex, ancestry, stature, unique skeletal markers, skeletal pathology, and antemortem trauma.

**POSITIVE IDENTIFICATION**

- The positive identification of an individual is established through information that is exclusive to only that individual (i.e., DNA, fingerprints, unique skeletal or dental morphology, or sinus patterns) and is derived by comparisons of ante- and postmortem information that are unique to a particular individual.

**COLLECTIVE IDENTIFICATION**

- The identification of an individual into a particular cultural, demographic, religious or ethnic group may estimate a collective identity. General descriptive characteristics about the individual place him/her within a particular group. For example, the age, sex, or ancestry of the individual may demonstrate group membership derived from biological factors or other physical evidence associated with the decedent (i.e., particular clothing or jewelry depicting religious affiliations).

**CONTEXTUAL IDENTIFICATION**

- For an individual or group of individuals, contextual identification is a similar to collective identity but can be applied at the individual or group level. This form of identification serves to inform about the status and context of the individual, such as "Foreign born individuals," Migrant workers," or "Homeless."

- In this context, the characteristics about an individual are consistent with certain population characteristics, but limited to strict "group" membership. Increasingly this category is useful along Border States in the USA where many unknown, unidentified decedents fall into categories such as migrant workers, transients, or victims of human trafficking.

- Within this context, the outcome of the investigation may eventually lead to a presumptive identification, but geographical and temporal distance may complicate locating family members for more information, DNA sampling, etc.

# EXECUTIVE SUMMARY

## LIST OF ABBREVIATIONS

| | |
|---|---|
| HHRR: | Human Rights |
| ICC: | International Criminal Court |
| ICRC | International Committee for the Red |
| ICTR: | International Criminal Tribunal for the Rwanda |
| ICTY: | International Criminal Tribunal for the Former Yugoslavia |
| IHL: | International Humanitarian Law |
| IHRL: | International Human Rights Law |
| LASUCOM: | Lagos State University, College of Medicine, Nigeria |
| MP: | Missing Person |
| NCIC: | National Crime Information Center |
| NCMEC: | National Center for Missing and Exploited Children |
| OTP: | Office of the Prosecutor, ICTY, United Nations |
| PMI: | Postmortem Interval |
| RHI: | Research in Human Identification |
| UID: | Unidentified Decedent |
| UT: | University of Tennessee |

# Section I.
# Case Information

# SECTION I. CASE INFORMATION

Demographic information is fundamental when creating databases or conducting research using multiple samples. A step-by-step explanation is provided for the primary Demographic Data Form entitled "Protocol for Skeletal Data Collection." Each space has a description of what information should be gathered and recorded per individual. This form can be used during any type of data collection, especially in skeletal and archaeological collections. A more specific Demographic Data Form and Data Collection sheet to be used specifically when collecting data in autopsy scenarios, entitled "Protocol for Data Collection at Autopsy" is also provided. This data collection form does not contain the first section about the museum, location, and history of the skeletal collection. These forms should be completed for every individual, whether or not they are identified at the time of data collection.

**TYPE OF CASE:** Data collection is varied depending on whether it is collected at Autopsy for Fresh Cases or Skeletal Remains (i.e. the context may also be Forensic or a Museum Collection).

**DATA COLLECTION DEPENDS ON CONTEXT, RESEARCH OBJECTIVES, AND STATE OF PRESERVATION**

| AT "FRESH" AUTOPSY | SKELETONIZED CASES |
|---|---|
| • Demography & Birth Year | • Demography& Birth Year |
| • Cause and Manner of Death | • Cause and Manner of Death |
| • Location Body Recovered | • Location Body Recovered |
| • Crime Scene Form | • Crime Scene Form |
| • Stage of Decomposition | • Taphonomy |
| • Presence Nutritional or Metabolic Disorders | • Presence of Nutritional or Metabolic Disorders |
| • Rib and Pubic Symphysis Phases | • Osteological Protocol for Morphological and Metric Traits for Sex, Age, Stature and Ancestry |
| • Weight and Stature | • 3D Craniometrics |
| • Hyoid Fusion | • Chemical & Elemental Isotope Sample |
| • Chemical & Elemental Isotope Sample | • Pathology and Trauma |
| • Pathology and Trauma | • Facial Approximations or Forensic Imaging |
| • Facial Approximations or Forensic Imaging for Public Viewing | • DNA Sample |
| • DNA Sample | |

# PROTOCOL FOR SKELETAL DATA COLLECTION

**COLLECTION INFORMATION**

LOCATION: **MEDICAL EXAMINER OFFICE, MUSEUM OR COLLECTION NAME**
POPULATION: **POPULATION ANCESTRY OR ETHNICITY**
COLLECTION HISTORY: **DESCRIPTION OF COLLECTION'S ORIGIN**
RECORDER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**
DATE: **WRITE IN DATE FORM WAS COMPLETED**

**INDIVIDUAL INFORMATION**

CASE/ID NUMBER**: WRITE COMPLETE CASE NUMBER**
STATUS: **IDENTIFIED** OR **UNKNOWN: CIRCLE ONE**
TIME/DATE OF DEATH**: LIST THE TIME AND DATE OF DEATH**
TIME/DATE OF RECOVERY**: LIST THE TIME AND DATE OF RECOVERY**
WHERE WAS THE BODY FOUND? (I.E. DONATED, FORENSIC, ANATOMICAL, ARCHAEOLOGICAL):
**LIST THE LOCATION/TYPE OF PLACE WHERE THE BODY WAS RECOVERED. BE AS SPECIFIC AS POSSIBLE.**

POST-MORTEM CONDITION (SKELETAL OR PROCESSED): **CIRCLE AND/OR DESCRIBE**
MANNER OF DEATH: **INDICATE MANNER OF DEATH**
CAUSE OF DEATH (LIST PRIMARY AND SECONDARY MECHANISMS): **LIST THE SPECIFIC MECHANISMS OF DEATH**

**DEMOGRAPHIC INFORMATION**

AGE AT DEATH (**EXACT AGE** OR **ESTIMATED AGE RANGE?**): **LIST THE AGE AT DEATH (IN YEARS OR LIST BIRTHDATE) AND INDICATE IF THIS IS CONFIRMED (KNOWN) BECAUSE INDIVIDUAL IS IDENTIFIED, OR ESTIMATED, BECAUSE PERSON IS UNIDENTIFIED.**

SEX: **CHOOSE ONE AND INDICATE KNOWN OR ESTIMATED**
___ MALE ___ FEMALE ___ UNKNOWN (**KNOWN** OR **ESTIMATED**?)

CADAVER STATURE: (CM OR FT): **WRITE STATURE AND CIRCLE UNITS**

CADAVER WEIGHT: (K OR LB): **WRITE WEIGHT AND CIRCLE UNITS**

ETHNICITY: **LIST ETHNICITY OR NATIONALITY**

IS THIS DEMOGRAPHIC INFORMATION **CONFIRMED** OR **ESTIMATED**?
**INDICATE IF THIS DATA IS KNOWN/COMES FROM AN IDENTIFIED REMAINS OR ESTIMATED/PERSON IS UNIDENTIFIED**

# PROTOCOL FOR SKELETAL DATA COLLECTION

**IS THERE ANY EVIDENCE THIS PERSON SUFFERED FROM *OSTEOPOROSIS, METABOLIC,* OR *NUTRITIONAL DEFICIENCIES*?** IF SO, WHAT? **LIST ANY MEDICAL HISTORY OR OBSERVATIONS THAT SUGGEST THE PERSON HAD *OSTEOPOROSIS, METABOLIC,* OR *NUTRITIONAL DEFICIENCIES.***

**IS THERE ANY EVIDENCE OF SUBSTANCE ABUSE? IF SO, WHAT?**
**LIST ANY MEDICAL HISTORY THAT SUGGESTIONS SUBSTACE ABUSE AND LIST SUBSTANCES.**

**METRIC ANALYSIS FOR STATURE, SEX AND ANCESTRY ESTIMATION (ADULTS AND SUBADULTS)**
***WERE THESE COMPLETED? (CHECK IF YES CHECK AND CIRCLE METHOD OF MEASUREMENT):***

_____ CRANIAL METRIC (**3D DIGITIZER, DIRECT MEASUREMENT,** OR **X-RAY**)
_____ POST-CRANIAL METRICS (**DIRECT MEASUREMENT** OF BONE OR **RADIOGRAPHIC IMAGE**)
_____ DENTAL METRICS (**DIRECT MEASUREMENT** OF BONE OR **RADIOGRAPHIC IMAGE**)
_____ AGE ESTIMATION (**KNOWN** OR **ESTIMATED**)

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The Case File Checklist provided here should be used for any forensic or non-forensic case consultation. This will be used to keep a record of what procedures and techniques were actually used for future reference.

## CHECKLIST FOR EACH CASE

- CRIME SCENE/BURIAL FORM
- TAPHONOMY/PMI
- SKELETAL INVENTORY
- AGE AT DEATH ESTIMATION
- SEX ASSESSMENT
- FACIAL APPROXIMATION OR FORENSIC IMAGING
- CRANIAL AND POST-CRANIAL METRIC FORMS
- PERIMORTEM INJURIES OR SKELETAL TRAUMA
- UNIQUE SKELETAL MARKERS OR CONGENITAL ANOMALIES
- SKELETAL PATHOLOGY
- TRABECULAR BONE OR SKELETAL MORPHOLOGY FOR RADIOGRAPHIC COMPARISONS
- ODONTOGRAMS: DENTAL INVENTORY, PATHOLOGY, MODIFICATION, OR ANOMALY
- ADDITIONAL METHODS: RADIOGRAPHY, PHOTOGRAPHY, 3D SCANNING, AND BONE SAMPLING (I.E., DNA OR CHEMICAL/ELEMENTAL ISOTOPES)

# DATA COLLECTION AT AUTOPSY

***DATA COLLECTED FOR ALL CASES, WHETHER KNOWN OR UNIDENTIFIED AT AUTOPSY.*

**CASE INFORMATION**

CASE NUMBER: **WRITE THE FULL CASE NUMBER**
STATUS: **IDENTIFIED** OR **UNKNOWN: BE SURE TO CIRCLE ONE ANSWER**
TIME/DATE OF DEATH**: LIST THE TIME AND DATE OF DEATH**
TIME/DATE OF RECOVERY**: LIST THE TIME AND DATE OF RECOVERY**
WHERE WAS THE BODY FOUND (I.E. RESIDENCE, PUBLIC SPACE, OUTSIDE, ETC): **LIST THE LOCATION/TYPE OF PLACE WHERE THE BODY WAS RECOVERED. BE SPECIFIC AS POSSIBLE.**

POSTMORTEM CONDITION (SKELETAL OR PROCESSED): **CIRCLE AND/OR DESCRIBE**
STAGE OF DECOMPOSTION

MANNER OF DEATH (**CHECK ONLY ONE**):

___ HOMICIDE
___ SUICIDE
___ ACCIDENT
___ NATURAL
___ UNKNOWN

CAUSE OF DEATH (LIST PRIMARY AND SECONDARY MECHANISMS):
**LIST THE SPECIFIC CAUSE AND MECHANISMS OF DEATH**

**DEMOGRAPHIC INFORMATION**

AGE AT DEATH (EXACT AGE OR ESTIMATED AGE RANGE?): **LIST THE AGE AT DEATH (IN YEARS OR LIST BIRTHDATE) AND INDICATE IF THIS IS CONFIRMED (KNOWN) BECAUSE INDIVIDUAL IS IDENTIFIED, OR ESTIMATED, BECAUSE PERSON IS UNIDENTIFIED.**

SEX (**CHECK ONE**): ___ MALE
___ FEMALE
___ UNKNOWN

CADAVER STATURE: (CM): **MEASURE STATURE**

CADAVER WEIGHT: (K): **BODY WEIGHT**

ETHNICITY**: LIST ETHNICITY OR NATIONALITY**

IS THIS DEMOGRAPHIC INFORMATION **CONFIRMED** OR **ESTIMATED**?
**INDICATE IF THIS DATA IS KNOWN/COMES FROM AN IDENTIFIED REMAINS OR ESTIMATED/PERSON IS UNIDENTIFIED**

# DATA COLLECTION AT AUTOPSY

IS THERE ANY EVIDENCE THIS PERSON SUFFERED FROM *OSTEOPOROSIS, METABOLIC,* OR *NUTRITIONAL DEFICIENCIES*? IF SO, WHAT?

**LIST ANY MEDICAL HISTORY OR OBSERVATIONS AT AUTOPSY THAT SUGGEST PERSON HAD *OSTEOPOROSIS, METABOLIC,* OR *NUTRITIONAL DEFICIENCIES.***

WERE PHOTOGRAPHS TAKEN OF ANY ELEMENTS? YES OR NO

**PHOTOGRAPHS SHOULD BE TAKEN OF ELEMENTS ASSESSED; INDICATE THAT THE PHOTOGRAPHS WERE TAKEN.**

# SKELETAL INVENTORY

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER, IF AVAILABLE**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER, IF DIFFERENT AND AVAILABLE**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

---

**CRANIUM AND MANDIBLE COMPLETENESS CODES:** *(1= >75%, 2=25-72%, 3=<25%, 9=NOT PRESENT)*

| CRANIUM | | FACE | | ORBIT, PALATE, NOSE | |
|---|---|---|---|---|---|
| FRONTAL | _____ | MAXILLA (L) | _____ | LACRIMAL (L) | _____ |
| PARIETAL (L) | _____ | MAXILLA (R) | _____ | LACRIMAL (R) | _____ |
| PARIETAL (R) | _____ | ZYGOMATIC (L) | _____ | VOMER | _____ |
| OCCIPITAL | _____ | ZYGOMATIC (R) | _____ | PALATINE (L) | _____ |
| TEMPORAL (L) | _____ | NASAL (L) | _____ | PALATINE (R) | _____ |
| TEMPORAL (R) | _____ | NASAL (R) | _____ | INF. NASAL CONCHA (L) | _____ |
| SPHENOID | _____ | MANDIBLE | _____ | INF. NASAL CONCHA (R) | _____ |
| ETHMOID | _____ | | | | |

| MISCELLANEOUS | | ARTICULAR JOINT SURFACES | | |
|---|---|---|---|---|
| HYOID | _____ | MANIDUBLAR FOSSA | LEFT_____ | RIGHT_____ |
| MALLEUS (L) | _____ | MASTOID PROCESS | LEFT_____ | RIGHT_____ |
| MALLEUS (R) | _____ | OCCIPITAL CONDYLES | LEFT_____ | RIGHT_____ |
| INCUS (L) | _____ | MANDIBULAR CONDYLES | LEFT_____ | RIGHT_____ |
| INCUS (R) | _____ | | | |
| STAPES (L) | _____ | | | |
| STAPES (R) | _____ | | | |

**TEETH:** *("X" = LOST POSTMORTEM, "/" = LOST ANTEMORTEM, "0" = PRESENT)*
**MARK APPROPRIATELY OVER EACH TOOTH NAME.**

PERMANENT:

| RIGHT: | | | | | | | | LEFT: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M3 | M2 | M1 | P2 | P1 | C | I2 | I1 | I1 | I2 | C | P1 | P2 | M1 | M2 | M3 |
| M3 | M2 | M1 | P2 | P1 | C | I2 | I1 | I1 | I2 | C | P1 | P2 | M1 | M2 | M3 |

DECIDUOUS:

| RIGHT: | | | | | LEFT: | | | | |
|---|---|---|---|---|---|---|---|---|---|
| M2 | M1 | C | I2 | I1 | I1 | I2 | C | M1 | M2 |
| M2 | M1 | C | I2 | I1 | I1 | I2 | C | M1 | M2 |

# SKELETAL INVENTORY

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

**POST-CRANIAL COMPLETENESS CODES:** *(1= >75%, 2=25-72%, 3=<25%, 9=NOT PRESENT. USE TRINARY CODES FOR ALL LONG BONES, INCLUDING METACARPALS AND METATARSALS.)*

**FOR ALL LONG BONES/CLAVICLES/METACARPALS & METATARSALS, USE TRINARY CODES, SUCH AS "112," TO REFER TO THE CODED PERCENT PRESENT OF THE PROXIMAL END, DIAPHYSIS, AND DISTAL END, RESPECTIVELY.**

| POST-CRANIA | LEFT | RIGHT |
|---|---|---|
| SCAPULA | | |
| CLAVICLE | | |
| HUMERUS | | |
| RADIUS | | |
| ULNA | | |
| FEMUR | | |
| TIBIA | | |
| FIBULA | | |
| PATELLA | | |
| ILIUM | | |
| ISHIUM | | |
| PUBIS | | |
| MANUBRIUM | | |
| STERNAL BODY | | |
| XIPHOID | | |
| SACRUM | | |
| COCCYX | | |

| CARPALS | LEFT | RIGHT |
|---|---|---|
| NAVICULAR | | |
| LUNATE | | |
| TRIANGULAR | | |
| PISIFORM | | |
| GR. MULT. | | |
| LS.MULT. | | |
| CAPITATE | | |
| HAMATE | | |

| TARSALS | LEFT | RIGHT |
|---|---|---|
| CALCANEUS | | |
| TALUS | | |
| CUBOID | | |
| 1ST CUNEIFORM | | |
| 2ND CUNEIFORM | | |
| 3RD CUNEIFORM | | |
| NAVICULAR | | |

| METACARPALS | LEFT | RIGHT |
|---|---|---|
| MC 1 | | |
| MC 2 | | |
| MC 3 | | |
| MC 4 | | |
| MC 5 | | |

NO. PHALANGES:_____

| METATARSALS | LEFT | RIGHT |
|---|---|---|
| MT 1 | | |
| MT 2 | | |
| MT 3 | | |
| MT 4 | | |
| MT 5 | | |

NO. PHALANGES:_____

| RIB | LEFT | RIGHT |
|---|---|---|
| RIB 1 | | |
| RIB 2 | | |
| RIB 3 | | |
| RIB 4 | | |
| RIB 5 | | |
| RIB 6 | | |
| RIB 7 | | |
| RIB 8 | | |
| RIB 9 | | |
| RIB 10 | | |
| RIB 11 | | |
| RIB 12 | | |

| ARTICULAR SURFACES | LEFT | RIGHT |
|---|---|---|
| AURICULAR SURFACE | | |
| PUBIC SYMPHYSIS | | |
| ACETABULUM | | |
| GLENOID FOSSA | | |

**VERTEBRAE**

| CERVICAL | THORACIC | | LUMBAR | |
|---|---|---|---|---|
| C1 _____ | T1 _____ | T8 _____ | L1 _____ | |
| C2 _____ | T2 _____ | T9 _____ | L2 _____ | |
| C3 _____ | T3 _____ | T10 _____ | L3 _____ | |
| C4 _____ | T4 _____ | T11 _____ | L4 _____ | |
| C5 _____ | T5 _____ | T12 _____ | L5 _____ | |
| C6 _____ | T6 _____ | | | |
| C7 _____ | T7 _____ | | | |

# Section II.
# Contextual Information

# SECTION II. CONTEXTUAL INFORMATION

Contextual Information includes information about the scene, burial factors, taphonomy, and the postmortem interval (PMI). Increasingly, archaeological methods (referred to as **FORENSIC ARCHAEOLOGY**) are being adopted for crime scene processing. Scientific approaches to processing a crime scene are very similar to an archaeological site in that the very act of collecting evidence means investigators are destroying the scene. Therefore, meticulous steps need to be taken to ensure that all evidence is properly documented, collected, and stored. **CHAIN OF CUSTODY**, the paper trail that accounts for what evidence is present and the timeline for when evidence was handled and by whom must be maintained. Scientific inquiry into the accuracy of anthropological data and methods ensures that the evidence is admissible and at the same time, not exculpatory. When this process is violated, investigators risk the chance evidence will be deemed inadmissible, or that her/his credibility may be challenged. Contextual information consists of several components:

### DEMOGRAPHIC SUMMARY

- Basic data about individuals such as age, sex, and the location/jurisdiction of remains

### BURIAL FORM/TAPHONOMY/PMI

- Data on burial factors, taphonomic processes, the postmortem interval, and basic crime scene data

### INVENTORY

- Inventory of skeletal and dental remains and/or elements under study

# ESTABLISHING CONTEXT

Forensic archaeology methods may include prospection or survey work, soil analysis, excavation, mapping, scene documentation, and recovery. In some cases, investigators have reason to believe a grave exists in a particular place, however information on the exact location may be lacking. Therefore, a systematic search of the property will ensure that either the burial is located or that the area can be excluded. This is a very important point because in cases where a methodical, scientific approach is not used, the search may not yield a burial and investigators are left uncertain as to whether the area can be excluded from further searches.

There are a number of methods available to aid in locating clandestine graves. As with any tool kit, it is important that investigators know the potential value and limitations of each method or tool available. *Not all methods work in all situations or environments.* Forensic anthropologists are able to provide guidance to law enforcement on which tools will best serve their needs, given the age of the burial, the particular type of vegetation and terrain present, the soil matrix and amount of prior disturbance to the site from previous human activities. It is also important to know that some methods are destructive, therefore it is not only a matter of choosing the right methods to get the job done but also the right sequence of methods, employing the least destructive methods first. *The order of tools or methods used should be designed in advance of the search.*

**DATA ON BURIAL LOCATION AND TYPE, ASSOCIATED EVIDENCE, AND THE METHODS OF RECOVERY MAY ASSIST WITH RECONSTRUCTING THE CIRCUMSTANCES SURROUNDING A DEATH ARE IMPORTANT FOR:**

- ESTABLISHING CONTEXT
- DISTINGUISHING PERIMORTEM TRAUMA FROM POSTMORTEM AGENTS
- ESTIMATING THE POSTMORTEM INTERVAL (PMI)
- COMPLETENESS OF RECOVERY
- SORTING COMMINGLING REMAINS
- FACIAL IMAGING

# ESTABLISHING CONTEXT

Contextual information may affect interpretations about the circumstances surrounding death and the biological profile in some cases. The best indicators to establish the context are on the remains themselves. Both taphonomic features and antemortem human modification to teeth and bones may provide insight into the relative timing and provenience of the remains. Traits indicative of non-modern (non-forensic) remains may include: severe dental attrition, intentional cranial modification, or evidence of burial customs and/or body preparation for intentional burials. In contrast, dental modifications such as amalgams are indicative of recent origins. However, it cannot always be assumed that a lack of dental or medical intervention means the remains are *Historic* or not legally significant. Some populations in the USA and globally do not have adequate dental and medical care and therefore, untreated pathological, traumatic or dental conditions may be more indicative of basic human security issues than provenience, *per se*.

While it is assumed that soft tissues decompose over time, bones may remain greasy or "wet" for years following death. In dry climates, soft tissues may become mummified and preserve for hundreds of years. In wet environments, fatty tissues in the body may turn into adipocere (grave wax) and may also remain intact for hundreds of years. Therefore, the presence of adipocere, desiccated or mummified tissues does not always contribute to establishing PMI.

**IN FORENSIC CASEWORK WHEN HUMAN IDENTIFICATION IS KNOWN:**
The PMI is calculated as the time since the individual was last seen alive until the time the human remains were discovered.

**IN FORENSIC CASEWORK WHEN HUMAN IDENTIFICATION IS UNKNOWN:**
The PMI should be conservatively estimated using some of the published timelines, given for the particular environment or climate. This interval will vary and the reliability of the methods used will vary depending on the amount of time that has passed since death, the particular burial factors (i.e. buried or surface, container or no container), and the state of preservation.

# STAGES OF DECOMPOSITION

Given the number of variables and range of factors that influence the postmortem interval, PMI estimation usually ranges from several days to several months or years. Galloway and co-workers (1989) and Bass (1997) define several stages of decomposition adapted here and can be characterized generally as the following:

- FRESH
  - Generally the first 24 hours following death
  - Egg masses may start to form or other initial insect activity
  - *Algor mortis, rigor mortis*, and *livor mortis* occur
  - Slight discoloration of body tissues due to *putrefaction*

- EARLY DECOMPOSITION/BLOAT
  - Body tissues bloat and increase dramatically in size
  - Skin slippage begins to occur
  - Marbling of the vascular system is very pronounced
  - Body fluids purge from the mouth, nose and eyes
  - Purging of body fluids will often kill nearby vegetation and stain the soil a dark color

- ADVANCE DECOMPOSITION
  - Facial bones become skeletonized
  - Body is no longer bloated
  - Soft tissues continue to break down
  - Adipocere forms in wet environments, either in water or wet graves

- MUMMIFIED OR SKELETONIZATION
  - Soft tissues become completely desiccated and dry or absent leaving only skeletonized remains
  - Remains may be disarticulated due to animal and bird scavenging
  - Over time, cortex of bone begins to show cracking and erosion
  - Bones may become stained from sun bleaching, decaying vegetation, or chemical properties of the soil

**Stages and information adapted from Bass (1997), Clark et al. (1997), Galloway et al. (1989) and Perper 2006.*

# ESTIMATING PMI

**LIST WHICH OF THE FOLLOWING ARE PRESENT OR ABSENT:**

- Rigor mortis
- Lividity (note locations)
- Skin Slippage
- Postmortem Bullae
- Marbling
- Bloating
- Green Discoloration
- Purged fluids from mouth or nose
- Mummified Tissue
- Adipocere
- Decomposition Odor
- Mold growth on the body
- Postmortem blood clotting
- Soil stain under/around body
- Decomposed Brain Tissue
- Skeletonization and Extent: None, ≤25%, ≈50%, ≥75%, ≈100%
- For skeletonized remains, what taphonomic stage best describes the remains?
- If any portions of the body are skeletonized or mummified, list/describe in detail. If skeletonized, describe presence/absence of soft tissue (i.e., dessicated ligaments).
- Also list specific areas of sun bleaching and/or an animal scavenging.



# TAPHONOMY

**TAPHONOMY:** There are various interpretations, models, and definitions regarding decomposition, taphonomy, and taphonomic processes as they relate to interpretations of the postmortem modification and the length of the postmortem interval (PMI). Generally, taphonomy refers to the multiple processes that effect human remains following death. Careful documentation of observations made at the crime scene, burial variables, and modifications to skeletal remains is needed. Collectively, this information will enable interpretations about the PMI and differentiation between perimortem trauma and postmortem damage.

**CAREFUL DOCUMENTATION OF TAPHONOMY ENABLES INTERPRETATIONS ABOUT:**

- POSTMORTEM INTERVAL
- POSTMORTEM CONDITIONS THAT MAY FACILITATE OR COMPLICATE IDENTIFICATION AND/OR THE DETERMINATION OF THE CAUSE AND MANNER OF DEATH
- SYSTEMATICALLY IDENTIFYING FACTORS THAT INFLUENCE THE PRESERVATION OR DECOMPOSITION OF HUMAN REMAINS AND OTHER EVIDENCE, WHICH MAY FACILITATE FUTURE RECOVERIES
- ESTIMATING THE LIKELIHOOD OF EXTRACTING VIABLE DNA SAMPLES FROM DIFFERENTIALLY PRESERVED REMAINS

| CHARACTERISTICS | VARIABLES |
|---|---|
| BONE PRESERVATION | GOOD WITH OUTER CORTEX INTACT TO POOR WITH EXFOLIATION OF OUTER BONE SURFACE |
| DISCOLORATION | STAINING CAUSED BY SOIL, VEGETATION, THE PRESENCE OF METALS OR OTHER CHEMICALS |
| ADHERENT MATERIALS | PLANT ROOTS, SOIL, LICHENS, BARNACLES |
| ANIMAL SCAVENGING | GNAWING OR CARNIVORE TOOTH MARKS, DISMEMBERMENT |
| HUMAN MODIFICATION | INFLICTED TRAUMA, BURIAL MODIFICATION, DISMEMBERMENT, EVIDENCE OF ORTHOPEDIC HARDWARE |

# METHODS FOR ESTIMATING THE POSTMORTEM INTERVAL

| METHOD | CHARACTERISTICS | GENERAL TIME FRAME |
|---|---|---|
| DECOMPOSITION | LIVOR , RIGOR, & ALGOR MORTIS | <36 HOURS |
| | DISCOLORATION | DAYS |
| | BLOATING | WEEKS |
| | SKELETONIZATION | MONTHS-YEARS |
| ENTOMOLOGY | SUCCESSIONAL WAVE OF INSECTS | 1 MONTH – 1 YEAR |
| | LIFE CYCLE OF SPECIES | <1 MONTH |
| BOTANY | ROOT GROWTH THROUGH REMAINS | >1 YEAR |
| | TREE RINGS | >1 YEAR |
| SOIL CHEMISTRY | INCREASED ELEVATIONS OF PH, PHOSPHATES, VOLATILE FATTY ACIDS | MONTHS-YEARS |
| PRESERVATION OF MATERIAL EVIDENCE | PAPER | WEEKS TO MONTHS |
| | NATURAL FIBERS | MONTHS- YEARS |
| | SYNTHETIC FIBERS* | MONTHS-YEARS |
| | **PRESERVES LONGER THAN NATURAL FIBERS* | |
| ANIMAL SCAVENGING | BIRDS, RODENTS, CARNIVORES | DAYS – YEARS |

MANY FACTORS AFFECT THE RATE OF DECOMPOSITION AND THEREFORE THE PMI IS HIGHLY VARIABLE, SUCH FACTORS INCLUDE:

| Intrinsic (Individual Variation) | Extrinsic (Bio-Geo-Ecological Factors) | Contextual (Human Modification to Body Following Death) |
|---|---|---|
| - Weight | - Location of body | - Use of chemicals, lime, or acids |
| - Age | - Temperature | - Dismemberment |
| - Disease | - Humidity | - Use of container (i.e. blanket) |
| - Trauma | - Water Intrusion | - Burning |
| - Presence of Drugs | - Access by Insects to Body | - Buried, Surface, or Water Burial |
| | - Local Flora | |
| | - Fauna and Scavenger Access | |
| | - Soil Type | |

**ACCUMULATED DEGREE DAYS (ADD)** are calculated by adding the average daily temperature over a given period of time. Since temperature is one of the most influential factors in the rate of decomposition, using ADD provides a standard scale that can be applied to any place on earth. For example, for a body to decompose to the point where bloating occurs, it may take an average of 285 degree days. In Alaska, where average temperatures are 65 degrees, this may equal 4.5 days, whereas in Florida, with average temperatures of 95 degrees it may take only 3 days. In this example, the time since death may vary by as much as 1.5 days, depending on the temperature and geographical location (Vass *et al.* 1992).

The **Human Remains Recovery** form should be filled out either at the scene or from police reports and scene photographs, indicating whether the information comes from direct observation or documented sources. Techniques and methods adapted from archaeology are used to process outdoor crime scenes involving human remains, including the search and recovery of evidence, documentation, photography, mapping, excavation, evidence collection and storage. The methods that the lab uses for surface and burial recovery of human remains allows for a thorough investigation and as complete a recovery of all human remains and evidence as possible and establishes contextual information for interpretations about the scene, how and when it was created, disturbance or modifications following the death and/or burial event, etc.

# HUMAN REMAINS RECOVERY

POLICE/ME CASE NUMBER: **WRITE POLICE AND ME CASE NUMBER**
CASE NUMBER: **WRITE LAB CASE NUMBER**
DATE/TIME: **INDICATE DATE AND TIME OF ARRIVAL TO SCENE**
PERSONNEL: **INCLUDE ALL PERSONNEL INVOLVED WITH RECOVERY FROM LAB**
ADDRESS: **ADDRESS OF SCENE**
GPS (UTM): **GPS COORDINATES OF SCENE AND/OR LOCATION OF REMAINS**
POLICE AGENCY: **WRITE OUT POLICE AGENCY**
MEDICAL EXAMINER OFFICE: **WRITE OUT ME OFFICE NAME**
SURFACE OR BURIAL: **INDICATE TYPE OF RECOVERY**
DESCRIPTION OF ENVIRONMENT:
**DESCRIBE OVERALL ENVIRONMENT, INCLUDING ASSOCIATED STRUCTURES, VEGITATION, DESCRIPTION OF LANDSCAPE, PROXIMITY TO ROADS, ETC.**

---

PRESENCE OF (CIRCLE ALL THAT APPLY): CLOTHING, INSECTS, JEWELRY, ARTIFACTS
OTHER AND DESCRIPTION:
**WRITE OUT ALL ASSOCIATED ARTIFACTS FOUND WITH REMAINS**

---

FIELD METHODS UTILIZED FOR GRAVE SEARCH/RECOVERY:
**DESCRIBE ALL FIELD METHODS OR TOOLS USED FOR SEARCH AND RECOVERY, INCLUDING TOOLS, AS WELL AS SEARCH AND EXCAVATION TECHNIQUES.**

---

SIZE OF GRAVE: **MEASURE X,Y,Z DEMENSIONS OF GRAVE, IF APPROPRIATE**
ORIENTATION: **DESCRIBE ORIENTATION OF GRAVE OR REMAINS ON SURFACE**
BODY POSITION: **DESCRIBE POSITION OF REMAINS IN BURIAL OR ON SURFACE**
COLOR AND CONDITION OF HUMAN REMAINS: **DESCRIBE TAPHONOMY OF REMAINS**

**PROVIDE SKETCH ILLUSTRATING ORIENTATION IN BOX BELOW** (NOT TO SCALE).

N

# TAPHONOMY DATA FORM

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

---

**FOR EACH BONE AND ASPECT, LIST THE SPECIFIC LOCATION AND EXTENT OF THE FOLLOWING, DESCRIBE ALL FINDINGS:**

I. COLOR OF BONE:

II. STATE OF SKELETAL PRESERVATION:

III. ADHERENT MATERIALS:

IV. TYPE OF BURIAL: SURFACE, NEAR SURFACE, CONTAINER, BURIAL

V. SURFACE WEATHERING: FLAKING LONGITUDINAL CRACKING BENDING/WARP

   a. AMOUNT OF SURFACE WEATHERING:

VI. BURIAL DAMAGE: FRACTURES OR DAMAGE TO CORTEX?

VII. ROOT DAMAGE:

VIII. EXCAVATION DAMAGE:

IX. CORTICAL EROSION:

X. ANIMAL SCAVENGING:

   a. TYPE OF ALTERATION:

   b. LOCATION:

XI. SUN BLEACHING (LIST LOCATION):

XII. WATER DAMAGE:

   a. SURFACE CRACKING OR DAMAGE

   b. ALGAE STAINING OR ADHERENT MATERIALS

   c. AQUATIC INSECT EGG CASINGS

XIII. FIRE DAMAGE

   a. COLOR: WHITE/YELLOW/BROWN/GREY/BLACK WHITE/GREY/BLUE WHITE

   b. SHRINKAGE: 0-2.5% 1-2% 10-15% >15%

   c. TYPE OF FRACTURES: CHECKERBOARD CRESCENT LONGITUDINAL RING

---

# BONE TAPHONOMY

**CHOOSE THE STAGE THAT BEST DESCRIBES THE REMAINS.**

**(ADAPTED FROM BEHRENSMEYER (1978) IN: BUIKSTRA AND UBELAKER 1994)**

- "Stage 0: Bone surface shows no signs of cracking of flaking due to weathering.
- Stage 1: Bone shows cracking, normally parallel to the fiber structure (e.g. longitudinal in long bones). Articular surfaces may show mosaic cracking.
- Stage 2: Outermost concentric thin layers of bone show flaking, usually associated with cracks, in that the bone edges along the cracks tend to separate and flake first. Long thin flakes, with one or more sides still attached to the bone, are common in the initial part of Stage 2. Deeper and more extensive flaking follows, until most of the outermost bone is gone. Crack edges are usually angular in cross section.
- Stage 3: Bone surface is characterized by patches of rough, homogeneously weathered compact bone, resulting in fibrous texture. In these patches, all the external, concentric layers of bone have been removed. Gradually the patches extend to cover the entire bone surface. Weathering does not penetrate deeper than 1.0-1.5mm at this stage, and bone fibers are still firmly attached to each other. Crack edges usually are rounded in cross section.
- Stage 4: The bone surface is coarsely fibrous and rough in texture; large and small splinters occur and may be loose enough to fall away from the bone if it is moved. Weathering penetrates into inner cavities. Cracks are open and have splintered or rounded edges.
- Stage 5: Bone is falling apart, with large splinters. Bone easily broken by moving. Original bone shape may be difficult to determine. Cancellous bone usually exposed, when present, and may outlast all traces of the former more compact, outer parts of the bones."

# ESTIMATING PMI

## I. SCAVENGING ACTIVITY: ANSWER YES OR NO TO THE FOLLOWING:

- WAS THERE POST-MORTEM MODIFICATION TO THE BODY?
  **THIS MAY INCLUDE ANIMAL, INSECT OR HUMAN ACTIVITY**

- WAS THE BODY MOVED FOLLOWING THE DEATH EVENT?
  **YES OR NO**

- EVIDENCE OF SCAVENGER ACTIVITY?
  **LIST SPECIFIC MODIFICATION NOTED AND LOCATION ON REMAINS**

- IF YES, WHAT TYPE OF SCAVENGER? **LIST ALL THAT APPLY AND DESCRIBE THE PATTERN AND EXTENT OF SCAVENGING.**

- IF INSECT ACTIVITY WAS PRESENT, DESCRIBE WHAT SPECIES WERE PRESENT AND THE MOST ADVANCED STAGES OF DEVELOPMENT. **SPECIFY THE EXTENT OF TISSUE LOSS DUE TO SCAVENGING.**

- IF LARVAE WERE FOUND NEAR THE BODY, WHERE WERE THEY FOUND (I.E., UNDER CARPET), AND HOW MANY ROOMS HAD THEY OCCUPIED?
  **LIST AND BE AS SPECIFIC AS POSSIBLE.**

## II. DECOMPOSITION STAGE DATA:

- ACCORDING TO THE STAGES OUTLINE BY GALLOWAY (1989), WHAT STAGE BEST DESCRIBES THE CONDITION OF THE HUMAN REMAINS?
  - FRESH
  - EARLY OR BLOATED
  - ADVANCED OR DECAY
  - SKELETONIZED
  - MUMMIFIED TISSUES
  - SKELETAL BREAKDOWN

## III. LIST ANY OBSERVED DECOMPOSITIONAL CHANGES (I.E. LIVIDITY, SEE ATTACHED LIST):

## IV. TEMPERATURE DATA:

- WAS THE AIR TEMPERATURE AT THE TIME OF DEATH OR DISCOVERY KNOWN?

- IF NO, THEN WHAT WAS THE AVERAGE, HIGH, AND LOW TEMPERATURES FOR THAT PARTICULAR DAY? (AREA SPECIFIC: MAY HAVE TO GO BACK TO THIS WITH LOCAL WEATHER DATA).

- LIST LOCATION OF NEAREST WEATHER STATION WHERE CLIMATIC DATA COLLECTED

# Section III.
# Biological Profile

# SECTION III. BIOLOGICAL PROFILE

The methods and techniques available to estimate individual characteristics about a person from skeletal remains, sets forensic anthropology apart from forensic pathology. This Protocol outlines procedures for creating biological profiles (i.e., ancestry, sex, age-at-death, stature, facial approximations, etc.) from skeletal and dental remains by comparison with standard exemplars and models derived largely from known individuals.

**BIOLOGICAL PROFILE**: Biological profiles are estimated from skeletal and dental data. The completeness of the profile depends on what data is available due to recovery and/or preservation. To begin, a skeletal inventory must be made of all elements present. Additionally, the case number, museum and/or collection information, recorder's initials and date will be included on all forms filled out, front and back.

### OSTEOMETRICS

- Linear Craniometrics
- 3D Cartisian Coordinate Data
- Post-cranial Osteometrics
- Ancestry, Stature, Sex, and Juvenile Age Estimation

### AGE ESTIMATION

- Juvenile and Adult Age Estimation from Dental and Skeletal Traits

### SEX ASSESSMENT

- Morphological features of the skull and pelvis
- Osteometric data for cranial and post-cranial data
- Linear and 3D Cartisian Coordinate Data

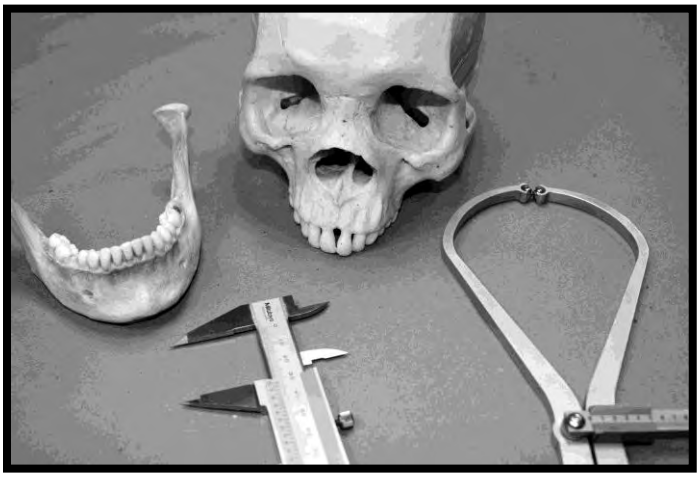
### FACIAL APPROXIMATIONS

- Demographic Profile
- Facial Trauma and Unique Features
- Taphonomy and PMI Factors
- Contextual Identification

# METRIC ANALYSES

Metric analyses are important in forensic anthropology as it reduces the subjectivity of ancestry and sex estimations and enables statistically quantified classification and error rates to be used in research, reports, and court room testimony. The standard definitions for metric analysis, including cranial and postcranial measurements are defined by Moore-Jansen et al. (1994).

Skeletal size and shape is greatly influenced by genetics. For example, the more similar the craniofacial morphology of two groups; the more closely the groups are related to one another. Therefore, classification of an unknown individual into a known population through metric analysis can help establish ancestry. Additionally, metric data can be used to estimate sex as males and females are highly sexually dimorphic. Metric analyses for sex and ancestry typically have lower error rates than morphological methods alone. Post-cranial metrics are also under genetic control, but have been shown to be more susceptible to environmental influence such as nutrition, disease, and physical activity. Therefore, stature is highly variable among individuals and also populations. For stature, population and sex specific methods should be used when possible.

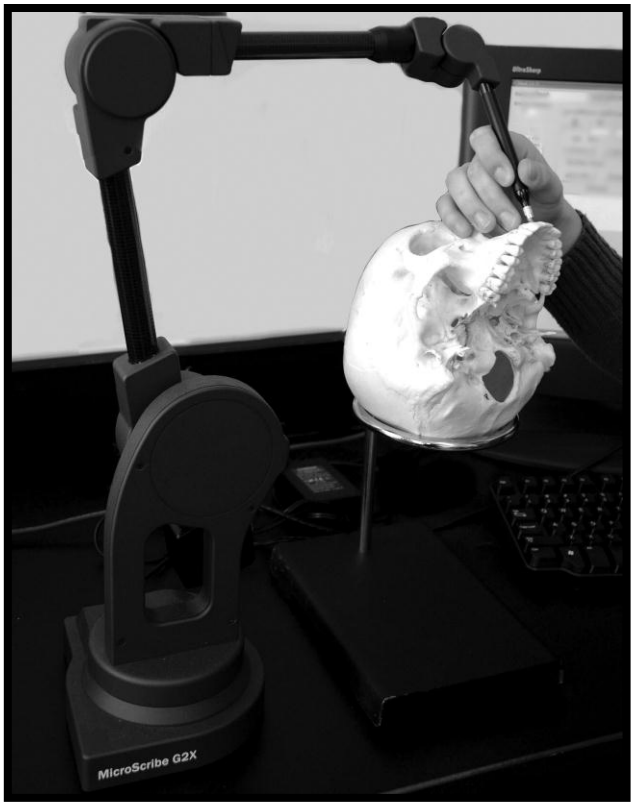


**COLLECTING CRANIOMETRIC DATA:** Two main types of data are used in the metric analysis of cranial form, which include traditional linear inter-landmark distance measurements and landmark *x, y,* and *z* coordinate data. Linear inter-landmark distance measurements are simple distances defined by craniometric anatomical landmarks. These measurements can be collected using spreading and sliding calipers or a digitizer. The procedure for collecting the measurements using calipers includes placing the ends of the caliper on the appropriate anatomical landmarks and reading the distance (in *mm*) between the two points.

# COLLECTING DATA WITH 3D DIGITIZER

The collection of 3D Cartesian coordinate data requires the use of a digitizer, which collects the *x*, *y*, and *z* coordinates of anatomical landmarks. Three-dimensional craniometric data is particularly useful because it allows for the endpoints of traditional linear measurements (or *x* and *y*) to be analyzed spatially with regard to the *z* coordinate. Therefore, 3D Cartesian landmark data has the ability to provide more information about the overall shape of an object.

To collect this type of data, a MicroScribe Series G2 is used. Additionally, the data collection computer software ThreeSkull is used because of its ability to simultaneously compute the traditional caliper derived inter-landmark distance measurements (Ousley 2004) while capturing 3D coordinate point data. The anatomical 3D Cartesian coordinate landmark data that are collected by the digitizer correspond with the endpoints of the linear inter-landmark distances from which the spreading or sliding calipers are placed. Since the collection of 3D landmark data involves the *z* coordinate, any shift of the specimen could result in data collection error. A data collection protocol is recommended to check for observer error and specimen stability before beginning to collect data to reduce the component of error.




First, secure the cranium with clay to a lifted ring or tripod of clay. Before beginning to digitize, make sure the digitizer is on a flat and stable surface, that all landmarks can be reached by the digitizer arm, and that the cranium is secure.

Second, the *x*, *y*, and *z* coordinates of each landmark are collected by placing the tip of the digitizer stylus on an anatomical landmark and depressing the attached foot pedal or pressing the handheld button. *Once data collection begins, do not move the object.* Coordinate data for each landmark can be collected or bypassed. Any comments about cranial deformation, the age and sex of the individual,

trauma, pathology, preservation, completeness, or other factors that may influence the metric data should be included for affected cases within the database. It is recommended that coordinate data be collected on juveniles and that their age or approximate age be included in the comments. Juvenile status should not preclude data collection for craniometric or coordinate variables.

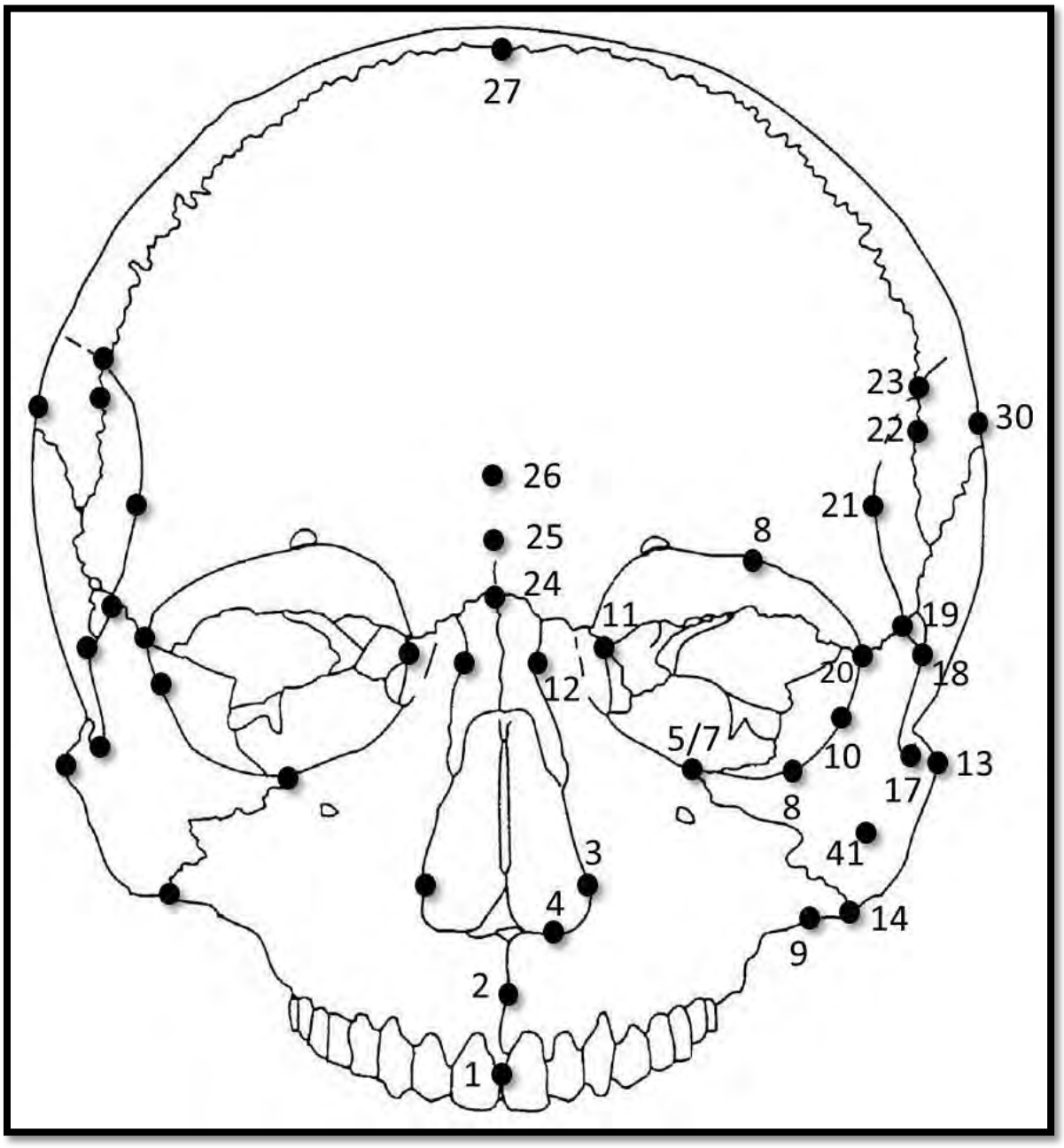
Third, once all available landmarks have been collected, ThreeSkull saves the 3D coordinate data and calculated inter-landmark distances in two separate files. It is recommended that the data be exported or copied into excel-like spreadsheets for the purpose of printing those out as hard copies for the case file.

## LIST OF CRANIAL LANDMARKS

| | Landmark | Abbrv | Unpaired/ Paired | | Landmark | Abbrv | Unpaired/ Paired |
|---|---|---|---|---|---|---|---|
| 1 | prosthion-estimated | proHEST | Unpaired | 24 | nasion | nas | Unpaired |
| 2 | subspinale | ssp | Unpaired | 25 | glabella | glb | Unpaired |
| 3 | alare L/R | alarl/r | Paired | 26 | supraglabellare | spglb | Unpaired |
| 4 | most inferior nasal border L/R | nlhil/r | Paired | 27 | bregma | brg | Unpaired |
| 5 | zygoorbitale L/R | zygool/r | Paired | 28 | lambda | lam | Unpaired |
| 6 | inferior orbital border L/R | obhi | Paired | 29 | asterion L/R | astl/r | Paired |
| 7 | superior orbital border L/R | obhs | Paired | 30 | eurion L/R | eurl/r | Paired |
| 8 | cheek height superior point L/R | wmhs | Paired | 31 | radiometer point L/R | radptl/r | Paired |
| 9 | cheek height inferior point L/R | wmhi | Paired | 32 | porion L/R | porl/r | Paired |
| 10 | ectoconchion L/R | ectl/r | Paired | 33 | mastoideale L/R | mastl/r | Paired |
| 11 | dacryon L/R | dacl/r | Paired | 34 | radiculare (zyg root) L/R | aubl/r | Paired |
| 12 | nasomaxillary suture pinch L/R | wnbl/r | Paired | 35 | opisthion | ops | Unpaired |
| 13 | zygion L/R | zygl/r | Paired | 36 | basion | bas | Unpaired |
| 14 | zygomaxillare L/R | zygoml/r | Paired | 37 | FOB point L/R | fobl/r | Paired |
| 15 | zygotemporale superior L/R | zytsl/r | Paired | 38 | alveolon (rubber band) | alv | Unpaired |
| 16 | zygotemporale inferior L/R | zytil/r | Paired | 39 | ectomolare L/R | ecml/r | Paired |
| 17 | jugale L/R | jugl/r | Paired | 40 | M1 anterior point L | avrpt | Unpaired |
| 18 | marginal process lateral L/R | mpll/r | Paired | 41 | maximum malar projection pt L or R | mlspt | Unpaired |
| 19 | frontomalare temporale L/R | fmtl/r | Paired | 42 | metopion | met | Unpaired |
| 20 | frontomalare anterior L/R | fmal/r | Paired | 43 | parietal subtense point | paspt | Unpaired |
| 21 | frontotemporale L/R | wfbl/r | Paired | 44 | opisthocranion (GOL) | opg | Unpaired |
| 22 | Maximum frontal point L/R | xfbl/r | Paired | 45 | occiptal subtense point | ocspt | Unpaired |
| 23 | stephanion L/R | stpl/r | Paired | | | | |

## LANDMARK DIAGRAMS

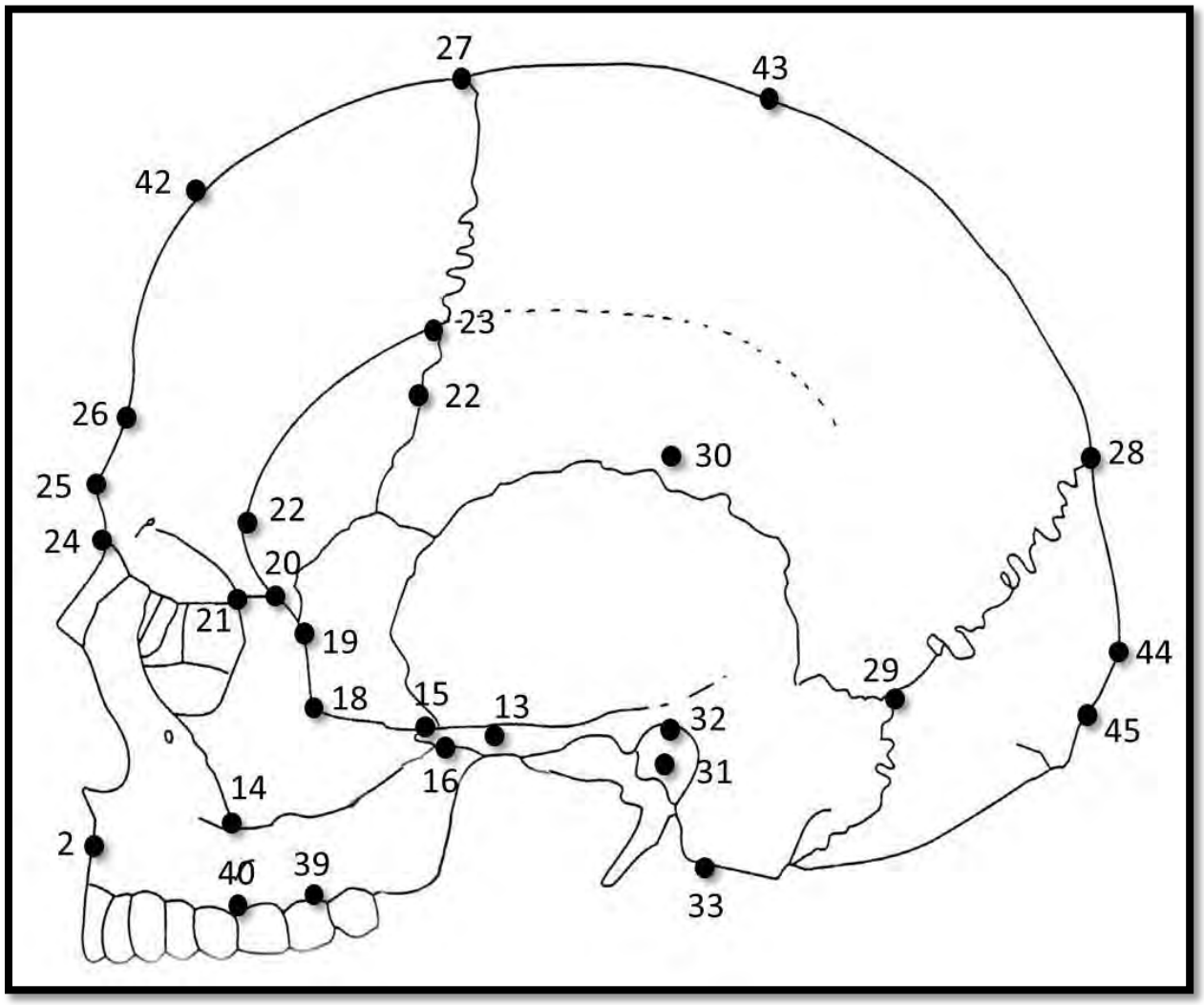
REFER TO TABLE WITH LIST OF CRANIAL LANDMARKS ON PAGE 31




ANTERIOR VIEW

## LANDMARK DIAGRAMS

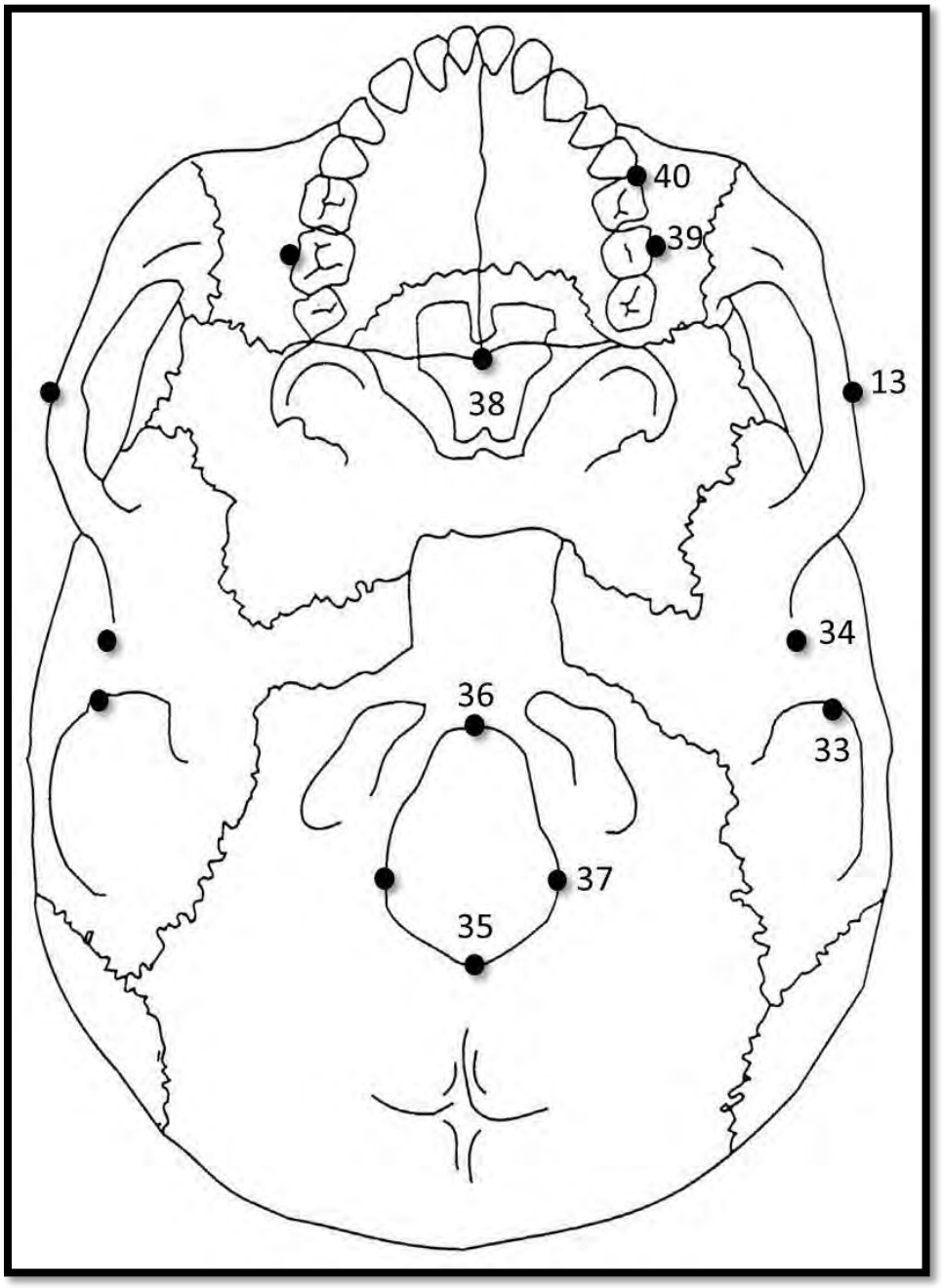
REFER TO TABLE WITH LIST OF CRANIAL LANDMARKS ON PAGE 31




LATERAL VIEW

# LANDMARK DIAGRAMS

REFER TO TABLE WITH LIST OF CRANIAL LANDMARKS ON PAGE 31.




INFERIOR VIEW

# CRANIAL MEASUREMENTS

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

**TAKE ALL MEASUREMENTS IN MILLIMETERS WITH EITHER SLIDING OR SPREADING CALIPERS OR A MANDIBULOMETER.**

## Cranial (mm)

| | | | Left | Right |
|---|---|---|---|---|
| 1. Maximum Length | (g-op) | _____ | | |
| 2. Maximum Breadth | (eu-eu) | _____ | | |
| 3. Bizygomatic Breadth | (zy-zy) | _____ | | |
| 4. Basion-Bregma | (ba-b) | _____ | | |
| 5. Cranial Base Length | (ba-n) | _____ | | |
| 6. Basion-Prosthion Length | (ba-pr) | _____ | | |
| 7. Max. Alveolar Breadth | (ecm-ecm) | _____ | | |
| 8. Max. Alveolar Length | (pr-alv) | _____ | | |
| 9. Biauricular Breadth | (AUB) | _____ | | |
| 10. Upper Facial Height | (na-pr) | _____ | | |
| 11. Min. Frontal Breadth | (ft-ft) | _____ | | |
| 12. Upper Facial Breadth | (fmt-fmt) | _____ | | |
| 13. Nasal Height | (n-ns) | _____ | | |
| 14. Nasal Breadth | (al-al) | _____ | | |
| 15. Orbital Breadth | (d-ec) | | _____ | _____ |
| 16. Orbital Height | (OBH) | | _____ | _____ |
| 17. Biorbital Breadth | (ec-ec) | | _____ | |
| 18. Interorbital Breadth | (d-d) | | _____ | |
| 19. Frontal Chord | (n-b) | | _____ | |
| 20. Parietal Chord | (b-l) | | _____ | |
| 21. Occipital Chord | (l-o) | | _____ | |
| 22. For. Magnum Length | (ba-o) | | _____ | |
| 23. For. Magnum Breadth | (FOB) | | _____ | |
| 24. Mastoid Length | (MDH) | | _____ | _____ |
| 25. Biasterion Breadth | (ASB) | | _____ | |
| 26. Zygomaxillary Breadth | (ZMB) | | _____ | |
| 27. Mid-orbital Width | (MOW) | | _____ | |

## Mandibular (mm)

| | | Left | Right | | |
|---|---|---|---|---|---|
| Chin Height | (GNI) | _____ | | Maximum Ramus Height~ | _____ |
| Body height @ mental for | (HMF) | _____ | _____ | Mandible Length~ | _____ |
| Body thickness @ mental for | (TMF) | _____ | _____ | Mandible Angle~ | _____ |
| Bigonial Breadth | (GOG) | _____ | | | |
| Bicondylar Breadth | (CDL) | _____ | | | |
| Minimum Ramus Breadth | (WRB) | _____ | _____ | | |

All standard cranial and mandibular measurements may be found in Buikstra and Ubelaker (1994); Moore-Jensen et al. 1994
~ Mandibular Measurement that should only be taken with mandibulometer.

# MICROSCRIBE RESULTS – LINEAR METRICS

**THIS FORM IS BASED ON THE LINEAR MEASUREMENTS COLLECTED BY THREESKULL (OUSLEY 2004) FOR THE PURPOSE OF PRINTING DATA OR CREATING A HARD COPY FOR CASE FILE.**

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
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OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

**RECORD RESULTING MEASUREMENTS FROM MICROSCRIBE COLLECTION**

| Catkey | Indiv | Repeat | RECR | GOL | NOL | BNL | BBH | XCB | XFB |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| WFB | ZYB | AUB | ASB | BPL | NPH | NLH | JUB | NLB | MAB |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| MAL | MDH | OBH | OBB | DKB | NDS | WNB | SIS | ZMB | SSS |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| FMB | NAS | EKB | DKS | IML | XML | MLS | WMH | GLS | STB |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| FRC | FRS | FRF | PAC | PAS | PAF | OCC | OCS | OCF | FOL |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| FOB | NAR | SSR | PRR | DKR | ZOR | FMR | EKR | ZMR | AVR |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| BRR | VRR | LAR | OSR | BAR | NAA | PRA | BAA | NBA | BBA |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| BRA | SSA | NFA | DKA | NDA | SIA | FRA | PAA | OCA | STA |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| CBA | BFA | BPA | FXA | RFA | RPA | ROA | BSA | SBA | SLA |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| TBA | UFBR | UFHT | GNI | HML | TML | GOG | CDL | WRB | XRH |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| MLT | MAN | Date | Reshaped | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

COMMENTS:

# 3D COORDINATE ANALYSIS

**THIS FORM IS BASED ON THE 3D DATA COLLECTED BY THREESKULL (OUSLEY 2004) FOR THE PURPOSE OF PRINTING DATA OR CREATING A HARD COPY FOR CASE FILE.**

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

**COPY 3-D COORDINATE DATA FROM RESULTING 3D FILE**

| Order | CATKEY | Indiv | Repeat | LMAbbrev | X | Y | Z |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
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# POSTCRANIAL MEASUREMENTS

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

**TAKE ALL MEASUREMENTS IN MM WITH EITHER OSTEOMETRIC BOARD, SLIDING OR SPREADING CALIPERS**

| | | Left | Right |
|---|---|---|---|
| 1. Clavicle max length* | (CML-CLAXLN) | _____ | _____ |
| 2. Clavicle A-P diam midshaft* | (CSD-CLAAPD) | _____ | _____ |
| 3. Clav S-I diam midshaft* | (CVD-CLAVRD) | _____ | _____ |
| 4. Scapula max height* | (SML-SCAPHT) | _____ | _____ |
| 5. Scapula max breadth* | (SMB-SCAPBP) | _____ | _____ |
| 6. Scapula spine length | (SLS) | _____ | _____ |
| 7. Scapula supraspinous length | (SSL) | _____ | _____ |
| 8. Scapula infraspinous length | (ISL) | _____ | _____ |
| 9. Scap glenoid cavity breadth | (GCB) | _____ | _____ |
| 10. Scap glenoid cavity height | (GCH) | _____ | _____ |
| 11. Scap glenoid to inf angle | (GIL) | _____ | _____ |
| 12. Manubrium length | (MML) | _____ | |
| 13. Mesosternum length | (MSL) | _____ | |
| 14. Stenebra 1 width | (S1W) | _____ | |
| 15. Stenebra 3 width | (S3W) | _____ | |
| 16. Humerus max length* | (HML-HUMXLN) | _____ | _____ |
| 17. Hum prox epiph breadth | (BUE) | _____ | _____ |
| 18. Hum max diam midshaft* | (MDS-HUMMXD) | _____ | _____ |
| 19. Hum min diam midshaft* | (MDM-HUMMWD) | _____ | _____ |
| 20. Hum max vert diam head* | (MDH-HUMHDD) | _____ | _____ |
| 21. Hum epicondylar breadth* | (EBR-HUMEBR) | _____ | _____ |
| 22. Hum least circum of shaft | (LCS) | _____ | _____ |
| 23. Radius max length* | (RML-RADXLN) | _____ | _____ |
| 24. Radius max diam head | (RDH) | _____ | _____ |
| 25. Radius A-P diam of shaft* | (RSD-RADAPD) | _____ | _____ |
| 26. Radius M-L diam of shaft* | (RTD-RADTVD) | _____ | _____ |
| 27. Radius neck shaft circum | (MCS) | _____ | _____ |
| 28. Ulna max length* | (UML-ULNXLN) | _____ | _____ |
| 29. Ulna physiological length* | (UPL-ULNPHL) | _____ | _____ |
| 30. Ulna max br olecranon | (BOP) | _____ | _____ |
| 31. Ulna min br olecranon | (MBO) | _____ | _____ |
| 32. Ulna max wd olecranon | (WOP) | _____ | _____ |
| 33. Ulna olec-radial notch | (ORL) | _____ | _____ |
| 34. Ulna olec-coronoid length | (OCL) | _____ | _____ |
| 35. Ulna A-P diam shaft* | (UAB-ULNDVD) | _____ | _____ |
| 36. Ulna M-L diam midshaft* | (UMD-ULNTVD) | _____ | _____ |
| 37. Ulna least circum shaft* | (UMD-ULNCIR) | _____ | _____ |
| 38. Sacrum anterior length* | (SAL-SACAHT) | _____ | |
| 39. Sacrum A-S breadth* | (SAB-SACABR) | _____ | |
| 40. Sacrum max breadth S1* | (SMB-SACS1B) | _____ | |
| 41. Innominate height* | (INH-INNOHT) | _____ | _____ |
| 42. Iliac breadth* | (ILB-ILIABR) | _____ | _____ |
| 45. Femur max length* | (FML-FEMXLN) | _____ | _____ |
| 46. Femur bicondylar length* | (FOL-FEMBLN) | _____ | _____ |
| 47. Femur trochanteric length | (FTL) | _____ | _____ |
| 48. Fem subtroch A-P diam | (APD) | _____ | _____ |
| 49. Fem subtroch M-L diam | (MLD) | _____ | _____ |
| 50. Fem A-P diam midshaft* | (APS-FEMMAP) | _____ | _____ |
| 51. Fem M-L diam midshaft* | (MLS-FEMMTV) | _____ | _____ |
| 52. Fem max vert diam head* | (VDH-FEMHDD) | _____ | _____ |
| 53. Fem max horiz diam head | (HHD) | _____ | _____ |
| 54. Fem A-P diam lat condyle | (APL) | _____ | _____ |
| 55. Fem A-P diam med condyle | (APM) | _____ | _____ |
| 56. Fem epicondylar breadth* | (FEB-FEMEBR) | _____ | _____ |
| 57. Fem bicondylar breadth | (BCB) | _____ | _____ |
| 58. Fem min vert diam neck | (VDN) | _____ | _____ |
| 59. Femur circum midshaft* | (FCS-FEMCIR) | _____ | _____ |
| 60. Tibia condylo-malle length* | (TML-TIBXLN) | _____ | _____ |
| 61. Tibia max br prox epiph* | (BPE-TIBPEB) | _____ | _____ |
| 62. Tibia max br dist epiph* | (BDE-TIBDEB) | _____ | _____ |
| 63. Tibia A-P diam nut for* | (APN-TIBNFX) | _____ | _____ |
| 64. Tibia M-L diam nut for* | (MLM-TIBNFT) | _____ | _____ |
| 65. Tibia position of nut for | (CFL) | _____ | _____ |
| 66. Tibia cirum at nut for* | (PCN-TIBCIR) | _____ | _____ |
| 67. Fibula maximum length* | (BML-FIBXLN) | _____ | _____ |
| 68. Fibula max diam midshaft* | (FMD-FIBMDM) | _____ | _____ |
| 69. Calcaneus maximum length* | (CLL-CALCXL) | _____ | _____ |
| 70. Calcaneus middle breadth* | (CMB-CALCBR) | _____ | _____ |

*** Standard measurements** *(Moore-Jensen et al. 1994).* **Numbers refer to associated Zobeck definition** *(Zobeck 1983).*

# POSTCRANIAL MEASUREMENTS

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

| | MEASUREMENT | | LEFT (MM) | RIGHT (MM) |
|---|---|---|---|---|
| 1. | Clavicle max length | (CML-CLAXLN) | | |
| 2. | Clavicle A-P diam. midshaft | (CSD-CLAAPD) | | |
| 3. | Clavicle S-I diam. midshaft | (CVD-CLAVRD) | | |
| 4. | Manubrium length | | | |
| 5. | Mesosternum length | | | |
| 6. | Stenebra 1 Width | | | |
| 7. | Stenebra 3 Width | | | |
| 8. | Humerus max Length | (HML-HUMXLN) | | |
| 9. | Humerus max. diam. head | (MDH-HUMHDD) | | |
| 10. | Hum proxepiph breadth | (BUE) | | |
| 11. | Hum max diam midshaft | (MDS-HUMMXD) | | |
| 12. | Hum epicondylar breadth | (EBR-HUMEBR) | | |
| 13. | Radius max length | (RML-RADXLN) | | |
| 14. | Radius max diam head | (RDH) | | |
| 15. | Radius A-P diam of shaft | (RSD-RADAPD) | | |
| 16. | Radius M-L diam of shaft | (RTD-RADTVD) | | |
| 17. | Ulna max length | (UML-ULNXLN) | | |
| 18. | Ulna physiological length | (UPL-ULNPHL) | | |
| 19. | Ulna A-P diam shaft | (UAB-ULNDVD) | | |
| 20. | Ulna M-L diam midshaft | (UMD-ULNTVD) | | |
| 21. | Femur max length | (FML-FEMXLN) | | |
| 22. | Femur bicondylar length | (FOL-FEMBLN) | | |
| 23. | Femur max. vert. head | (VDH-FEMHDD) | | |
| 24. | Fem A-P diam midshaft | (APS-FEMMAP) | | |
| 25. | Fem M-L diam midshaft | (MLS-FEMMTV) | | |
| 26. | Fem max vert diam head | (VDH-FEMHDD) | | |
| 27. | Fem epicondylar breadth | (FEB-FEMEBR) | | |
| 28. | Femur circum midshaft | (FCS-FEMCIR) | | |
| 29. | Tibia condylo-malle length | (TML-TIBXLN) | | |
| 30. | Tibia max br prox epiph | (BPE-TIBPEB) | | |
| 31. | Tibia max br dist epiph | (BDE-TIBDEB) | | |
| 32. | Tibia A-P diam nut for | (APN-TIBNFX) | | |
| 33. | Tibia M-L diam nut for | (MLM-TIBNFT) | | |
| 34. | Tibia cirum at nut for | (PCN-TIBCIR) | | |
| 35. | Fibula maximum length | (BML-FIBXLN) | | |
| 36. | Fibula max diam midshaft | (FMD-FIBMDM) | | |

# ANCESTRY ESTIMATION

Ancestry or population affiliation is estimated through metric analysis. Metric analyses estimate different populations depending on which tool is used and the reference populations, i.e., discriminant functions (Giles and Elliot 1962), FORDISC 3.1.285 (Ousley and Jantz 2005), or 3D-ID (Slice and Ross 2009).

**FORDISC 3.1.285** uses discriminant functions calculated from two reference data sets, the Forensic Data Bank (cranial and post-cranial measurements) or the worldwide craniometric data collected by W.W. Howells (Ousley and Jantz 2005). The Howells data were collected for bio-distance studies and includes worldwide populations. Fordisc allows investigators to classify an "unknown" individual into one of the reference populations through Bayesian posterior and typicality probabilities. Posterior probabilities are the probabilities of group membership within one of the chosen groups. Thus, the sum of the posterior probabilities equals 1. Typicality probabilities make no assumptions about group membership. Both posterior and typicality probabilities must be interpreted carefully. Prior probabilities are NOT incorporated into the Bayesian calculation, therefore, the posterior probability cannot be interpreted as a reasonable probability that the cranium originated in a specific group. Rather, posterior probabilities should be viewed an "index of similarity" of the unknown subject to the reference populations.

**3D-ID: GEOMETRIC MORPHOMETRIC CLASSIFICATION OF CRANIA FOR FORENSIC SCIENTISTS:** 3D-ID is a Java supported program that can be downloaded for free via the internet at http://www.3d-id.org/. This program uses 3D Cartesian landmark data collected with a digitizer to estimate ancestry and sex. The program uses Geometric Morphometrics, which are modern techniques of size and shape analysis, to classify and assign an unknown cranium to one of the reference samples. A total of 34 standard anatomical landmarks are used by the program. Not all landmarks need to be entered for 3D-ID to classify a cranium. Note that 3D-ID will classify an unknown specimen to the most closely related reference sample, and therefore, as with FORDISC caution should be used during the interpretation of results as an appropriate reference sample may not be available for comparison.

# SEX ASSESSMENT

Sex assessments among adults are based on morphological features and metric analyses of the skull and pelvis which are highly sexually dimorphic. Due to secondary sex traits, skeletal differences between males and females are readily discernible because of size, robusticity, and development. Rather than treating these indicators as dichotomous male or female traits, standard practice in forensic anthropology is to measure dimorphic traits on an ordinal scale. The scale ranges from 1 to 5 and can be interpreted as a range from "Female" to "Probable Female" to "Indeterminate" to "Probable Male" to "Male." These morphological traits are then "*averaged"* by the investigator to estimate sex. The "maleness" or "femaleness" among individuals of various populations may differ due to biological differences in sexual dimorphism, stature and physique, and general robustness.

Discriminant function analyses of linear measures are commonly used and are described in standard anthropology protocols (Bass 2005, Giles 1964, İşcan 2005, Spradley and Jantz 2011, Stein and İşcan 1998). Metric analysis has been shown to be even more accurate for sex estimation than morphological methods alone. Different populations vary in the degree to which they are sexually dimorphic. Therefore, applying one standard to different populations can be precarious (Ferllini 1999). Sexual dimorphism is highly varied by population because of human variation with regard to size. Therefore, it is recommended to use population specific methods for sex estimation when available.

It is not recommended that sex estimation be used for juveniles younger than puberty in a forensic context as method accuracy is not sufficiently high enough for forensic investigations in most cases. Several methods for assessing sex among juvenile remains have been developed (Saunders 2008). However, the reliability of these methods varies with a <80% accuracy rate. Since the goal of creating a biological profile is to limit the potential pool of matches, without falsely excluding a missing child, sex estimation among juveniles is typically left open-ended and age ranges are provided for both boys and girls. Providing age ranges for both juvenile males and females are especially important as males' growth and develop occurs, on average, several years behind females. The *Photographic Atlas for Human Identification,* produced by the research initiative into human identification (NIJ-2008-DN-BX-K163), provides photographic examples of sexually dimorphic variation in the cranial facial region.

# SEX ASSESSMENT – MORPHOLOGICAL TRAITS

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

**1 = FEMALE, 2 = PROBABLE FEMALE, 3= INDETERMINATE, 4=PROBABLE MALE, 5=MALE**

| I. **CRANIUM** | **LEFT** | **MIDLINE** | **RIGHT** |
|---|---|---|---|
| GLABELLA (1-5) | | _____ | |
| SUPRAORBITAL MARGIN (1-5) | _____ | | _____ |
| EXTERNAL NUCHAL PROTURB. (1-5) | | _____ | |
| MASTOID PROCESS (1-5) | _____ | | _____ |
| MENTAL EMINENCE (1-5) | | _____ | |

*(Phenice 1969; Acsádi and Nemeskéri 1970)*

| **CRANIAL FEATURES** | **FEMALE** | **MALE** |
|---|---|---|
| FOREHEAD | VERTICAL | RETREATING |
| NUCHAL LINES | ABSENT/SLIGHT | DEVELOPED |
| SUPRAMEATAL CREST | ABSENT/SLIGHT | DEVELOPED |
| GONIAL ANGLE | >125° | ~90° |

| II. **OS COXA** | **LEFT** | **RIGHT** |
|---|---|---|
| VENTRAL ARC (1-5) | _____ | _____ |
| SUBPUBIC CONCAVITY (1-5) | _____ | _____ |
| ISCHIOPUBIC RAMUS RIDGE (1-5) | _____ | _____ |
| GREATER SCIATIC NOTCH (1-5) | _____ | _____ |
| PREAURICUALR SURFACE (1-5) | _____ | _____ |

*(Phenice 1969; Buikstra and Ubelaker 1994)*

| **PELVIC FEATURES** | **FEMALE** | **MALE** |
|---|---|---|
| SUPERIOR INLET | OVAL SHAPED | HEART SHAPED |
| PUBIC BONE | RECTANGULAR | TRIANGULAR |
| VENTRAL ARC | PRESENT | ABSENT |
| AURICULAR SURFACE | RAISED | FLAT |
| SCARS OF PARTURITION | PRESENT | ABSENT |

| III. **SACRUM** | **FEMALE** | **MALE** |
|---|---|---|
| BODY SHAPE | STRAIGHT | CURVED |
| BODY-TO-ALA RATIO | BODY = ALA | BODY > ALA |
| AURICULAR SURFACE | 1-2 SEGMENTS | 1-3 SEGMENT |

# SEX ASSESSMENT - MORPHOLOGY

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

| | | | SECTIONING POINTS (MM) *(Sectioning points from Bass 2005)* | |
|---|---|---|---|---|
| **IV.** | **HUMERUS** | **MM** | **FEMALE** | **MALE** |
| | MAXIMUM HEAD DIAMETER | _____ | < 43 | > 47 |
| | TRANSVERSE HEAD DIAMETER | _____ | < 37 | > 44 |
| | BIEPICONDYLAR WIDTH | _____ | < 56 | > 63 |
| | SEPTAL APERTURE | | PRESENT | ABSENT |
| **V.** | **STERNUM** | | | |
| | MANUBRIUM LENGTH X 100 / BODY LENGTH | _____ | RATIO >58MM | <43MM |
| **VI.** | **FEMUR** | | | |
| | MAXIMUM HEAD DIAMETER | _____ | < 42.5 | > 47.5 |
| | BICONDYLAR WIDTH | _____ | < 72 | > 78 |
| | MIDSHAFT CIRCUMFERENCE | _____ | | |
| | *AMERICAN INDIANS* | | < 81 | > 81 |
| | *AMERICAN WHITES/BLACKS* | | < 86 | > 86 |
| | HEAD-NECK ANGLE | _____ | ~ 90° | > 120° |
| **VII.** | **TIBIA** | | | |
| | MIDSHAFT CIRCUMFERENCE AT NF | _____ | | |
| | *AMERICAN WHITES* | | *< 90.2* | *> 90.2* |
| | *AMERICAN BLACKS* | | *< 92.8* | *> 92.8* |
| | *AMERICAN INDIANS* | | < 91.2 | > 91.2 |

## SECTIONING POINTS FOR LONG BONE LENGTHS*

### EUROPEAN AMERICAN

| Measurement | Abbrev. | Sectioning Point | Classification Rate |
|---|---|---|---|
| Humerus Maximum Length | HUMXLN | 317 | 63.04 |
| Radius Maximum Length | RADXLN | 233 | 74.22 |
| Ulna Maximum Length | ULNXLN | 251 | 81.06 |
| Femur Maximum Length | FEMXLN | 441 | 78.64 |
| Tibia Condyllo-Malleolar Length | TIBXLN | 355 | 83.62 |
| Fibula Maximum Length | FIBXLN | 359 | 79.85 |

(n = 27 males and 78 females)

### AFRICAN AMERICAN

| Measurement | Abbrev. | Sectioning Point | Classification Rate |
|---|---|---|---|
| Humerus Maximum Length | HUMXLN | 323 | 82.03 |
| Radius Maximum Length | RADXLN | 249 | 82.61 |
| Ulna Maximum Length | ULNXLN | 267 | 83.71 |
| Femur Maximum Length | FEMXLN | 458 | 74.78 |
| Tibia Condyllo-Malleolar Length | TIBXLN | 371 | 76.48 |
| Fibula Maximum Length | FIBXLN | 373 | 79.06 |

(n = 299 males and 139 females)

*American data comes from the Robert J. Terry Collection, Smithsonian Institution, Washington, D.C.

# SEX ESTIMATES FOR EAST EUROPEAN POPULATIONS

## SECTIONING POINTS FOR MAXIMUM FEMUR HEAD DIAMETERS

**MAXIMUM FEMUR HEAD DIAMETERS OF EASTERN EUROPEAN SAMPLES AND EUROPEAN-AMERICANS** *(Jantz et al. 2008)*

| | Males | | | Females | | |
|---|---|---|---|---|---|---|
| Group | N | Mean | S.D. | N | Mean | S.D. |
| Kosovo | 446 | 49.496 | 2.752 | 73 | 43.986 | 2.486 |
| Bosnia | 31 | 50.484 | 2.293 | - | - | - |
| American | 303 | 48.670 | 2.935 | 147 | 42.170 | 2.258 |

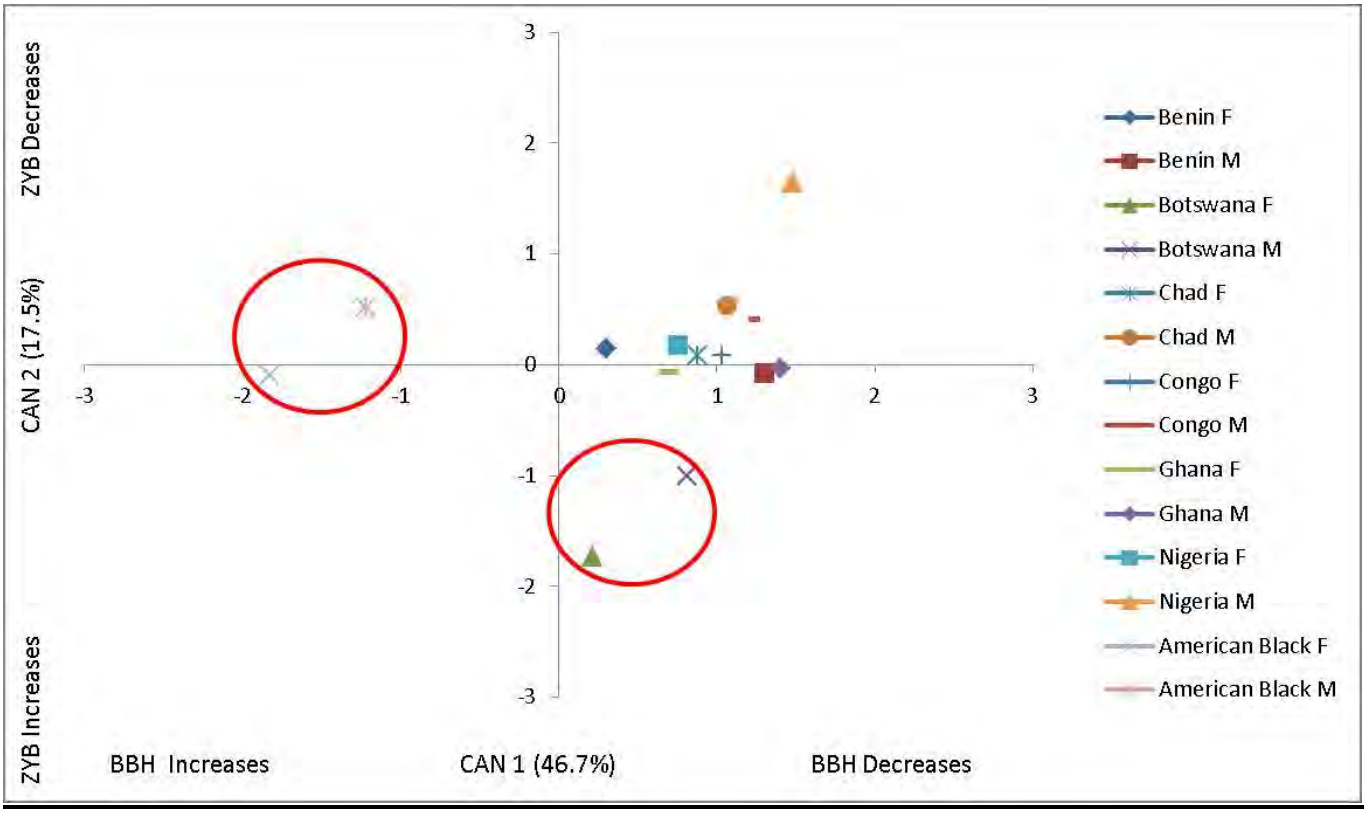
**SECTIONING POINTS FOR MAXIMUM FEMUR HEAD DIAMETERS AND SEX CLASSIFICATION RATES FOR KOSOVANS AND EUROPEAN-AMERICANS** *(Jantz et al. 2008)*

| **Group** | **Sect. Pt** | **Males** | | **Females** | |
|---|---|---|---|---|---|
| | | No. correct | % correct | No. correct | % correct |
| Kosovo | 46.741 | 389/446 | 87.2 | 66/73 | 90.4 |
| American | 45.420 | 271/303 | 89.4 | 134/147 | 91.2 |

# CRANIAL SEXUAL DIMORPHISM AMONG AFRICAN AND DIASPORA POPULATIONS

Craniometric analyses for 331 individuals were used to assess the regional variation of sexual dimorphism in six African populations, representing both western and southern Africa, as well as a comparison to an American population with African and European ancestry. Botswana males and females appear to be the most differentiated of all the groups with the mean value for males 5.76% larger than that for females. Therefore, classification functions and sectioning points for sex estimation differentiating Botswana from Diaspora populations are provided.

**TOTAL CANONICAL STRUCTURE:**



# BOTSWANA SEX ESTIMATION

**BOTSWANA SEX ESTIMATION CLASSIFICATION FUNCTIONS**

| Element | Classification Function |
|---|---|
| Cranium | (0.38309*GOL)+(0.38309*XCB)+(0.67821*ZYB)+(0.21559*BBH)+ (-0.53515*AUB) +(0.41511*NLH)+(-0.8825*NLB)+(-0.89632*OBH)+(-137) |
| Humerus | (0.05902*HUMXLN)+(0.45757*BUE)+(0.53245*HUMEBR)+(-68.20684) |
| Femur | (0.73072*FEMHDD)+(0.21374*FEMEBR)+(-46.22531) |
| Tibia | (0.67289*TIBPEB)+(-47.75888) |

**BOTSWANA SEX ESTIMATION CROSS-VALIDATION**

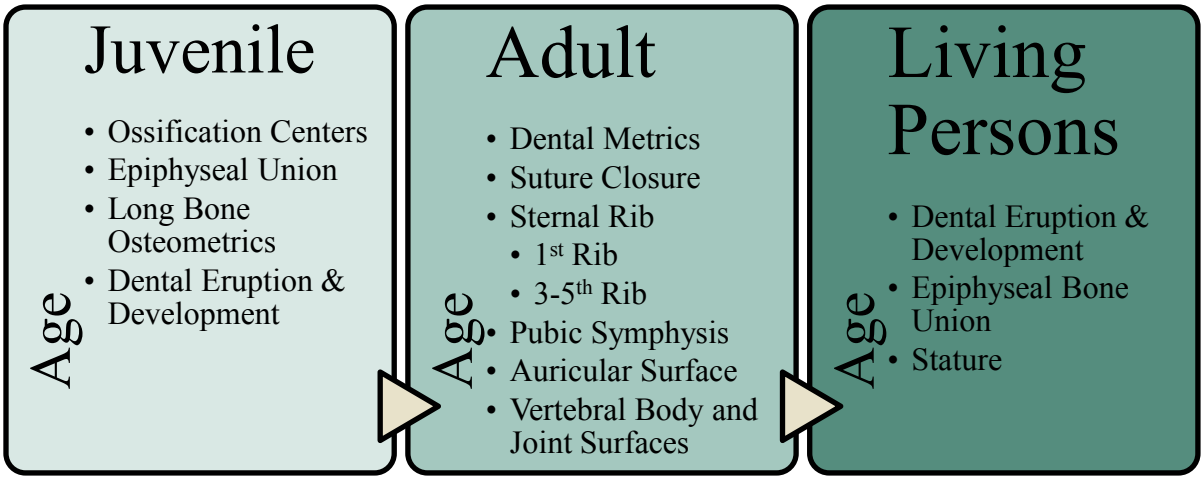
| Element | Male Cross-Validation Rate | Female Cross-Validation Rate | Total Cross-Validation Rate |
|---|---|---|---|
| Cranium | 90.32% | 90.32% | 90.32% |
| Humerus | 85.19% | 92.59% | 88.89% |
| Femur | 88.46% | 92.59% | 90.53% |
| Tibia | 78.57% | 86.67% | 82.62% |

**BOTSWANA SEX ESTIMATION:**
**POSTCRANIAL SECTIONING POINTS AND CROSS-VALIDATED CLASSIFICATION RATES**

| Measurement | Abbrev. | Male (n) | Female (n) | Sectioning Point (mm) | Classification Rate |
|---|---|---|---|---|---|
| Humeral Head Diameter | HUMHDD | 27 | 27 | 40 | 88.89% |
| Humerus Epicondylar Breadth | HUMEBR | 27 | 29 | 57 | 87.29% |
| Humerus Prox. Epiphyseal Breadth | BUE | 27 | 27 | 44 | 87.04% |
| Femoral Head Diameter | FEMHDD | 26 | 27 | 42 | 86.83% |
| Radius A-P Diameter at Midshaft | RADAPD | 26 | 30 | 12 | 85.65% |
| Radius Maximum Length | RADXLN | 25 | 29 | 240 | 85.38% |
| Ulna Maximum Length | ULNXLN | 25 | 29 | 256 | 85.38% |
| Ulna Dorso-Volar Diameter | ULNDVD | 26 | 30 | 15 | 84.23% |
| Radius Max. Diameter of Head | RDH | 26 | 30 | 21 | 83.72% |
| Tibia Prox. Epiphyseal Breadth | TIBPEB | 28 | 28 | 71 | 82.62% |

# BIOMARKERS OF AGE

When collecting data for estimating adult age-at-death, there are multiple techniques that can be used. Many of the techniques on the forms provided in this Protocol can be found in Buikstra and Ubekaler's *Standards for Data Collection from Human Skeletal Remains* (1994). Recalibrated age parameters for diverse populations are listed, where appropriate. *Note that population specific age parameters are only recommended when variation in aging is directly tested and found to be significant.* Population specific measures are not always appropriate and caution should be used when applying different parameters for age estimation. Examples of the variation in biomarkers used at various ages are included. Although there is known variation between male and female individuals for the associated age ranges, for the purposes of this Protocol, the male and female photos were grouped together because of the similar morphology in each phase, except where noted among older aged adults.



# LIVING PERSONS & AGE INTERVALS

Differentiating between juveniles and adults based on dental and skeletal remains is generally guided by the eruption and root development of the second and third molars, fusion of the vertebral body to the epiphyseal rings, fusion of the first and second sacral bodies, and fusion of the medial clavicle. In some cases, the need to provide an age estimate for a living person may arise. In these cases, the questions about identity tend to be whether the person is a juvenile or adult or whether one of two possible identities can be excluded. In both of these scenarios, the ways in which age methods may be applied are different from unknown decedent cases because the objectives may be very different. If the goal of analysis is to construct an age interval for a unknown person, then the age range has to be accurate while still wide enough to not falsely exclude a possible match. The particular type of identification or goal of the analysis should be considered when choosing the right methods and statistical models to estimate age and create an age range.

**CONSTRUCTING AN AGE INTERVAL:** For individual age estimates, numerous skeletal and dental traits can and should be used in combination for each case. *The greater number of variables used, the wider the age range is likely to become or the more information that has to be weighed.* Multiple methods may be particularly useful for determining the lowest and highest end of the range. Berg and Kimmerle (2006) found that strong age correlations exist among multiple investigators, but the correlations erode among older individuals. They also found the following trends:

- Construction of the age-at-death interval is greatly influenced by the results of each scoring method and the confidence each investigator has in a given method.
- The aging techniques are not generally the problem when age estimates are inaccurate; rather there is variation *in how to construct the age intervals.*
- Investigators weigh various techniques differently from one another, and tend to vary on a case-by-case basis.
- Standardized reporting of age intervals by anthropologists to law enforcement and medical examiners who input the data into state and national databanks will aid in the identification process. Any variation in this process such as how data are obtained,

analyzed, and reported risks misclassification. Therefore, the goals and intended purpose of the conclusions should be clear at each stage of the investigation. In other words, depending on what traits are available for review, one may report a wide range, such as 45+ years or a more modified version, such as 40-55 year category. Determining what range to provide is important when thinking about how it is used, and how it may be entered into databases which will then exclude individuals from searches who fall outside of a given parameter.

**THE OVERALL AGE RANGE WILL DEPEND IN PART ON THE CONTEXT AND INTENDED USE OF THE INTERVAL (I.E., TO EXCLUDE/INCLUDE A POSSIBLE IDENTIFICATION) OR TO LIST AGE PARAMETERS IN A DATABASE FOR UNIDENTIFIED REMAINS. BASED ON THE GOAL OF THE INVESTIGATOR, A WIDE OR NARROW AGE INTERVAL MAY BE PREFERRED AND SHOULD BE CONSTRUCTED ACCORDINGLY.**

# ADULT AGE ESTIMATION

## THE SKULL

- **CRANIAL SUTURE CLOSURE**
  - Sutures are open and fuse with age.

- **LAMDENIN TOOTH METRICS**
  - With age, tooth height becomes less, alveolar resorption increases, and root increases in translucency.

- **HYOID FUSION**
  - Fusion of the hyoid body and greater horn is rare under 20 years of age. Partial or complete fusion is common before the fourth decade but may remain unilaterally fused for a long period of time. There are significant differences in timing between males and females.

## THE THORAX

- **1ST STERNAL RIB END**
  - The costal face and tubercle facet change throughout life. The margins of the costal face initially are narrow with a shallow cavity, and become irregular with a filled in cavity as one ages. The tubercle facet is relatively smooth in young adults and morphs into an irregularly shaped facet with micro or macroporosity and lipped margins later in life.

- **4TH STERNAL RIB END**
  - Young adults exhibit a flat billowed surface. With age, the surface become deep, irregular, pitted with porosity and overall the bone exhibits a loss bone density and osteophyte formation around the surface. Increasingly spicules become large and cartilage may ossify.

- **VERTEBRAL BODIES**
  - The rim fuses to the vertebral body in late adolescence. With advancing age, small spicules form on the anterior rim and eventually around the rim. The bodies become depressed in age and irregular in texture. Porosity forms along with osteophytes.

# ADULT AGE ESTIMATION

## THE PELVIS

- **AURICULAR SURFACE OF THE ILIUM**
  - The surface in young adults is evenly billowed and regular in shape.
  - Older aged adults exhibit irregular shape, pitting with either micro- or macro-porosity. Also, osteophytic growth forms around the rim.

- **PUBIC SYMPHYSIS OF THE PUBIC BONE**
  - Young adults exhibit evenly spaced billowing. The rim eventually fills in and the surface becomes smooth. With advanced age, the rim will become irregular and pitted. The bone will lose density. Macroporosity will be evident on surface.

## JOINTS & BONE DENSITY

- **ARTICULAR SURFACES OF JOINTS**
  - With age joints exhibit degenerative processes: including a raised or elevated rim, osteophyte formation, and micro- and macroporosity. In regions where the cartilage becomes destroyed, the two articulating bones may be in direct contact and result in a greater amount of porosity and eburnation.

- **BONE DENSITY**
  - Overall, with age there is a loss of bone density. This may be evident throughout the skeleton, and will be particularly noticeable in areas with a large amount of trabecular bone. It may also be more pronounced in females than males, as females experience greater bone loss with age. Bone density may also vary among populations, as well as throughout the skeleton, which may offset the estimation of age.

# ADULT BIOMARKERS FOR AGE ESTIMATION

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

**FINAL AGE ESITMATE:** _____

**I. CRANIAL SUTURE CLOSURE** *(Meindl and Lovejoy 1985)*
*0=OPEN, 1=MINIMAL, 2=SIGNIFICANT CLOSURE, 3=COMPLETE, 9 =UNOBSERVABLE*

| EXTERNAL CRANIAL VAULT | | INTERNAL CRANIAL VAULT | |
|---|---|---|---|
| MIDLAMDOIDAL | _____ | MID CORONAL | _____ |
| LAMBDA | _____ | MID SAGITTAL | _____ |
| OBELION | _____ | MIDLAMDOIDAL | _____ |
| ANTERIOR SAGITTAL | _____ | | |
| BREGMA | _____ | **INTERNAL SCORE**: | _____ |

**VAULT TOTAL:** _____

MIDCORONAL _____
PTERION _____
SPHENOFRONTAL _____
INTERIOR SPHENOFRONTAL _____
SUPERIOR SPHENOFRONTAL _____

**LATERAL-ANTERIOR TOTAL**:_____

**II. MAXILLARY SUTURE CLOSURE** *(Mann et al. 1987;Buikstra and Ubelaker 1994)*
*0=OPEN, 1=MINIMAL, 2=SIGNIFICANT CLOSURE, 3=COMPLETE, 9 =UNOBSERVABLE*

| Suture Closure | Amount of Closure (0-3) | Age |
|---|---|---|
| Incisive Suture (IN)<br>*20-25 yr. | | |
| Intermaxillary Suture (AMP)<br>*50+ yr. | | |
| Palatomaxillary Suture (TP)<br>Medial *40+ yr.; Lateral *35+ yr. | | |
| Interpalatine Suture (PMP)<br>*25-30 yr. | | |
| Greater Palatine Foramen Suture<br>*30-85 yr. | | |

**Approximate Age of Complete Closure*

# ADULT BIOMARKERS FOR AGE ESTIMATION

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

| **III. PUBIC SYMPHYSIS** | **LEFT** | **RIGHT** | **MEAN AGE & INTERVAL** |
|---|---|---|---|
| AURICULAR SURFACE *(Lovejoy et al. 1985; Meindl and Lovejoy 1989)* | _____ | _____ | _____ |
| SUCHEY-BROOKS (1-6) *(Brooks and Suchey 1990)* | _____ | _____ | _____ |
| BERG (7 PHASES) *(Berg 2008)* | _____ | _____ | _____ |

| **IV. STERNAL RIB END** | **LEFT** | **RIGHT** | **MEAN AGE & INTERVAL** |
|---|---|---|---|
| İŞCAN 4TH RIB | _____ | _____ | _____ |
| DIGANGI 1ST RIB | _____ | _____ | _____ |

*(İşcan et al. 1984; DiGangi et al. 2009)*

| **V. HYOID FUSION** | **LEFT** | **RIGHT** |
|---|---|---|
| FUSION SCORE (0 OR 1) | _____ | _____ |
| MOBILITY SCORE (0 OR 1) | _____ | _____ |

HYOID OBSERVATIONS _____

**VI. LAMENDIN DENTAL METRICS (TOOTH NUMBER_____)** *(Lamendin et al. 1992)*

| **Dental Metrics** | (mm) |
|---|---|
| Tooth Number: | |
| Root Height: | |
| CMJ: | |
| Translucency: | |

**Lamendin Regression Formula**

P = Periodontitis Height (CMJ) * 100 / (Root Height)
T = Translucency Height * 100 / (Root Height)

Age = (0.18 * P) + (0.42 * T) + 25.53

**Lamendin Age Intervals and Pertinent Error Ranges:**

| *Age Intervals* | 26-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70-79 | 80-89 |
|---|---|---|---|---|---|---|---|
| *Mean Error (years)* | 24.8 | 15.5 | 9.9 | 7.3 | 6.3 | 11.6 | 18.9 |

**VII.** VERTEBRAL AND JOINT CHANGES (DESCRIBE ANY AGE RELATED CHANGES – LOCATION, TYPE OF RESPONSE AND EXTENT):

**VIII.** COMMENTS:

# VARIATION IN AGE BIOMARKERS ACROSS POPULATIONS



**Pictured Above:** Pubic symphyses from males (left) aged 80-84 years old, and females (right) aged 80-84 years old. The morphology of the male symphyseal faces appear "younger" than the females with less porosity, lipping and erosion along the rim. The morphological differences result from metabolic/hormonal differences between elderly males and females.

The issue of population variation in aging and the morphological variation due to genetic differences has remained open to debate. It is well established that differences exist between males and females at all ages and among diverse populations. Resolving the issue of whether age parameters can be applied across populations is important since the ability to accurately estimate age among different groups hinges on the issue of what *standard* to use.

There are several possible explanations for apparent population variation. It may be that there are genetic or environmental differences among the populations that affect the adult aging process in terms of the timing of sequential changes. Kemkes-Grottenthaler (2002) suggests significant biological variation in the aging processes of various populations resulting from environmental differences that affect the metabolic rate such as caloric intake and osteoporosis. The large body of research on this topic also supports environmental rather than genetic factors

for observed variation in the timing of age related skeletal changes. Alternatively, population variation may less a question of populations aging "quicker" or "slower" than one another, rather it may be a question of different age distributions among comparative the samples, as suggested by Hoppa (2000). Numerous researchers have demonstrated that age parameters may be biased in the direction of the reference sample, known as *age mimicry*, and have resulted in unreliable age estimators (Bocquet-Appel 1982; Konigsberg et al. 1994). Therefore, caution should be used when applying population specific age parameters.

# AGE ESTIMATION FROM PUBIC SYMPHYSIS

Definitions quoted from Buikstra and Ubelaker 1994:23-24 based on Brooks and Suchey (1990) and Suchey and Katz (1986).

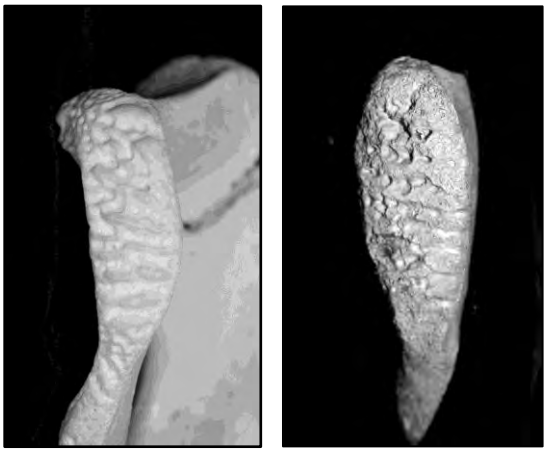
**SUCHEY-BROOKS PUBIC SYMPHYSIS PHASE DESCRIPTIONS**

| | |
|---|---|
| **"Phase I** | Symphyseal face has a billowing surface composed of ridges and furrows which includes the pubic tubercle. The horizontal ridges are well marked. Ventral beveling may be commencing. Although ossific nodules may occur on the upper extremity, a key feature of this phase is the lack of delimitation for either extremity (upper or lower). |
| **Phase II** | Symphyseal face may still show ridge development. Lower and upper extremities show early stages of delimitation, with or without ossific nodules. Ventral rampart may begin formation as extension from either or both extremities. |
| **Phase III** | Symphyseal face shows lower extremity and ventral rampart in process of completion. Fusing ossific nodules may form upper extremity and extend along ventral border. Symphyseal face may either be smooth or retained distinct ridges. Dorsal plateau is complete. No lipping of symphyseal dorsal margin or bony ligamentous outgrowths. |
| **Phase IV** | Symphyseal face is generally fine grained, although remnants of ridge and furrow system may remain. Oval outline usually complete at this stage, though a hiatus may occur in upper aspect of ventral circumference. Pubic tubercle is fully separated from the symphyseal face through definition of upper extremity. Symphyseal face may have a distinct rim. Ventrally, bony ligamentous outgrowths may occur in inferior portion of pubic bone adjacent to symphyseal face. Slight lipping may occur on dorsal border. |
| **Phase V** | Slight depression of the face relative to a completed rim. Moderate lipping is usually found on the dorsal border with prominent ligamentous outgrowths on the ventral border. Little or no rim erosion, though breakdown possible on superior aspect of ventral border. |
| **Phase VI** | Symphseal face shows ongoing depression as rim erodes. Ventral ligamentous attachments are marked. Pubic tubercle may appear as a separate bony nob. Face may be pitted or porous, giving an appearance of disfigurement as the ongoing process of erratic ossification proceeds. Crenelations may occur, with the shape of the face often irregular." |

# AGE VARIATION IN PUBIC SYMPHYSIS

(Phases based on Brooks and Suchey 1990; Suchey and Katz 1986)

**PHASE I**



*Left Photo:*
*European American*
*Male – 13 years*

*Right Photo:*
*Mozambique Male – 20 years*

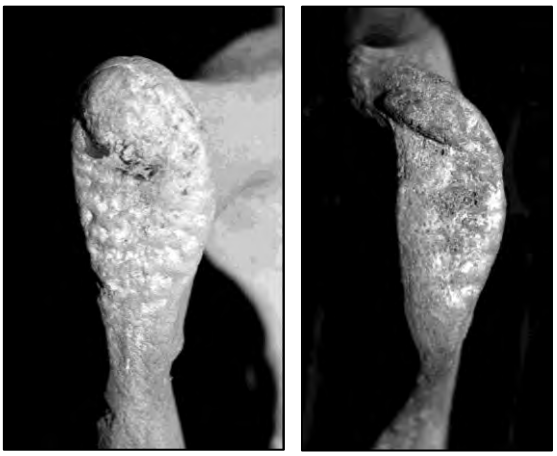
**PHASE II**



*Left Photo:*
*Zimbabwe Male – 18 years*

*Right Photo:*
*European American*
*Female – 22 years*

**PHASE III**



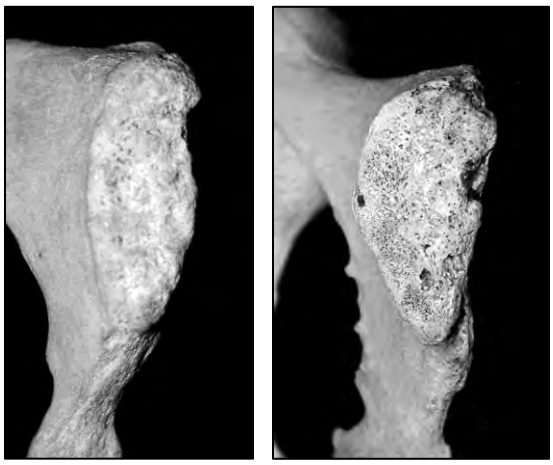
*Left Photo:*
*Mozambique Male – 23 years*

*Right Photo:*
*Malawi Male – 25 years*

# AGE VARIATION IN PUBIC SYMPHYSIS

(Phases based on Brooks and Suchey 1990; Suchey and Katz 1986)

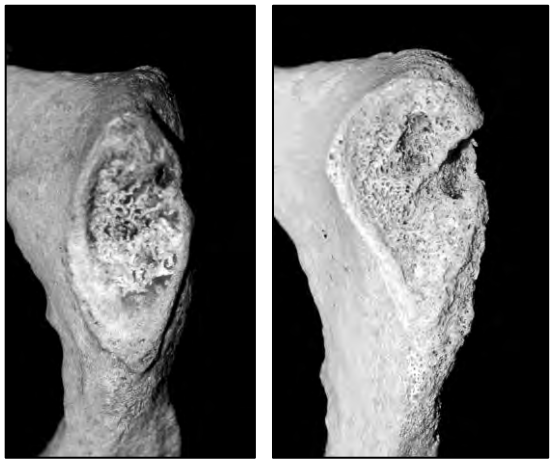
**PHASE IV**



*Left Photo:*
*Botswana Female – 27 years*

*Right Photo:*
*Botswana Female – 56 years*

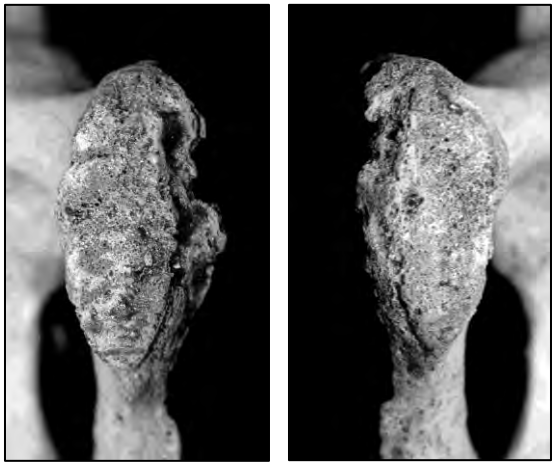
**PHASE V**



*Left Photo:*
*Botswana Male – 75 years*

*Right Photo:*
*Zimbabwe Male – 45 years*

**PHASE VI**



*Left Photo:*
*Mozambique Female –40 years*

*Right Photo:*
*Mozambique Female – 40 years*

## INDIVIDUAL AGE ESTIMATION FOR THE PUBIC SYMPHYSIS REPORTED IN SUCHEY-BROOKS (1990)

| Phase | n | Mean Age (Years) | Standard Deviation | Observed Age Range |
|---|---|---|---|---|
| Males (n=739) | | | | |
| | 1 | 18.5 | 2.1 | 15-23 |
| | 2 | 23.4 | 3.6 | 19-34 |
| | 3 | 28.7 | 6.5 | 21-46 |
| | 4 | 35.2 | 9.4 | 23-57 |
| | 5 | 45.6 | 10.4 | 27-66 |
| | 6 | 61.2 | 12.2 | 34-86 |
| Females (n=273) | | | | |
| | 1 | 19.4 | 2.6 | 15.0 - 24.0 |
| | 2 | 25.0 | 4.9 | 19.0 - 40.0 |
| | 3 | 30.7 | 8.1 | 21.0 - 53.0 |
| | 4 | 38.2 | 10.9 | 26.0 - 70.0 |
| | 5 | 48.1 | 14.6 | 25.0 - 83.0 |
| | 6 | 60.0 | 12.4 | 42.0 - 87.0 |

## INDIVIDUAL AGE ESTIMATION FOR THE PUBIC SYMPHYSIS AMONG AN AMERICAN POPULATION

*Descriptive statistics for each Suchey-Brooks symphyseal phase, American sample.*

| Phase | | n | Mean Age (Years) | SE (Mean) | 95% CI (Mean) | Standard Deviation | Observed Age Range |
|---|---|---|---|---|---|---|---|
| Males | | | | | | | |
| | 1 | 318 | 19.9 | 0.19 | 19.6 - 20.4 | 3.462 | 15.0 - 65.0 |
| | 2 | 215 | 26.6 | 0.57 | 25.5 - 27.7 | 8.364 | 17.0 - 78.0 |
| | 3 | 95 | 31.5 | 1.00 | 29.5 - 33.5 | 9.772 | 22.0 - 70.0 |
| | 4 | 386 | 40.4 | 0.65 | 39.1 - 41.7 | 12.726 | 20.0 - 88.0 |
| | 5 | 399 | 51.7 | 0.76 | 50.2 - 53.2 | 15.140 | 21.0 - 98.0 |
| | 6 | 145 | 61.3 | 1.19 | 58.9 - 63.6 | 14.361 | 23.0 - 92.0 |
| Females | | | | | | | |
| | 1 | 46 | 21.9 | 0.65 | 20.6 - 23.2 | 4.435 | 16.0 - 40.0 |
| | 2 | 79 | 31.7 | 1.19 | 29.4 - 34.1 | 10.603 | 18.0 - 74.0 |
| | 3 | 24 | 36.5 | 2.39 | 31.5 - 41.5 | 11.739 | 20.0 - 66.0 |
| | 4 | 146 | 44.3 | 1.09 | 42.1 - 46.4 | 13.223 | 22.0 - 95.0 |
| | 5 | 110 | 55.7 | 1.74 | 52.2 - 59.1 | 18.210 | 22.0 - 101.0 |
| | 6 | 113 | 59.8 | 1.94 | 56.0 - 63.7 | 20.619 | 21.0 - 102.0 |
| Total | | | | | | | |
| | 1 | 364 | 20.2 | 0.19 | 19.8 - 20.6 | 3.647 | 15.0 - 65.0 |
| | 2 | 294 | 28.0 | 0.54 | 26.9 - 29.0 | 9.286 | 17.0 - 78.0 |
| | 3 | 119 | 32.5 | 0.95 | 30.6 - 34.4 | 10.343 | 20.0 - 70.0 |
| | 4 | 532 | 41.5 | 0.56 | 40.3 - 42.6 | 12.968 | 20.0 - 95.0 |
| | 5 | 509 | 52.5 | 0.71 | 51.2 - 53.9 | 15.920 | 21.0 - 101.0 |
| | 6 | 258 | 60.6 | 1.08 | 58.5 - 62.8 | 17.360 | 21.0 - 102.0 |

*(Kimmerle et al. 2008)*

## INDIVIDUAL AGE ESTIMATION FOR THE PUBIC SYMPHYSIS AMONG NIGERIAN POPULATIONS

*Descriptive statistics for Suchey-Brooks pubic symphyseal phases, Nigerian Sample.*

| Phase | *n* | Mean Age (Years) | 95% CI Mean Age | Standard Deviation | Observed Age Range |
|---|---|---|---|---|---|
| Males (n=159) | | | | | |
| 1 | 15 | 15.7 | 23.9 – 39.6 | 4.0 | 11-22 |
| 2 | 12 | 31.7 | 23.9 – 26.5 | 12.4 | 17-54 |
| 3 | 23 | 38.7 | 33.3 – 44.2 | 12.3 | 23-71 |
| 4 | 31 | 41.0 | 36.0 – 46.0 | 13.7 | 25-71 |
| 5 | 46 | 53.3 | 49.2 – 57.4 | 13.8 | 27 - 81 |
| 6 | 24 | 60.3 | 25.2 - 95.5 | 14.2 | 44 - 69 |
| Females (n=75) | | | | | |
| 1 | 4 | 24.3 | 15.6 - 32.9 | 5.4 | 20 - 32 |
| 2 | 5 | 31.0 | 22.1 - 39.9 | 7.2 | 20 - 40 |
| 3 | 24 | 38.5 | 33.2 - 43.8 | 11.6 | 23 - 69 |
| 4 | 12 | 46.1 | 37.2 – 54.9 | 13.9 | 27 - 79 |
| 5 | 17 | 51.4 | 43.2 – 59.6 | 16.0 | 30 - 75 |
| 6 | 10 | 52.8 | 39.2 – 65.6 | 15.7 | 32 - 74 |

## INDIVIDUAL AGE ESTIMATION FOR THE PUBIC SYMPHYSIS AMONG BALKAN POPULATIONS

*Descriptive statistics for Suchey-Brooks pubic symphyseal phases, Balkan Sample.*

| Phase | *n* | Mean Age (Years) | 95% CI Mean Age | Standard Deviation | Observed Age Range |
|---|---|---|---|---|---|
| Males | | | | | |
| 1 | 13 | 20.3 | 18.9 - 21.7 | 2.25 | 17.0 - 25.9 |
| 2 | 6 | 24.2 | 19.1 - 29.2 | 4.79 | 20.0 - 33.0 |
| 3 | 21 | 30.5 | 27.0 - 33.9 | 7.53 | 22.0 - 45.0 |
| 4 | 66 | 42.6 | 39.7 - 45.5 | 11.88 | 24.0 - 74.0 |
| 5 | 71 | 48.7 | 45.9 - 51.4 | 11.47 | 23.7 - 74.0 |
| 6 | 37 | 62.7 | 58.2 - 67.2 | 13.42 | 34.0 - 85.0 |
| Females | | | | | |
| 1 | 9 | 20.3 | 17.7 - 22.9 | 3.39 | 17.0 - 28.0 |
| 2 | 1 | 22.0 | - | - | - |
| 3 | 7 | 30.3 | 23.4 - 37.1 | 7.43 | 21.0 - 44.0 |
| 4 | 9 | 44.2 | 34.1 - 54.3 | 13.11 | 26.0 - 65.0 |
| 5 | 9 | 53.6 | 40.8 - 66.4 | 16.65 | 27.0 - 79.0 |
| 6 | 49 | 68.1 | 63.8 - 72.3 | 14.79 | 33.0 - 96.0 |
| Total | | | | | |
| 1 | 22 | 20.3 | 19.1 - 21.5 | 2.69 | 17.0 - 28.0 |
| 2 | 7 | 23.9 | 19.8 - 28.0 | 4.56 | 21.0 - 33.0 |
| 3 | 28 | 30.4 | 27.6 - 33.3 | 7.37 | 21.0 - 45.0 |
| 4 | 75 | 42.8 | 40.0 - 45.5 | 11.95 | 24.0 - 74.0 |
| 5 | 80 | 49.2 | 46.5 - 51.9 | 12.13 | 23.7 - 79.0 |
| 6 | 86 | 65.8 | 62.7 - 68.8 | 14.39 | 33.0 - 96.0 |

*(Kimmerle et al. 2008)*

## HIGHEST POSTERIOR DENSITY REGION FOR PUBIC SYMPHYSEAL PHASE - COMBINED MALES/FEMALES, BALKAN HAZARD MODEL

| Pubic Symphyseal Phase | Posterior Density (years) | CI | Lower - Upper Bound (years) |
|---|---|---|---|
| Phase 1 | -- | 95% | 15.0 - 24.8 |
| | | 90% | 15.0 - 23.4 |
| | | 75% | 15.0 - 21.1 |
| | | 50% | 15.0 - 18.7 |
| Phase 2 | 23.3 | 95% | 16.6 - 30.1 |
| | | 90% | 17.6 - 29.2 |
| | | 75% | 19.2 - 27.4 |
| | | 50% | 20.9 - 25.7 |
| Phase 3 | 28.0 | 95% | 20.0 - 42.9 |
| | | 90% | 20.9 - 39.5 |
| | | 75% | 22.6 - 35.7 |
| | | 50% | 24.6 - 32.2 |
| Phase 4 | 39.7 | 95% | 20.6 - 64.6 |
| | | 90% | 23.1 - 61.5 |
| | | 75% | 27.4 - 54.8 |
| | | 50% | 32.1 - 48.3 |
| Phase 5 | 50.9 | 95% | 20.8 - 74.5 |
| | | 90% | 25.3 - 71.6 |
| | | 75% | 33.1 - 66.2 |
| | | 50% | 40.6 - 60.3 |
| Phase 6 | 67.3 | 95% | 39.8 - 88.7 |
| | | 90% | 44.5 - 85.7 |
| | | 75% | 51.8 - 80.7 |
| | | 50% | 58.4 - 75.4 |

*(Kimmerle et al. 2008)*

## HIGHEST POSTERIOR DENSITY REGION FOR EACH PUBIC SYMPHYSEAL PHASE AMONG MALES, BALKAN SAMPLE

| Pubic Symphyseal Phase | Posterior Density (years) | CI | Lower - Upper Bound (years) |
|---|---|---|---|
| Phase 1 | -- | 95% | 15.0 - 23.9 |
| | | 90% | 15.0 - 22.6 |
| | | 75% | 15.0 - 20.5 |
| | | 50% | 15.0 - 18.4 |
| Phase 2 | 23.2 | 95% | 17.4 - 29.9 |
| | | 90% | 18.2 - 28.9 |
| | | 75% | 19.6 - 27.0 |
| | | 50% | 21.0 - 25.4 |
| Phase 3 | 27.8 | 95% | 20.1 - 41.9 |
| | | 90% | 20.9 - 39.4 |
| | | 75% | 22.5 - 35.4 |
| | | 50% | 24.5 - 31.9 |
| Phase 4 | 39.7 | 95% | 19.9 - 67.4 |
| | | 90% | 22.4 - 63.1 |
| | | 75% | 26.8 - 55.9 |
| | | 50% | 31.7 - 48.9 |
| Phase 5 | 52.8 | 95% | 20.6 - 76.3 |
| | | 90% | 25.4 - 73.6 |
| | | 75% | 33.7 - 68.3 |
| | | 50% | 41.9 - 62.4 |
| Phase 6 | 69.0 | 95% | 42.3 - 89.6 |
| | | 90% | 47.0 - 86.7 |
| | | 75% | 54.0 - 81.9 |
| | | 50% | 60.5 - 76.8 |

*(Kimmerle et al. 2008)*

## HIGHEST POSTERIOR DENSITY REGION FOR EACH PUBIC SYMPHYSEAL PHASE AMONG FEMALES, BALKAN SAMPLE

| Pubic Symphyseal Phase | Posterior Density (years) | CI | Lower - Upper Bound (years) |
|---|---|---|---|
| Phase 1 | -- | 95% | 15.0 - 31.9 |
| | | 90% | 15.0 - 28.6 |
| | | 75% | 15.0 - 23.9 |
| | | 50% | 15.0 - 19.9 |
| Phase 2 | 22.4 | 95% | 15.0 - 38.9 |
| | | 90% | 15.0 - 35.1 |
| | | 75% | 16.3 - 30.6 |
| | | 50% | 18.5 - 26.9 |
| Phase 3 | 26.5 | 95% | 15.0 - 47.0 |
| | | 90% | 16.2 - 43.8 |
| | | 75% | 18.7 - 37.8 |
| | | 50% | 21.6 - 32.6 |
| Phase 4 | 35.3 | 95% | 19.7 - 66.1 |
| | | 90% | 21.4 - 60.1 |
| | | 75% | 24.7 - 51.2 |
| | | 50% | 28.5 - 43.8 |
| Phase 5 | 44.9 | 95% | 26.2 - 77.9 |
| | | 90% | 28.4 - 72.9 |
| | | 75% | 32.2 - 64.3 |
| | | 50% | 36.7 - 55.7 |
| Phase 6 | 74.9 | 95% | 40.6 - 93.3 |
| | | 90% | 45.5 - 91.2 |
| | | 75% | 54.5 - 87.5 |
| | | 50% | 63.6 - 83.2 |

*(Kimmerle et al. 2008)*

# AGE ESTIMATION FROM STERNAL RIBS

(Definitions quoted from Bass 2005 based on İşcan *et al.* 1984 and 1985)

**Male Sternal Rib Phase Descriptions**

| | |
|---|---|
| **"Phase 0** | The articular surface is flat or billowy with a regular rim and round edges. The bone itself is smooth, firm, and very solid. |
| **Phase I** | Amorphous indentation is beginning to show in the articular surface, but billowing still may be present. The rim is rounded and regular. In some cases, scallops may start to appear at the edges. The bone is still firm and solid. |
| **Phase II** | The pit is now deeper and has assumed a V-shaped appearance formed by the anterior and posterior walls. The walls are thick and smooth with a scalloped or slightly wavy rim with rounded edges. The bone is firm and solid. |
| **Phase III** | The deepening pit has taken on a narrow-to-moderate U-shape. Walls still are fairly thick with rounded edges. Some scalloping still may be present, but the rim is becoming more irregular. The bone is still quite firm and solid. |
| **Phase IV** | Pit depth is increasing, but the shape still is a narrow to moderately wide U. The walls are thinner, but the edges remain rounded. The rim is more irregular, with no uniform scalloped pattern remaining. There is some decrease in the weight and firmness of the bone. The overall quality of the bone, however, still is good. |
| **Phase V** | There is little change in pit depth, but the shape in this phase is predominantly a moderately wide U. Walls show further thinning, and the edges are becoming sharp. Irregularity is increasing in the rim. The scalloped pattern is gone completely and has been replaced with irregular bony projections. The condition of the bone is fairly good. There are, however, some signs of deterioration, with evidence of porosity and loss of density. |
| **Phase VI** | The pit is noticeably deep with a wide U-shape. The walls are thin with sharp edges. The rim is irregular and exhibits some rather long bony projections that frequently are more pronounced at the superior and inferior borders. The bone is noticeably lighter in weight, thinner, and more porous, especially inside the pit. |
| **Phase VII** | The pit is deep, with a wide to very wide U-shape. The walls are thin and fragile with sharp, irregular edges and bony projections. The bone is light in weight and brittle, with significant deterioration in quality and obvious porosity. |
| **Phase VIII** | The pit is very deep and widely U-shaped. In some cases, the floor of the pit is absent or filled with bony projections. The walls are extremely thin, fragile, and brittle, with sharp, highly irregular edges and bony projections. The bone is very light weight, thin, brittle, friable, and porous. "Window" formation sometimes is seen in the walls." |

# AGE ESTIMATION FROM STERNAL RIBS

(Definitions quoted from Bass 2005 based on İşcan *et al.* 1984 and 1985)

**Female Sternal Rib Phase Descriptions**

| | |
|---|---|
| **"Phase 0** | The regular, rounded rim of the articular rim is bordered externally by a bony overlay. The medial surface of the juvenile rib is ridged or billowy with no pit formation. |
| **Phase I** | The still smooth, rounded, rim is now slightly more wavy. Initial pit indentation begins, with billowing still present on the articular surface. |
| **Phase II** | The rounded, wavy rim is first beginning to show some scallops forming at the edge. The pit is now V-shaped and surrounded by thick, smooth walls. |
| **Phase III** | The rounded rim now exhibits a pronounced, regular scalloped pattern. The still V-shaped pit has widened as the walls flare and thin slightly, but there is only a modest, if any, increase in depth. |
| **Phase IV** | Phase IV clearly shows the central arc. Scallops remain at the still rounded rim, but the divisions are not as pronounced, and the edges look somewhat worn down. The noticeably deeper, flared V- or U-shaped pit has widened again as the walls become thinner. Some plaque-like deposit may begin to form in the pit. |
| **Phase V** | No regular scalloping remains at the now sharpened edge of the increasingly irregular rim. The central arc is still present. The interior pit is now a very flared V or U with appreciably thinner walls and may contain plaque-like deposit covering most of the interior of the pit. |
| **Phase VI** | The central arc is less obvious on the sharp rim, which is starting to show irregular projections of bone. There is a noticeably deeper and wider U-shaped pit with thinning walls, along with increased roughening and porosity inside the pit. Porosity and deterioration of bone can also be seen inside the pit. |
| **Phase VII** | The central arc is obscured as the rim becomes very sharp and irregular. The depth of the flared U-shaped pit appears slightly shallower than in the proceeding phase. Bony projections can be seen arising from bone the rim and floor of the pit, along with evident deterioration of the bone itself. |
| **Phase VIII** | An extremely sharp, irregular rim with brittle projections of bone is now prominent at the superior and/or inferior margins of the rib. Projections also are seen extending from the floor of the pit. These bony processes can be seen nearly filling the widely U-shaped pit surrounded by very thin, badly deteriorated, porous walls with "window" formation." |

# STERNAL RIB AGING TECHNIQUE

(Iscán *et al.* 1984 and 1985)

## PHASE 0



*Euro-American Male – 13 years*

## PHASE I



*Mozambique Male – 23 years*

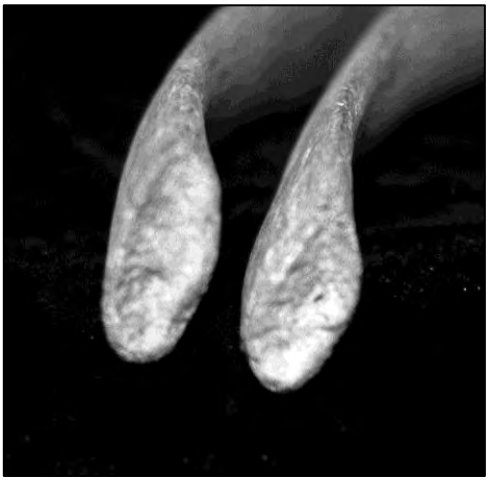


*Zimbabwe Male – 18 years*

## PHASE II



*Euro-American Female – 22 years*



*Malawi Male – 25 years*

# STERNAL RIB AGING TECHNIQUE

(Iscán *et al.* 1984 and 1985)

## PHASE III



*Botswana Female – 27 years*

## PHASE IV



*Malawi Male – 39 years*

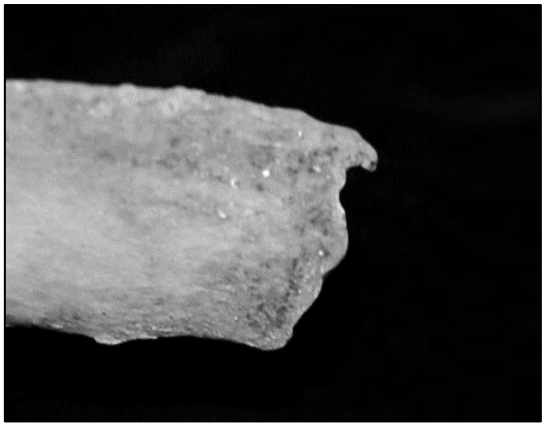


*Botswana Female – 32 years*

## PHASE V



*Mozambique Female – 40 years*

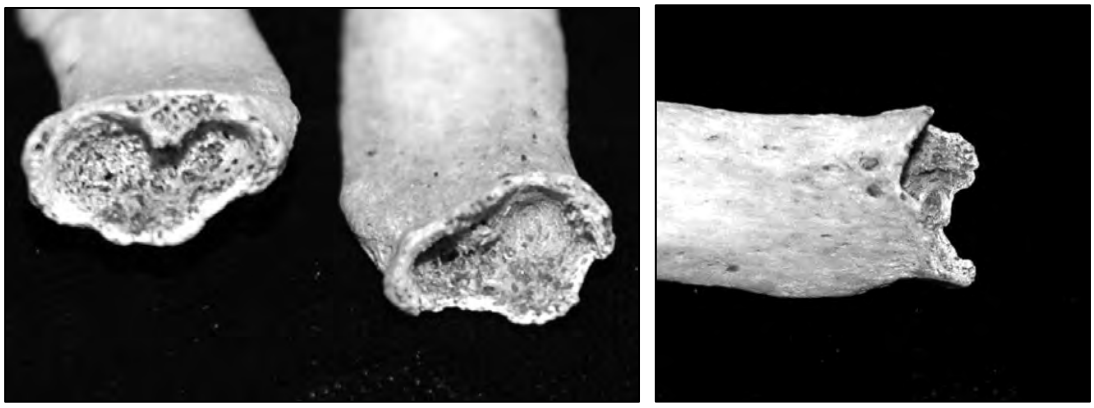


*Botswana Female – 32 years*

# STERNAL RIB AGING TECHNIQUE

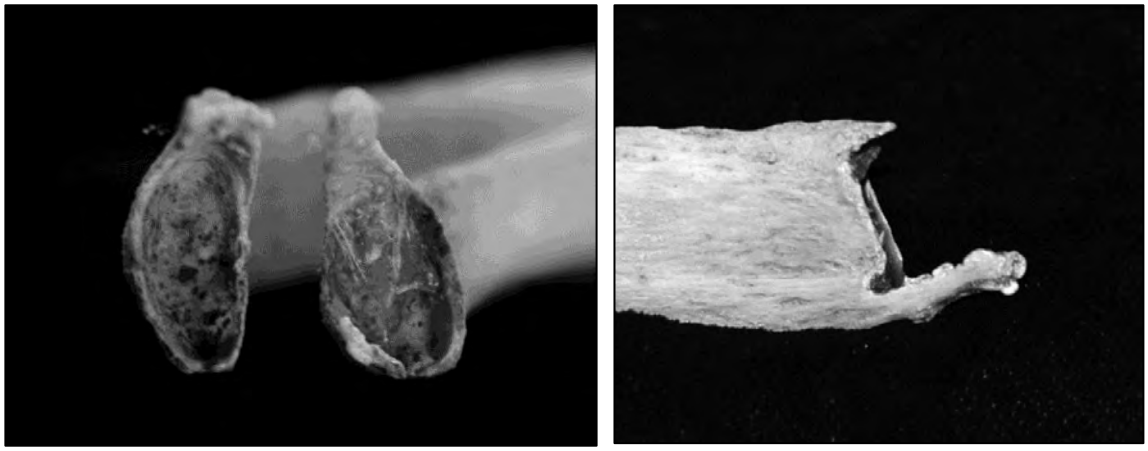
(Iscán *et al.* 1984 and 1985)

## PHASE VI



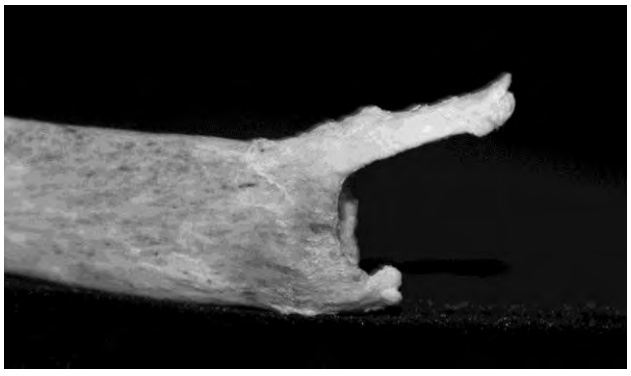
*(Both Photos)Botswana Male – 49 years*

## PHASE VII



*Euro-American Male – 62 years* *Botswana Male – 58 years*

## PHASE VIII



*Euro-American Male – 65 years*

## INDIVIDUAL AGE ESTIMATION FOR THE STERNAL 4TH RIBS AMONG AMERICAN POPULATIONS

(LOTH AND İŞCAN 1989)

| | 4th Rib Phase | 95% Age Range (Years) |
|---|---|---|
| US Males (n=118) | 0 | <13 |
| | 1 | 14-15 |
| | 2 | 16-19 |
| | 3 | 20-24 |
| | 4 | 24-32 |
| | 5 | 33-46 |
| | 6 | 43-58 |
| | 7 | 59-71 |
| | 8 | |
| US Females (n=86) | 0 | <16 |
| | 1 | 17-19 |
| | 2 | 20-23 |
| | 3 | 24-28 |
| | 4 | 25-32 |
| | 5 | 33-42 |
| | 6 | 43-55 |
| | 7 | >55 |
| | 8 | |

## INDIVIDUAL AGE ESTIMATION FOR STERNAL RIB IN BALKAN POPULATIONS

*Population-specific standards of age for the sternal rib end for Balkan males.*

| Rib Phase | Posterior Density (years) | CI | Lower - Upper Bound (years) |
|---|---|---|---|
| Phases 1 & 2 | 17.0 | 95% | 15.0-25.60 |
| | | 90% | 15.0-23.74 |
| | | 75% | 15.0-20.88 |
| | | 50% | 15.0-18.27 |
| Phase 3 | 24.97 | 95% | 15.23-45.33 |
| | | 90% | 16.14-41.51 |
| | | 75% | 17.99-35.76 |
| | | 50% | 20.43-30.80 |
| Phase 4 | 28.80 | 95% | 15.0-53.55 |
| | | 90% | 15.0-48.77 |
| | | 75% | 15.88-41.53 |
| | | 50% | 20.79-36.76 |
| Phase 5 | 47.10 | 95% | 19.89-72.24 |
| | | 90% | 23.72-68.92 |
| | | 75% | 30.45-62.94 |
| | | 50% | 37.29-56.62 |
| Phase 6 | 54.10 | 95% | 21.50-78.15 |
| | | 90% | 36.39-75.29 |
| | | 75% | 34.84-69.85 |
| | | 50% | 43.05-63.79 |
| Phase 7 | 60.58 | 95% | 29.67-83.26 |
| | | 90% | 34.98-80.23 |
| | | 75% | 43.20-74.97 |
| | | 50% | 50.73-69.38 |
| Phase 8 | 69.85 | 95% | 41.42-90.39 |
| | | 90% | 46.52-87.58 |
| | | 75% | 54.14-82.79 |
| | | 50% | 60.99-77.76 |

*(Kimmerle and Konigsberg 2009)*

## INDIVIDUAL AGE ESTIMATION FOR STERNAL RIB IN BALKAN POPULATIONS

*Population-specific standards of age for the sternal rib end for Balkan females*.*

| Rib Phase | Posterior Density (years) | CI | Lower - Upper Bound (years) |
|---|---|---|---|
| Phases 1-4 | -- | 95% | 15.0-32.76 |
| | | 90% | 15.0-29.56 |
| | | 75% | 15.0-24.70 |
| | | 50% | 15.0-20.32 |
| Phase 5 | 52.79 | 95% | 18.38-80.67 |
| | | 90% | 22.64-77.93 |
| | | 75% | 30.84-72.10 |
| | | 50% | 39.73-64.94 |
| Phase 6 | 63.07 | 95% | 24.13-86.02 |
| | | 90% | 29.89-83.53 |
| | | 75% | 40.01-78.76 |
| | | 50% | 50.09-73.17 |
| Phase 7 | 70.67 | 95% | 40.73-89.75 |
| | | 90% | 46.11-87.29 |
| | | 75% | 54.27-83.03 |
| | | 50% | 61.56-78.37 |
| Phase 8 | 80.95 | 95% | 57.79-96.20 |
| | | 90% | 62.04-94.21 |
| | | 75% | 68.37-90.74 |
| | | 50% | 73.94-87.0 |

**The small number of females represented in the second, third and fourth phases precluded the development of reliable standards for these phases (Kimmerle and Konigsberg 2009).*

# HYOID FUSION

Ossification of the hyoid bone occurs slowly over time and as the greater cornua fuses with the hyoid body, chances of traumatic injuries increase (Dionne et al. 2011; Seasons et al. 2011). Wide variation exists in the unilateral and bilateral fusion patterns of the hyoid bone. Unilateral fusion was observed as early as at 8 years of age while bilateral fusion was first visible in a 23 year-old. Fusion and mobility are scored as "Open" or "Closed." Fusion refers to the amount of bone that is fused, as determined by direct observation or on x-rays. Mobility is measured as a stress test and whether the two bones are flexible as measured at autopsy following dissection. Measures of fusion and mobility are important connections in cases of hanging or strangulation.

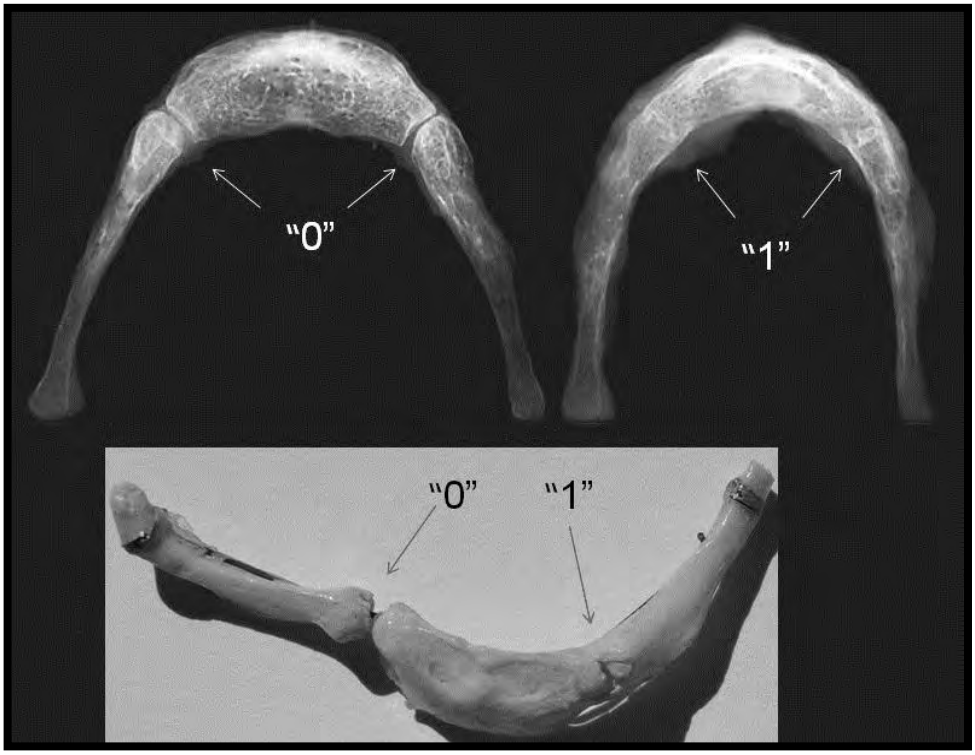
**SCORING SYSTEM**

**FUSION: (PICTURED BELOW)**

- **"0": COMPLETELY UNFUSED CORNUA**
- **"1": PARTIALLY OR COMPLETELY FUSED CORNUA**

**MOBILITY:**

- **"0": COMPLETELY UNFUSED CORNUA**
- **"1": PARTIALLY OR COMPLETELY FUSED CORNUA**



# HYOID FUSION

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

---

I. FINAL AGE ESTIMATE: **LIST AGE ESTIMATION**

II. PRESENCE OF HYOID TRAUMA: **DESCRIBE LOCATION AND TYPE OF FRACTURE (I.E., COMPLETE OR INCOMPLETE)**

III. IS THE MECHANISM OF INJURY KNOWN? **LIST MECHANISM OF HYOID FRACTURE IF KNOWN (I.E., MANUAL STRANGULATION, LIGATURE STRANGULATION, HANGING, BLUNT TRAUMA)**

IV. FUSION SCORE: **SCORE 0 OR 1**
- "0": COMPLETELY UNFUSED CORNUA
- "1": PARTIALLY OR COMPLETELY FUSED CORNUA

V. IS THIS SCORE BASED ON DIRECT OBSERVATION OR FROM X-RAY FILM? **LIST METHOD OF OBSERVATION**

VI. MOBILITY SCORE: **SCORE 0 OR 1**
- "0": COMPLETELY UNFUSED CORNUA
- "1": PARTIALLY OR COMPLETELY FUSED CORNUA

**GENERAL AGE TRENDS:**

- Fusion observed as young as 8 years old, and completely open at 80 years old.
- Unilateral fusion most common by 35-45 years.
- Bilateral fusion may occur 20-29 years, average age of bilateral fusion is 51 years.
- No significant differences among groups based on ancestry.
- Significant differences observed for males/females. Males tend to fuse at younger ages than females by several years.
- Individuals with a history of substance abuse also demonstrated bilateral fusion at an earlier age (48.93 years) than non-drug users (53.88 years).
- Hyoid fractures are more common when fusion is present than in non-fused hyoids.
- Hyoid fractures observed in cases of hanging, manual and ligature strangulation.

# JUVENILE BIOMARKERS FOR AGE ESTIMATION

Juvenile age estimation is based on dental development, dental eruption, epiphyseal union, and long bone length. Several sources provide methods and recommendations for aging juveniles (Bass 2005, Scheuer and Black 2000, Schaefer *et al.* 2009).

- **DENTAL CALCIFICATION:** Tooth formation begins with the formation of cusps within the alveolus and terminates with the closure of the root apices. Any estimation about age from dental remains should include gross inspection and radiographic analysis. The development of each tooth should be compared to the chart and age parameters provided by Moorees et al. (1963), the preferred reference. In addition, for third molar development, refer to Mincer et al. (1993). This method is most useful during childhood, when mixed dentition is present, but can also be used to distinguish juveniles from adults during late adolescence. Therefore, this method is also effective for estimating age of living individuals.

- **DENTAL ERUPTION:** Dental eruption refers to the pattern and timing of teeth through the alveolar process and gum line. Refer to the dental charts provided by Ubelaker (1989) for age parameters.

- **EPIPHYSEAL FUSION:** The timing of the appearance of epiphyses and their fusion to articular aspects of bone (i.e. the humeral head and humeral shaft) are useful for aging juvenile remains, infancy to 30 years old, but is most useful during adolescence. This method is scored as fusion beginning, partial or complete. Note that the line of fusion may be evident for some period of time following union and should be noted as such (Krogman and İşcan 1986).

- **LONG BONE LENGTHS**: The maximum length of long bones, as well as the length and diameter of cranial bones are useful for estimating age, particularly for infants and toddlers (Ubelaker 1978; Scheuer and Black 2000).



# JUVENILE BIOMARKER FORM

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**FINAL AGE ESITMATE:** _____

**I. Dental Development** *(Mincer et al. 1993 and Moorees, Fanning, and Hunt 1963a, b)*

*Deciduous*

Maxillary I1 _____ I2 _____ C _____ M1 _____ M2 _____

Mandibular I1 _____ I2 _____ C _____ M1 _____ M2 _____

*Permanent*

Maxillary I1 _____ I2 _____ C _____ PM1_____ PM2 _____ M1 _____ M2 _____ M3 _____

Mandibular I1 _____ I2 _____ C _____ PM1_____ PM2 _____ M1 _____ M2 _____ M3 _____

**II. Dental Eruption** *(Ubelaker 1978):* AGE _____

ESTIMATE AGE RANGE ACCORDING TO ERUPTION CHART

**III. Epiphyseal Union** (0-3) *(Krogman and İşcan 1986)* AGE _____

CODE EPIPHYSEAL UNION FROM 0 (UNFUSED) TO 3 (COMPLETELY FUSED)

| | | | |
|---|---|---|---|
| Metopic suture | _____ | Clav.sternal end | _____ |
| Mental symphysis | _____ | Humerus, prox. | _____ |
| Lateral to Basilar | _____ | Humerus, distal | _____ |
| Lateral to Squamous | _____ | Humerus, epicondyle | _____ |
| Basilar suture | _____ | Radius, prox. | _____ |
| C: halves to arch | _____ | Radius, distal | _____ |
| C: arch to centrum | _____ | Ulna, distal | _____ |
| C: vert. sup. rim | _____ | Illium to Pubis | _____ |
| C: vert. inf. rim | _____ | Ischium to Pubis | _____ |
| T: halves to arch | _____ | Ischium to Illium | _____ |
| T: arch to centrum | _____ | Ischial tuberosity | _____ |
| T: vert. sup. rim | _____ | Iliac crest | _____ |
| T: vert. inf. rim | _____ | Femur, prox. | _____ |
| L: halves to arch | _____ | Femur, gr. troch. | _____ |
| L: arch to centrum | _____ | Femur, lsr. troch. | _____ |
| L: vert. sup. rim | _____ | Femur, distal | _____ |
| L: vert. inf. rim | _____ | Tibia, prox. | _____ |
| Scap.glenoid cavity | _____ | Tibia, distal | _____ |
| Scap.acromion | _____ | Fibula, prox. | _____ |
| Scap.inf. angle | _____ | Fibula, distal | _____ |
| Scap.medial border | _____ | S1-S2 _____ | S3-S4 _____ |
| Clav.sternal end | _____ | S2-S3 _____ | S4-S5 _____ |

# JUVENILE BIOMARKER FORM

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
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MEASURE UNFUSED CRANIAL ELEMENTS AND DIAPHYSES (NOT INCLUDING EPIPHYSES) AND ESTIMATE AGE ACCORDING TO REFERENCE.

**IV. Juvenile Cranial Measurements** (in mm) AGE _____
*(Age parameters found in Schaefer et al. 2009)*

Occipital Bone:

Basilaris Max. Width _____

Basilaris Sagittal Length _____

Sphenoid:

Body Length _____

Body Width _____

| Temporal Bone: | LEFT | RIGHT |
|---|---|---|
| Squama Height | | |
| Squama Width | | |
| Pars Petrosa Length | | |
| Pars Petross Width | | |

**V. Juvenile Postcranial Measurements** (in mm) AGE _____
*(Age parameters found in Ubelaker 1978)*

| | LEFT | RIGHT |
|---|---|---|
| Clavicle Max. Length | | |
| Scapula Max. Length | | |
| Humerus Max. Length | | |
| Radius Max. Length | | |
| Ulna Max. Length | | |
| Ilium Max. Length | | |
| Os Pubis Max. Length | | |
| Femur Max. Length | | |
| Tibia Max. Length | | |
| Fibula Max. Length | | |

# JUVENILE DENTAL DEVELOPMENT FOR AGE

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
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AGE ESTIMATION:_____

*(Adapted from Mincer et al. 1993 and Moorees et al. 1963 a, b)*

| TOOTH | SIDE | STAGE | AGE INTERVAL |
|---|---|---|---|
| dc | _____ | _____ | _____ |
| dm1 | _____ | _____ | _____ |
| dm2 | _____ | _____ | _____ |
| $I^1$ | _____ | _____ | _____ |
| $I^2$ | _____ | _____ | _____ |
| $C^1$ | _____ | _____ | _____ |
| $P^1$ | _____ | _____ | _____ |
| $P^2$ | _____ | _____ | _____ |
| $M^1$ | _____ | _____ | _____ |
| $M^2$ | _____ | _____ | _____ |
| $M^3$ | _____ | _____ | _____ |
| $I_1$ | _____ | _____ | _____ |
| $I_2$ | _____ | _____ | _____ |
| $C_1$ | _____ | _____ | _____ |
| $P_1$ | _____ | _____ | _____ |
| $P_2$ | _____ | _____ | _____ |
| $M_1$ | _____ | _____ | _____ |
| $M_2$ | _____ | _____ | _____ |
| $M_3$ | _____ | _____ | _____ |

# DENTAL ANTHROPOLOGY

The collection of dental data is important for all forms of identification and a systemized protocol allows for easier entry of the data into an electronic database. Observations are listed and described below that correspond to the data collection forms for both adult and juvenile dentition. Each tooth will have codes for all observations listed.

**OBS. 1: TOOTH TYPE**

1 Permanent
2 Deciduous

**OBS. 2: TOOTH STATUS**

1 Present – Tooth Only
2 Present – Tooth in Socket, Fully Erupted
3 Partially Erupted
4 Unerupted
5 Congenitally Missing
6 Absent Ante-mortem
7 Absent Post-mortem
8 Arch Missing
9 Missing, Reason Unknown

**OBS. 3: MESIO-DISTAL DIAMETER**

- The maximum diameter measured to the nearest 0.1 mm between the mesial and distal contact points.
- In incisors and canines, the mesio-distal diameter is the maximum mesio-distal diameter of the tooth (dial calipers).

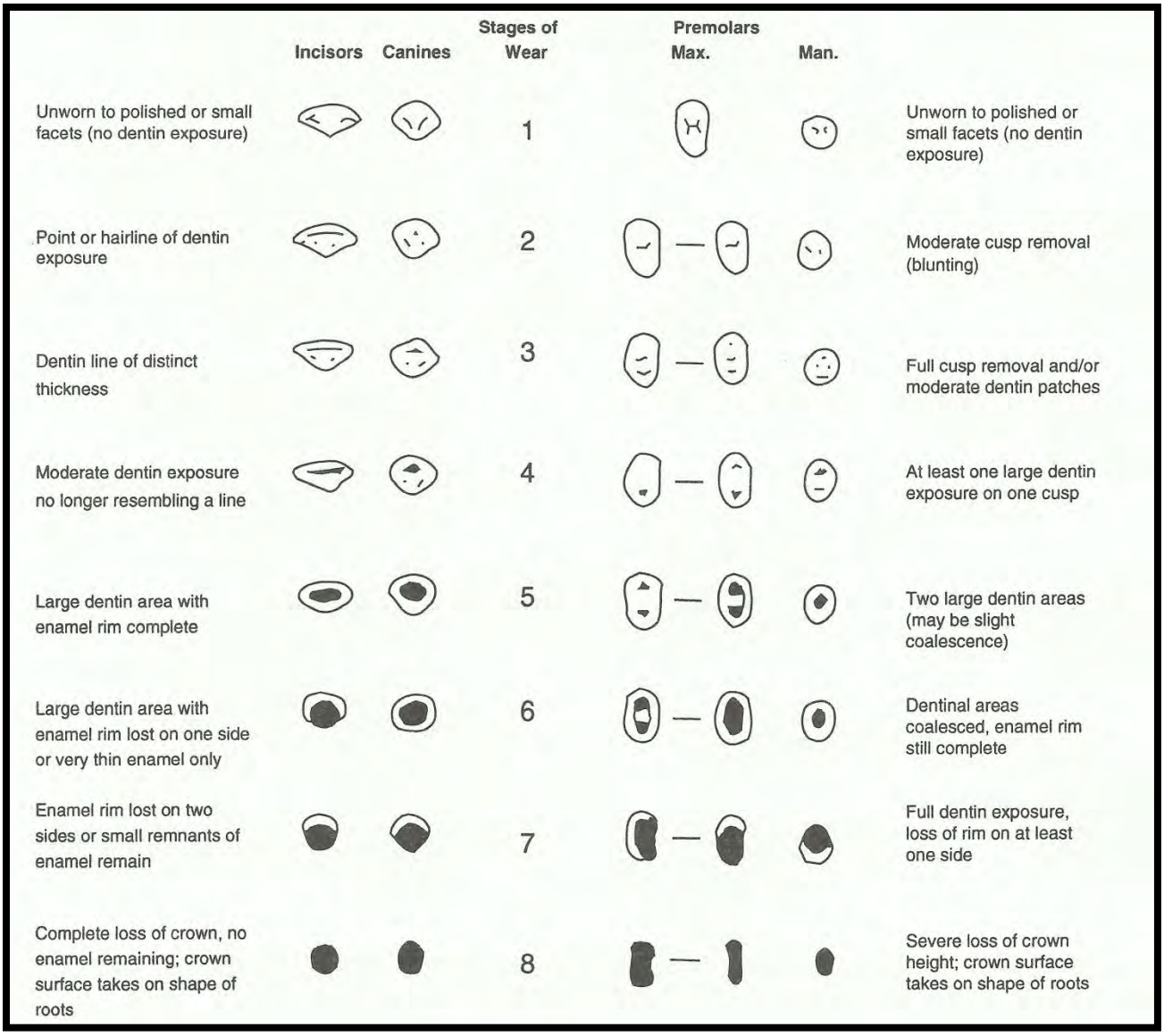
**OBS. 4: BUCCO-LINGUAL DIAMETER**

- The maximum bucco-lingual diameter taken at a right angle to the axis of the mesio-distal diameter, measured to the nearest 0.1 mm (dial calipers).

**OBS. 5: ATTRITION (AS DEFINED BY SMITH 1984)**

- Scored 1-8. Refer to diagram and descriptions for each score definition.

## ATTRITION DIAGRAM




**SURFACE WEAR SCORING SYSTEM FOR INCISORS, CANINES, AND PREMOLARS.**
(Reprinted from Smith 1984 in: Buikstra and Ubelaker 1994)

**ATTRITION DESCRIPTIONS** (Definitions quoted from Smith 1984:214)

0 Missing or cannot be coded.

1 Unworn to polished or small facets (no dentin exposure).

2 Moderate cusp removal (blunting).For incisor teeth, point or hairline of dentin exposure. Deciduous molars may show cusp dentin, but permanent molars show full no more than two pinpoint exposures.

3 Incisors and canines show dentin line of distinct thickness. Premolars show full cusp removal and/or moderate dentin. Molars show full cusp removal and/or some dentin exposure, pinpoint to moderate.

4 Incisors and canines show moderate dentin exposure, no longer resembling on one cusp. Premolars have several large dentin exposures on one cusp. Molars have several large dentin exposures, still discrete.

5 Incisors and canines show large dentin area with enamel rim complete. Premolars show two large dentin areas which may be slightly coalesced. Molars show two dentinal areas coalesced.

6 Incisors and canines show large dentin area with enamel rim lost on side or very thin enamel only. Premolars show dentinal areas coalesced but enamel rim still complete. Molars show three dentinal areas coalesced or four coalesced with an enamel island.

7 Incisors and canines show enamel rim lost on two sides or small remnants of enamel remain. Premolars show full dentin exposure with the loss of rim on at least one side. Molars show dentin exposed on entire surface but with the enamel rim largely intact.

8 Incisors and canines show complete loss of crown with no enamel remaining. The crown surface takes on the shape of the roots. Premolars show severe loss of crown height with the crown surface taking on the shape of the roots. Molars show severe loss of the height and breakdown of the enamel rim. Crown surface also takes on the shape of the roots.

*Obs. 6-8: In comments, add metrics and describe in greater detail.*

**OBS. 6**: **CARIES DEGREE AND STATUS** (defined by Powell 1985)

0 Missing or could not be coded.
1 No pathology evident.
2 Pit or slight fissural start of a lesion.
3 Lesion ranging from more than degree "2" to less than ½ crown surface.
4 Destruction of more than ½ of the surface, although not complete destruction.
5 Complete destruction of tooth surface.
6 Complete destruction and involves root.

**OBS. 7**: **CARIES LOCATION**

*List all that apply:*

0 Missing or cannot be coded.
1 Occlusal
2 Buccal
3 Lingual
4 Interproximal – Medial
5 Interproximal – Distal
6 Cervical (CEJ)
7 Root (below CEJ)

**OBS. 8**: **ABSCESS STATUS** (defined by Powell 1985)

*List all that apply:*

0 Missing or cannot be coded.
1 No pathology evident.
2 Periodontal abscess with destruction of alveolar bone.
3 Periapical abscess with destruction of bone or perforation of cortex.
4 Bone resorbed (antemortem loss, tooth abscessed out).
5 Bone resorbed (antemortem loss, indeterminate).

**OBS. 9**: **CALCULUS** (Brothwell 1972)

0 Missing or cannot be coded.
1 None
2 Slight (discrete areas of calculus on one or more surfaces).
3 Moderate (coalesced areas of calculus deposit on one or more surfaces).
4 Heavy (three-dimensional calculus deposit on one or more surfaces).

**OBS. 10**: **HYPOPLASIA PRESENCE** (Pederson and Scott 1951)

0 Missing or cannot be coded.
1 None
2 Present

**OBS. 11**: **HYPOPLASIA PITTING/GROOVING** (Pederson and Scott 1951)

*List all that apply:*

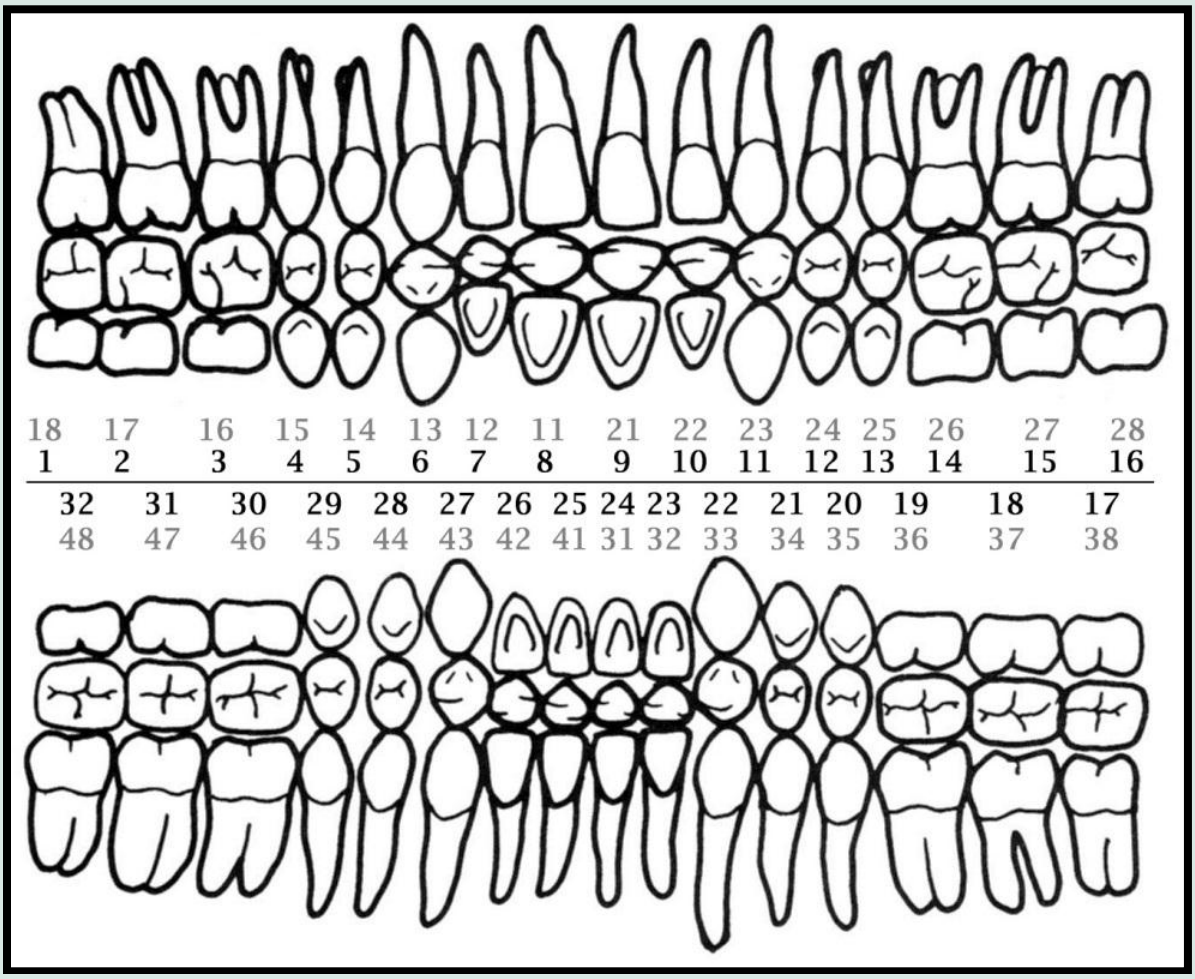
1 Missing or cannot be coded.
2 Pitting
3 Linear bands or grooves
4 Both linear bands and pitting

**OBS. 12**: **HYPOPLASIA HEIGHT** (Pederson and Scott 1951)

- Measured to the nearest 0.1 mm from the lowest hypoplastic band to the cement-enamel junction over the midline of the root (dial calipers).

# ADULT DENTAL DATA

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**




MARK THE DIAGRAM WITH THE FOLLOWING:

X = TOOTH IS MISSING
C = CAVITY OR PATHOLOGY
F = TOOTH FRACTURES
M = TOOTH MODIFIED

NUMBERING SYSTEM:
**BLACK** = AMERICAN SYSTEM
GREY = EUROPEAN SYSTEM

# ADULT DENTAL DATA

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**RECORD OBSERVATION CODES ACCORDING TO DESCRIPTIONS AND DIAGRAMS PROVIDED.**
**BOTH ADULT AND JUVENILE DENTITION ARE INCLUDED TO ALLOW FOR MIXED DENTAL CODING.**

| | Observation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tooth** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
| **1** / 18 | | | | | | | | | | | | |
| **2** / 17 | | | | | | | | | | | | |
| **3** / 16 | | | | | | | | | | | | |
| **4** / 15 | | | | | | | | | | | | |
| **5** / 14 | | | | | | | | | | | | |
| **6** / 13 | | | | | | | | | | | | |
| **7** / 12 | | | | | | | | | | | | |
| **8** / 11 | | | | | | | | | | | | |
| **9** / 21 | | | | | | | | | | | | |
| **10** / 22 | | | | | | | | | | | | |
| **11** / 23 | | | | | | | | | | | | |
| **12** / 24 | | | | | | | | | | | | |
| **13** / 25 | | | | | | | | | | | | |
| **14** / 26 | | | | | | | | | | | | |
| **15** / 27 | | | | | | | | | | | | |
| **16** / 28 | | | | | | | | | | | | |
| **17** / 38 | | | | | | | | | | | | |
| **18** / 37 | | | | | | | | | | | | |
| **19** / 36 | | | | | | | | | | | | |
| **20** / 35 | | | | | | | | | | | | |
| **21** / 34 | | | | | | | | | | | | |
| **22** / 33 | | | | | | | | | | | | |
| **23** / 32 | | | | | | | | | | | | |
| **24** / 31 | | | | | | | | | | | | |
| **25** / 41 | | | | | | | | | | | | |
| **26** / 42 | | | | | | | | | | | | |
| **27** / 43 | | | | | | | | | | | | |
| **28** / 44 | | | | | | | | | | | | |
| **29** / 45 | | | | | | | | | | | | |
| **30** / 46 | | | | | | | | | | | | |
| **31** / 47 | | | | | | | | | | | | |
| **32** / 48 | | | | | | | | | | | | |

# JUVENILE DENTAL DATA

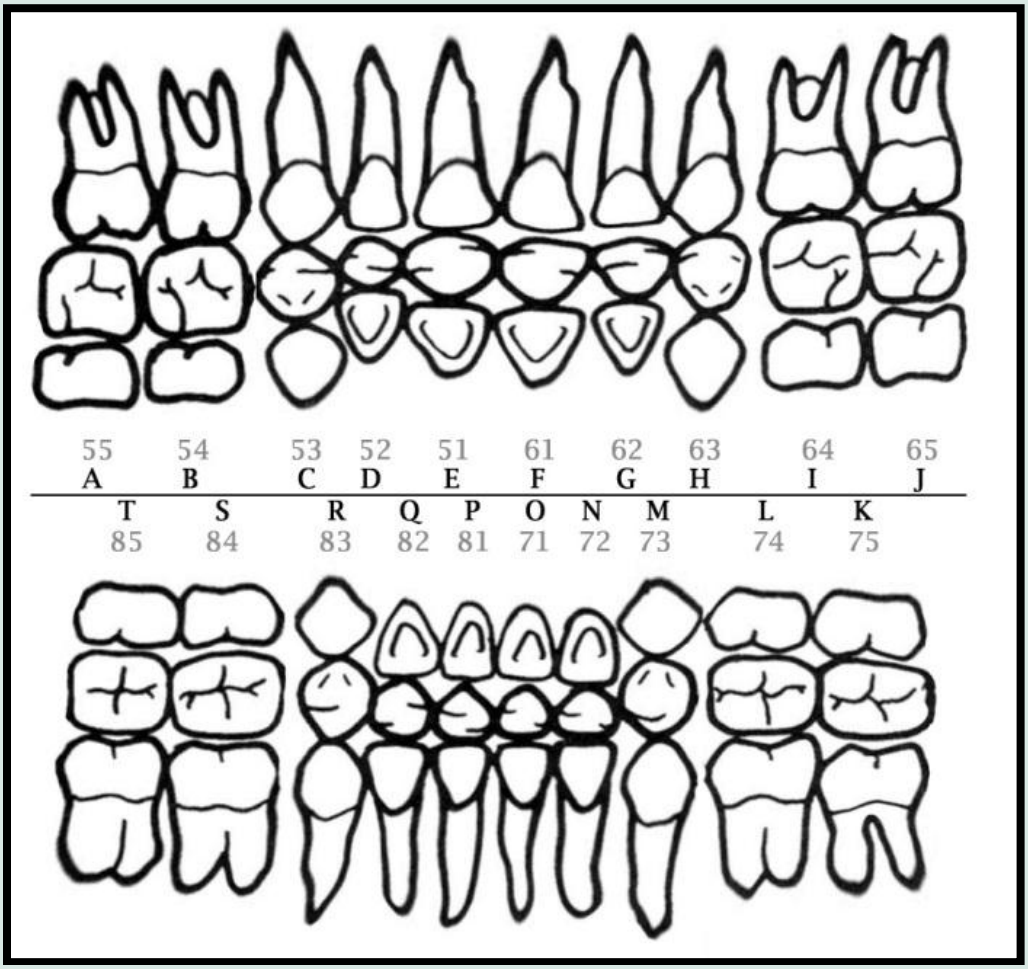
CASE NUMBER: **WRITE IN FULL CASE NUMBER**
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OBSERVER: **LIST ALL OBSERVERS WHO CONTRIBUTED TO THIS FORM**

**PARTICULAR ATTENTION MUST BE GIVEN TO CASES WITH MIXED DENTITION AS THESE WILL REQUIRE BOTH FORMS.**

| | Observation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tooth** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
| **A** / 55 | | | | | | | | | | | | |
| **B** / 54 | | | | | | | | | | | | |
| **C** / 53 | | | | | | | | | | | | |
| **D** / 52 | | | | | | | | | | | | |
| **E** / 51 | | | | | | | | | | | | |
| **F** / 61 | | | | | | | | | | | | |
| **G** / 62 | | | | | | | | | | | | |
| **H** / 63 | | | | | | | | | | | | |
| **I** / 64 | | | | | | | | | | | | |
| **J** / 65 | | | | | | | | | | | | |
| **K** / 75 | | | | | | | | | | | | |
| **L** / 74 | | | | | | | | | | | | |
| **M** / 73 | | | | | | | | | | | | |
| **N** / 72 | | | | | | | | | | | | |
| **O** / 71 | | | | | | | | | | | | |
| **P** / 81 | | | | | | | | | | | | |
| **Q** / 82 | | | | | | | | | | | | |
| **R** / 83 | | | | | | | | | | | | |
| **S** / 84 | | | | | | | | | | | | |
| **T** / 85 | | | | | | | | | | | | |

# JUVENILE DENTAL DATA

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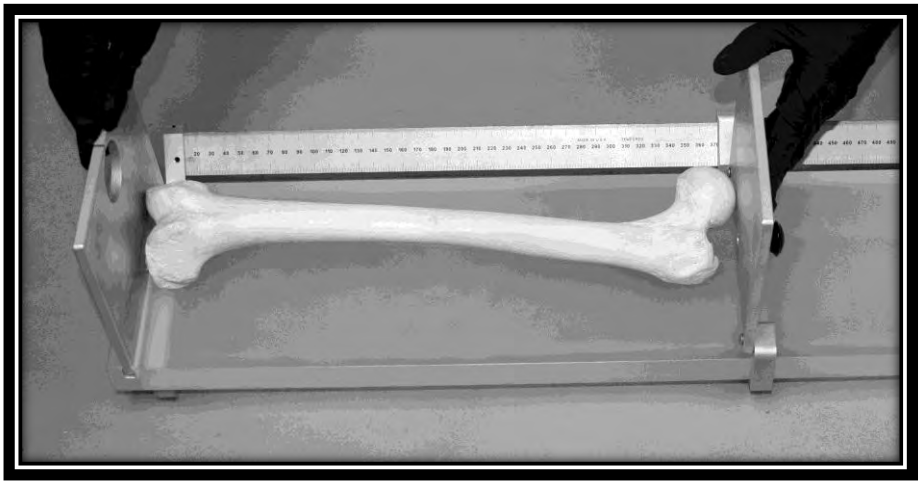



MARK THE DIAGRAM WITH THE FOLLOWING:

X = TOOTH IS MISSING
C = CAVITY OR PATHOLOGY
F = TOOTH FRACTURES
M = TOOTH MODIFIED

NUMBERING SYSTEM:
**BLACK** = AMERICAN SYSTEM
GREY = EUROPEAN SYSTEM

# STATURE ESTIMATION



The value of stature as a cornerstone of the biological profile of an individual rests on the assumption that there is a record against which an estimation of that stature can be compared. It has been demonstrated by numerous researchers that records such as a driver's license generally do not accurately reflect the real height of an individual. The reported antemortem height for males and estimated statures using multiple formulae equations for Balkan populations are listed below to illustrate the difference that can occur when using population specific methods, as well as varying statistical models (Ross and Konigsberg 2002; Jantz et al. 2008; Kimmerle et al. 2008). It is recommended that investigators use population specific methods for stature whenever possible.

| | **Croatians (n=85)** | | **Kosovans (n=70)** | |
|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. |
| **Antemortem Height** | **178.17** | **6.328** | **175.79** | **7.372** |
| Ross & Konigsberg (2002) | 175.76 | 5.434 | 172.87 | 6.256 |
| Sarajlic (2001) | 176.07 | 6.167 | 172.78 | 7.098 |
| Trotter & Gleser (1952) | 174.56 | 5.476 | 171.65 | 6.303 |
| Trotter & Gleser (1958) | 175.83 | 5.337 | 172.99 | 6.143 |

# STATURE ESTIMATION FORM

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
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---

**STATURE ESTIMATION MALES:**

| Population | Long Bone | Side | Formula | Stature | SE +/- |
|---|---|---|---|---|---|
| **American Whites** | Humerus | Left/Right | _____ (cm) × 3.08 + 70.45 = | | 4.05 |
| | Femur | Left/Right | _____ (cm) × 2.38 + 61.41 = | | 3.27 |
| | Tibia | Left/Right | _____ (cm) × 2.52 + 78.62 = | | 3.37 |
| **American Blacks** | Humerus | Left/Right | _____ (cm) × 3.26 + 62.10 = | | 4.43 |
| | Femur | Left/Right | _____ (cm) × 2.11 + 70.35 = | | 3.94 |
| | Tibia | Left/Right | _____ (cm) × 2.19 + 86.02 = | | 3.78 |

**STATURE ESTIMATION FEMALES:**

| Population | Long Bone | Side | Formula | Stature | SE +/- |
|---|---|---|---|---|---|
| **American Whites** | Humerus | Left/Right | _____ (cm) × 3.36 + 57.97 = | | 4.45 |
| | Femur | Left/Right | _____ (cm) × 2.47 + 54.74 = | | 3.72 |
| | Tibia | Left/Right | _____ (cm) × 2.90 + 59.24 = | | 3.66 |
| **American Blacks** | Humerus | Left/Right | _____ (cm) × 3.08 + 64.67 = | | 4.25 |
| | Femur | Left/Right | _____ (cm) × 2.28 + 59.76 = | | 3.41 |
| | Tibia | Left/Right | _____ (cm) × 2.45 + 72.65 = | | 3.70 |

*Formulae adapted from Trotter (1970) and Jantz (1992).*

# Section IV.
# Additional Tools for Human Identification

# Section IV. Additional Tools for Human Identification

## Documentation, Sampling, & Additional Testing

- Photography
- Radiography
- 3D Laser Scanning
- Facial Approximations and Forensic Imaging
- Chemical and Elemental Isotope Samples
- DNA Sampling
- Skeletal Fracutre Reconstructions
- Casting

# PHOTOGRAPHY

## STANDARD PHOTOGRAPHS

Take photographs before skeletal remains are washed and after they are washed or processed.

1) OVERALL VIEW IN ANATOMICAL ORDER
    a. Lay out skeletal remains and take overall photograph with case number.
2) SKULL
    a. Photograph all views including: Occlusal Surfaces of Dentition, Frontal, Posterior, Right and Left Laterals, Superior and Basilar Views
    b. Photograph skull with and without tissue depth markers in Frankfort horizontal position (anterior and lateral views)
3) AGE MARKERS (PUBIC SYMPHYSIS, STERNAL RIB, ETC.)
4) UNIQUE TRAITS/CONGENITAL ANOMALIES/ENTHESOPATHIES
5) SKELETAL PATHOLOGY
6) ANTE- AND PERIMORTEM TRAUMA (ALL VIEWS AND CLOSE-UP)
7) TAPHONOMIC PROCESSES, COLOR VARIATION, DIVERSE STAGES OF WEATHERING, ANIMAL SCAVENGING

## DEMONSTRATIVE PHOTOGRAPHS

Demonstrative photographs can be useful for showing trauma in Court and should be taken in addition to standard photos, when appropriate. For example, if trauma is present on the left radius, then in addition to the trauma pictures of the left radius, take a photograph of the right and left radii together to show what is "normal" and what is "trauma". Demonstrative examples can be important for presentation in Court and if entered into the original case file, will be generally be admissible without issue. In contrast, creating comparative examples later, which are not directly related to the case, may or may not be admissible in the proceedings, depending on the circumstances of the case or type of Court.

# RADIOGRAPHY

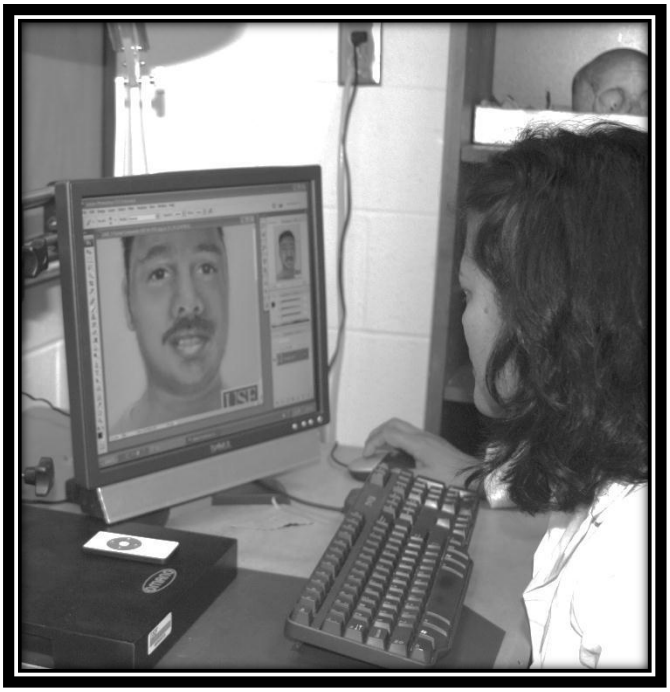
A range of x-rays should be taken for each case prior to processing, as a matter of standard practice, including the following listed below. Note that these are particularly useful for age estimation and health/nutritional status (i.e. long bone images enable detection of Harris Lines). The utility of radiographs for skeletal trauma varies with the type of trauma and level of decomposition. In skeletal cases where fractures have been reconstructed, there is little radiographic value. However, in *fresh* cases or when gunfire or shrapnel injuries are present, radiography can be very useful for detecting metal fragments. Note that when taking measurements from radiographs, calibration correction may be necessary.

## STANDARD RADIOGRAPHS

1) A-P SKULL
2) LATERAL SKULL
3) DENTAL RADIOGRAPHS
4) DISTAL AND PROXIMAL ENDS OF LONG BONES
5) SKELETAL PATHOLOGY & TRAUMA
6) UNIQUE TRAITS
7) CLOTHING

# FACIAL APPROXIMATION

Facial imaging consists of the development of an approximation of what the decedent may have looked like prior to death, through 2D computer generated composites. These images may be based on postmortem or autopsy photographs or reconstructed from skeletal remains. Information generated for the **BIOLOGICAL PROFILE** is used in combination with the unique boney architecture of the skull. Photographic reconstructions of clothing, jewelry, artifacts, or teeth are also possible. These images are given to law enforcement. The images are shown to the public to illicit a response.



Approximations or reconstructions are never used to make a positive identification, but rather are used to trigger the memory of someone who knew the victim, thereby creating a **PRESUMPTIVE IDENTIFICATION**. Ancestry combined with contextual information about mobility, birth origins, and burial factors create an integrated biological profile of the decedent. Using these data combined with images of the skull, a facial reconstruction or approximation can be completed for public viewing. Forensic imaging such as facial approximations is not used for positive identification of the victim, but rather to create a likeness of the individual which should help trigger the memory of a family member or witness who may recognize the decedent or artifact. The recognition of even one facial feature can trigger memory and thereby lead witnesses to come forward and provide law enforcement agencies with new information about a case.

## PROCESS FOR CREATING 2D COMPOSITE IMAGES FROM SKELETAL REMAINS

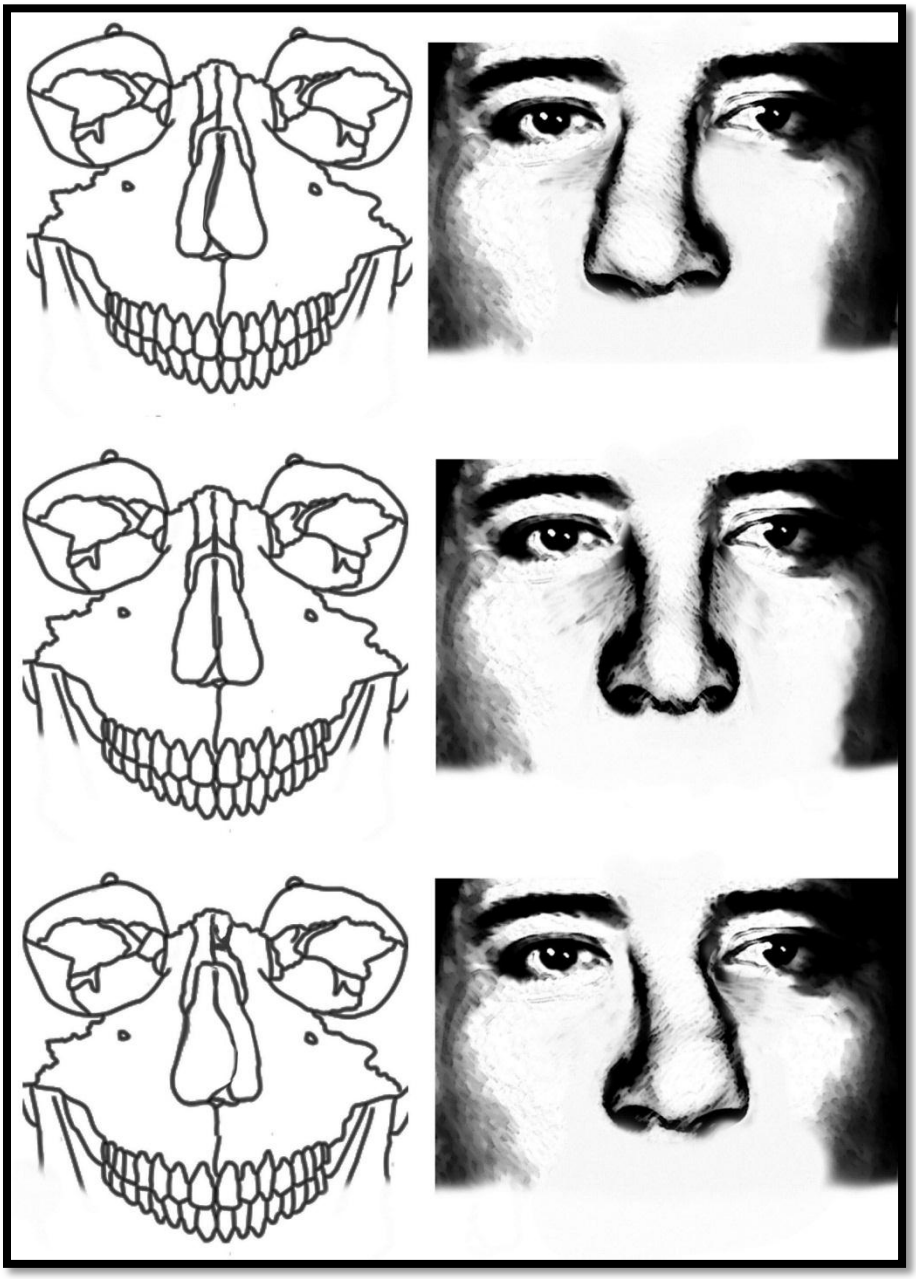
- **CREATE A BIOLOGICAL PROFILE:** Use this information to choose parameters for tissue depths and unique or other subjective factors such as healed nasal or facial trauma, asymmetries, pathology, etc.
- **PLACE FACIAL TISSUE MARKERS ON LANDMARKS OF THE SKULL AND MANDIBLE:** The use of tissue markers is very important for estimating the correct size and shape of the face. Different standards are published based on ancestry, sex, and weight.
- **PHOTOGRAPH THE SKULL:** Make certain the skull is in the Frankfort Horizontal position.
- **REFERENCES:** Use reference photographs matching the biological description of the decedent to build a 2D composite over the face.
- **CREATING SOFT TISSUES AND BLENDING FEATURES:** Facial features are placed over skeletal anatomy and images can be modified to add or change facial hair, hair styles or color, type of clothing based on contextual variables, artifacts, or scars.
- **SAVING IMAGE:** Convert reconstruction to a black and white image as to eliminate bias in skin, eye or hair color. Also use artistic finish to blend/smudge facial composite.



## PROCESS FOR CREATING 2D COMPOSITE IMAGES FROM DECOMPOSING REMAINS

- **CREATE A BIOLOGICAL PROFILE:** Use soft tissue to obtain as much information as possible. Use radiographs or extracted skeletal elements as needed.
- **PHOTOGRAPH THE FACE:** Surround face with clean, solid colored towel and position face in the Frankfort horizontal position if possible.
- **REFERENCES:** Use reference photographs matching the biological description of the decedent to build a 2D composite over the face.
- **CREATING SOFT TISSUES AND BLENDING FEATURES:** Use available soft tissue features while correcting the decomposition process. Images can be modified to add or change facial hair, hair styles or color, type of clothing based on contextual variables, artifacts, or scars.
- **SAVING IMAGE:** Convert reconstruction to a black and white image as to eliminate bias in skin, eye or hair color. Also use artistic finish to blend/smudge facial composite.

# SOFT TISSUE VARIATION DUE TO HEALED NASAL FRACTURES



Fractures to the nasal bone will cause soft tissue deformation on side of fracture. If fracture extends to adjacent maxilla, deformation will be more pronounced. Broken nasals and a deviated septum will cause the nose to bend or tilt asymmetrically. **Top:** Fracture on right nasal bone with soft tissue deformation to the right of the nose. **Middle:** Fracture bilaterally across the right and left nasal bones, with deformation and asymmetry to the adjacent soft tissues. **Bottom:** Fracture on left nasal bone with deformation to the structure of the nose and adjacent soft tissue deformation.

# FACIAL APPROXIMATION FORM

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
PERSONNEL: **LIST ALL PERSONNEL WHO CONTRIBUTED TO THIS FORM**

---

**THIS FORM IS MEANT TO BE USED WHEN CREATING A FACIAL APPROXIMATION OR ESTIMATION. IT CONTAINS BASIC CONTEXTUAL INFORMATION ABOUT THE DECEDENT IDENTIFIED AND IS ESTIMATED FROM THE SKELETAL REMAINS TO ASSIST WITH DEVELOPING PHENOTYPIC TRAITS ABOUT THE DECEDENT.**

SKELETAL OR DECOMPOSITION: **STATE OF PRESERVATION OF REMAINS**

METHOD OF TISSUE PROCESSING: **DESCRIBE ANY METHODS OR CHEMICALS USED TO REMOVE SOFT TISSUES**

METHOD OF FACIAL RECONSTRUCTION: **CLAY, 2D COMPOSITE, SKETCH, 3D RECONSTRUCTION**

HAS A PRIOR RECONSTRUCTION BEEN COMPLETED? **IF SO, WAS IT CONSULTED?**

**BIOLOGICAL PROFILE**

SEX: **ESTIMATION FROM SKELETAL REMAINS OR SOFT TISSUES?**
AGE:
ANCESTRY:
STATURE, WEIGHT AND BUILD:

**ANTEMORTEM FACIAL TRAUMA OR PATHOLOGY:** **DESCRIBE LOCATION AND EXTENT OF ANY CRANIOFACIAL ANOMALIES OR TRAUMA THAT MAY AFFECT THE SOFT TISSUES OR PHENOTYPE**

**UNIQUE IDENTIFICATION MARKERS:** **ARE THERE ANY OTHER UNIQUE FEATURES ABOUT THIS FACE?**
TATTOOS, SCARS, MOLES, OTHER:
ASYMMETRIES?
TMJ?

EDENTULOUS OR SUBSTANTIAL DENTAL ANOMALIES: **PRESENCE OR ABSENCE OF TEETH**

CONTEXTUAL IDENTIFICATION: **ADDITIONAL EVIDENCE, INVESTIGATIVE FACTORS OR SCENE INFORMATION THAT MAY HELP ESTABLISH A CONTEXTUAL IDENTIFICATION AND INFORM AS TO WHAT THE PERSON MAY HAVE LOOKED LIKE/HAIRSTYLE/CLOTHING/ETC.**

GENERAL DESCRIPTION: **OTHER COMMENTS**

IMAGES CREATED:
____ FACIAL APPROXIMATION – SKELETAL
____ FACIAL APPROXIMATION – DECOMPOSED
____ CLOTHING – LIST: **LIST ARTICLES OF CLOTHING RECONSTRUCTED**
____ TEETH – LIST: **LIST TOOTH NUMBERS USED IN APPROXIMATION**

# TISSUE DEPTHS FOR FACIAL APPROXIMATION

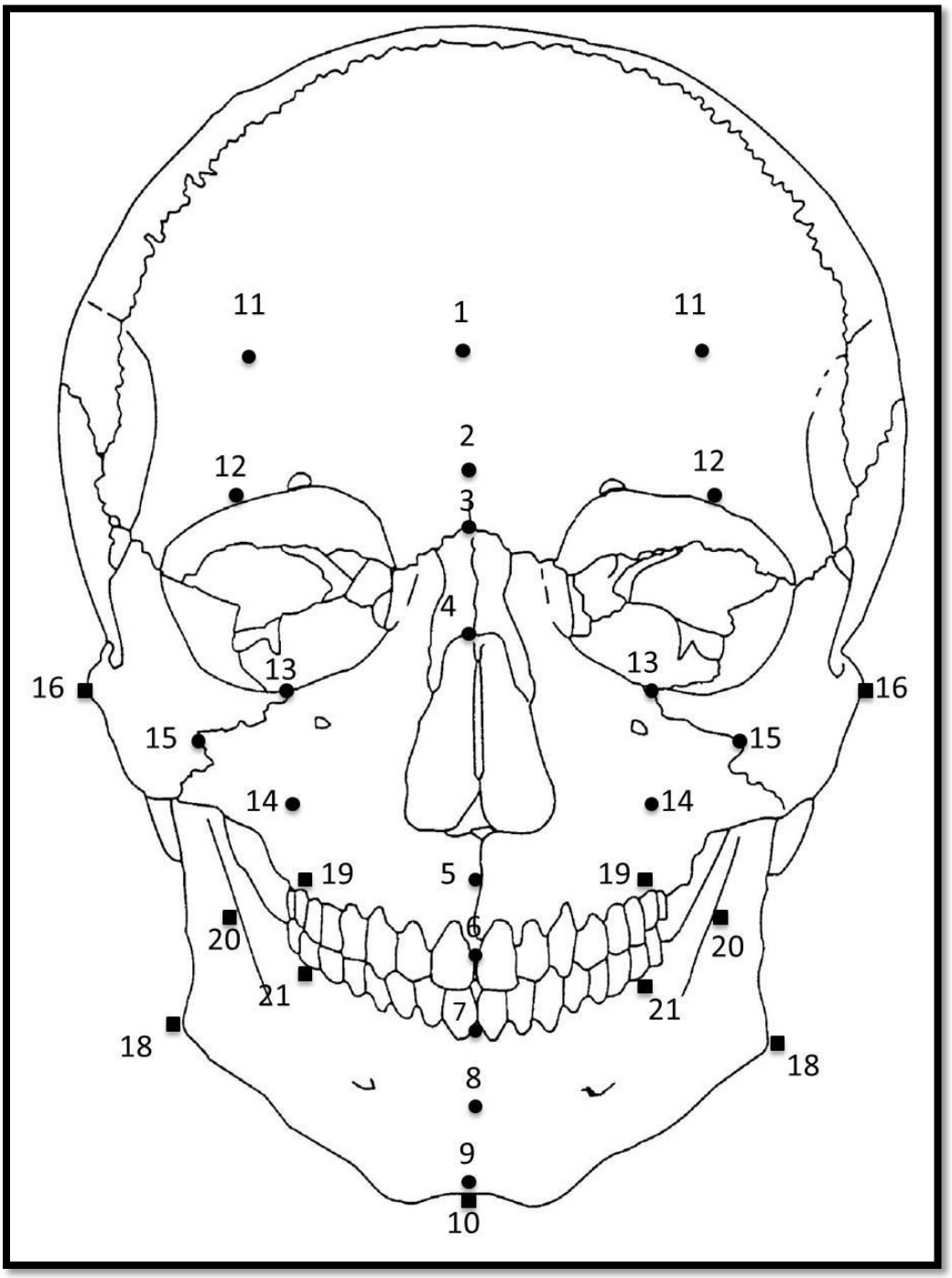
**Facial Tissue Thickness of European Americans** (in *mm*).

| | Emaciated | | Normal | | Obese | |
|---|---|---|---|---|---|---|
| **Measurement** | **Male (3)** | **Female (3)** | **Male (37)** | **Female (19)** | **Male (8)** | **Female (3)** |
| **Midline** | | | | | | |
| 1. Supraglabella | 2.25 | 2.50 | 4.25 | 3.50 | 5.50 | 4.25 |
| 2. Glabella | 2.50 | 4.00 | 5.25 | 4.75 | 7.50 | 7.50 |
| 3. Nasion | 4.25 | 5.25 | 6.50 | 5.50 | 7.50 | 7.00 |
| 4. End of nasals | 2.50 | 2.25 | 3.00 | 2.75 | 3.50 | 4.25 |
| 5. Midphiltrum | 6.25 | 5.00 | 10.00 | 8.50 | 11.00 | 9.00 |
| 6. Upper lip margin | 9.75 | 6.25 | 9.75 | 9.00 | 11.00 | 11.00 |
| 7. Lower lip margin | 9.50 | 8.50 | 11.00 | 10.00 | 12.75 | 12.25 |
| 8. Chin-lip fold | 8.75 | 9.25 | 10.75 | 9.50 | 12.75 | 13.75 |
| 9. Mental eminence | 7.00 | 8.50 | 11.25 | 10.00 | 14.00 | 14.25 |
| 10. Beneath chin | 4.50 | 3.75 | 7.25 | 5.75 | 10.75 | 9.00 |
| **Bilateral** | | | | | | |
| 11. Frontal eminence | 3.00 | 2.75 | 4.25 | 3.50 | 5.50 | 5.00 |
| 12. Supraorbital | 6.25 | 5.25 | 8.25 | 7.00 | 10.25 | 10.00 |
| 13. Suborbital | 2.75 | 4.00 | 5.75 | 6.00 | 8.25 | 8.50 |
| 14. Inferior malar | 8.50 | 7.00 | 13.25 | 12.75 | 15.25 | 14.00 |
| 15. Lateral orbit | 5.00 | 6.00 | 10.00 | 10.75 | 13.75 | 14.75 |
| 16. Zygomatic arch, midway | 3.00 | 3.50 | 7.25 | 7.50 | 11.75 | 13.00 |
| 17. Supragllenoid | 4.25 | 4.25 | 8.50 | 8.00 | 11.25 | 10.50 |
| 18. Gonion | 4.50 | 5.00 | 11.50 | 12.00 | 17.50 | 17.50 |
| 19. Supra M2 | 12.00 | 12.00 | 19.50 | 19.25 | 25.00 | 23.75 |
| 20. Occusal line | 12.00 | 11.00 | 18.25 | 17.00 | 23.50 | 20.25 |
| 21. Sub M2 | 10.00 | 9.50 | 16.00 | 15.50 | 19.75 | 18.75 |

Table of measurements for flesh thickness, adapted from J.S. Rhine and C.E. Moore, Forensic Anthropology: Maxwell Museum Technical Series No. 1 (1982).

## TISSUE DEPTH LANDMARK DIAGRAMS

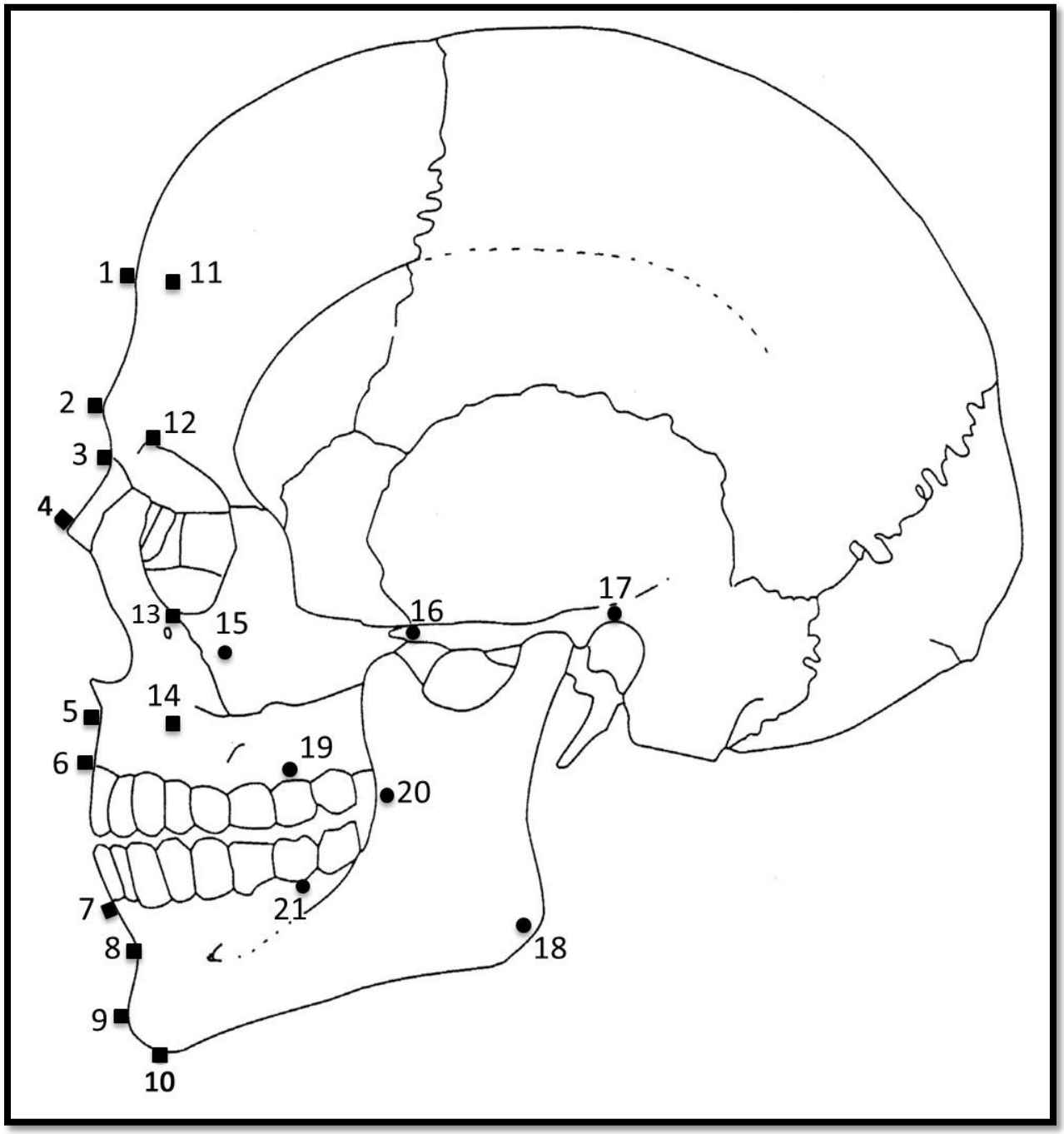
REFER TO FACIAL TISSUE THICKNESS TABLE ON PAGE 96.




ANTERIOR VIEW

## TISSUE DEPTH LANDMARK DIAGRAMS

REFER TO FACIAL TISSUE THICKNESS TABLE ON PAGE 96.




LATERAL VIEW

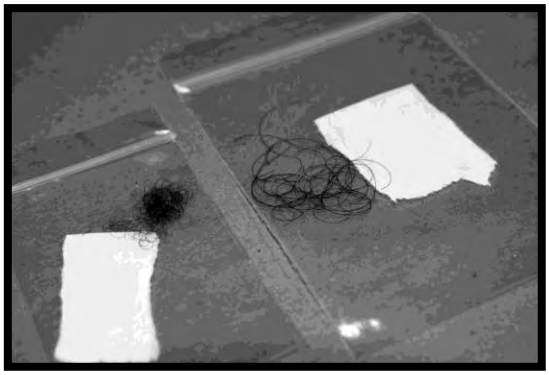
# STRONTIUM-LEAD ISOTOPE AND ELEMENTAL ANALYSIS

The chemical analysis of human remains may provide scientific information on what foods were consumed and in what quantities, since isotopic and elemental values in plants and animals are passed on to their consumers. Tooth samples inform about diet at the time they formed; bone samples provide the average diet over the last seven to ten years of an individual's life; and hair root samples provide information about recent diet in the months or few years prior to death (depending on the length of hair).

Bone (and tooth root) collagen mainly represents dietary protein, while bone and tooth root apatite (and tooth enamel) represent the whole diet. These analyses can be used to address annual and seasonal dietary patterns, changes since childhood, and human mobility. More specifically, stable carbon isotopes vary based on different plant photosynthetic pathways (e.g. maize is quite different from wheat and rice) and between terrestrial and marine foods, with these foods varying considerably in availability in different parts of the world; nitrogen isotopes inform us about the importance of meat and fish in the diet, as well as the use of plant fertilizers; and oxygen isotopes help identify specific geographic locations based on distance from the sea, temperature, and altitude. Trace element analysis of barium and strontium also may be used to assess the importance of seafood in the diet along with geographic locations. These methods complement strontium isotope analysis in addressing human mobility and identification.

Strontium (Sr) and lead (Pb) are metals that readily substitute for calcium (Ca) and so accumulate in body tissues and bones in vivo. In contrast to Ca, which has relatively uniform isotopic composition, Sr and Pb isotopic compositions can vary widely depending on local geological and environmental factors. Therefore, we can use the Sr and Pb isotope composition of skeletal material to determine the birthplace and geographic mobility of a given person or remains.





# ISOTOPE SAMPLES

CASE NUMBER: **WRITE IN FULL CASE NUMBER**
MEDICAL EXAMINER CASE NUMBER: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
POLICE AGENCY & CASE NUMBER: **WRITE IN POLICE AGENCY / CASE NUMBER**
DATE: **WRITE IN DATE FORM WAS COMPLETED**
PERSONNEL: **LIST ALL PERSONNEL WHO CONTRIBUTED TO THIS FORM AND SAMPLE COLLECTION**
AGE: **ESTIMATED AGE OF DECEDENT**
SEX: **ESTIMATED SEX OF DECEDENT**
CONTEXTUAL INFORMATION: **LIST ANY INFORMATION KNOWN ABOUT HISTORY OR CONTEXT OF REMAINS**

| Sample | Bone Location or Tooth Number | Side | Purpose/Lab for Analysis |
|---|---|---|---|
| 1. | **FOR EACH SAMPLE, PROVIDE APPROPRIATE INFORMATION** | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |

Signature and Date of Person Who Collected Samples

| Sample | Date of Shipment/Transfer | Location of Shipment/Transfer | Initials | Confirmation of Receipt |
|---|---|---|---|---|
| 1. | **FOR EACH SAMPLE, PROVIDE INFORMATION FOR CHAIN OF CUSTODY** | | | |
| 2. | | | | |
| 3. | | | | |
| 4. | | | | |
| 5. | | | | |

# 3D LASER SCANNING

Scanning skeletal elements using a laser 3D scanner can greatly aid in the process of identification by allowing a specific bone to be sent anywhere in the world via a digital copy. While there are a number of models that range in quality and price, this form is designed for the NextEngine Desktop 3D Scanner HD coupled with the ScanStudio HD software package, both available from NextEngine, Inc. Accuracy for this model depends on whether Macro Mode or Wide Mode is used, and ranges from ±0.005 in. (0.0127 cm) to ±0.015 in. (0.0381 cm), respectively. Maximum resolution ranges from 400 points per in. (157.5 points per cm) in Macro Mode to 150 points per in. (59 points per cm) in Wide Mode.





Other software packages used to create these 3D PDF files include MeshLab, a freeware 3D modeling program developed by the Visual Computing Lab – ISTI – CNR (available at http://meshlab.sourceforge.net), and Adobe Acrobat X Pro, available from Adobe Systems, Inc. (www.adobe.com). In order to properly view these files, Adobe Reader 9 or later is required. The newest version of Adobe Reader is available free from Adobe Systems, Inc.

# 3-D LASER SCANNING

## GENERALIZED PROCEDURE:

*(Adapted from Kimmerle and Powell 2012)*

1. The object was placed on the AutoDrive and held in place using the PartGripper that was included with the NextEngine Desktop 3D Scanner HD. The settings were chosen depending on the size of the object, and the scan was run.
    a. For larger objects use Wide Mode, and for smaller objects use Macro Mode.
    b. For Wide Mode:
        i. Extend the AutoDrive to the maximum extent of the standard connection cord. This places the AutoDrive within the proper range of the scanner and allows the largest possible objects to be scanned.
        ii. The PartGripper may need to be lowered as close as possible to the AutoDrive to fit larger objects.
    c. For Macro Mode:
        i. Put the AutoDrive in a position that places the object to be scanned in the proper range, as specified by the Scan Settings page of the ScantStudio software.
        ii. The PartGripper may need to be raised in order for the object to sit within the correct window.
    d. Two (or more) scans may be required, each with a different rotation of the element being scanned. This ensures that all faces of the object are scanned.

2. After all scans were completed, any project with multiple scans were then stitched together using the Align Tool in ScanStudio.
    a. Alignment becomes more accurate with more markers placed. It is highly recommended to use more than the minimum requirement of three. For the included scans, roughly six markers were used for alignment.
    b. It is useful to use both morphological features and true color objects to place markers.
    c. If necessary, the use of the paint pen included with the scanner can be useful in situations where there are very few morphological or true color objects to use for alignment. The paint is removable with water.

3. After alignment, the scans were fused using the Fuse tool.
    a. The lower the tolerance is set, the sharper the edges will be in the final model. The scans in this document used a tolerance of 0.

4. The use of any of the Polish tools may be useful in the production of the final model.
    a. Care must be exercised because the use of these tools compromises the accuracy of the scans. The only tool used in the creation of these scans was the Fill tool.
    b. This was only used on small gaps in the model or areas of non-interest.
        i. Filling areas of non-interest (like a hole in the lingual side of a molar that is intact on the actual object) prevents incorrect deductions about the object the model is based on (like the presence of caries that are not actually there).

    c. The objects were then saved as both the native ScanStudio.scn file type and the more universal *.obj file type. This allows ScanStudio to open the object again if necessary, and allows further use of the scan in other programs.

5. The *.obj file was then imported into MeshLab. Further cleaning and repairing is possible in this program.
    a. The “Merge Close Vertices” filter located under Filters > Cleaning and Repairing is useful for micro gaps that may be present in the scan.
    b. The Fill Hole tool has also been used in some scans to repair areas that would not fill in ScanStudio.
        i. The Fill Hole tool in MeshLab does not produce as clean of fills as the Fill tool in ScanStudio.

6. The scan was then exported as a .u3d file. The *.u3d file was then used to create a 3D PDF in Adobe Acrobat X Pro.
    a. These PDFs were first constructed in an alternative text editor for ease of use, but can be completely created inside Acrobat.
    b. The file was then opened in Acrobat and the Add Multimedia tool was used to insert the *.u3d file into the document.
    c. The document can then be saved as a PDF which can be opened by Adobe Reader, version 9 or later.

# 3-D Laser Scanning

Case Number: **WRITE IN FULL CASE NUMBER**
Medical Examiner Case Number: **WRITE IN MEDICAL EXAMINER CASE NUMBER**
Police Agency & Case Number: **WRITE IN POLICE AGENCY / CASE NUMBER**
Date: **WRITE IN DATE FORM WAS COMPLETED**
Personnel: **LIST ALL PERSONNEL WHO CONTRIBUTED TO THIS FORM AND SAMPLE COLLECTION**

**Settings:**

Scan Saved As (File Name): **LIST FILE NAME**

Skeletal Element(s): **NAME OF BONE BEING SCANNED**

Notable Pathologies, Congenital Anomalies, or Trauma present?

Present Absent

If present, list below:

| Pathology, Anomaly or Trauma | Location |
|---|---|
| **LIST ANY ABNORMAL CONDTION, DISEASE PROCESS OR TRAUMA** | |
| | |
| | |

Mode: Wide Macro

Scan Positioning: 360° Bracket Single

Scan Color: Dark Normal Light

Number of Divisions (1-16): _____

Resolution: *Circle your chosen definition range, and circle 1, 2, or 3 for the first, second, or third notch within the selected range.*

| Quick | | | Standard Definition | | | High Definition | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 55 PPI | 80 PPI | 125 PPI | 180 PPI | 280 PPI | 500 PPI | 1.1K PPI | 2.0K PPI | 4.4K PPI |

Additional Notes:

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# Appendix

# FORENSIC ANTHROPOLOGY
# CASE FOLDER CHECKLIST

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

**CHECKLIST** *(INITIAL IF PLACED IN FOLDER)*:

_____ Case Summary

_____ Field/Crime Scene Form

_____ Skeletal Inventory

_____ Sex Assessment

_____ Age Estimation

_____ Ancestry Estimation

_____ Stature Estimation

_____ Dental Analysis

_____ Taphonomy/PMI

_____ Metrics Forms

_____ Skeletal Pathology/Unique Markers

_____ Skeletal Trauma

_____ Isotopes Sampling/Analysis

_____ Facial Approximation/Forensic Imaging

_____ Photography

_____ 3-D Scanning and/or Radiography

_____ Report

_____ CD Copies

_____ Samples Retained/Chain of Custody

# PROTOCOL FOR DATA COLLECTION ~ RHI

**ANTHROPOLOGICAL METHODS FOR IDENTIFICATION**

---

**COLLECTION INFORMATION**

MUSEUM:
LOCATION/POPULATION:
COLLECTION HISTORY:
RECORDER:
DATE:

---

**INDIVIDUAL INFORMATION**

CASE/ID NUMBER**:**
STATUS: **IDENTIFIED** OR **UNKNOWN:**
TIME/DATE OF DEATH**:**
TIME/DATE OF RECOVERY**:**
WHERE WAS THE BODY FOUND? (I.E. DONATED, FORENSIC, ANATOMICAL, ARCHAEOLOGICAL):

POST-MORTEM CONDITION (SKELETAL OR PROCESSED):
CAUSE OF DEATH (LIST PRIMARY AND SECONDARY MECHANISMS):

**DEMOGRAPHIC INFORMATION**

AGE AT DEATH (**EXACT AGE** OR **ESTIMATED AGE RANGE?**):

SEX: ___ MALE ___ FEMALE ___ UNKNOWN (**KNOWN** OR **ESTIMATED**?)

CADAVER STATURE: (CM OR FT):
CADAVER WEIGHT: (K OR LB):
ETHNICITY:
IS THIS DEMOGRAPHIC INFORMATION **CONFIRMED** OR **ESTIMATED**?

**IS THERE ANY EVIDENCE THIS PERSON SUFFERED FROM *OSTEOPOROSIS, METABOLIC,* OR *NUTRITIONAL DEFICIENCIES*?** IF SO, WHAT?

**IS THERE ANY EVIDENCE OF SUBSTANCE ABUSE? IF SO, WHAT?**

**METRIC ANALYSIS FOR STATURE, SEX AND ANCESTRY ESTIMATION (ADULTS AND JUVENILES)**

_____ CRANIAL METRIC (**3D DIGITIZER, DIRECT MEASUREMENT,** OR **X-RAY**)
_____ POST-CRANIAL METRICS (**DIRECT MEASUREMENT** OF BONE OR **RADIOGRAPHIC IMAGE**)
_____ DENTAL METRICS (**DIRECT MEASUREMENT** OF BONE OR **RADIOGRAPHIC IMAGE**)
_____ AGE ESTIMATION (**KNOWN** OR **ESTIMATED**)

# PROTOCOL FOR DATA COLLECTION AT AUTOPSY:

## ANTHROPOLOGICAL METHODS FOR IDENTIFICATION

***DATA COLLECTED FOR ALL CASES, WHETHER KNOWN OR UNIDENTIFIED AT AUTOPSY.*

---

**CASE INFORMATION**

CASE NUMBER:
STATUS: **IDENTIFIED** OR **UNKNOWN**
TIME/DATE OF DEATH**:**
TIME/DATE OF RECOVERY**:**
WHERE WAS THE BODY FOUND (I.E. RESIDENCE, PUBLIC SPACE, OUTSIDE, ETC):

---

POST-MORTEM CONDITION (SKELETAL OR PROCESSED):

MANNER OF DEATH:

___ HOMICIDE
___ SUICIDE
___ ACCIDENT
___ NATURAL
___ UNKNOWN

CAUSE OF DEATH (LIST PRIMARY AND SECONDARY MECHANISMS):

**DEMOGRAPHIC INFORMATION**

AGE AT DEATH (EXACT AGE OR ESTIMATED AGE RANGE?):

SEX**:** ___ MALE
___ FEMALE
___ UNKNOWN

CADAVER STATURE: (CM)**:** _____

CADAVER WEIGHT: (K OF LB): _____

ETHNICITY**:** _____

IS THIS DEMOGRAPHIC INFORMATION **CONFIRMED** OR **ESTIMATED**?

**IS THERE ANY EVIDENCE THIS PERSON SUFFERED FROM *OSTEOPOROSIS, METABOLIC,* OR *NUTRITIONAL DEFICIENCIES*?** IF SO, WHAT?

WERE PHOTOGRAPHS TAKEN OF ANY ELEMENTS? YES OR NO

---

# SKELETAL INVENTORY

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

**CRANIUM AND MANDIBLE COMPLETENESS CODES:** *(1= >75%, 2=25-72%, 3=<25%, 9=NOT PRESENT)*

| **CRANIUM** | | **FACE** | | **ORBIT, PALATE, NOSE** | |
|---|---|---|---|---|---|
| FRONTAL | _____ | MAXILLA (L) | _____ | LACRIMAL (L) | _____ |
| PARIETAL (L) | _____ | MAXILLA (R) | _____ | LACRIMAL (R) | _____ |
| PARIETAL (R) | _____ | ZYGOMATIC (L) | _____ | VOMER | _____ |
| OCCIPITAL | _____ | ZYGOMATIC (R) | _____ | PALATINE (L) | _____ |
| TEMPORAL (L) | _____ | NASAL (L) | _____ | PALATINE (R) | _____ |
| TEMPORAL (R) | _____ | NASAL (R) | _____ | INF. NASAL CONCHA (L) | _____ |
| SPHENOID | _____ | MANDIBLE | _____ | INF. NASAL CONCHA (R) | _____ |
| ETHMOID | _____ | | | | |

| **MISCELLANEOUS** | | **ARTICULAR JOINT SURFACES** | | |
|---|---|---|---|---|
| HYOID | _____ | MANIDUBLAR FOSSA | LEFT_____ | RIGHT_____ |
| MALLEUS (L) | _____ | MASTOID PROCESS | LEFT_____ | RIGHT_____ |
| MALLEUS (R) | _____ | OCCIPITAL CONDYLES | LEFT_____ | RIGHT_____ |
| INCUS (L) | _____ | MANDIBULAR CONDYLES | LEFT_____ | RIGHT_____ |
| INCUS (R) | _____ | | | |
| STAPES (L) | _____ | | | |
| STAPES (R) | _____ | | | |

**TEETH:** *("X" = LOST POSTMORTEM, "/" = LOST ANTEMORTEM, "0" = PRESENT)*

PERMANENT:

| RIGHT: | | | | | | | | LEFT: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M3 | M2 | M1 | P2 | P1 | C | I2 | I1 | I1 | I2 | C | P1 | P2 | M1 | M2 | M3 |
| M3 | M2 | M1 | P2 | P1 | C | I2 | I1 | I1 | I2 | C | P1 | P2 | M1 | M2 | M3 |

DECIDUOUS:

| RIGHT: | | | | | LEFT: | | | | |
|---|---|---|---|---|---|---|---|---|---|
| M2 | M1 | C | I2 | I1 | I1 | I2 | C | M1 | M2 |
| M2 | M1 | C | I2 | I1 | I1 | I2 | C | M1 | M2 |

# SKELETAL INVENTORY

CASE NUMBER:
DATE:
OBSERVER:

**POST-CRANIAL COMPLETENESS CODES:** *(1= >75%, 2=25-72%, 3=<25%, 9=NOT PRESENT. USE TRINARY CODES FOR ALL LONG BONES, INCLUDING METACARPALS AND METATARSALS.)*

| POST-CRANIA | LEFT/RIGHT | CARPALS | LEFT/RIGHT | TARSALS | LEFT/RIGHT |
|---|---|---|---|---|---|
| SCAPULA | _____ _____ | NAVICULAR | _____ _____ | CALCANEUS | _____ _____ |
| CLAVICLE | _____ _____ | LUNATE | _____ _____ | TALUS | _____ _____ |
| HUMERUS | _____ _____ | TRIANGULAR | _____ _____ | CUBOID | _____ _____ |
| RADIUS | _____ _____ | PISIFORM | _____ _____ | 1ST CUNEIFORM | _____ _____ |
| ULNA | _____ _____ | GR. MULT. | _____ _____ | 2ND CUNEIFORM | _____ _____ |
| FEMUR | _____ _____ | LS. MULT. | _____ _____ | 3RD CUNEIFORM | _____ _____ |
| TIBIA | _____ _____ | CAPITATE | _____ _____ | NAVICULAR | _____ _____ |
| FIBULA | _____ _____ | HAMATE | _____ _____ | | |
| PATELLA | _____ _____ | | | | |
| ILIUM | _____ _____ | **METACARPALS** | | **METATARSALS** | |
| ISHIUM | _____ _____ | MC 1 | _____ _____ | MT 1 | _____ _____ |
| PUBIS | _____ _____ | MC 2 | _____ _____ | MT 2 | _____ _____ |
| MANUBRIUM | _____ | MC 3 | _____ _____ | MT 3 | _____ _____ |
| STERNAL BODY | _____ | MC 4 | _____ _____ | MT 4 | _____ _____ |
| XIPHOID | _____ | MC 5 | _____ _____ | MT 5 | _____ _____ |
| SACRUM | _____ | | | | |
| COCCYX | _____ | NO. PHALANGES: | _____ | NO. PHALANGES: | _____ |

| | LEFT/RIGHT | ARTICULAR SURFACES | LEFT/RIGHT |
|---|---|---|---|
| RIB 1 | _____ _____ | AURICULAR SURFACE | _____ _____ |
| RIB 2 | _____ _____ | PUBIC SYMPHYSIS | _____ _____ |
| RIB 3 | _____ _____ | ACETABULUM | _____ _____ |
| RIB 4 | _____ _____ | GLENOID FOSSA | _____ _____ |
| RIB 5 | _____ _____ | | |
| RIB 6 | _____ _____ | | |
| RIB 7 | _____ _____ | | |
| RIB 8 | _____ _____ | | |
| RIB 9 | _____ _____ | | |
| RIB 10 | _____ _____ | | |
| RIB 11 | _____ _____ | | |
| RIB 12 | _____ _____ | | |

**VERTEBRAE**

| CERVICAL | THORACIC | | LUMBAR |
|---|---|---|---|
| C1 _____ | T1 _____ | T8 _____ | L1 _____ |
| C2 _____ | T2 _____ | T9 _____ | L2 _____ |
| C3 _____ | T3 _____ | T10 _____ | L3 _____ |
| C4 _____ | T4 _____ | T11 _____ | L4 _____ |
| C5 _____ | T5 _____ | T12 _____ | L5 _____ |
| C6 _____ | T6 _____ | | |
| C7 _____ | T7 _____ | | |

# HUMAN REMAINS RECOVERY/SCENE FORM

POLICE/ME CASE NUMBER:
CASE NUMBER:
DATE/TIME:
PERSONNEL:
ADDRESS:
GPS (UTM):
POLICE AGENCY:
MEDICAL EXAMINER OFFICE:
SURFACE OR BURIAL:
DESCRIPTION OF ENVIRONMENT:

PRESENCE OF (CIRCLE ALL THAT APPLY): CLOTHING, INSECTS, JEWELRY, ARTIFACTS
OTHER AND DESCRIPTION:

FIELD METHODS UTILIZED FOR GRAVE SEARCH/RECOVERY:

SIZE OF GRAVE:
ORIENTATION:
BODY POSITION:
COLOR AND CONDITION OF HUMAN REMAINS:

(SKETCH NOT TO SCALE)

N

POLICE CASE NUMBER:
CASE NUMBER:
DATE/TIME:

SCENE NOTES:

# TAPHONOMY DATA FORM

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

**FOR EACH BONE AND ASPECT, LIST THE SPECIFIC LOCATION AND EXTENT OF THE FOLLOWING:**

I. COLOR OF BONE:

II. STATE OF PRESERVATION:

III. ADHERENT MATERIALS:

IV. TYPE OF BURIAL: SURFACE, NEAR SURFACE, CONTAINER, BURIAL

V. SURFACE WEATHERING: FLAKING LONGITUDINAL CRACKING BENDING/WARP

   a. AMOUNT OF SURFACE WEATHERING:

VI. BURIAL DAMAGE: FRACTURES OR DAMAGE TO CORTEX?

VII. ROOT DAMAGE:

VIII. EXCAVATION DAMAGE:

IX. CORTICAL EROSION:

X. ANIMAL SCAVENGING:

   a. TYPE OF ALTERATION:

   b. LOCATION:

XI. SUN BLEACHING:

XII. WATER DAMAGE:

   a. SURFACE CRACKING OR DAMAGE

   b. ALGAE STAINING OR ADHERENT MATERIALS

   c. AQUATIC INSECT EGG CASINGS

XIII. FIRE DAMAGE

   a. COLOR: WHITE/YELLOW/BROWN/GREY/BLACK WHITE/GREY/BLUE WHITE

   b. SHRINKAGE: 0-2.5% 1-2% 10-15% >15%

   c. TYPE OF FRACTURES: CHECKBOARD CRESCENT LONGITUDINAL RING

# ESTIMATING PMI

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

## SCAVENGING ACTIVITY:

- WAS THERE POSTMORTEM MODIFICATION TO THE BODY?
- WAS THE BODY MOVED FOLLOWING THE DEATH EVENT?
- EVIDENCE OF SCAVENGER ACTIVITY?
- IF YES, WHAT TYPE OF SCAVENGER?
- IF INSECT ACTIVITY WAS PRESENT, DESCRIBE WHAT SPECIES WERE PRESENT AND THE MOST ADVANCED STAGES OF DEVELOPMENT.
- IF LARVAE WERE FOUND NEAR THE BODY, WHERE WERE THEY FOUND (I.E., UNDER CARPET), AND HOW MANY ROOMS HAD THEY OCCUPIED?

## DECOMPOSITION STAGE DATA:

- ACCORDING TO THE STAGES OUTLINE BY GALLOWAY (1989), WHAT STAGE BEST DESCRIBES THE CONDITION OF THE HUMAN REMAINS?
    - FRESH
    - EARLY OR BLOATED
    - ADVANCED OR DECAY
    - SKELETONIZED
    - MUMMIFIED TISSUES
    - SKELETAL BREAKDOWN

## TEMPERATURE DATA:

- WAS THE AIR TEMPERATURE AT THE TIME OF DEATH OR DISCOVERY KNOWN?
- IF NO, THEN WHAT WAS THE AVERAGE, HIGH, AND LOW TEMPERATURES FOR THAT PARTICULAR DAY? (AREA SPECIFIC: MAY HAVE TO GO BACK TO THIS WITH LOCAL WEATHER DATA).

# CRANIAL MEASUREMENTS

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

## Cranial (mm)

| | | Left | Right |
|---|---|---|---|
| 1. Maximum Length | (g-op) | _____ | |
| 2. Maximum Breadth | (eu-eu) | _____ | |
| 3. Bizygomatic Breadth | (zy-zy) | _____ | |
| 4. Basion-Bregma | (ba-b) | _____ | |
| 5. Cranial Base Length | (ba-n) | _____ | |
| 6. Basion-Prosthion Length | (ba-pr) | _____ | |
| 7. Max. Alveolar Breadth | (ecm-ecm) | _____ | |
| 8. Max. Alveolar Length | (pr-alv) | _____ | |
| 9. Biauricular Breadth | (AUB) | _____ | |
| 10. Upper Facial Height | (na-pr) | _____ | |
| 11. Min. Frontal Breadth | (ft-ft) | _____ | |
| 12. Upper Facial Breadth | (fmt-fmt) | _____ | |
| 13. Nasal Height | (n-ns) | _____ | |
| 14. Nasal Breadth | (al-al) | _____ | |
| 15. Orbital Breadth | (d-ec) | _____ | _____ |
| 16. Orbital Height | (OBH) | _____ | _____ |
| 17. Biorbital Breadth | (ec-ec) | _____ | |
| 18. Interorbital Breadth | (d-d) | _____ | |
| 19. Frontal Chord | (n-b) | _____ | |
| 20. Parietal Chord | (b-l) | _____ | |
| 21. Occipital Chord | (l-o) | _____ | |
| 22. For. Magnum Length | (ba-o) | _____ | |
| 23. For. Magnum Breadth | (FOB) | _____ | |
| 24. Mastoid Length | (MDH) | _____ | _____ |
| 25. Biasterion Breadth | (ASB) | _____ | |
| 26. Zygomaxillary Breadth | (ZMB) | _____ | |
| 27. Mid-orbital Width | (MOW) | _____ | |

## Mandible (mm)

| | | Left | Right | | |
|---|---|---|---|---|---|
| Chin Height | (GNI) | _____ | | Maximum Ramus Height~ | _____ |
| Body height @ mental for | (HMF) | _____ | _____ | Mandible Length~ | _____ |
| Body thickness @ mental for | (TMF) | _____ | _____ | Mandible Angle~ | _____ |
| Bigonial Breadth | (GOG) | _____ | | | |
| Bicondylar Breadth | (CDL) | _____ | | | |
| Minimum Ramus Breadth | (WRB) | _____ | _____ | | |

All standard cranial and mandibular measurements (Moore-Jensen et al. 1994; Buikstra and Ubelaker, 1994)
~Mandibular Measurement that should only be taken with mandibulometer.

# MICROSCRIBE RESULTS – LINEAR METRICS

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

| Catkey | Indiv | Repeat | RECR | GOL | NOL | BNL | BBH | XCB | XFB |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| WFB | ZYB | AUB | ASB | BPL | NPH | NLH | JUB | NLB | MAB |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| MAL | MDH | OBH | OBB | DKB | NDS | WNB | SIS | ZMB | SSS |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| FMB | NAS | EKB | DKS | IML | XML | MLS | WMH | GLS | STB |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| FRC | FRS | FRF | PAC | PAS | PAF | OCC | OCS | OCF | FOL |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| FOB | NAR | SSR | PRR | DKR | ZOR | FMR | EKR | ZMR | AVR |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| BRR | VRR | LAR | OSR | BAR | NAA | PRA | BAA | NBA | BBA |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| BRA | SSA | NFA | DKA | NDA | SIA | FRA | PAA | OCA | STA |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| CBA | BFA | BPA | FXA | RFA | RPA | ROA | BSA | SBA | SLA |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| TBA | UFBR | UFHT | GNI | HML | TML | GOG | CDL | WRB | XRH |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| MLT | MAN | Date | Reshaped | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

Comments:

# 3D COORDINATE ANALYSIS

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

| Order | CATKEY | Indiv | Repeat | LMAbbrev | X | Y | Z |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

# POSTCRANIAL MEASUREMENTS

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

| | | Left | Right |
|---|---|---|---|
| 1. Clavicle max length* | (CML-CLAXLN) | _____ | _____ |
| 2. Clavicle A-P diam midshaft* | (CSD-CLAAPD) | _____ | _____ |
| 3. Clav S-I diam midshaft* | (CVD-CLAVRD) | _____ | _____ |
| 4. Scapula max height* | (SML-SCAPHT) | _____ | _____ |
| 5. Scapula max breadth* | (SMB-SCAPBP) | _____ | _____ |
| 6. Scapula spine length | (SLS) | _____ | _____ |
| 7. Scapula supraspinous length | (SSL) | _____ | _____ |
| 8. Scapula infraspinous length | (ISL) | _____ | _____ |
| 9. Scap glenoid cavity breadth | (GCB) | _____ | _____ |
| 10. Scap glenoid cavity height | (GCH) | _____ | _____ |
| 11. Scap glenoid to inf angle | (GIL) | _____ | _____ |
| 12. Manubrium length | (MML) | _____ | |
| 13. Mesosternum length | (MSL) | _____ | |
| 14. Stenebra 1 width | (S1W) | _____ | |
| 15. Stenebra 3 width | (S3W) | _____ | |
| 16. Humerus max length* | (HML-HUMXLN) | _____ | _____ |
| 17. Hum prox epiph breadth | (BUE) | _____ | _____ |
| 18. Hum max diam midshaft* | (MDS-HUMMXD) | _____ | _____ |
| 19. Hum min diam midshaft* | (MDM-HUMMWD) | _____ | _____ |
| 20. Hum max vert diam head* | (MDH-HUMHDD) | _____ | _____ |
| 21. Hum epicondylar breadth* | (EBR-HUMEBR) | _____ | _____ |
| 22. Hum least circum of shaft | (LCS) | _____ | _____ |
| 23. Radius max length* | (RML-RADXLN) | _____ | _____ |
| 24. Radius max diam head | (RDH) | _____ | _____ |
| 25. Radius A-P diam of shaft* | (RSD-RADAPD) | _____ | _____ |
| 26. Radius M-L diam of shaft* | (RTD-RADTVD) | _____ | _____ |
| 27. Radius neck shaft circum | (MCS) | _____ | _____ |
| 28. Ulna max length* | (UML-ULNXLN) | _____ | _____ |
| 29. Ulna physiological length* | (UPL-ULNPHL) | _____ | _____ |
| 30. Ulna max br olecranon | (BOP) | _____ | _____ |
| 31. Ulna min br olecranon | (MBO) | _____ | _____ |
| 32. Ulna max wd olecranon | (WOP) | _____ | _____ |
| 33. Ulna olec-radial notch | (ORL) | _____ | _____ |
| 34. Ulna olec-coronoid length | (OCL) | _____ | _____ |
| 35. Ulna A-P diam shaft* | (UAB-ULNDVD) | _____ | _____ |
| 36. Ulna M-L diam midshaft* | (UMD-ULNTVD) | _____ | _____ |
| 37. Ulna least circum shaft* | (UMD-ULNCIR) | _____ | _____ |
| 38. Sacrum anterior length* | (SAL-SACAHT) | _____ | |
| 39. Sacrum A-S breadth* | (SAB-SACABR) | _____ | |
| 40. Sacrum max breadth S1* | (SMB-SACS1B) | _____ | |
| 41. Innominate height* | (INH-INNOHT) | _____ | _____ |
| 42. Iliac breadth* | (ILB-ILIABR) | _____ | _____ |
| 45. Femur max length* | (FML-FEMXLN) | _____ | _____ |
| 46. Femur bicondylar length* | (FOL-FEMBLN) | _____ | _____ |
| 47. Femur trochanteric length | (FTL) | _____ | _____ |
| 48. Fem subtroch A-P diam | (APD) | _____ | _____ |
| 49. Fem subtroch M-L diam | (MLD) | _____ | _____ |
| 50. Fem A-P diam midshaft* | (APS-FEMMAP) | _____ | _____ |
| 51. Fem M-L diam midshaft* | (MLS-FEMMTV) | _____ | _____ |
| 52. Fem max vert diam head* | (VDH-FEMHDD) | _____ | _____ |
| 53. Fem max horiz diam head | (HHD) | _____ | _____ |
| 54. Fem A-P diam lat condyle | (APL) | _____ | _____ |
| 55. Fem A-P diam med condyle | (APM) | _____ | _____ |
| 56. Fem epicondylar breadth* | (FEB-FEMEBR) | _____ | _____ |
| 57. Fem bicondylar breadth | (BCB) | _____ | _____ |
| 58. Fem min vert diam neck | (VDN) | _____ | _____ |
| 59. Femur circum midshaft* | (FCS-FEMCIR) | _____ | _____ |
| 60. Tibia condylo-malle length* | (TML-TIBXLN) | _____ | _____ |
| 61. Tibia max br prox epiph* | (BPE-TIBPEB) | _____ | _____ |
| 62. Tibia max br dist epiph* | (BDE-TIBDEB) | _____ | _____ |
| 63. Tibia A-P diam nut for* | (APN-TIBNFX) | _____ | _____ |
| 64. Tibia M-L diam nut for* | (MLM-TIBNFT) | _____ | _____ |
| 65. Tibia position of nut for | (CFL) | _____ | _____ |
| 66. Tibia cirum at nut for* | (PCN-TIBCIR) | _____ | _____ |
| 67. Fibula maximum length* | (BML-FIBXLN) | _____ | _____ |
| 68. Fibula max diam midshaft* | (FMD-FIBMDM) | _____ | _____ |
| 69. Calcaneus maximum length* | (CLL-CALCXL) | _____ | _____ |
| 70. Calcaneus middle breadth* | (CMB-CALCBR) | _____ | _____ |

**Numbers refer to associated Zobeck definition** *(Zobeck 1983)*.
*** Standard measurements***(Moore-Jensen et al. 1994)*

# POSTCRANIAL MEASUREMENTS

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

| | MEASUREMENT | | LEFT (MM) | RIGHT (MM) |
|---|---|---|---|---|
| 1. | Clavicle max length | (CML-CLAXLN) | | |
| 2. | Clavicle A-P diam. midshaft | (CSD-CLAAPD) | | |
| 3. | Clavicle S-I diam. midshaft | (CVD-CLAVRD) | | |
| 4. | Manubrium length | | | |
| 5. | Mesosternum length | | | |
| 6. | Stenebra 1 Width | | | |
| 7. | Stenebra 3 Width | | | |
| 8. | Humerus max Length | (HML-HUMXLN) | | |
| 9. | Humerus max. diam. head | (MDH-HUMHDD) | | |
| 10. | Hum prox epiph breadth | (BUE) | | |
| 11. | Hum max diam midshaft | (MDS-HUMMXD) | | |
| 12. | Hum epicondylar breadth | (EBR-HUMEBR) | | |
| 13. | Radius max length | (RML-RADXLN) | | |
| 14. | Radius max diam head | (RDH) | | |
| 15. | Radius A-P diam of shaft | (RSD-RADAPD) | | |
| 16. | Radius M-L diam of shaft | (RTD-RADTVD) | | |
| 17. | Ulna max length | (UML-ULNXLN) | | |
| 18. | Ulna physiological length | (UPL-ULNPHL) | | |
| 19. | Ulna A-P diam shaft | (UAB-ULNDVD) | | |
| 20. | Ulna M-L diam midshaft | (UMD-ULNTVD) | | |
| 21. | Femur max length | (FML-FEMXLN) | | |
| 22. | Femur bicondylar length | (FOL-FEMBLN) | | |
| 23. | Femur max. vert. head | (VDH-FEMHDD) | | |
| 24. | Fem A-P diam midshaft | (APS-FEMMAP) | | |
| 25. | Fem M-L diam midshaft | (MLS-FEMMTV) | | |
| 26. | Fem max vert diam head | (VDH-FEMHDD) | | |
| 27. | Fem epicondylar breadth | (FEB-FEMEBR) | | |
| 28. | Femur circum midshaft | (FCS-FEMCIR) | | |
| 29. | Tibia condylo-malle length | (TML-TIBXLN) | | |
| 30. | Tibia max br prox epiph | (BPE-TIBPEB) | | |
| 31. | Tibia max br dist epiph | (BDE-TIBDEB) | | |
| 32. | Tibia A-P diam nut for | (APN-TIBNFX) | | |
| 33. | Tibia M-L diam nut for | (MLM-TIBNFT) | | |
| 34. | Tibia cirum at nut for | (PCN-TIBCIR) | | |
| 35. | Fibula maximum length | (BML-FIBXLN) | | |
| 36. | Fibula max diam midshaft | (FMD-FIBMDM) | | |

# SEX ASSESSMENT - MORPHOLOGY

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

**1 = FEMALE, 2 = PROBABLE FEMALE, 3= INDETERMINATE, 4=PROBABLE MALE, 5=MALE**

| **I.** **CRANIUM** | **LEFT** | **MIDLINE** | **RIGHT** |
|---|---|---|---|
| GLABELLA (1-5) | | _____ | |
| SUPRAORBITAL MARGIN (1-5) | _____ | | _____ |
| EXTERNAL NUCHAL PROTURB. (1-5) | | _____ | |
| MASTOID PROCESS (1-5) | _____ | | _____ |
| MENTAL EMINENCE (1-5) | | _____ | |

*(Phenice 1969; Acsádi and Nemeskéri 1970)*

| **CRANIAL FEATURES** | **FEMALE** | **MALE** |
|---|---|---|
| FOREHEAD | VERTICAL | RETREATING |
| NUCHAL LINES | ABSENT/SLIGHT | DEVELOPED |
| SUPRAMEATAL CREST | ABSENT/SLIGHT | DEVELOPED |
| GONIAL ANGLE | >125° | ~90° |

| **II.** **INNOMINATE** | **LEFT** | **RIGHT** |
|---|---|---|
| VENTRAL ARC (1-3) | _____ | _____ |
| SUBPUBIC CONCAVITY (1-3) | _____ | _____ |
| ISCHIOPUBIC RAMUS RIDGE (1-3) | _____ | _____ |
| GREATER SCIATIC NOTCH (1-5) | _____ | _____ |
| PREAURICUALR SURFACE (1-4) | _____ | _____ |

*(Techniques found in Phenice 1969 and Buikstra and Ubelaker 1994)*

| **PELVIC FEATURES** | **FEMALE** | **MALE** |
|---|---|---|
| SUPERIOR INLET | OVAL SHAPED | HEART SHAPED |
| PUBIC BONE | RECTANGULAR | TRIANGULAR |
| VENTRAL ARC | PRESENT | ABSENT |
| AURICULAR SURFACE | RAISED | FLAT |
| SCARS OF PARTURITION | PRESENT | ABSENT |

| **III.** **SACRUM** | **FEMALE** | **MALE** |
|---|---|---|
| BODY SHAPE | STRAIGHT | CURVED |
| BODY-TO-ALA RATIO | BODY = ALA | BODY > ALA |
| AURICULAR SURFACE | 1-2 SEGMENTS | 1-3 SEGMENT |

# SEX ASSESSMENT - MORPHOLOGY

CASE NUMBER:
DATE:
OBSERVER:

| | | | SECTIONING POINTS (MM) *(Sectioning points from Bass 2005)* | |
|---|---|---|---|---|
| **IV.** | **HUMERUS** | **MM** | **FEMALE** | **MALE** |
| | MAXIMUM HEAD DIAMETER | _____ | < 43 | >47 |
| | TRANSVERSE HEAD DIAMETER | _____ | <37 | >44 |
| | BIEPICONDYLAR WIDTH | _____ | <56 | >63 |
| | SEPTAL APERTURE | | PRESENT | ABSENT |
| **V.** | **STERNUM** | | | |
| | MANUBRIUM LENGTH X 100 / BODY LENGTH | _____ | RATIO >58MM | <43MM |
| **VI.** | **FEMUR** | | | |
| | MAXIMUM HEAD DIAMETER | _____ | < 42.5 | > 47.5 |
| | BICONDYLAR WIDTH | _____ | < 72 | > 78 |
| | MIDSHAFT CIRCUMFERENCE | _____ | | |
| | *AMERICAN INDIANS* | | < 81 | > 81 |
| | *AMERICAN WHITES/BLACKS* | | < 86 | > 86 |
| | HEAD-NECK ANGLE | _____ | ~ 90° | > 120° |
| **VII.** | **TIBIA** | | | |
| | MIDSHAFT CIRCUMFERENCE AT NF | _____ | | |
| | *AMERICAN WHITES* | | *< 90.2* | *> 90.2* |
| | *AMERICAN BLACKS* | | *< 92.8* | *> 92.8* |
| | *AMERICAN INDIANS* | | < 91.2 | > 91.2 |

# ADULT BIOMARKERS FOR AGE ESTIMATION

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

**FINAL AGE ESITMATE: _____**

**I. CRANIAL SUTURE CLOSURE** *(Meindl and Lovejoy 1985)*
*0=OPEN, 1=MINIMAL, 2=SIGNIFICANT CLOSURE, 3=COMPLETE, 9 =UNOBSERVABLE*

| **EXTERNAL CRANIAL VAULT** | | **INTERNAL CRANIAL VAULT** | |
|---|---|---|---|
| MIDLAMDOIDAL | _____ | MID CORONAL | _____ |
| LAMBDA | _____ | MID SAGITTAL | _____ |
| OBELION | _____ | MIDLAMDOIDAL | _____ |
| ANTERIOR SAGITTAL | _____ | | |
| BREGMA | _____ | **INTERNAL SCORE**: | _____ |

**VAULT TOTAL:** _____

MIDCORONAL _____
PTERION _____
SPHENOFRONTAL _____
INTERIOR SPHENOFRONTAL _____
SUPERIOR SPHENOFRONTAL _____

**LATERAL-ANTERIOR TOTAL**:_____

**II. MAXILLARY SUTURE CLOSURE** *(Mann et al. 1987; Buikstra and Ubelaker 1994)*
*0=OPEN, 1=MINIMAL, 2=SIGNIFICANT CLOSURE, 3=COMPLETE, 9 =UNOBSERVABLE*

| **Suture Closure** | **Amount of Closure (0-3)** | **Age** |
|---|---|---|
| Incisive Suture (IN)<br>*20-25 yr. | | |
| Intermaxillary Suture (AMP)<br>*50+ yr. | | |
| Palatomaxillary Suture (TP)<br>Medial *40+ yr.<br>Lateral *35+ yr. | | |
| Interpalatine Suture (PMP)<br>*25-30 yr. | | |
| Greater Palatine Foramen Suture<br>*30-85 yr. | | |

**Approximate Age of Complete Closure*

# ADULT BIOMARKERS FOR AGE ESTIMATION

CASE NUMBER:
DATE:
OBSERVER:

| **III. PUBIC SYMPHYSIS** | **LEFT** | **RIGHT** | **MEAN AGE & INTERVAL** |
|---|---|---|---|
| AURICULAR SURFACE *(Lovejoy et al. 1985; Meindl and Lovejoy 1989)* | _____ | _____ | _____ |
| SUCHEY-BROOKS (1-6) *(Brooks and Suchey 1990)* | _____ | _____ | _____ |
| BERG (7 PHASES) *(Berg 2008)* | _____ | _____ | _____ |

| **IV. STERNAL RIB END** | **LEFT** | **RIGHT** | **MEAN AGE & INTERVAL** |
|---|---|---|---|
| ISCAN 4TH RIB | _____ | _____ | _____ |
| DIGANGI 1ST RIB | _____ | _____ | _____ |

*(Iscan et al. 1984; DiGangi et al. 2009)*

| **V. HYOID FUSION** | **LEFT** | **RIGHT** |
|---|---|---|
| FUSION SCORE (0 OR 1) | _____ | _____ |
| MOBILITY SCORE (0 OR 1) | _____ | _____ |

HYOID OBSERVATIONS _____

**VI. LAMENDIN DENTAL METRICS (TOOTH NUMBER_____)** *(Lamendin et al. 1992)*

| **Dental Metrics** | (mm) |
|---|---|
| Tooth Number: | |
| Root Height: | |
| CMJ: | |
| Translucency: | |

**Lamendin Regression Formula**

P = Periodontitis Height (CMJ) * 100 / (Root Height)
T = Translucency Height * 100 / (Root Height)

Age = (0.18 * P) + (0.42 * T) + 25.53

**Lamendin Age Intervals and Pertinent Error Ranges:**

| *Age Intervals* | 26-29 | 30-39 | 40-49 | 50-59 | 60-69 | 70-79 | 80-89 |
|---|---|---|---|---|---|---|---|
| *Mean Error (years)* | 24.8 | 15.5 | 9.9 | 7.3 | 6.3 | 11.6 | 18.9 |

**VII.** VERTEBRAL AND JOINT CHANGES (DESCRIBE ANY AGE RELATED CHANGES – LOCATION, TYPE OF RESPONSE AND EXTENT):

**VIII.** COMMENTS:

# HYOID FUSION

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

I. FINAL AGE ESTIMATE:

II. PRESENCE OF HYOID TRAUMA:

III. IS THE MECHANISM OF INJURY KNOWN?

IV. FUSION SCORE:
- "0": COMPLETELY UNFUSED CORNUA
- "1": PARTIALLY OR COMPLETELY FUSED CORNUA

V. IS THIS SCORE BASED ON DIRECT OBSERVATION OR FROM X-RAY FILM?

VI. MOBILITY SCORE:
- "0": COMPLETELY UNFUSED CORNUA
- "1": PARTIALLY OR COMPLETELY FUSED CORNUA

# JUVENILE BIOMARKER FORM

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

**FINAL AGE ESITMATE: _____**

**I. Dental Development** *(Mincer et al. 1993 and Moorees, Fanning, and Hunt 1963a, b)*

*Deciduous*

Maxillary I1 _____ I2 _____ C _____ M1 _____ M2 _____

Mandibular I1 _____ I2 _____ C _____ M1 _____ M2 _____

*Permanent*

Maxillary I1 _____ I2 _____ C _____ PM1_____ PM2 _____ M1 _____ M2 _____ M3 _____

Mandibular I1 _____ I2 _____ C _____ PM1_____ PM2 _____ M1 _____ M2 _____ M3 _____

**II. Dental Eruption** *(Ubelaker 1978):* AGE _____

**III. Epiphyseal Union** (0-3) *(Krogman and Iscan 1986)* AGE _____

| | | | |
|---|---|---|---|
| Metopic suture | _____ | Clav. sternal end | _____ |
| Mental symphysis | _____ | Humerus, prox. | _____ |
| Lateral to Basilar | _____ | Humerus, distal | _____ |
| Lateral to Squamous | _____ | Humerus, epicondyle | _____ |
| Basilar suture | _____ | Radius, prox. | _____ |
| C: halves to arch | _____ | Radius, distal | _____ |
| C: arch to centrum | _____ | Ulna, distal | _____ |
| C: vert. sup. rim | _____ | Illium to Pubis | _____ |
| C: vert. inf. rim | _____ | Ischium to Pubis | _____ |
| T: halves to arch | _____ | Ischium to Illium | _____ |
| T: arch to centrum | _____ | Ischial tuberosity | _____ |
| T: vert. sup. rim | _____ | Iliac crest | _____ |
| T: vert. inf. rim | _____ | Femur, prox. | _____ |
| L: halves to arch | _____ | Femur, gr. troch. | _____ |
| L: arch to centrum | _____ | Femur, lsr. troch. | _____ |
| L: vert. sup. rim | _____ | Femur, distal | _____ |
| L: vert. inf. rim | _____ | Tibia, prox. | _____ |
| Scap. glenoid cavity | _____ | Tibia, distal | _____ |
| Scap. acromion | _____ | Fibula, prox. | _____ |
| Scap. inf. angle | _____ | Fibula, distal | _____ |
| Scap. medial border | _____ | S1-S2 _____ | S3-S4 _____ |
| Clav. sternal end | _____ | S2-S3 _____ | S4-S5 _____ |

# JUVENILE BIOMARKER FORM

CASE NUMBER:
DATE:
OBSERVER:

**IV. Juvenile Cranial Measurements** (in mm) AGE _____
*(Age parameters found in Schaefer et al. 2009)*

Occipital Bone:

Basilaris Max. Width _____

Basilaris Sagittal Length _____

Sphenoid:

Body Length _____

Body Width _____

| Temporal Bone: | LEFT | RIGHT |
|---|---|---|
| Squama Height | | |
| Squama Width | | |
| Pars Petrosa Length | | |
| Pars Petross Width | | |

**V. Juvenile Postcranial Measurements** (in mm) AGE _____
*(Age parameters found in Ubelaker 1978)*

| | LEFT | RIGHT |
|---|---|---|
| Clavicle Max. Length | | |
| Scapula Max. Length | | |
| Humerus Max. Length | | |
| Radius Max. Length | | |
| Ulna Max. Length | | |
| Ilium Max. Length | | |
| Os Pubis Max. Length | | |
| Femur Max. Length | | |
| Tibia Max. Length | | |
| Fibula Max. Length | | |

# JUVENILE DENTAL DEVELOPMENT

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

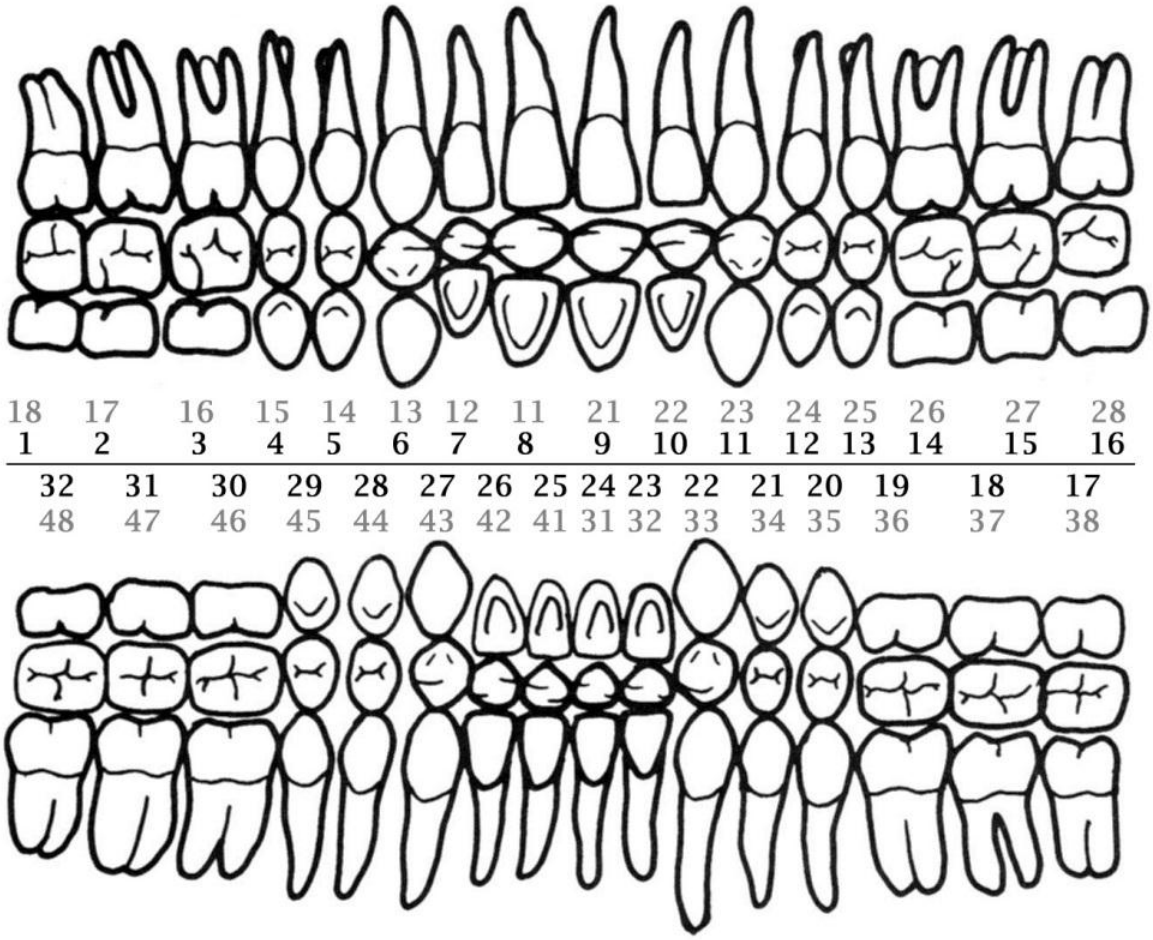
AGE ESTIMATION:_____

*(Adapted from Mincer et al. 1993 and Moorees et al. 1963 a, b)*

| TOOTH | SIDE | STAGE | AGE INTERVAL |
|---|---|---|---|
| dc | _____ | _____ | _____ |
| dm1 | _____ | _____ | _____ |
| dm2 | _____ | _____ | _____ |
| $I^1$ | _____ | _____ | _____ |
| $I^2$ | _____ | _____ | _____ |
| $C^1$ | _____ | _____ | _____ |
| $P^1$ | _____ | _____ | _____ |
| $P^2$ | _____ | _____ | _____ |
| $M^1$ | _____ | _____ | _____ |
| $M^2$ | _____ | _____ | _____ |
| $M^3$ | _____ | _____ | _____ |
| $I_1$ | _____ | _____ | _____ |
| $I_2$ | _____ | _____ | _____ |
| $C_1$ | _____ | _____ | _____ |
| $P_1$ | _____ | _____ | _____ |
| $P_2$ | _____ | _____ | _____ |
| $M_1$ | _____ | _____ | _____ |
| $M_2$ | _____ | _____ | _____ |
| $M_3$ | _____ | _____ | _____ |

# ADULT DENTAL DATA

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:




MARK THE DIAGRAM WITH THE FOLLOWING:

X = TOOTH IS MISSING
C = CAVITY OR PATHOLOGY
F = TOOTH FRACTURES
M = TOOTH MODIFIED

NUMBERING SYSTEM:
**BLACK** = AMERICAN SYSTEM
GREY = EUROPEAN SYSTEM

# ADULT DENTAL DATA

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

| | Observation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tooth** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
| **1**/ 18 | | | | | | | | | | | | |
| **2**/ 17 | | | | | | | | | | | | |
| **3**/ 16 | | | | | | | | | | | | |
| **4**/ 15 | | | | | | | | | | | | |
| **5**/ 14 | | | | | | | | | | | | |
| **6**/ 13 | | | | | | | | | | | | |
| **7**/ 12 | | | | | | | | | | | | |
| **8**/ 11 | | | | | | | | | | | | |
| **9**/ 21 | | | | | | | | | | | | |
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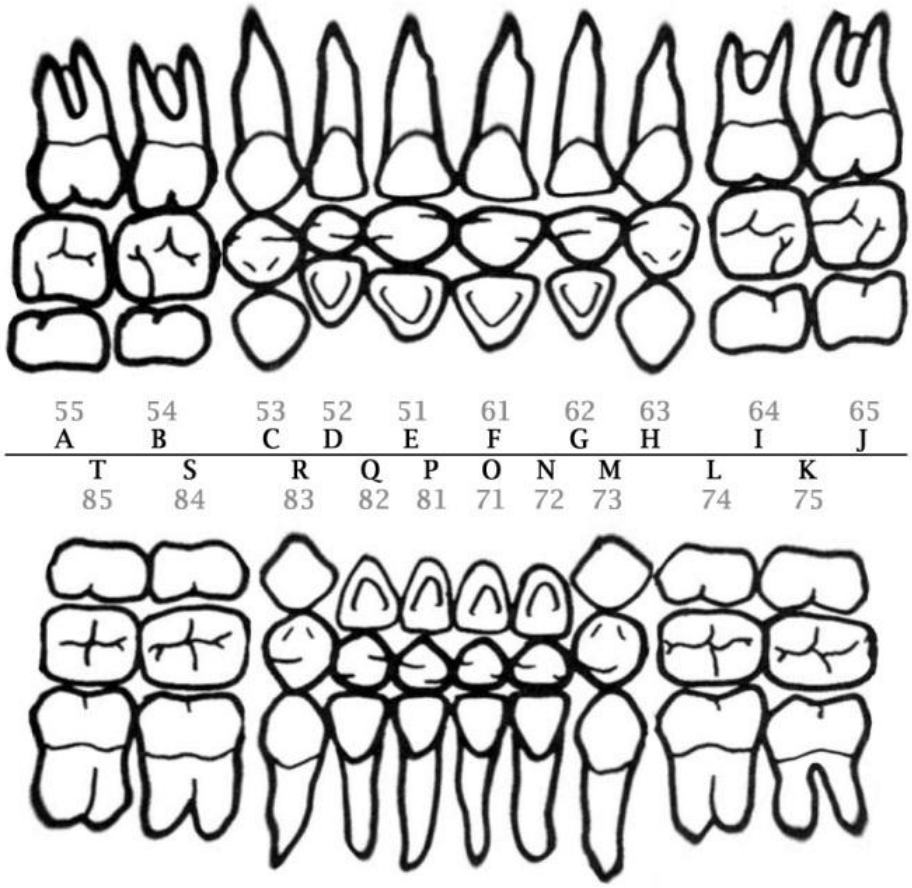
# JUVENILE DENTAL DATA

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

| | Observation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tooth** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
| **A** / 55 | | | | | | | | | | | | |
| **B** / 54 | | | | | | | | | | | | |
| **C** / 53 | | | | | | | | | | | | |
| **D** / 52 | | | | | | | | | | | | |
| **E** / 51 | | | | | | | | | | | | |
| **F** / 61 | | | | | | | | | | | | |
| **G** / 62 | | | | | | | | | | | | |
| **H** / 63 | | | | | | | | | | | | |
| **I** / 64 | | | | | | | | | | | | |
| **J** / 65 | | | | | | | | | | | | |
| **K** / 75 | | | | | | | | | | | | |
| **L** / 74 | | | | | | | | | | | | |
| **M** / 73 | | | | | | | | | | | | |
| **N** / 72 | | | | | | | | | | | | |
| **O** / 71 | | | | | | | | | | | | |
| **P** / 81 | | | | | | | | | | | | |
| **Q** / 82 | | | | | | | | | | | | |
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| **S** / 84 | | | | | | | | | | | | |
| **T** / 85 | | | | | | | | | | | | |

# JUVENILE DENTAL DATA

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:




MARK THE DIAGRAM WITH THE FOLLOWING:

X = TOOTH IS MISSING
C = CAVITY OR PATHOLOGY
F = TOOTH FRACTURES
M = TOOTH MODIFIED

NUMBERING SYSTEM:
**BLACK** = AMERICAN SYSTEM
**GREY** = EUROPEAN SYSTEM

# STATURE ESTIMATION

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
OBSERVER:

**STATURE ESTIMATION MALES:**

| Population | Long Bone | Side | Formula | Stature | SE +/- |
|---|---|---|---|---|---|
| **American Whites** | Humerus | Left/Right | _____ (cm) × 3.08 + 70.45 = | | 4.05 |
| | Femur | Left/Right | _____ (cm) × 2.38 + 61.41 = | | 3.27 |
| | Tibia | Left/Right | _____ (cm) × 2.52 + 78.62 = | | 3.37 |
| **American Blacks** | Humerus | Left/Right | _____ (cm) × 3.26 + 62.10 = | | 4.43 |
| | Femur | Left/Right | _____ (cm) × 2.11 + 70.35 = | | 3.94 |
| | Tibia | Left/Right | _____ (cm) × 2.19 + 86.02 = | | 3.78 |

**STATURE ESTIMATION FEMALES:**

| Population | Long Bone | Side | Formula | Stature | SE +/- |
|---|---|---|---|---|---|
| **American Whites** | Humerus | Left/Right | _____ (cm) × 3.36 + 57.97 = | | 4.45 |
| | Femur | Left/Right | _____ (cm) × 2.47 + 54.74 = | | 3.72 |
| | Tibia | Left/Right | _____ (cm) × 2.90 + 59.24 = | | 3.66 |
| **American Blacks** | Humerus | Left/Right | _____ (cm) × 3.08 + 64.67 = | | 4.25 |
| | Femur | Left/Right | _____ (cm) × 2.28 + 59.76 = | | 3.41 |
| | Tibia | Left/Right | _____ (cm) × 2.45 + 72.65 = | | 3.70 |

*Formulae borrowed from Trotter (1970) and Jantz (1992).*

# FACIAL APPROXIMATION

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
PERSONNEL:

SKELETAL OR DECOMPOSITION:

METHOD OF TISSUE PROCESSING:

METHOD OF FACIAL RECONSTRUCTION:

HAS A PRIOR RECONSTRUCTION BEEN COMPLETED?

**BIOLOGICAL PROFILE**

SEX:
AGE:
ANCESTRY:
STATURE, WEIGHT AND BUILD:

**ANTEMORTEM FACIAL TRAUMA OR PATHOLOGY:**

**UNIQUE IDENTIFICATION MARKERS:**

TATTOOS, SCARS, MOLES, OTHER:
ASYMMETRIES?
TMJ?

EDENTULOUS OR SUBSTANTIAL DENTAL ANOMALIES:

CONTEXTUAL IDENTIFICATION:

GENERAL DESCRIPTION:

IMAGES CREATED:
____ FACIAL APPROXIMATION – SKELETAL
____ FACIAL APPROXIMATION – DECOMPOSED
____ CLOTHING – LIST: _____
____ TEETH – LIST: _____

# ISOTOPE SAMPLES

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
PERSONNEL:
AGE:
SEX:
CONTEXTUAL INFORMATION:

| Sample | Bone Location or Tooth Number | Side | Purpose/Lab for Analysis |
|---|---|---|---|
| **1.** | | | |
| **2.** | | | |
| **3.** | | | |
| **4.** | | | |
| **5.** | | | |

Signature and Date of Person Who Collected Samples

| Sample | Date of Shipment/Transfer | Location of Shipment/Transfer | Initials | Confirmation of Receipt |
|---|---|---|---|---|
| **1.** | | | | |
| **2.** | | | | |
| **3.** | | | | |
| **4.** | | | | |
| **5.** | | | | |

# ISOTOPE SAMPLE LOG

| Case Number | Bone Location or Tooth Number & Side | Quantity of Samples | Initials |
|---|---|---|---|
| | | | |
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# 3-D LASER SCANNING

CASE NUMBER:
MEDICAL EXAMINER CASE NUMBER:
POLICE AGENCY & CASE NUMBER:
DATE:
PERSONNEL:

**SETTINGS:**

SCAN SAVED AS (FILE NAME):

SKELETAL ELEMENT(S):

NOTABLE PATHOLOGIES, CONGENITAL ANOMALIES, OR TRAUMA PRESENT?

PRESENT ABSENT

IF PRESENT, LIST BELOW:

| PATHOLOGY, ANOMALY OR TRAUMA | LOCATION |
|---|---|
| | |
| | |
| | |

MODE: WIDE MACRO

SCAN POSITIONING: 360° BRACKET SINGLE

SCAN COLOR: DARK NORMAL LIGHT

NUMBER OF DIVISIONS (1-16): _____

RESOLUTION: *CIRCLE YOUR CHOSEN DEFINITION RANGE, AND CIRCLE 1, 2, OR 3 FOR THE FIRST, SECOND, OR THIRD NOTCH WITHIN THE SELECTED RANGE.*

| QUICK | | | STANDARD DEFINITION | | | HIGH DEFINITION | | |
|---|---|---|---|---|---|---|---|---|
| 1<br>55 PPI | 2<br>80 PPI | 3<br>125 PPI | 1<br>180 PPI | 2<br>280 PPI | 3<br>500 PPI | 1<br>1.1K PPI | 2<br>2.0K PPI | 3<br>4.4K PPI |

ADDITIONAL NOTES:

# Interview Protocol for Missing, Endangered, and Unidentified Persons




Research in Human Identification



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Version 1.0.2012

Research funded by:

This project was supported by Award No. NIJ 2008-DN-BX-KI63 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

The opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect those of the Department of Justice.

To Cite:
Kimmerle EH, Massucci CJ, Tise ML. 2012. Interview Protocol for Missing, Endangered, and Unidentified Persons. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

# Interview Protocol for Missing, Endangered, and Unidentified Persons

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# EXECUTIVE SUMMARY

Interviewing survivors of massacre, torture or other acts of violent crime or witnesses to homicide presents specific problems when an investigator is attempting to establish *legal* reliability and/or credibility from memory recollection. Similar challenges exist in cold case investigations or when attempting to illicit information about missing persons from witnesses. The role of anthropologists in international criminal and humanitarian investigations is more varied than in typical American casework, extending from fieldwork to interviewing survivors, witnesses and family members who have experienced atrocity or loss. Even in American casework, forensic anthropologists who are tasked with clandestine grave searches must work very closely with law enforcement to understand information from witnesses that aids in the development of search strategies. Therefore, the ability of anthropologists and investigators to successfully interview family members and survivors is critical to successfully completing the mission.

Many cases of human rights violations, war crimes, enforced disappearances, extrajudicial executions, and cold case homicides are investigated years following the incident. During a traditional criminal investigation, the interview may be conducted in the early stages of an investigation, as opposed to interviews conducted during the process of the traditional "cold case" investigation. Because the purpose of an interview is to collect information, it may be conducted before evidence is analyzed or all of the factual information and investigation is known. Obviously, the more information the investigator knows about the crime and the suspect, the more meaningful will be the subsequent interview. However, on a practical level, the investigator should take advantage of any opportunity to conduct an interview regardless of sketchy facts or the absence of specific evidence. Additionally, beyond the scope of criminal investigations, truth commissions have often been established to provide a full accounting of the events that occurred to create an historical account and public record. Therefore, interviews related to crimes may be conducted for multiple purposes.

The purpose of this protocol is to provide best practice recommendations for conducting a direct, goal oriented interview that also allows interviewees the opportunity to tell their stories in the oral tradition. This technique allows for the broadest opportunity to gather information and identify evidence. Investigators who attempt to gather the *legal truth* from events that have

occurred in the past are faced with the challenge of corroboration and will be limited by the existence of evidence. These types of forensic interviews are a starting point for the anthropologists who are searching for physical evidence and can be used by law enforcement to corroborate physical evidence in instances such as cold case investigations. Investigators who are developing a forensic interview strategy must account for a variety of factors before they consider the validity of episodic memory such as the elapsed amount of time between the event and the interview, the psychological effects of trauma, the potential of outside influence upon the memory, cultural perspectives of the interviewees, the age of the interviewee at the time of the event and the time of the interview, and any other hidden agendas brought to the interview process (Massucci et al. 2011; Massucci et al. nd). The investigators and anthropologists have to understand that information (or evidence) provided through these witnesses have the greatest potential for being *legally* unreliable and this presents very specific challenges to the interviewer. This challenge is the purpose for creating a defined forensic interview strategy; a strategy that is shaped by traditional approaches to witness and suspect interviews from law enforcement and anthropology.

It is said that a good investigator does not necessarily make a good interviewer, nor does being a good interviewer mean that a person is a good investigator, but a productive criminal investigator must develop a solid foundation in these essential skills to be successful. All too often in law enforcement, the critical skills necessary to successfully investigate and preserve evidence for prosecution are not being taught in basic police training academies. In many cases the officer is expected to acquire the skills through on-the-job training once he is assigned to an investigation unit. The officer often experiences little or no in-service training covering the specific investigative skills he needs to develop in order to handle his job assignments. The same can be said for other forensic specialists, human rights workers and anthropologists working in post-conflict environments. Anthropologists gain training in ethnographic interviewing methods in cultural methods courses, however rarely is focus on forensic interviews. Likewise, in traditional forensic anthropology training little to no training is provided for investigations, interviewing, or international fieldwork.

# EXECUTIVE SUMMARY

The investigator, human rights worker, or anthropologist who is interviewing a victim or witness of some act of violence or trauma should expect to confront specific challenges. When this particular act of violence or trauma has occurred in the more distant past, these challenges can be compounded. Therefore, it is imperative that the investigator or anthropologist create very specific guidelines for the interview, while remaining highly adaptable during the process of interviewing to recover the maximum amount of credible and reliable data.

It should be required that the anthropologists or investigators who are planning to undertake an international project develop local contacts that can assist with establishing the initial perspective of the cultural challenges that should be anticipated. Further, the anthropologist should also conduct research to establish a clear vision of the cultural aspects of the local community at the time of the event and then identify changes or trends that have occurred since the initial incident. In addition to this research, it would be recommended that the anthropologist or investigator identify the status, education, religious perspectives, and governmental influences impacting on the interviewees.

In a prepared and scheduled interview the investigator should have a structured approach towards the interview with a desired goal. While the investigator will have specific topics to cover during the interview, the responses a subject offers may cause the investigator to explore unanticipated areas. The investigator must be prepared to follow-up in a number of areas because the significance of the information may not be known until later during the investigation. However, during the course of conducting the criminal interview, the process may often become very free-flowing and less structured. This is typically well handled if the investigator has the following tools available to them:

- A general protocol to support the interview process.
- Knowledge of the crime and crime scene.
- Experience with the interview process.
- An understanding of the interviewee and their culture.

# EXECUTIVE SUMMARY

The investigator should always take written notes during a formal interview in addition to creating a recorded record (such as a traditional oral interview). This is important because it can serve several important functions; it provides the interviewer that opportunity to document the subject's responses to interview questions and the investigator will be more aware of the subject's behavior by taking notes. At the outset of the interview the investigator should establish a pattern of note taking to so they will not inhibit the witness or suspect's response. If an investigator has not taken any notes during the early stages of the interview but then, all of a sudden, wrights down something the subject is said, the subject will attach significance to that statement and is likely to become much more guarded on subsequent answers. The investigator also has immediate access to prior or contradictory statements as the interview progresses or to use in subsequent interviews.

Note taking can also slow down the process and the pace of the questioning. It is much easier for a suspect or witness to lie to questions that are asked in a rapid fire manner. When faced with silence between each question and given time to think about his deceptive responses, the deceptive subject experiences greater anxiety and is more likely to the display behavior symptoms of deception. Furthermore, the literature on forensic interviews has shown that an innocent suspect may become confused or frustrated when a rapid-fire approach to questioning is used.

During the course of a criminal investigation, an interview may be conducted in a variety of environments, but the ideal environment for an interview is a room designed specifically for that purpose. If the international human rights worker or forensic anthropologist has the opportunity to create a comfortable and controlled room they should take advantage of this opportunity to increase the opportunity for success. Frequently, however, interviews are conducted wherever it is convenient to ask questions and a subject's home or office, in the backseat of a squad car, or on a street corner and in the process of working "in-county" the interviewer will be face with the challenge of adaptability.

The questionnaires for witnesses to mass graves and data collection for missing persons in international contexts were developed following research in Nigeria. These forms are meant to provide a basic outline for collecting antemortem data about a missing person, including

information about the individual characteristics of a person, the circumstances surrounding their disappearance, witnesses who may have information about the disappearance and contact information for the next of kin. The particular population, culture, and legal context will require these forms to be adapted and modified to fit the needs of a particular situation. Therefore, they are meant to provide a minimum amount of information that may be obtained in missing person cases or from witnesses about burials. Several resources are available for more information about missing person investigations, particularly in the context of international conflicts and mass disasters.

## ACKNOWLEDGEMENTS

We would like to thank the many individuals who worked with us in Lagos and Asaba, Nigeria and shared their memories and experiences with us to help build this protocol. In particular we would like to thank Emma Okocha, Ife Dike, Chuck Nduka Eze, John Obafunwa, Greg Berg, Tony Falsetti, Tom Bennett, Melissa Pope, and Casey Anderson.

# BEST PRACTICE GUIDELINES FOR FORENSIC INTERVIEWS

## CHARACTERISTICS OF A GOOD INTERVIEW

(Adapted from LeCompte and Schensul 1999:1-9)

- The interviews should be carried out in natural settings and not in a laboratory.
- The interview should involve intimate, face-to-face interaction with participants.
- The interview is an accurate reflection of participants' perspectives and behaviors.
- The interview uses inductive, interactive, and recursive data collection and analytic strategies to build local cultural theories.
- The interview uses multiple data sources, including both qualitative and quantitative data.
- The interview frames all human behavior and belief within a socio-political and historical context.
- The interview uses the concept of culture as a lens through which to interpret results.

## BEST PRACTICE CONSIDERATIONS FOR INTERVIEWS

- Makes sure terms and phrases are understandable to interviewee.
- Keep questions short.
- Use terminology appropriate to the respondents' command of language, cultural background, age, gender, level of knowledge, and any other relevant characteristics.
- Avoid leading questions.
- Avoid questions that use either positive or negative associations.
- Avoid double barreled questions that are really two questions in one.
- Try to avoid negatively worded questions like "do you agree or disagree with the following statement: teachers should not use language proficiency tests to group students' ability?"
- Avoid asking questions that require performing multiple tasks.
- Do not ask yes or no questions.
- Be sensitive to the cultural context or social meanings involved in the questions asked in the interview.

# INTERVIEW QUESTIONNAIRE FOR WITNESSES TO GRAVES

## I) BIOGRAPHICAL INFORMATION ABOUT WITNESS:

1) Name
2) Date of birth/age
3) Place of birth
4) Talk about the family connections and identities
5) When have you last lived in the village, town or region?
   a) Do you still visit?
6) What is your sense of community?

## II) ASSOCIATION WITH THE CRIME SCENE:

1) Where were you living when the event occurred?
2) Can you describe the village/community setting?
3) Can you describe a typical home design/structure?
4) Did you leave the area after this incident? If yes, with whom?

## III) PERSONAL RECOLLECTIONS OF THE EVENT:

1) Prior to the event (possibly allow them to develop a term for the incident and follow their lead) were you aware of any potential danger?

   a) Did you hear about other events (acts of violence)?
   b) Were there village discussions in the days prior?
   c) Did village members leave the village in the days prior to the event?
   d) Why did some members of the village stay and why did some leave?

2) Were you an (actual) witness the event?

3) When the event began, who were you with and how were you dressed?

4) Can you describe or discuss what you saw that day?
   a) Specific acts of violence or observed injuries?
   b) Reaction of the crowd at the onset of the incident and immediately after?
   c) Length of time – initial assault and the follow-up acts of murder?

5) If you were present, were you wounded or were you able to escape?

6) Do you know or could you recognize the people who were shooting?
   a) names/descriptions
   b) clothing
   c) weapons

7) Do you know why this happened?
8) When did the shooting/bombing end (in your area) and how long did the soldiers stay?
9) What did the surviving members do after the troops left?

## IV) ASSOCIATIONS OR IDENTIFIERS WITH VICTIMS:

- The interviewees may have covered this in the biographical section, also refer to the missing person data protocol for specific data to be collected on missing persons.

1) Did you lose any family members?
   a) names, age, descriptors
   b) clothing

2) Did you know other victims (friends, village leaders, etc)?
   a) names, ages, descriptors
   b) clothing

3) What did the surviving member do after the troops left?

## V) BURIAL SITES IDENTIFIERS:

1) Did you participate in the burial?
   a) Single or multiple sites?
   b) Bounties of the sites?
   c) Depth?
   d) Methods of burial
   e) Were any rites conducted?
   f) Was any one individual in charge of the process?

2) What physical changes have occurred to the village/town?
3) Physical description of the changes?
   a) Roads/fences
   b) Homes/development
   c) Population growth

4) What are the typical burial rights of the community, outside of this incident?
5) How do you feel this event should be remembered?
6) Are there any other thoughts you would like to share or events you would like to talk about that we have not asked you about?

# INTERVIEW QUESTIONNAIRE FOR WITNESSES TO GRAVES

**VI) MODIFICATIONS SPECIFIC TO AMERICAN COLD CASE – CLANDESTINE GRAVE SEARCHES:**

# INTERNATIONAL MISSING PERSON QUESTIONNAIRE

**BIOGRAPHICAL INFORMATION ABOUT VICTIM:**

Missing Person Case Number:_____

Surname of Missing Person: _____

First Name of Missing Person: _____

Other Names: _____

Last Known Address: _____

Marital Status: Married Single Divorced Widowed

If Married, Spouse Name: _____

Sex: Male Female

If Female: Pregnant: Yes/No Children: Yes/No Now Many Children: _____

Age: _____

Date of Birth: _____

Place of Birth: _____

Nationality:_____

Primary Language: _____

Occupation:_____

Religion: _____

**INFORMATION ABOUT THE EVENT:**

Date Last Seen: _____

Location Last Seen: _____

Circumstances Surrounding Event:

_____

_____

_____

_____

Relatives who are also missing (name and relationship):

_____

_____

# INTERNATIONAL MISSING PERSON QUESTIONNAIRE

**INFORMATION ABOUT VICTIM - DAY OF DISAPPEARANCE:**

Where were they last seen? _____

_____

Who were they last seen with? _____

_____

Where were they going? _____

_____

What were they doing? _____

_____

Name of Closest Living **Maternal** Relative: _____

Contact Information for Closest Living Maternal Relative: _____

_____

_____

_____

_____

**PHYSICAL DESCRIPTION**:

Height: Exact (cm): _____ Short Average Tall

Weight: Exact (kg): _____ Slim Average Obese

Are height and weight documented or estimated: Documented Estimated

Ethnic Group: _____

Eye Color: _____

Hair Color _____

Length: _____

Shape: _____

Baldness: _____

Other: _____

Facial hair: _____

None: _____

Moustache: _____

Beard: _____

Color: _____

Length: _____

# INTERNATIONAL MISSING PERSON QUESTIONNAIRE

**Distinguishing Physical Features:** (e.g. shape of ears, eyebrows, nose, chin, hands, deformities, etc.)

_____
_____
_____
_____

**Skin marks:** (e.g. Scars, tattoos, piercings, birthmarks, moles, etc.):

_____
_____
_____
_____

**Describe past injuries/broken bones/amputations** (include location, side, fractured bone, joint (e.g., knee), and if the person limped):

_____
_____
_____
_____

**Other major medical conditions** (e.g. operations, diseases, etc.):

_____
_____
_____
_____

**Implants** (i.e., pacemaker, artificial hip, IUD, metal plates or screws from operation, prosthesis, etc.):

_____
_____
_____
_____

# INTERNATIONAL MISSING PERSON QUESTIONNAIRE

**PERSONAL EFFECTS:**

**Clothing:**
What were they wearing when last seen/at time of murder or disappearance? Describe the type of clothes, colors, fabrics, brand names, repairs: describe in as much detail as possible).

_____

_____

_____

_____

_____

**Footwear:**
What were they wearing when last seen/at time of murder or disappearance? Describe in as much detail as possible.

Type of shoe: Boot Shoe Sandals Other: _____

Color: _____

Brand: _____

Size: _____

_____

_____

_____

**Eyewear:**
Did they wear glasses? **Yes** **No** **Unknown**
Color and shape of Frames? _____
Describe in as much detail as possible: _____

_____

_____

_____

_____

_____

# INTERNATIONAL MISSING PERSON QUESTIONNAIRE

**Personal items:**
Did they have any of the following on them at the time of the disappearance?

| | | | | |
|---|---|---|---|---|
| Watch: | Yes | No | Unknown | If yes, what did it look like?_____ |
| Jewelry: | Yes | No | Unknown | If yes, what did it look like?_____ |
| Wallet: | Yes | No | Unknown | If yes, what did it look like?_____ |
| Keys: | Yes | No | Unknown | If yes, what did it look like?_____ |
| Photographs: | Yes | No | Unknown | If yes, what did it look like?_____ |
| Medication: | Yes | No | Unknown | If yes, what did it look like?_____ |
| Cigarettes: | Yes | No | Unknown | If yes, what brand?_____ |

Any other item – describe in as much detail as possible:

_____

_____

_____

_____

**Identity documents: Yes No Unknown**
Was he/she carrying any type of identification papers or documents at the time of his/her disappearance? Such as an identity card, driving license, credit card. Describe the information contained.

_____

_____

**Habits:**
Was he/she a smoker (cigarettes, cigars, pipes)? **Yes No Unknown**
Did they use chewing tobacco, betel nut, alcohol, etc.? **Yes No Unknown**

**Medical Records**, **X-rays, dental records:** **Yes No Unknown**
Give details of any doctor, dentist, optometrist, or other medical record that may exist.

_____

_____

_____

**Photographs of missing person:** **Yes No Unknown**
Is there a photograph of this person available or a photocopy of any photographs?

# INTERNATIONAL MISSING PERSON QUESTIONNAIRE

**DENTAL CONDITION:**

Is the dental information documented from dental records or estimated from witness? _____

If documented, what records are available? _____

(Please describe general characteristic, especially taking into account the following):

Missing teeth: _____

Broken teeth: _____

Decayed teeth: _____

Discolorations, such as stains from disease, smoking or other: _____

Gaps between teeth: _____

Crowded or crooked (overlapping) teeth: _____

Jaw inflammation (abscess): _____

Adornments (inlays, filed teeth etc.): _____

Any other special feature: _____

**DENTAL TREATMENT:**

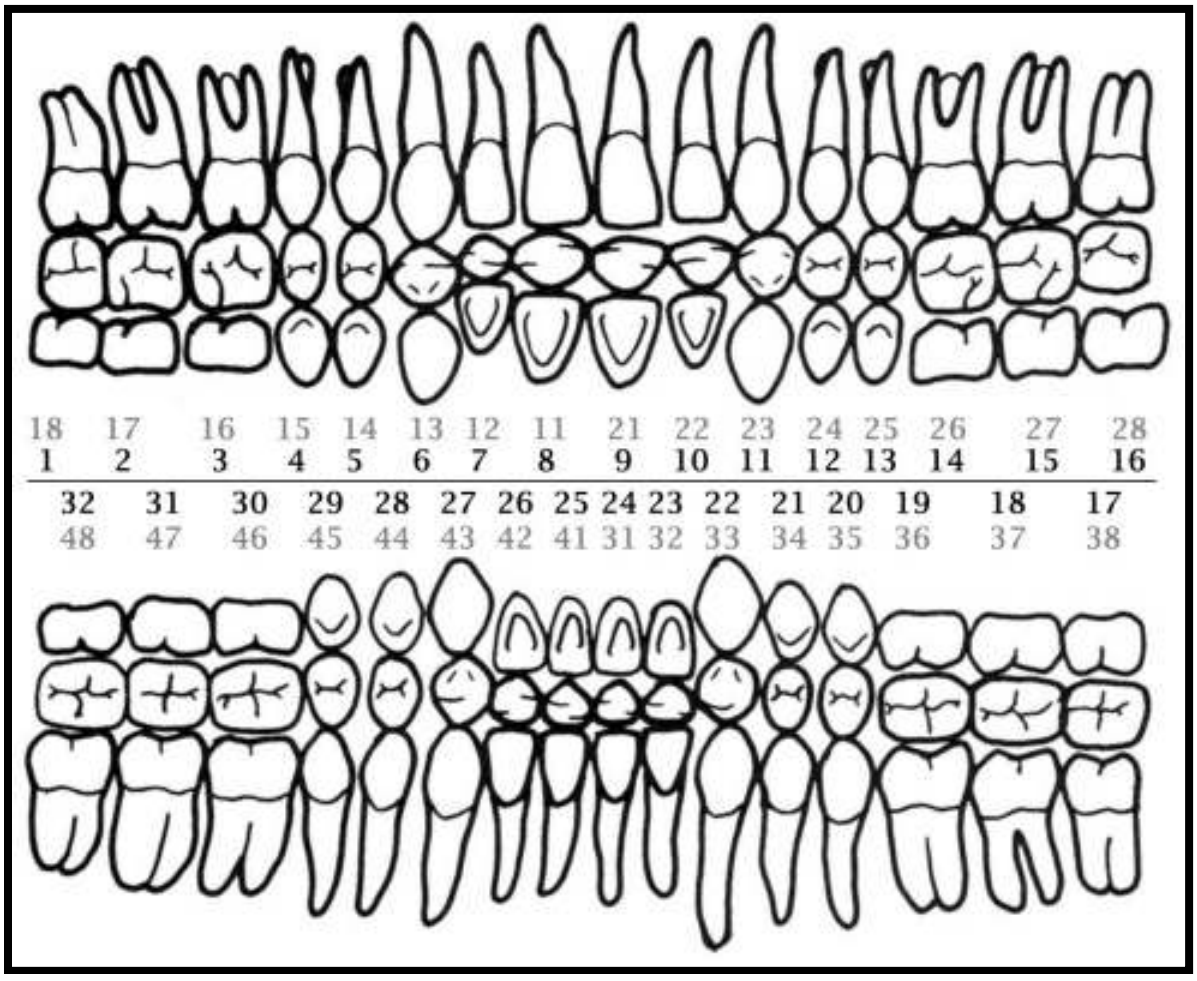
Had the missing person received any dental treatment such as Crowns, such as gold-capped teeth? Yes/No

| | | | |
|---|---|---|---|
| Color of Fillings: | Gold | Silver | White |
| False teeth (dentures): | Upper | Lower | |
| Bridge or other special dental treatment: | Yes | No | |
| Extraction: | Yes | No | |

***Also indicate wherever there is uncertainty (for example, the family member may know that an upper left front tooth is missing, but is unsure which one). If possible, use a drawing, and/or indicate the described features in the chart below. If the missing person is a child, please indicate which baby teeth have erupted, which have fallen out and which permanent teeth have erupted and use the chart below.*

# INTERNATIONAL MISSING PERSON QUESTIONNAIRE

**Adults:**

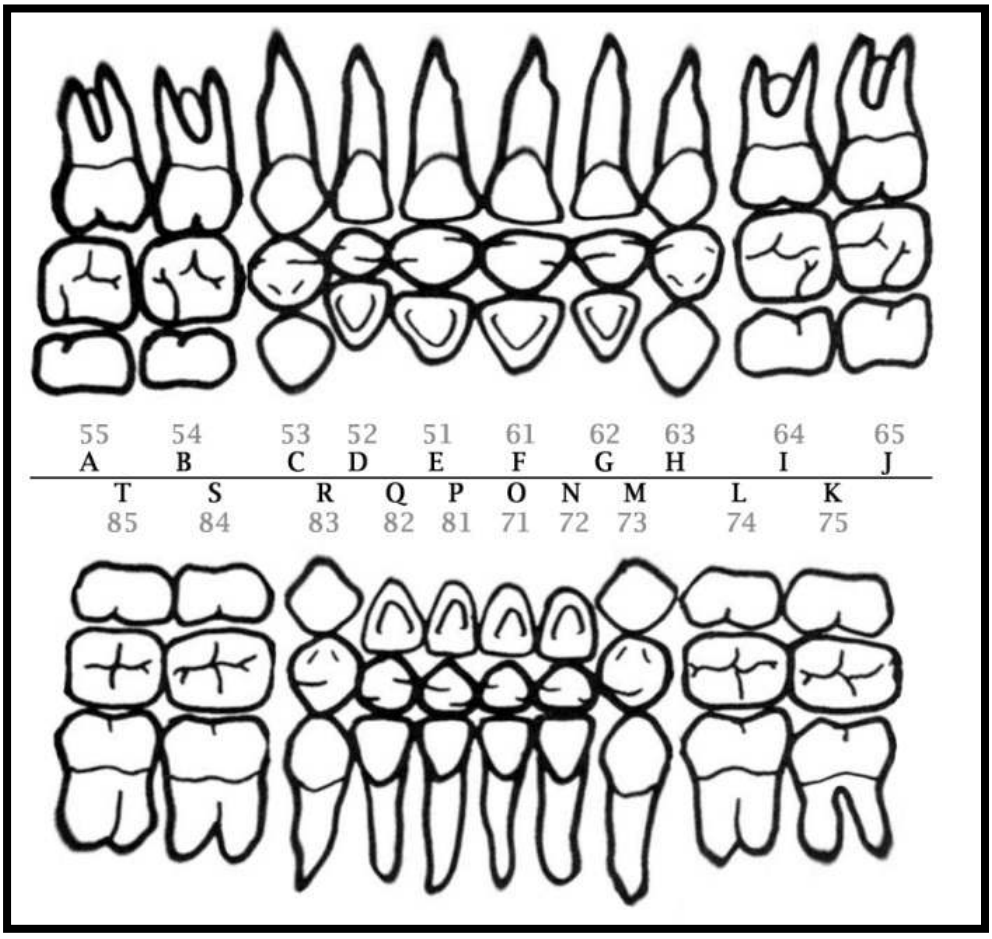



**Other notes to include on chart (mark specific tooth if known, or general area):**

**X = Tooth is missing**
**C = Cavity or pathology**
**F = Tooth Fractures**
**M = Tooth modified**

**Numbering System:**
**Black** = American System
**Grey** = European System

**Juveniles:**




**Other notes to include on chart (mark specific tooth if known, or general area):**

- **X = Tooth is missing**
- **C = Cavity or pathology**
- **F = Tooth Fractures**
- **M = Tooth modified**

**Numbering System:**
**Black** = American System
**Grey** = European System

# INTERNATIONAL MISSING PERSON QUESTIONNAIRE

**NAME AND CONTACT OF WITNESS PROVIDING THIS INFORMATION:**

Name: _____

Date: _____

Relationship to the Victim: _____

Contact Information (Address and Phone Number):_____

_____

_____

_____

**********

**Note:** The information collected in this form will be used for the search and identification of the missing person. Its content is confidential and any use outside of the intended context will need explicit consent by the interviewee.

**Place and date of interview: _____**

**Interviewer signature: _____**

**Interviewee signature: _____**

If requested, a copy of this form with contact details of interviewer will be made available to the interviewee.

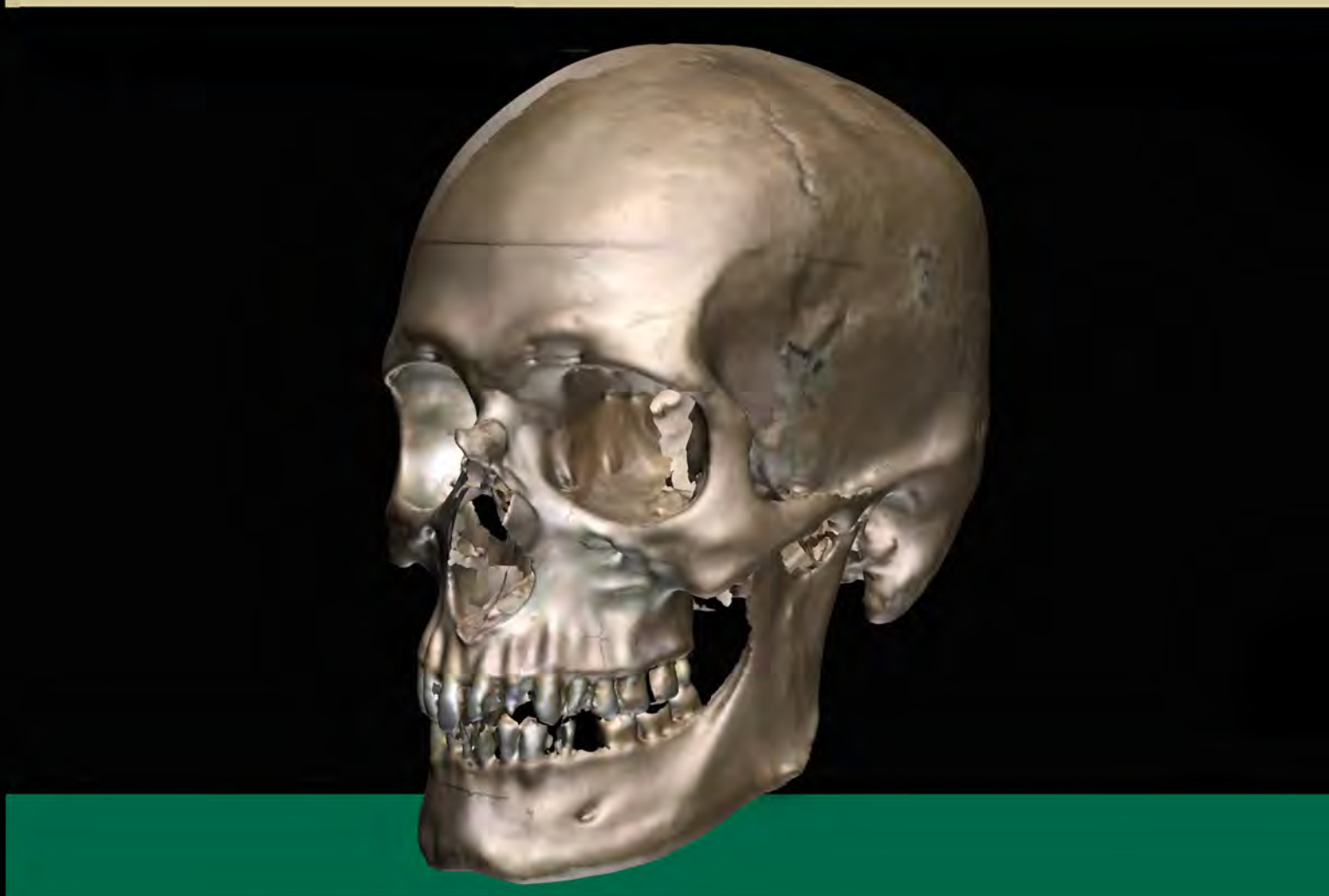
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Massucci C, Kimmerle EH, Tise ML. 2011. Forensic Interviews: Corroborating Evidence and Collecting Data for Anthropological Field Work. Proceedings of the 63nd Annual American Academy of Forensic Sciences, February 21-26. Chicago, Illinois. Colorado Springs, CO. Abstract H64, pp. 365.

Massucci CJ, Kimmerle EH, Tise ML. n.d. Pending final revisions, will be submitted Journal of Forensic Sciences. Forensic Interviews: Corroborating Evidence and Collecting Data for Anthropological Field Work.

# 3D Digital Refernce Guide for Research in Human Identification






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Version 1.0.2012

Research funded by:

This project was supported by Award No. NIJ 2008-DN-BX-KI63 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

The opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect those of the Department of Justice.

To Cite:
Kimmerle EH, Powell JW. 2012. 3D Digital Reference Guide for Research in Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

# 3D Digital Reference Guide for Research in Human Identification

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# EXECUTIVE SUMMARY

The estimation of biological parameters for human identification is a cornerstone of forensic anthropology and methods that accurately and reliability estimate an individual's biological profile are needed to narrow the pool of potential matches in the identification process. Interpretations of the degree and specific ways in which populations vary have not always been clear because of sampling or the particular type of statistical modeling used. As a result, there is an ever-greater need to investigate questions about the degree to which skeletal variation among populations differs with regard to growth, maturation, aging and the effects for individual and population analyses with regard to identification and for robust methods that meet criteria for inclusion of scientific standards in court. Moreover, reference and teaching materials are needed for varied contexts and international settings.

The following reference guide consisting of 3D images was developed as part of the Research in Human Identification initiative funded through the National Institute of Justice (NIJ-2008-BX-K163). The purpose of this guide is to provide examples of skeletal biomarkers and human skeletal variation relevant to human identification. The images are 3D models that can be useful for teaching or as reference materials in research and casework. Accurate measurements can be taken directly from the models. Several examples of basic cranial variation are provided, as well as examples of sexual dimorphism in the skull. Other images include juvenile and adult aging traits, skeletal pathology, congenital defects, and healed antemortem trauma.

While there are a number of scanner models that range in quality and price, these models were developed using the NextEngine Desktop 3D Scanner HD coupled with the ScanStudio HD software package, both available from NextEngine, Inc. (www.nextengine.com). Accuracy for this model depends on whether Macro Mode or Wide Mode is used, and ranges from ±0.005 in. (0.0127 cm) to ±0.015 in. (0.0381 cm), respectively. Maximum resolution ranges from 400 points per in. (157.5 points per cm) in Macro Mode to 150 points per in. (59 points per cm) in Wide Mode.

# EXECUTIVE SUMMARY

Other software packages used to create these 3D PDF files include MeshLab, a freeware 3D modeling program developed by the Visual Computing Lab – ISTI – CNR (available at http://meshlab.sourceforge.net), and Adobe Acrobat X Pro, available from Adobe Systems, Inc. (www.adobe.com).

The models only include meshes, with the original textures replaced by a solid gray surface color in order to showcase surface morphology. A single 3D model is generally comprised of multiple files of several file types, most of which fall into one of two categories: meshes and textures/materials. Mesh files (file types like .obj or .u3d) comprise the physical structure of the model, while texture and material files (file types like .tex or .mtl) contain the coloring of the surface, specified in a map that fits over the mesh like a skin.

# ACKNOWLEDGEMENTS

We would like to acknowledge and thank the following funding sources and people for allowing this research and data collection to take place: National Institute of Justice; Department of Information Technologies, University of South Florida (Howard Kaplan, Visulaization Specialist, for general assistance with 3D modeling); Department of Anthropology, University of South Florida (Liotta Noche-Dowdy, Graduate Assistant, Anna Rivera, Graduate Assistant, and Cristina Echazabal, Graduate Assistant)

# HOW TO USE THIS DOCUMENT

This document uses 3D PDFs to allow users to navigate around 3D models of different skeletal elements. In order to properly view these files, Adobe Reader 9 or later is required. The newest version of Adobe Reader is available free from Adobe Systems, Inc. (www.adobe.com).

- To activate the applet, left click on the scan that you wish to view. A toolbar should appear above the image. Instructions for some of these tools are listed below.

- To rotate the model, hold the left mouse button down and drag the mouse. This is the *Rotate* tool located in the Toolbar, and is the default tool that is selected.

- To pan, select the *Pan* tool from the toolbar, hold the left mouse button down, and drag the mouse. The model should move left, right, up, or down without rotating.

- To zoom, roll the mouse wheel with any tool selected. If the *Rotate* tool is selected, holding the right mouse button down and moving the mouse forward and backward will zoom in and out. The *Zoom* tool can also be selected from the toolbar, which will zoom in and out by holding the left mouse button and moving the mouse forward and backward.

- The view selection box allows the model to be positioned in preset views. Clicking the down arrow and selecting a view will automatically move the model to a corresponding view.

- The *3D Measurement Tool* allows measurements to be taken. All units are in mm. After selecting this tool, a number of options can be selected on the measurement tool bar that opens. Select the type of measurement to be performed, left click on the first point, and left click again on the second point. While this tool is selected, holding down Alt allows rotation while left clicking, holding Shift pans with left clicking, holding Alt + Shift zooms with left clicking, and holding Ctrl disables the automatic snap function.

- The *Model Render Tool* allows the model to be shown in different modes, such as solid (the default), wireframe, vertices, or illustration.

- The background color can be changed to your preference as well using the *Background Color* tool. White is selected by default.

# BASIC PROCEDURE AND TIPS ON METHODOLOGY

The models in this document were created using the generalized procedure outlined below.

1. Place the object on the AutoDrive and hold it in place using the included PartGripper from the NextEngine Desktop 3D Scanner HD.
2. Choose settings depending on the size of the object using the following tips, and run the scan.
    a. For larger objects use Wide Mode, and for smaller objects use Macro Mode.
    b. For Wide Mode:
        i. Extend the AutoDrive to the maximum extent of the standard connection cord. This places the AutoDrive within the proper range of the scanner and allows the largest possible objects to be scanned.
        ii. The PartGripper may need to be lowered as close as possible to the AutoDrive to fit larger objects.
    c. For Macro Mode:
        i. Put the AutoDrive in a position that places the object to be scanned in the proper range, as specified by the Scan Settings page of the ScanStudio software.
        ii. The PartGripper may need to be raised for the object to sit within the correct window.
    d. Two (or more) scans may be required, each with a different rotation of the element being scanned. This ensures that all faces of the object are scanned.
3. After all scans are completed, a project with multiple scans needs to be stitched together using the Align Tool in ScanStudio.
    a. Alignment becomes more accurate with more markers placed. It is highly recommended to use more than the minimum requirement of three. For the included scans, roughly six markers were used for alignment.
    b. It is useful to use both morphological features and true color objects to place markers.
    c. If necessary, the use of the paint pen included with the scanner can be useful in situations where there are very few morphological or true color objects to use for alignment. The paint is removable with water.
4. After alignment, fuse the scans using the *Fuse* tool.
    a. The lower the tolerance is set, the sharper the edges will be in the final model.
    b. The scans in this document used a tolerance of 0.
5. The use of any of the *Polish* tools may be useful in the production of the final model.
    a. Care must be exercised because the use of these tools may compromise the accuracy of the scans.
    b. The only tool used in the creation of these scans was the *Fill* tool.
        i. This was only used on small gaps in the model or areas of non-interest.

        ii. Filling areas of non-interest (like a hole in the lingual side of a molar that is intact on the actual object) prevents incorrect deductions about the object the model is based on (like the presence of caries that are not actually there).

6. Save the objects in both the native ScanStudio .scn file type and the more universal .obj file type.
    a. This allows ScanStudio to open the object again if necessary, and allows further use of the scan in other programs.
7. Import the .obj file into MeshLab. Further cleaning and repairing is possible in this program.
    a. The *Merge Close Vertices* filter located under *Filters* > *Cleaning and Repairing* is useful for micro gaps that may be present in the scan.
    b. The *Fill Hole* tool has also been used in some scans to repair areas that would not fill in ScanStudio.
        i. The *Fill Hole* tool in MeshLab does not produce as clean of fills as the *Fill* tool in ScanStudio.
8. Export the scan as a .u3d file.
9. Use the .u3d file to create a 3D PDF in Adobe Acrobat X Pro.
    a. These PDFs were first constructed in an alternative text editor for ease of use, but can be completely created inside Acrobat.
    b. The file was then opened in Acrobat and the *Add Multimedia* tool was used to insert the .u3d file into the document.
    c. The document can then be saved as a PDF which can be opened by Adobe Reader, version 9 or later.

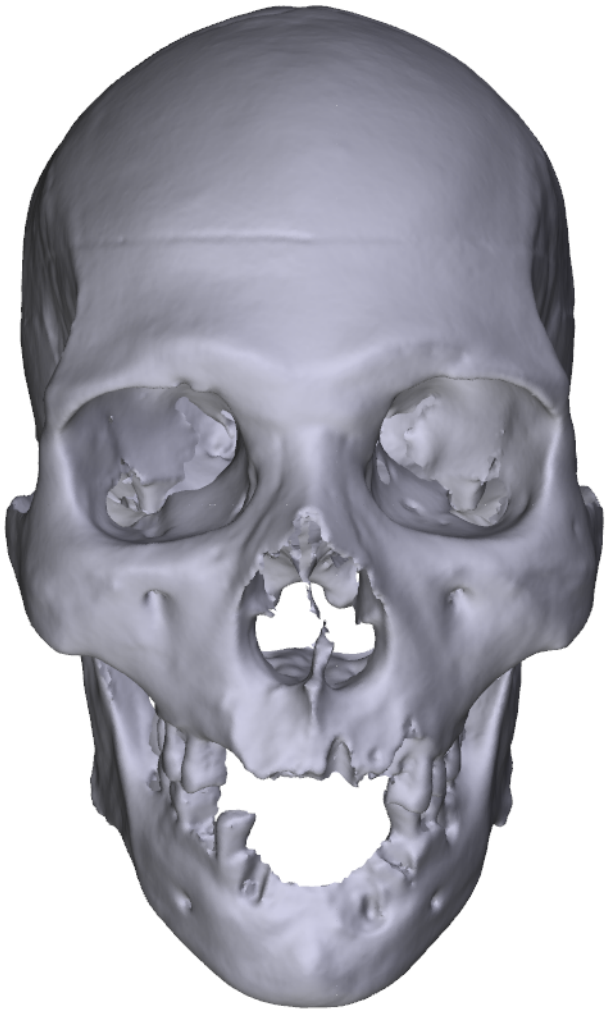


Figure 1. Male skull, USF Osteology Collection



Figure 2. Female skull, USF Osteology Collection

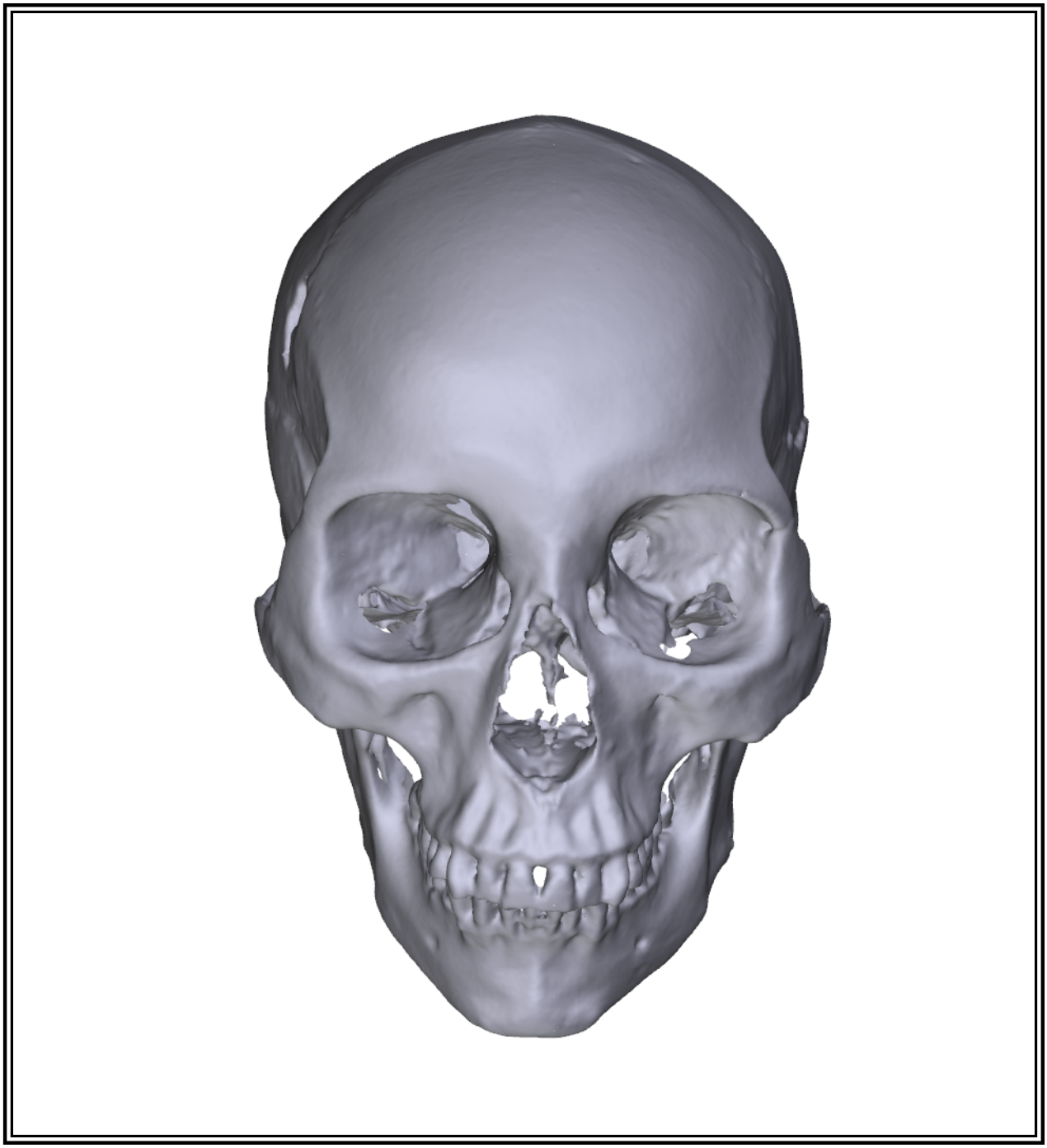


Figure 3. Complete adult male skull, USF Osteology Collection

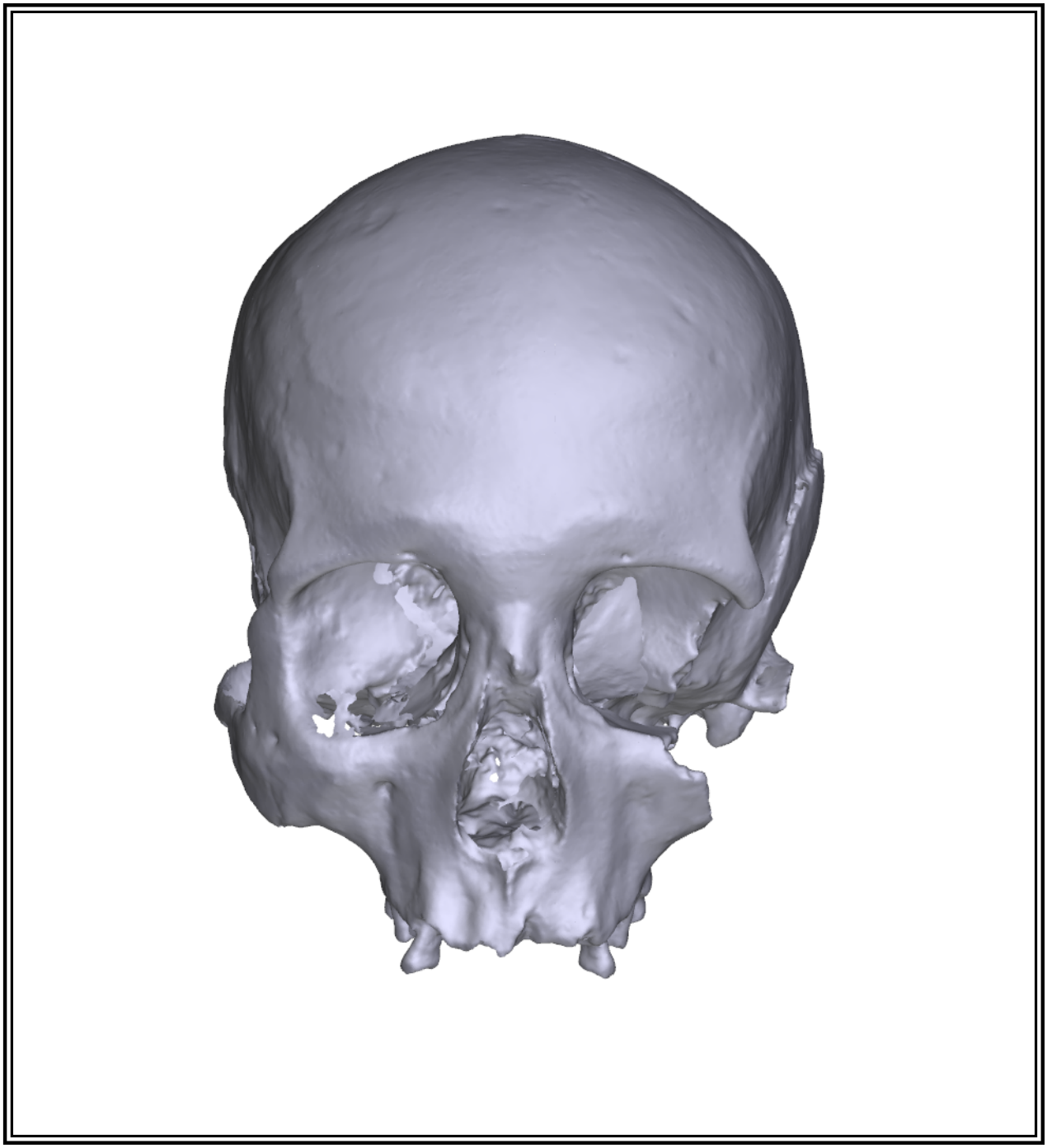


Figure 4. Entire adult male cranium, USF Osteology Collection

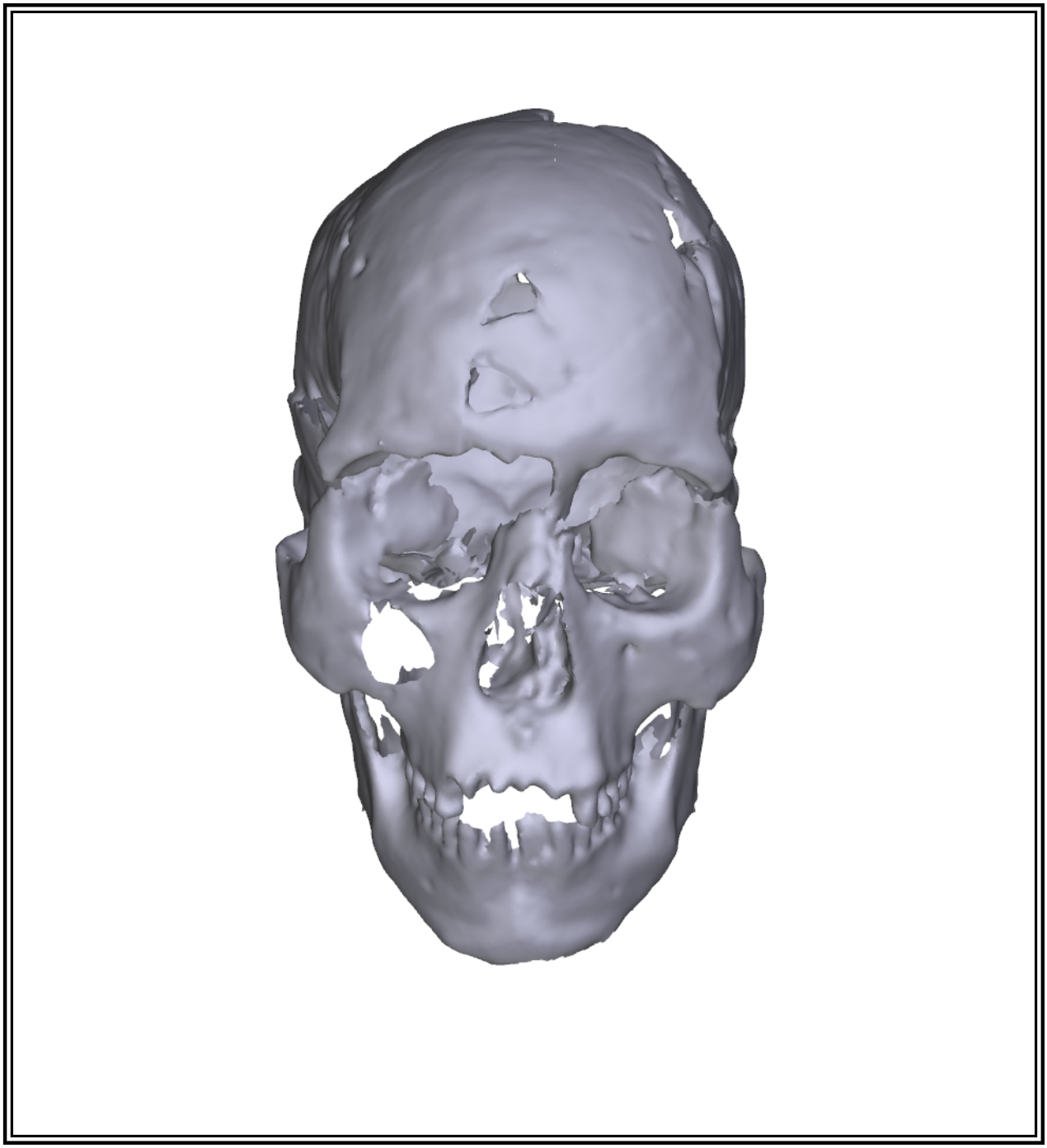


Figure 5. Reconstructed adult male skull, USF Osteology Collection

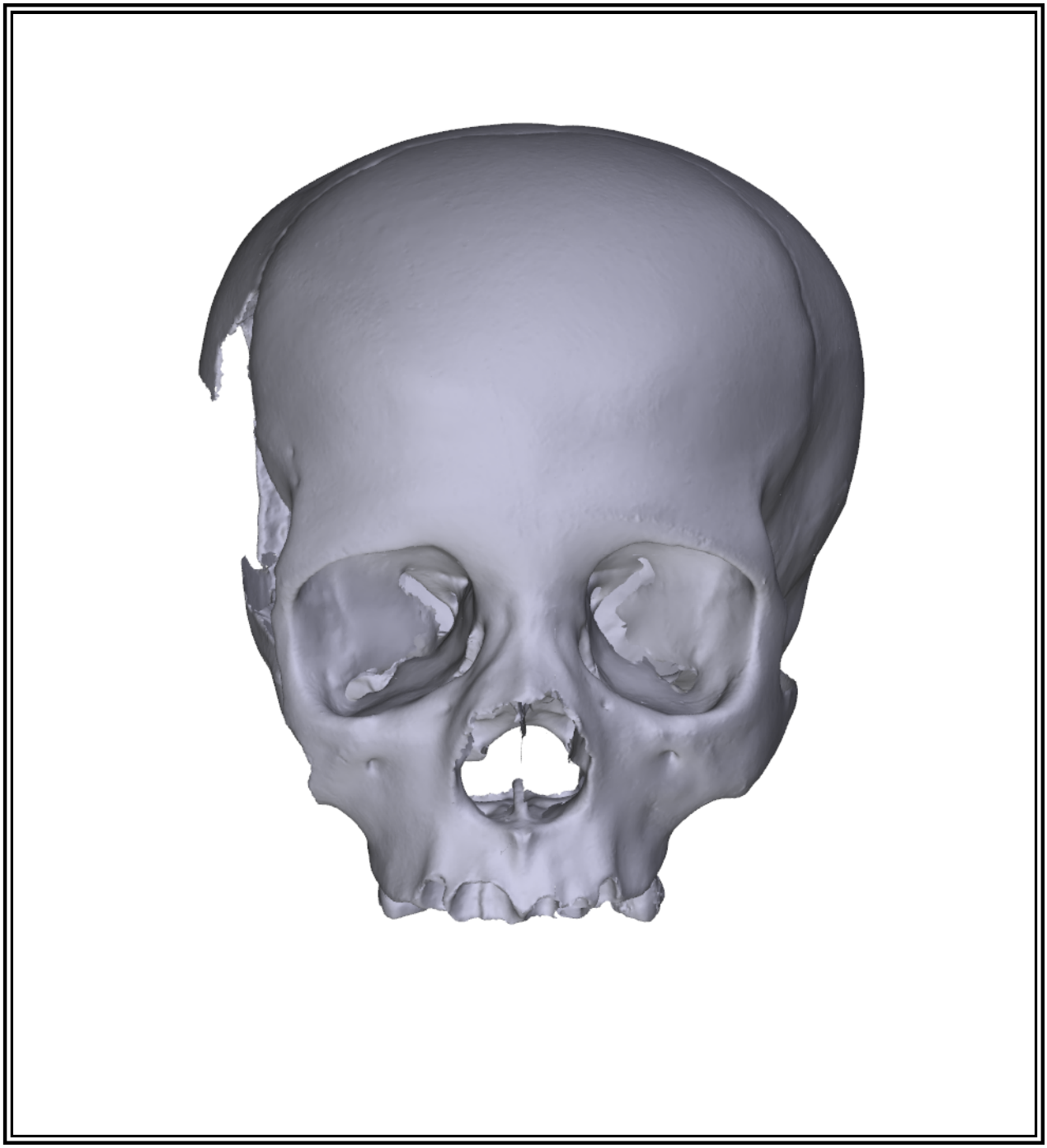


Figure 6. Partial juvenile skull, Precontact American Indian, approximately 10-15 years of age, with significant, intentional cranial modification, USF Osteology Collection

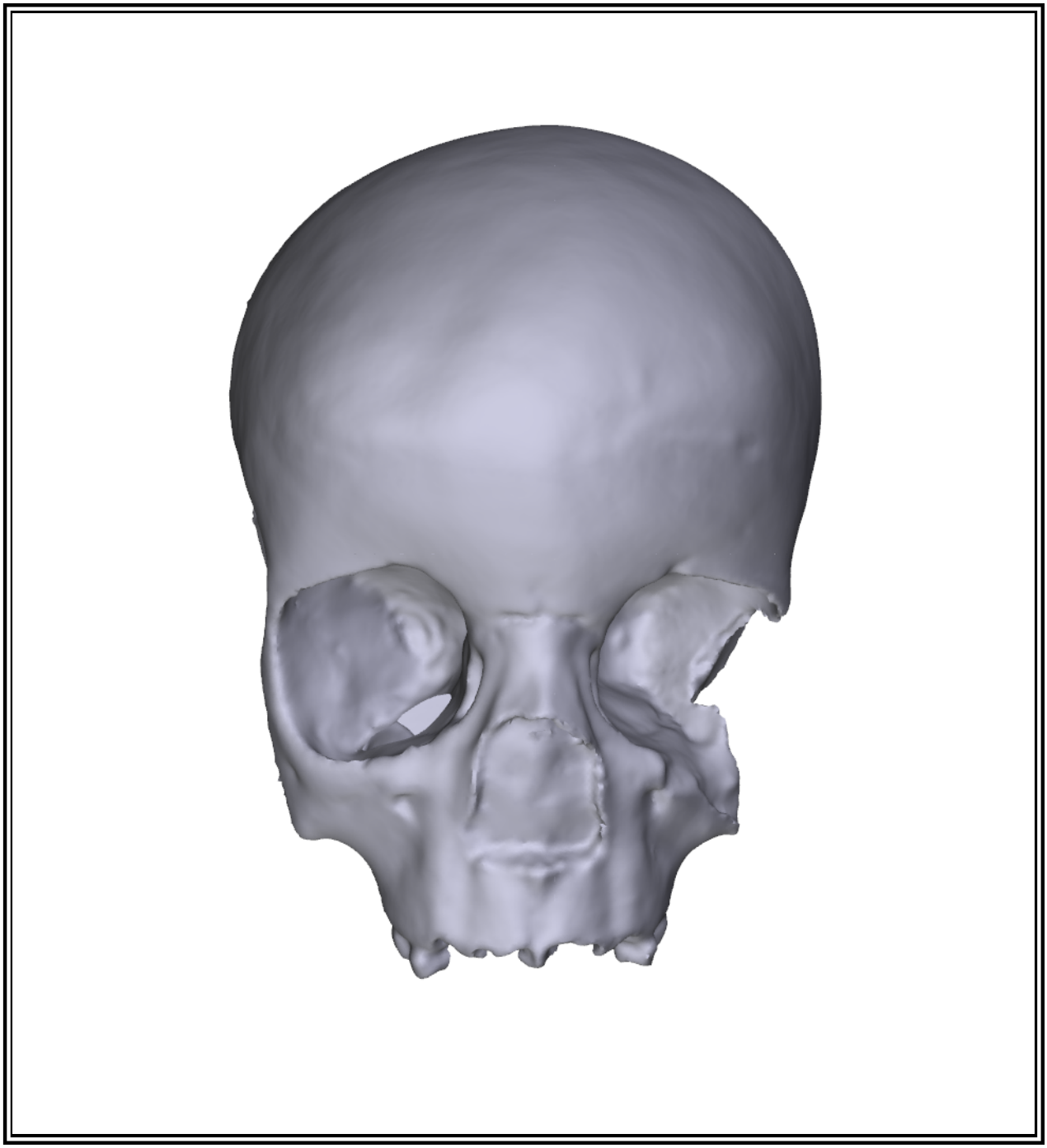


Figure 7. Ceramic cast of a juvenile splanchnocranium, approximately 4-8 years of age, USF Osteology Collection

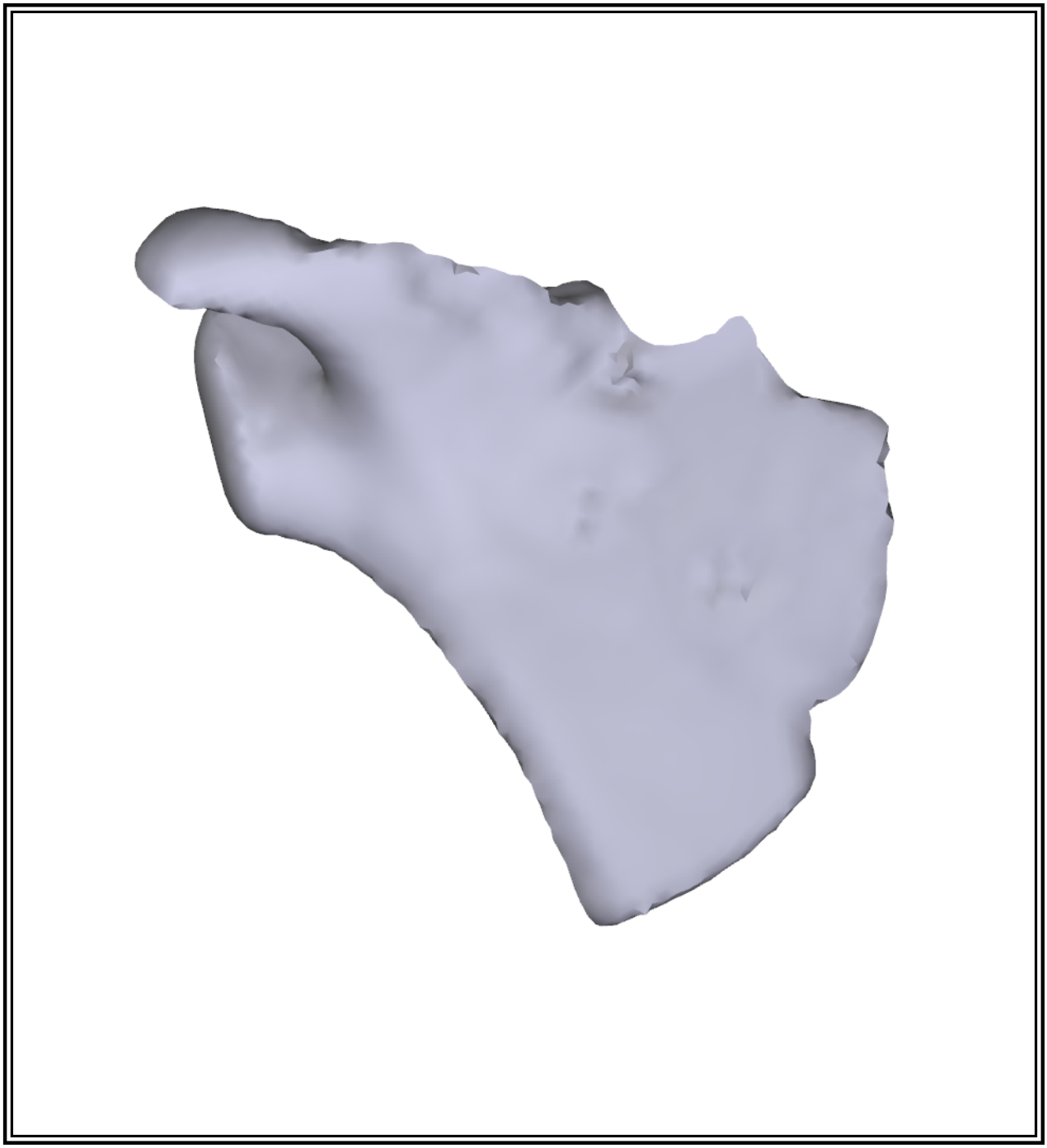


Figure 8. Prenatal (38-40 Wk.) left scapula, USF Osteology Collection

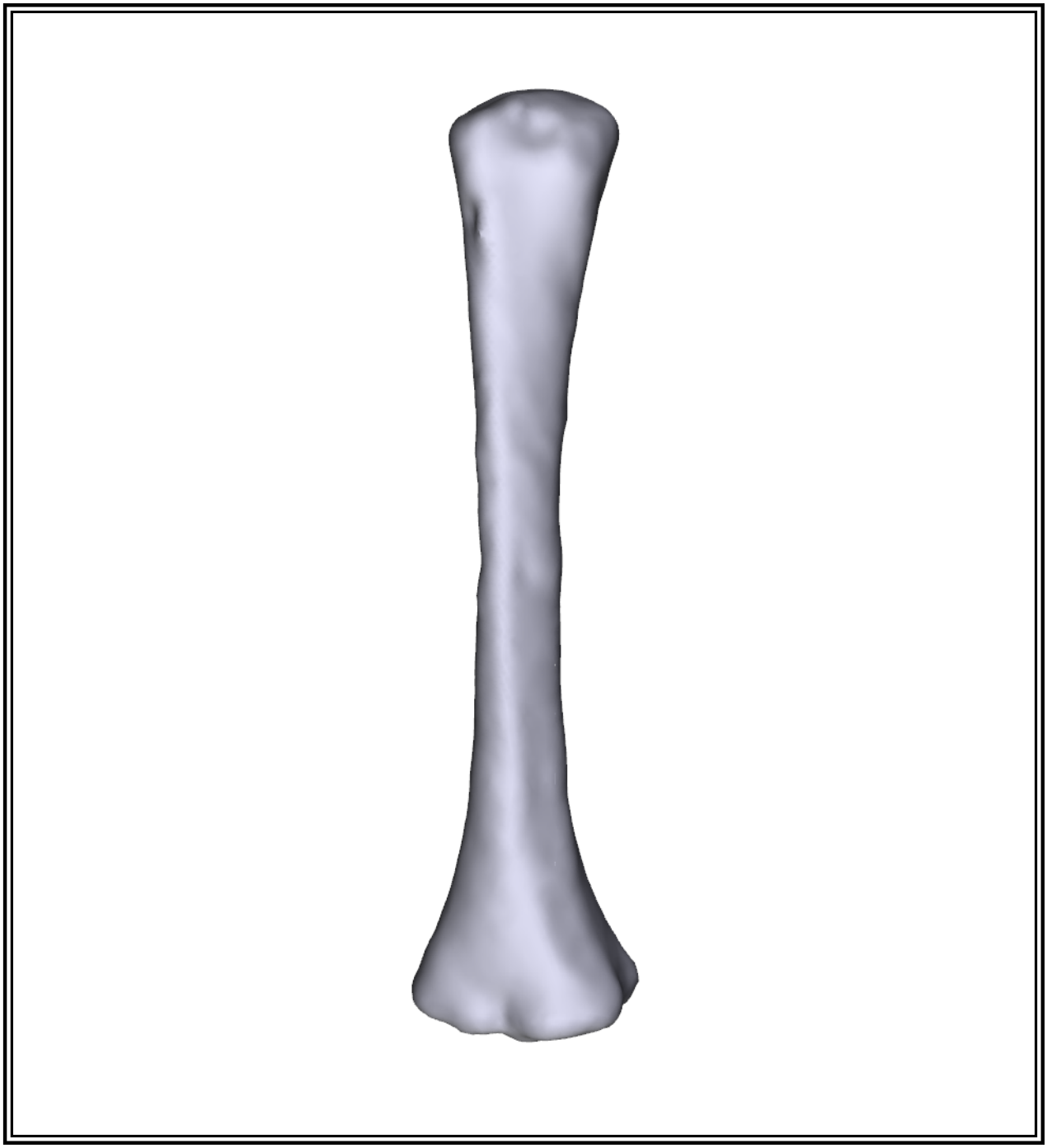


Figure 9. Prenatal (36-38 Wk.) right humerus, USF Osteology Collection

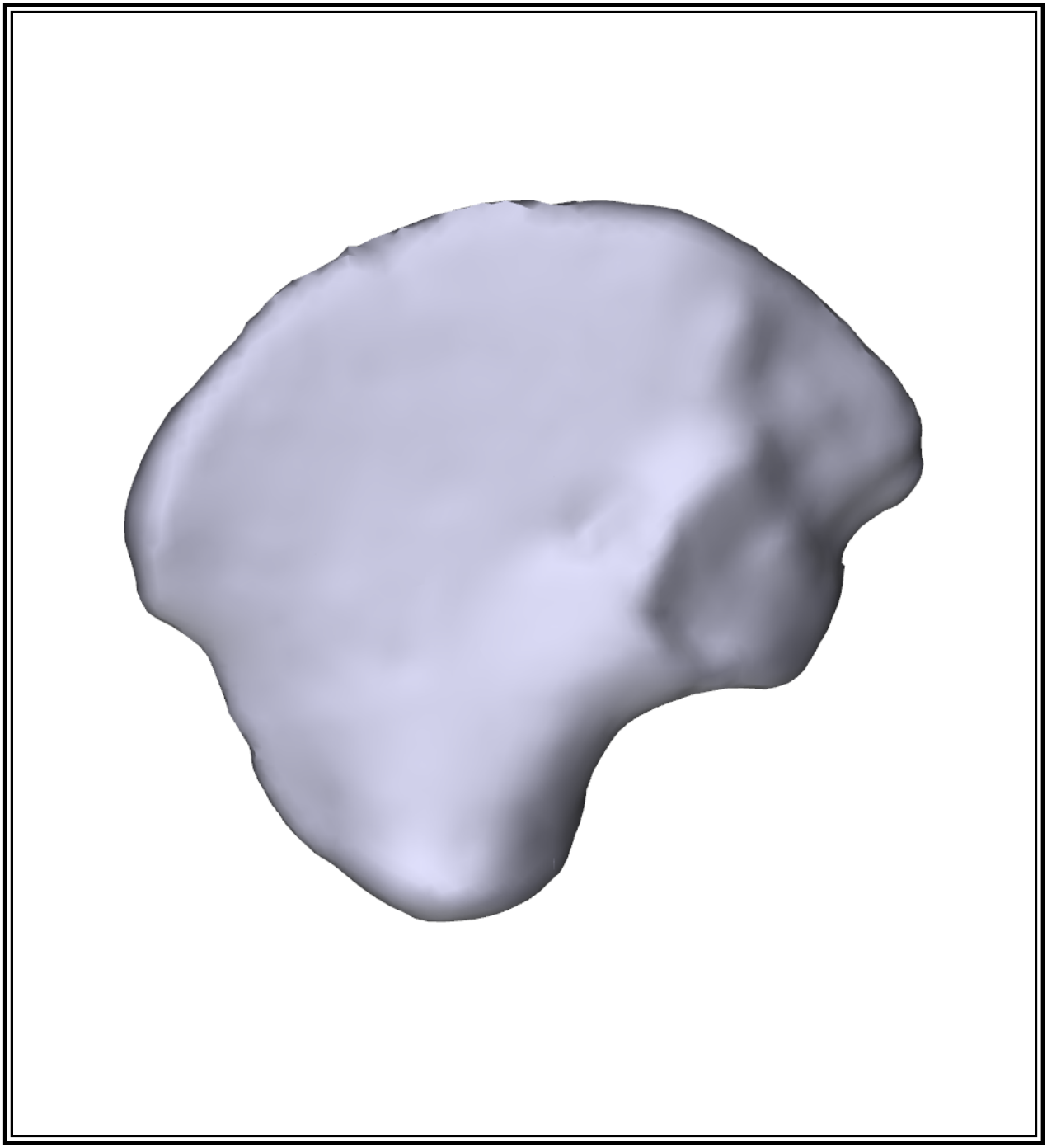


Figure 10. Prenatal (36-40 Wk.) right ilium, USF Osteology Collection

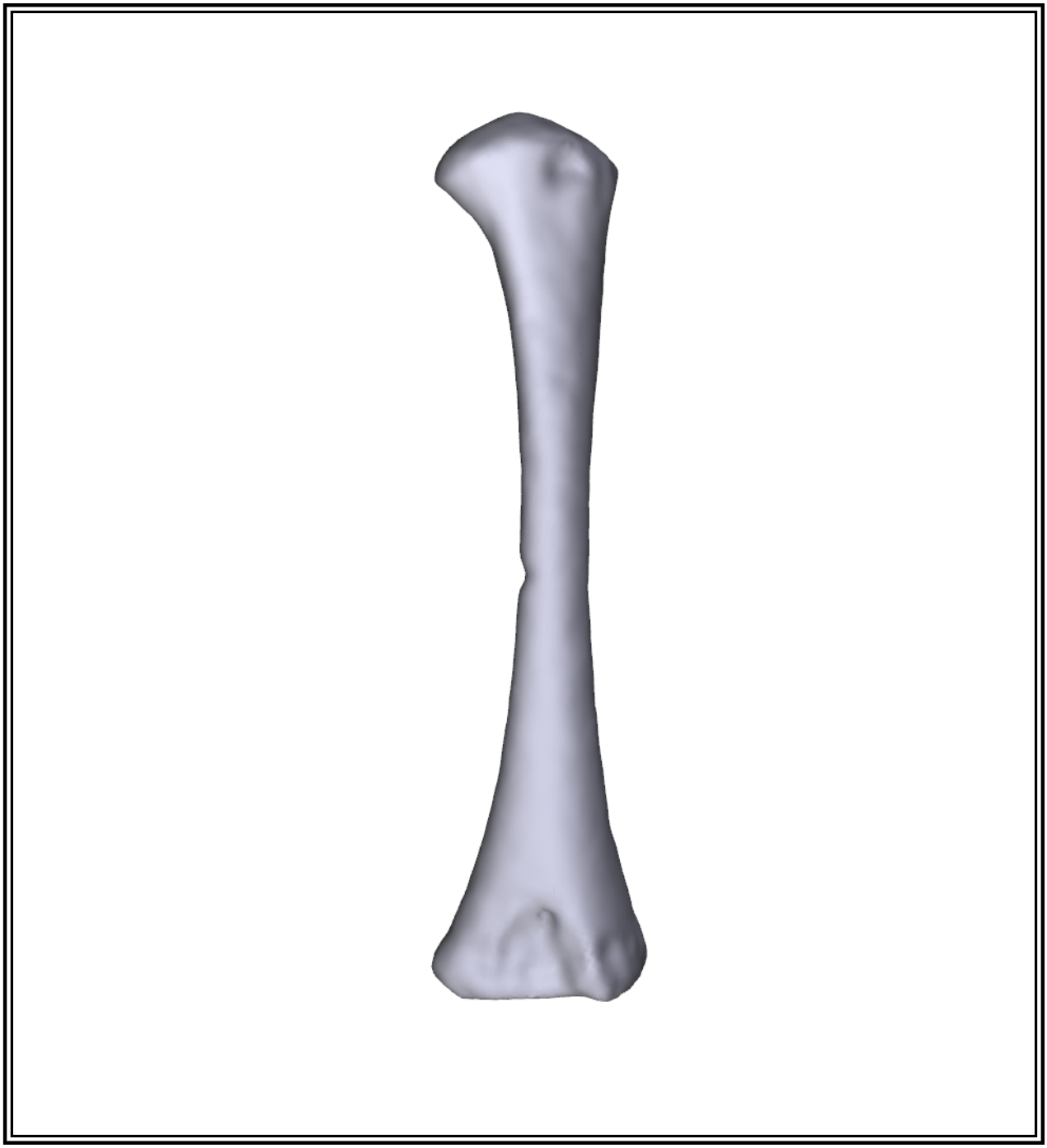


Figure 11. Prenatal (approx. 38 Wk.) left femur, USF Osteology Collection



Figure 12. Prenatal (Approx. 36 Wk.) left tibia, USF Osteology Collection

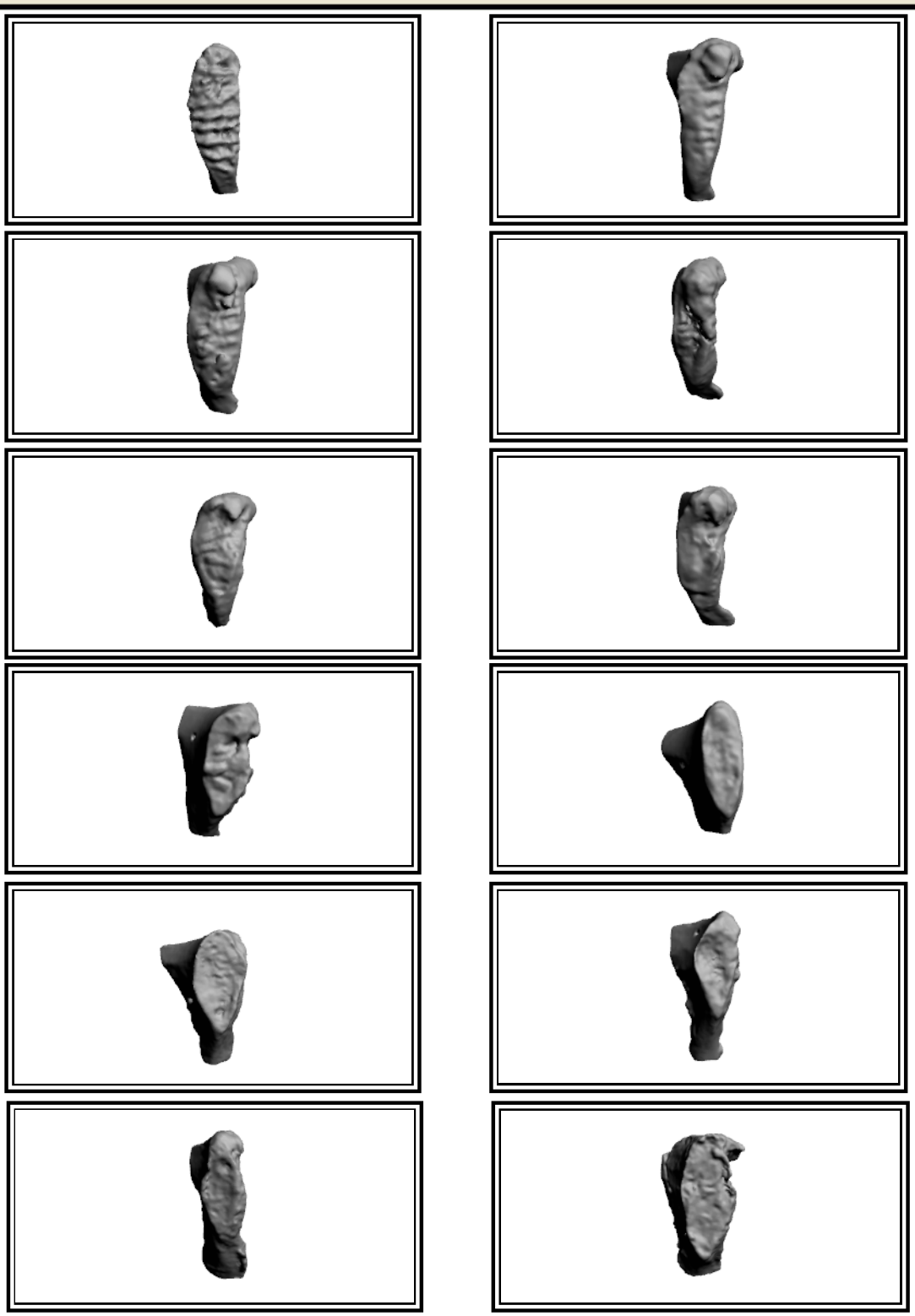


Figure 13. Suchey-Brooks Aging Method of the male pubic symphysis. Starting from the top, Phases I-VI, with early phase on the left and late phase on the right. Plastic casts, courtesy of France Casting (www.francecasts.com)

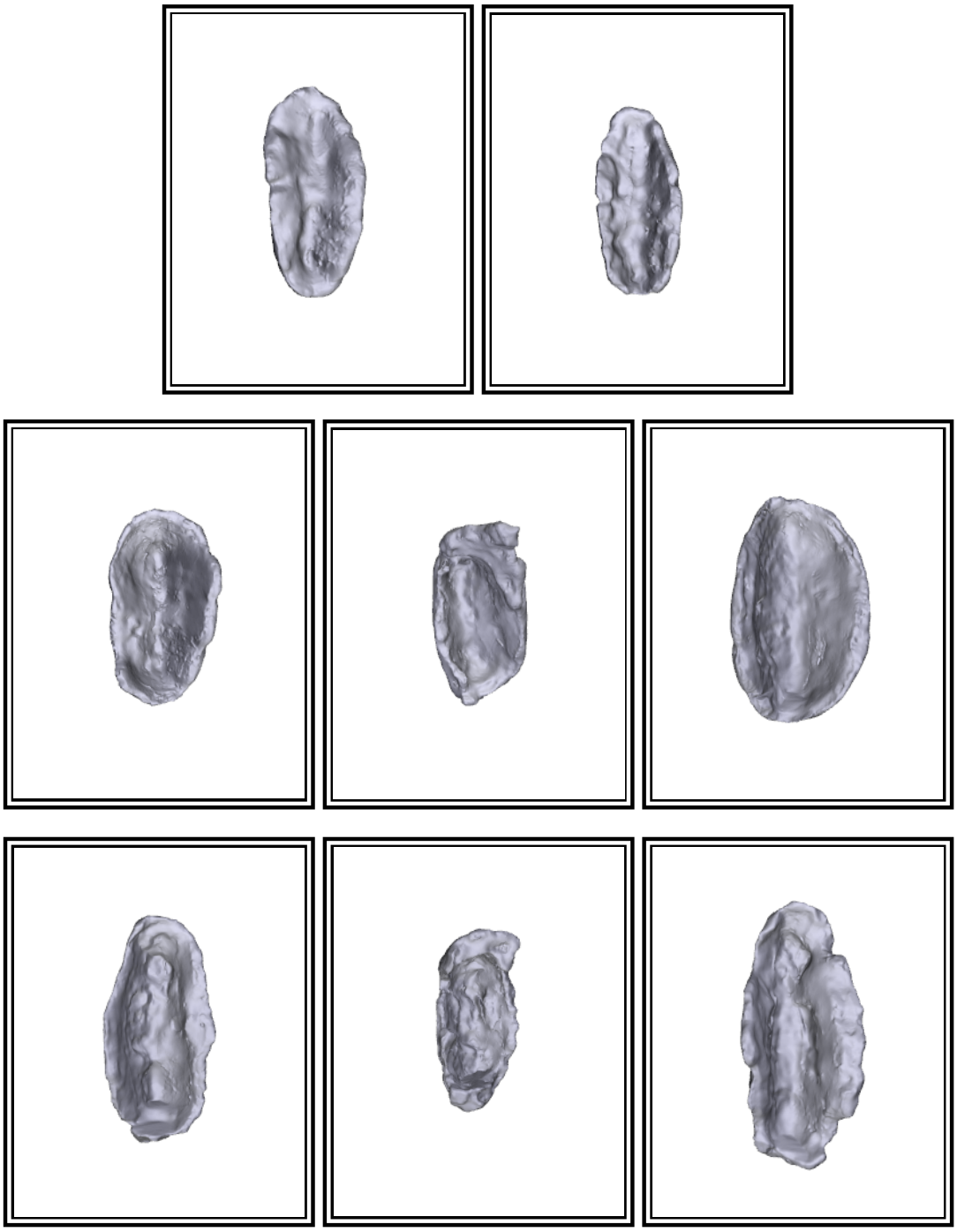


Figure 14. Iscán et al. Aging Method of the male sternal rib ends. Starting from the top, Phase 2, 5, and 7. Plastic casts, courtesy of France Casting (www.francecasts.com)

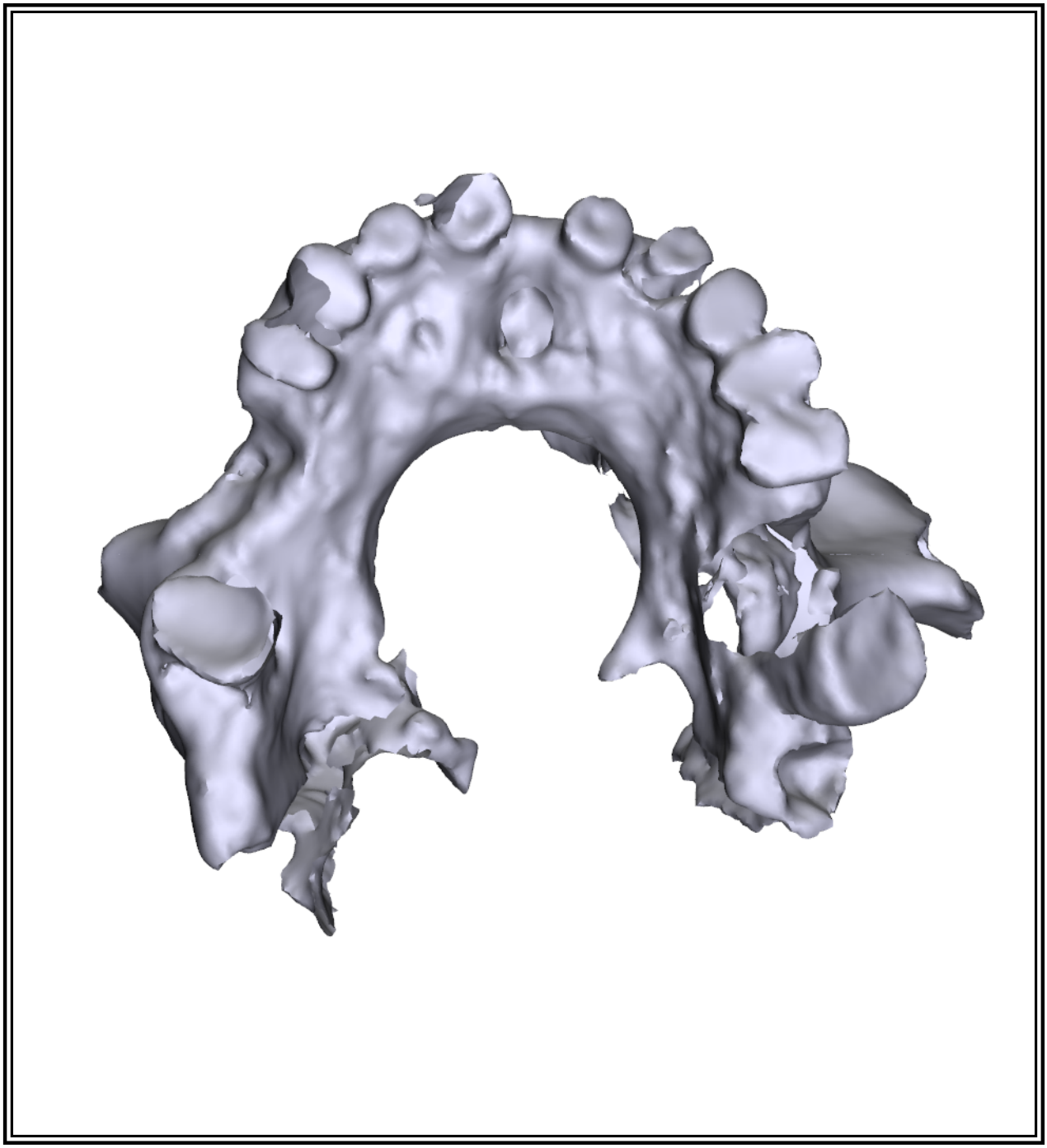


Figure 15. Congenital oval palatine defect, cleft palate, with survival into middle adulthood, USF Osteology Collection



Figure 16. Juvenile right humerus, age 7-9 years old. Active osteomyelitis, associated with healing fracture to lower shaft, USF Osteology Collection



Figure 17. Infectious disease, periostosis and woven bone growth, adult long bone shaft fragment, USF Osteology Collection



Figure 18. Lumbar vertebra, schmorl's node on superior body, osteoarthritic lipping, and compression fracture on posterior body, USF Osteology Collection

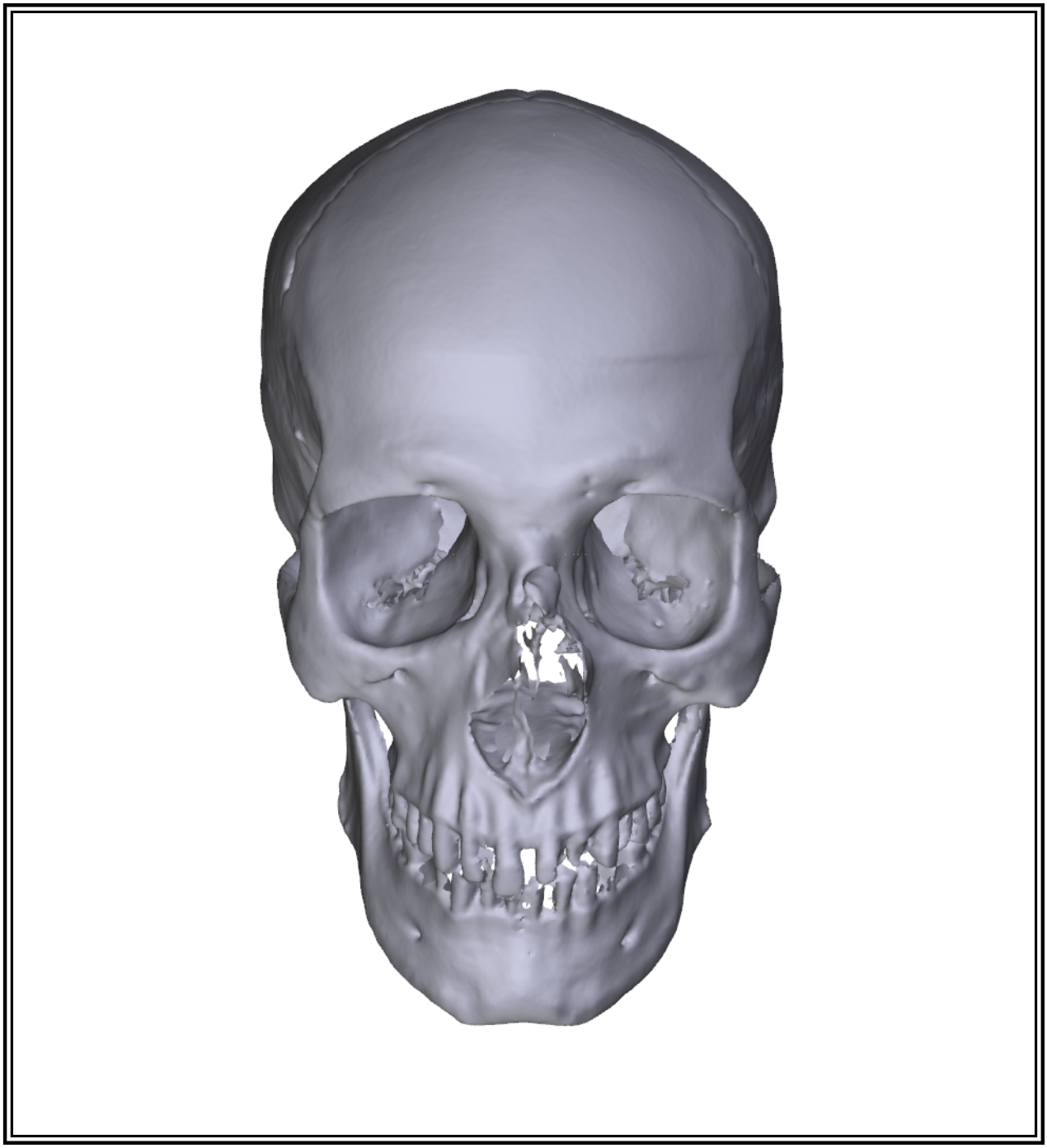


Figure 19. Skull with healed nasal fractures and extensive deformation, USF Osteology Collection

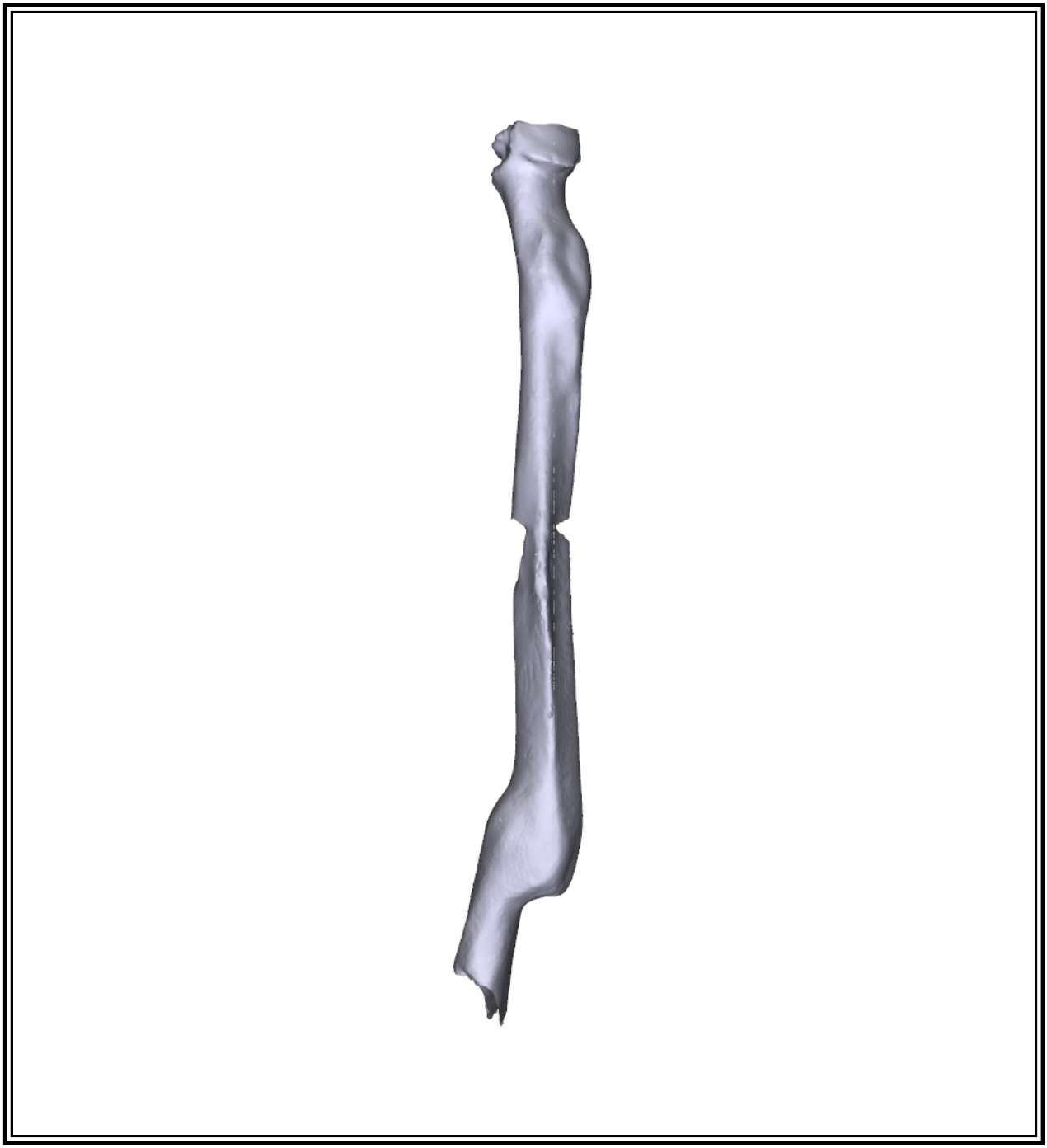
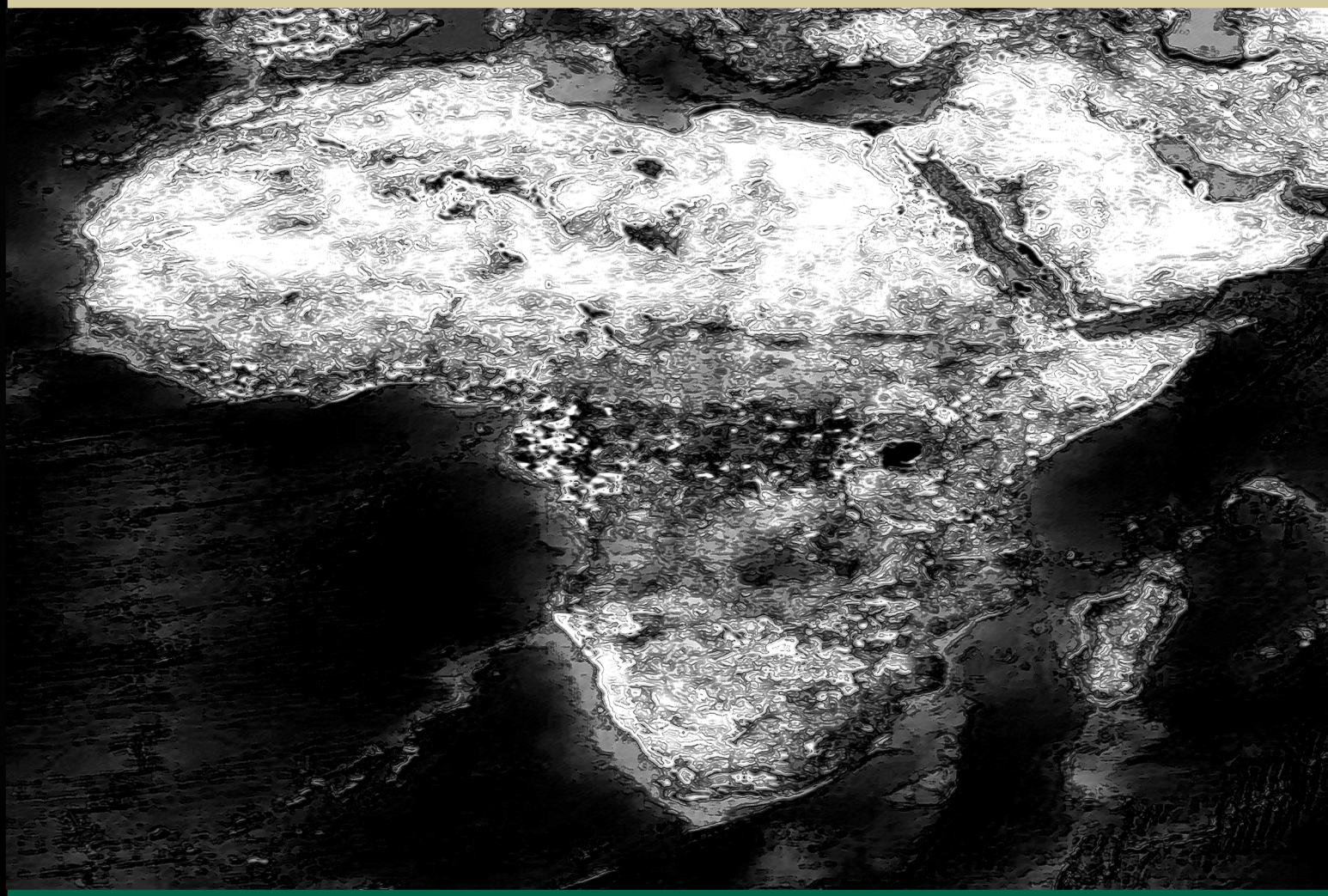


Figure 20. Left radius with healed (antemortem) complete fracture on distal aspect of shaft and postmortem damage in form of breakage near midshaft, USF Osteology Collection

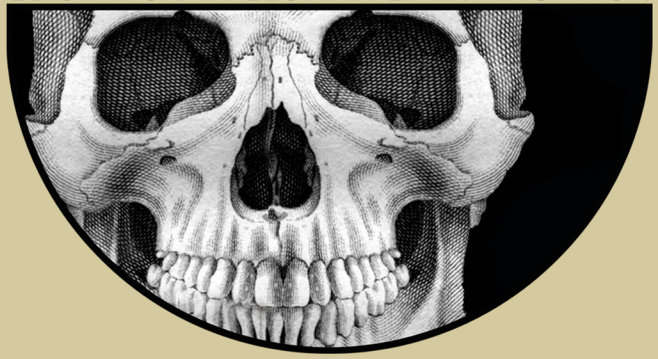


Figure 21. Proximal and medial phalanges with healed fracture and deformation, USF Osteology Collection

# Atlas for Biometric Variation Among African Populations for Human Identification



Research in Human Identification



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Graduate Assistant

Version 1.0.2012

Research funded by:

This project was supported by Award No. NIJ 2008-DN-BX-KI63 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

The opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect those of the Department of Justice.

To Cite:
Kimmerle EH, Pope MA, Tise ML. 2012. Atlas for Biometric Variation Among African Populations for Human Identification. Version 1.0.2012. University of South Florida: www.icfahr.usf.edu/rhi

# Atlas for Biometric Variation Among African Populations for Human Identification

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# EXECUTIVE SUMMARY

The estimation of biological parameters for human identification is a cornerstone of forensic anthropology. The increasing number of investigations into the problem of missing persons and unidentified remain requires the development of new methods and recalibration of existing methods in some cases to reflect diverse populations. There is an ever-greater need to investigate questions about the degree to which skeletal variation among populations differs with regard to growth, maturation, aging, and the effects for individual and population analyses for human identification.

This photographic atlas was created as part of the Research in Human Identification Initiative (www.icfahr.usf.edu/rhi). The images in this atlas come from the International Databank of Skeletal Biomarkers for Human Identification (NIJ-2008-DN-BX-K163). The purpose of putting together this series of images was to illustrate some of the skeletal variation among Africans and the African Diaspora, and to provide a visual reference of known reference materials to researchers and practitioners working in the area of human identification. Reference guides such as this are useful for practitioners in the field as well as for teaching efforts. This atlas is currently the only collection of images of its type and is merely a sampling of some of the skeletal variation observed among the populations included in this study.

From over 1,000 photographs taken of the aforementioned samples, more than 95 photographs were selected for this atlas. Photographs were selected to represent adult and juvenile cranial variation, sexual dimorphism in the skull, biomarkers for the estimation of juvenile and adult age, and several osteological markers of nutritional and metabolic disorders or syndromes. Images were taken of the following osteological collections: the American Museum of Natural History (AMNH), New York; Lagos State University College of Medicine (LASUCOM), Lagos, Nigeria; Maxwell Museum of Anthropology, University of New Mexico (UNM), Albuquerque, New Mexico; Muséum national d'Histoire naturelle (MNHN), Paris, France; National Museum of Natural History (NMNH), Smithsonian Institution, Washington, D.C.; Raymond A. Dart Collection of Human Skeletons (Dart), University of the Witwatersrand, Johannesburg, South Africa; and the Forensic Anthropology Laboratory Osteological Collection (FAL), University of South Florida (Table 1). An overview of sample sizes is provided in Table 2. In the majority of cases, age and sex was known. In a few select cases, ages were estimated.

Table 1. Skeletal collections examined for documenting African skeletal variation.

| Source | Acronym | Location |
|---|---|---|
| American Museum of Natural History | AMNH | New York, New York |
| Lagos State University College of Medicine | LASUCOM | Lagos, Nigeria |
| Maxwell Museum of Anthropology | UNM | University of New Mexico, Albuquerque, New Mexico |
| Muséum national d'Histoire naturelle | MNHN | Paris, France |
| National Museum of Natural History | NMNH | Smithsonian Institution, Washington, DC |
| Raymond A. Dart Collection of Human Skeletons | Dart | University of the Witwatersrand, Johannesburg, South Africa |
| Forensic Anthropology Laboratory Osteological Collection | FAL | Department of Anthropology, University of South Florida, Tampa Florida |

*Note that skeletal collections will be referenced according to their acronyms throughout the text.

Table 2. Summary of demographic parameters by museum and population.

| Museum | Population | Sample Size | Age Cohort* |
|---|---|---|---|
| AMNH | Cameroon | 19 | J/A |
| | Congo | 2 | J |
| | Ghana | 64 | J/A |
| | Kenya | 2 | J |
| | Nigeria | 31 | J/A |
| | Rwanda | 1 | J |
| | South Africa | 2 | J |
| | Tanzania | 2 | J |
| Dart | Botswana | 63 | J/A |
| | Malawi | 36 | A |
| | Mozambique | 48 | J/A |
| | Zimbabwe | 13 | J/A |
| LASUCOM | Nigeria | 655 | J/A |
| MNHN | Afro-Cuban | 4 | A |
| | Benin | 40 | J/A |
| | Cameroon | 6 | A |
| | Chad | 30 | J/A |
| | Congo | 40 | J/A |
| | Ghana | 2 | A |
| | Kenya | 25 | J/A |
| | Mali | 27 | A |
| | Sudan | 26 | J/A |
| NMNH | African American | 183 | J/A |
| | Cameroon | 2 | A |
| | Congo | 2 | A |
| | Gabon | 14 | J/A |
| | Ghana | 4 | A |
| | Kenya | 37 | J/A |
| | Liberia | 1 | A |
| | Senegal | 1 | A |
| | South Africa | 5 | J/A |
| UNM | New Mexico | 121 | J/A |

* "J" = juvenile; "A" = adult ( ≥ 18 years old).

# ACKNOWLEDGEMENTS

We would like to acknowledge and thank the following funding sources, museums, and people for allowing this research and data collection to take place: National Institute of Justice; American Museum of Natural History, New York (Gisselle Garcia-Pack, Curatorial Associate); Maxwell Museum of Anthropology, University of New Mexico, Albuquerque, New Mexico (Dr. Heather Edgar, Curator of Human Osteology, and Carmen Mosley, Graduate Assistant); Muséum national d'Histoire naturelle, Paris, France (Dr. Philippe Mennecier, Responsible for Conservation of Biological Anthropology Collections; Véronique LaBorde, Collections Manager); Raymond A. Dart Collection, University of Witwatersrand, Johannesburg, South Africa (Brendon Billings, Curator); National Museum of Natural History, Smithsonian Institution, Washington, D.C. (Dr. David Hunt, Physical Anthropology Collections Manager, and Rhonda Coolidge, Repatriation Osteology Laboratory); Department of Anthropology, University of South Florida (John W. Powell III, Graduate Assistant, and Katherine Page, Student Volunteer).

# Section 1:
# Human Cranial Variation in Juveniles



**Figure 1.1.** Juvenile cranial variation, frontal view.
From left to right, top to bottom: 1 month old female from Mozambique (Dart);
1 year old male from Mozambique (Dart), 6-8 year old from Bonjo,
Congo with retention of open metopic suture (MNHN);
6-8 year old from Buduma, Chad (MNHN).



**Figure 1.2.** Juvenile cranial variation, frontal view.
From left to right, top to bottom: 12-16 year olds from Elmina, Gold Coast, Ghana with pathological macroporosity on the cranial vault (AMNH); Mhutu, Rwanda (AMNH); Aruska, Tanzania (AMNH); and Kenya (MNHN).



**Figure 1.3.** Juvenile cranial variation, lateral view.
From left to right, top to bottom: 1 month old female from Mozambique (Dart);
Juveniles ages 6-10 years from Buduma, Chad (MNHN); Bonjo, Congo (MNHN);
and Elmina, Gold Coast, Ghana with pathological macroporosity
on the cranial vault (AMNH).

# Section 2:
# Adult Cranial Variation



**Figure 2.1.** Endocranial view of Afro-Cuban Male (MNHN).

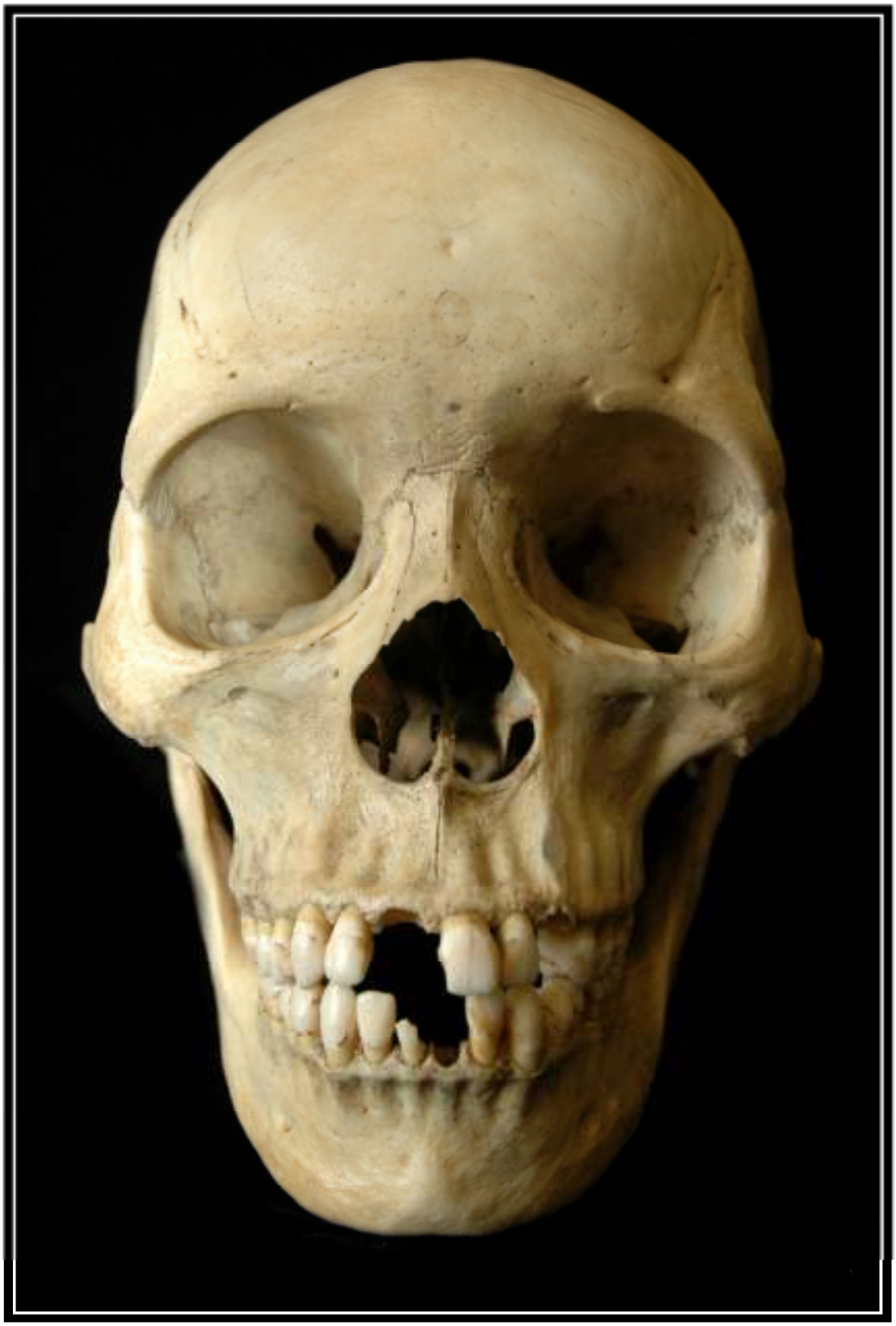


**Figure 2.2.** Adult male from Calabar, Nigeria (AMNH), frontal view.



**Figure 2.3.** Cranial variation among adult males from Nigeria, frontal view. From left to right, top to bottom: Cross River (AMNH); Calabar (AMNH); Calabar (AMNH); Upper Cross River (AMNH).



**Figure 2.4.** Adult female from Calabar, Nigeria (AMNH). Frontal view.



**Figure 2.5.** Cranial variation among adult females from Nigeria, frontal view (not to scale). (Left): Calabar (AMNH). (Top right): Atakpa, Calabar (AMNH). (Bottom right): Calabar (AMNH).



**Figure 2.6.** Examples of culturally modified teeth from various regions in Nigeria, frontal view. Adult males from (from top to bottom): Abeokuta, Dahome (AMNH); Upper Cross River (AMNH); and Cross River (AMNH).



**Figure 2.7.** African American male skull (NMNH), frontal view.



**Figure 2.8.** African American female skull (NMNH), frontal view.

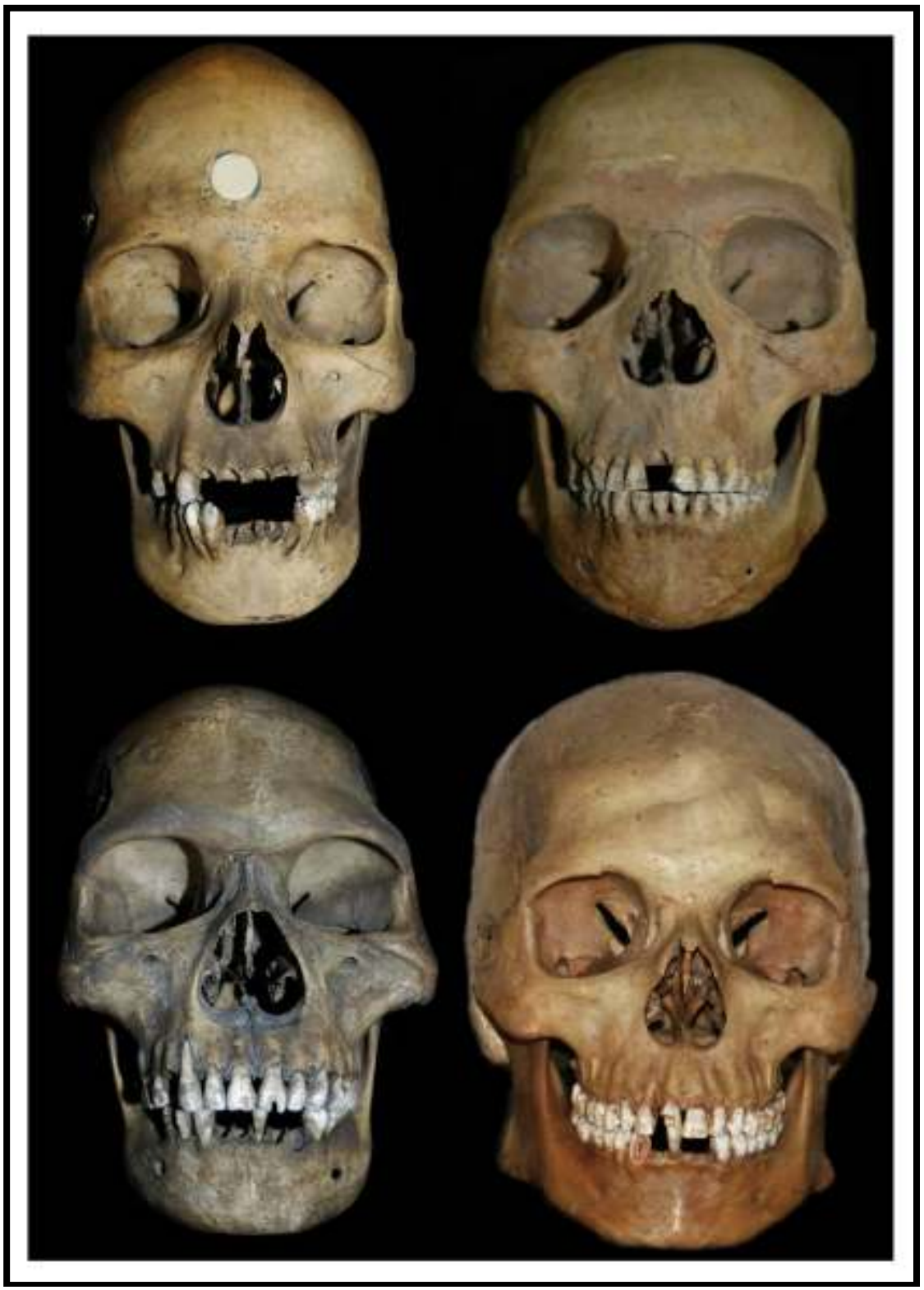


**Figure 2.9.** Cranial variation among adult males, frontal view. From left to right, top to bottom: Toucouleur, Mali (MNHN); Mozambique (Dart); Darfur (MNHN); and African American (NMNH).

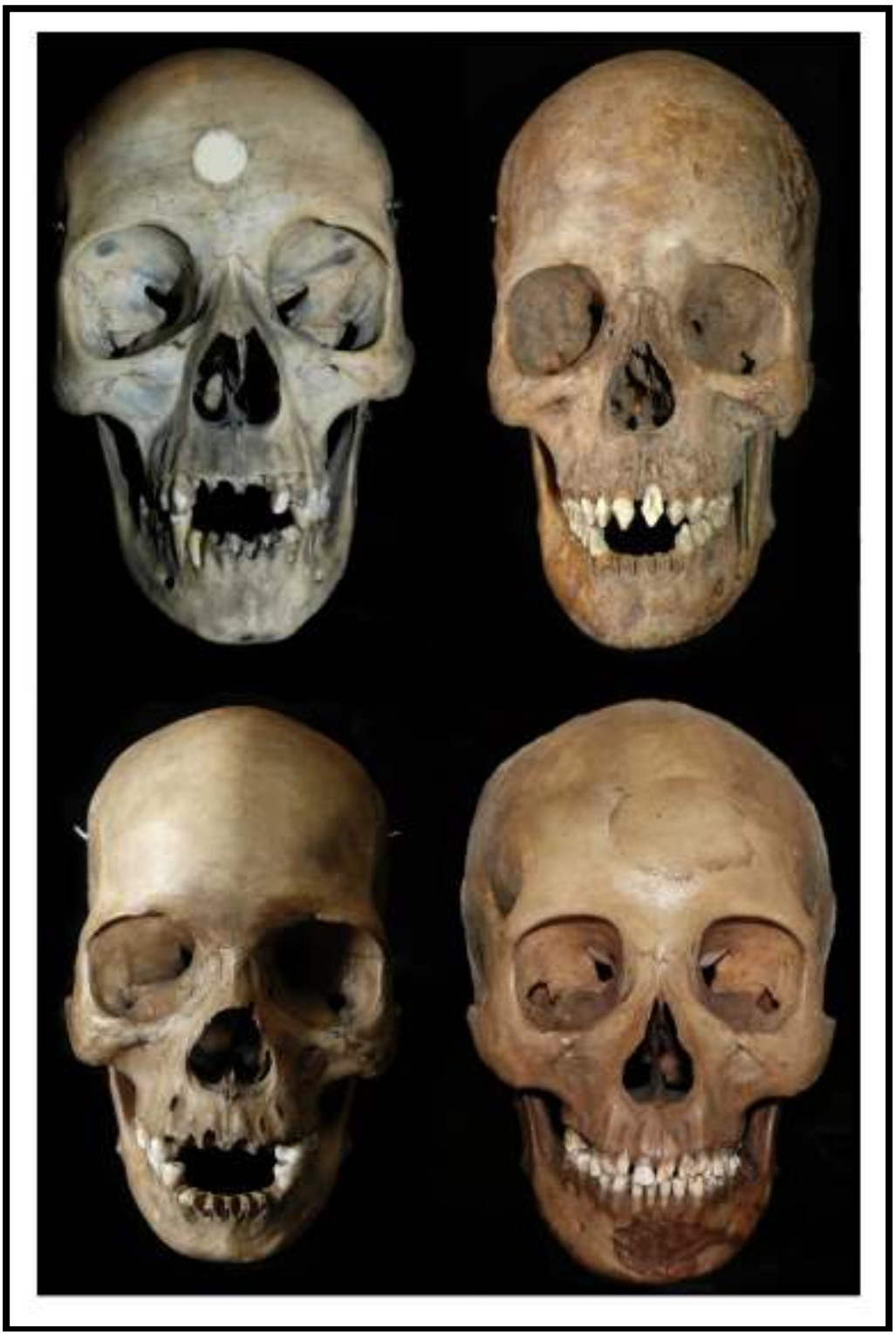


**Figure 2.10.** Cranial variation among adult females, frontal view. From left to right, top to bottom: Toucouleur, Mali (MNHN); Elmina, Gold Coast, Ghana (AMNH) with dental modification; Abuakua, Ashanti, Ghana (AMNH); and African American (NMNH).

# Section 3:
# Sexual Dimorphism in the Skull



**Figure 3.1.** Adult male from Calabar, Nigeria (AMNH), frontal view.



**Figure 3.2.** Adult female from Calabar, Nigeria (AMNH), frontal view.



**Figure 3.3.** Adult male from Calabar, Nigeria (AMNH), left lateral view.



**Figure 3.4.** Adult female from Calabar, Nigeria (AMNH), left lateral view.



**Figure 3.5.** Adult male from Tswana, Botswana (Dart), frontal view.



**Figure 3.6.** Adult female from Tswana, Botswana (Dart), frontal view.



**Figure 3.7.** Adult male from Tswana, Botswana (Dart), left lateral view.



**Figure 3.8.** Adult female from Tswana, Botswana (Dart), left lateral view.



**Figure 3.9.** Adult African American male skull (NMNH), frontal view.



**Figure 3.10.** Adult African American female skull (NMNH), lateral view.



**Figure 3.11.** Adult African American male skull (NMNH), lateral view.



**Figure 3.12.** Adult African American female skull (NMNH), lateral view.

# Section 4:
# Juvenile Remains:
# Biomarkers for Age Estimation



**Figure 4.1.** 1 year old female in anatomical position, from Mozambique (Dart).



**Figure 4.2.** Juvenile (age 11-15 years old) in anatomical position from Mhutu, Rwanda (AMNH).



**Figure 4.3.** 3 year old European American male in anatomical position (UNM).



**Figure 4.4.** Postcrania of 13 year old female in anatomical position from Rolanq, Botswana (Dart).



**Figure 4.5.** Examples of hyoid fusion among Nigerians (LASUCOM). From top: 1 year old female, 30 year old male (bilateral open), 43 year old male (unilateral open), and 62 year old male (bilateral fused).

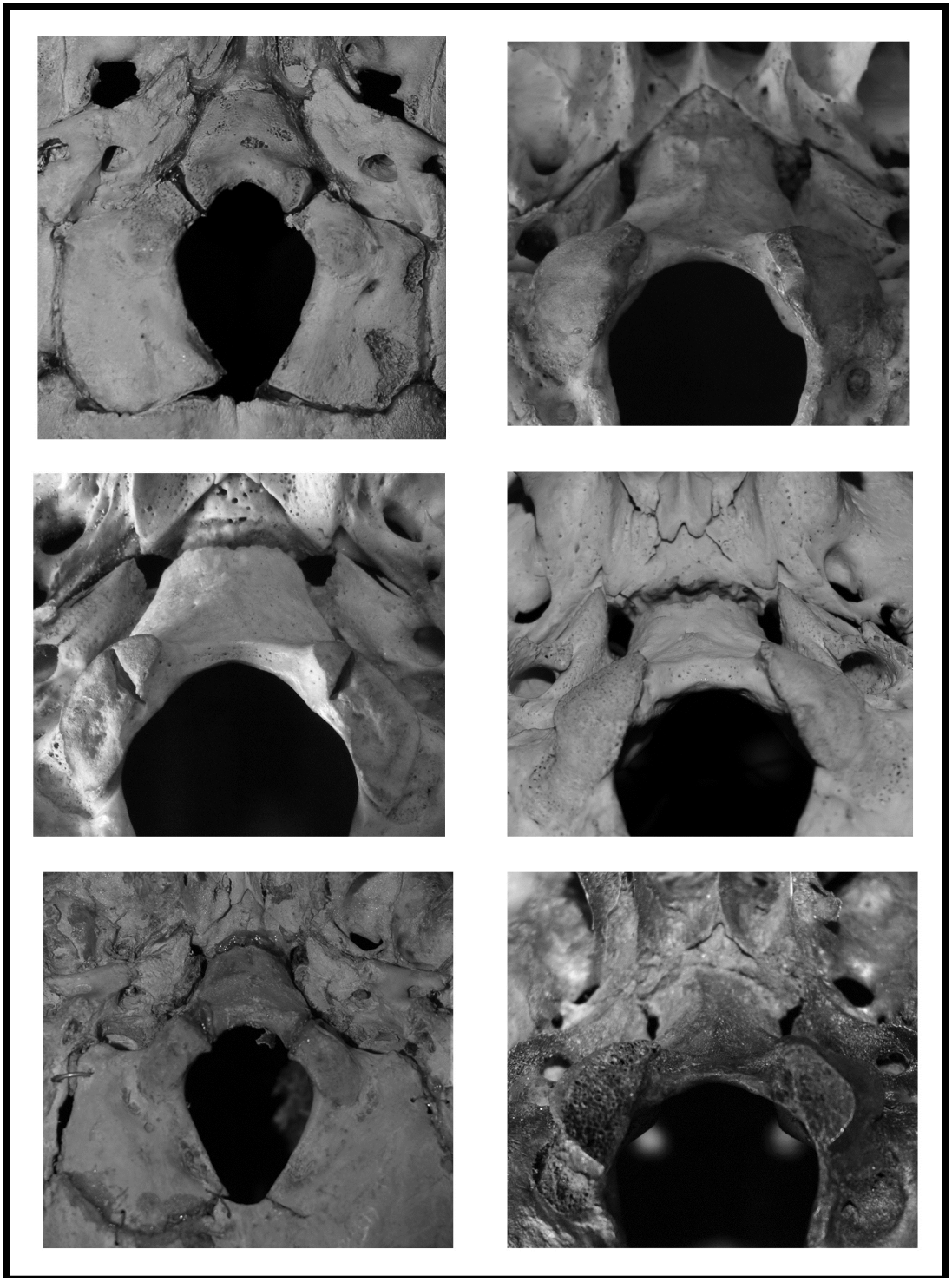


**Figure 4.6.** Examples of fusion at the basilar suture and base of the skull, inferior view. Examples come from African crania and range from completely open and unfused basilar and squamous portions (top left: 1 month old male from Mozambique; Dart) to fused with osteoarthritic degenerative changes on the occipital condyles (bottom right: adult female from Calabar, Nigeria; AMNH).



**Figure 4.7.** Juvenile and adult sterna, anterior view.
Left: manubrium and unfused sternal body segments
from a 13 year old female (Dart).
Right: manubrium and fused sternal body from an adult female.



**Figure 4.8.** Unfused distal epiphyses of the radii and ulnae from a 20 year old male, Mozambique (Dart), anterior view.



**Figure 4.9.** Partial fusion of the distal epiphyses of the tibiae and fibulae from a 13 year old female, Rolanq, Botswana (Dart), anterior view. Note also the presence of desiccated soft tissue and cartilage.



**Figure 4.10.** Various stages of fusion in the right os coxae, medial view. From top: open (3 year old male; Dart), partially fused (AMNH), and fused with the epiphyseal line still evident (13 year old female; Dart).

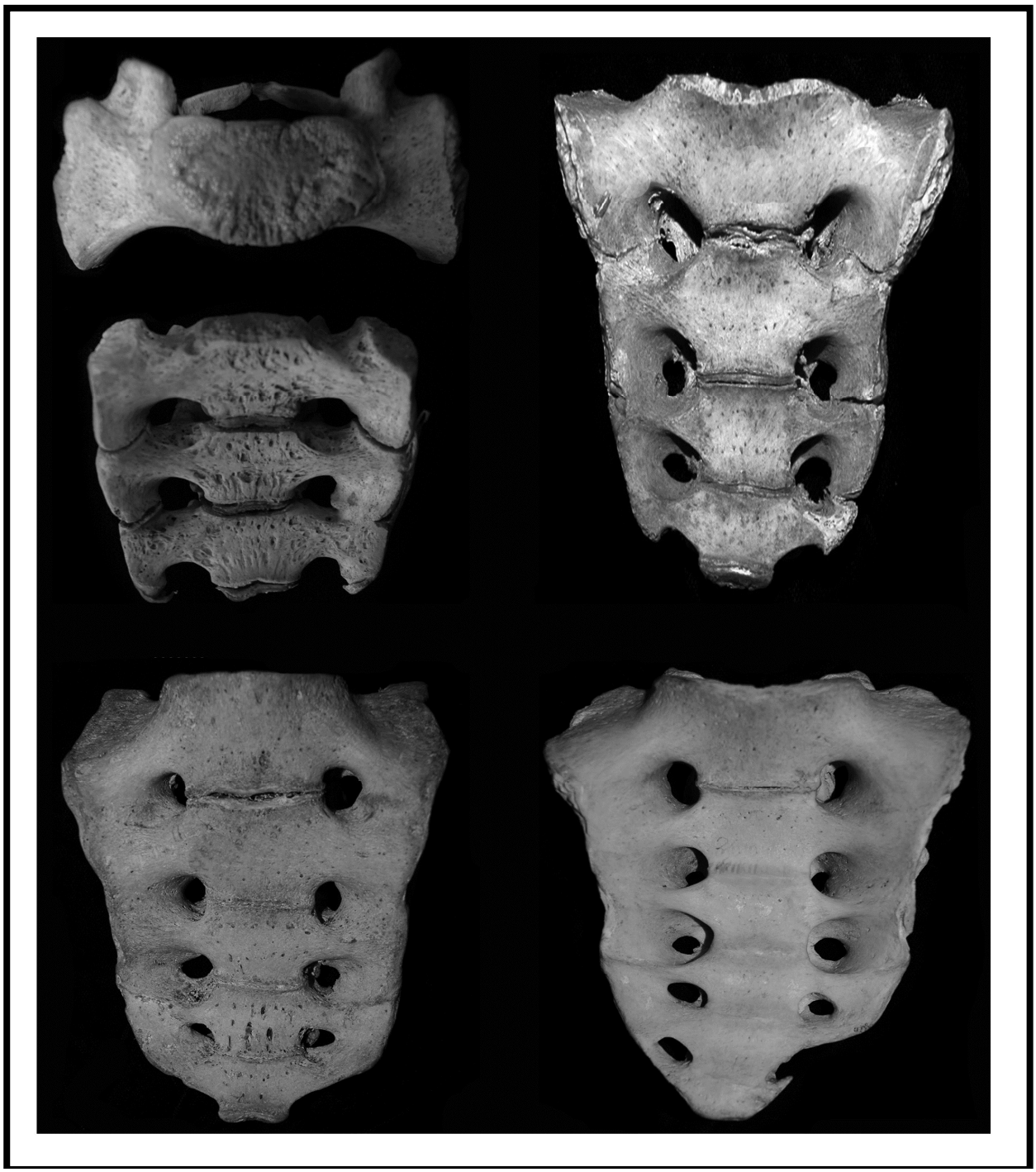


**Figure 4.11.** Various stages of sacral fusion, anterior view.
From left to right, top to bottom: completely unfused (12-15 year old from Mhutu, Rwanda; AMNH); minimally fused (13 year old female from Rolanq, Botswana; Dart); and partially and fully fused sacral vertebrae (25 year old male from Malawi and 27 year old female from Tswana, Botswana; Dart).

# Section 5:
# Adult Biomarkers for Age Estimation

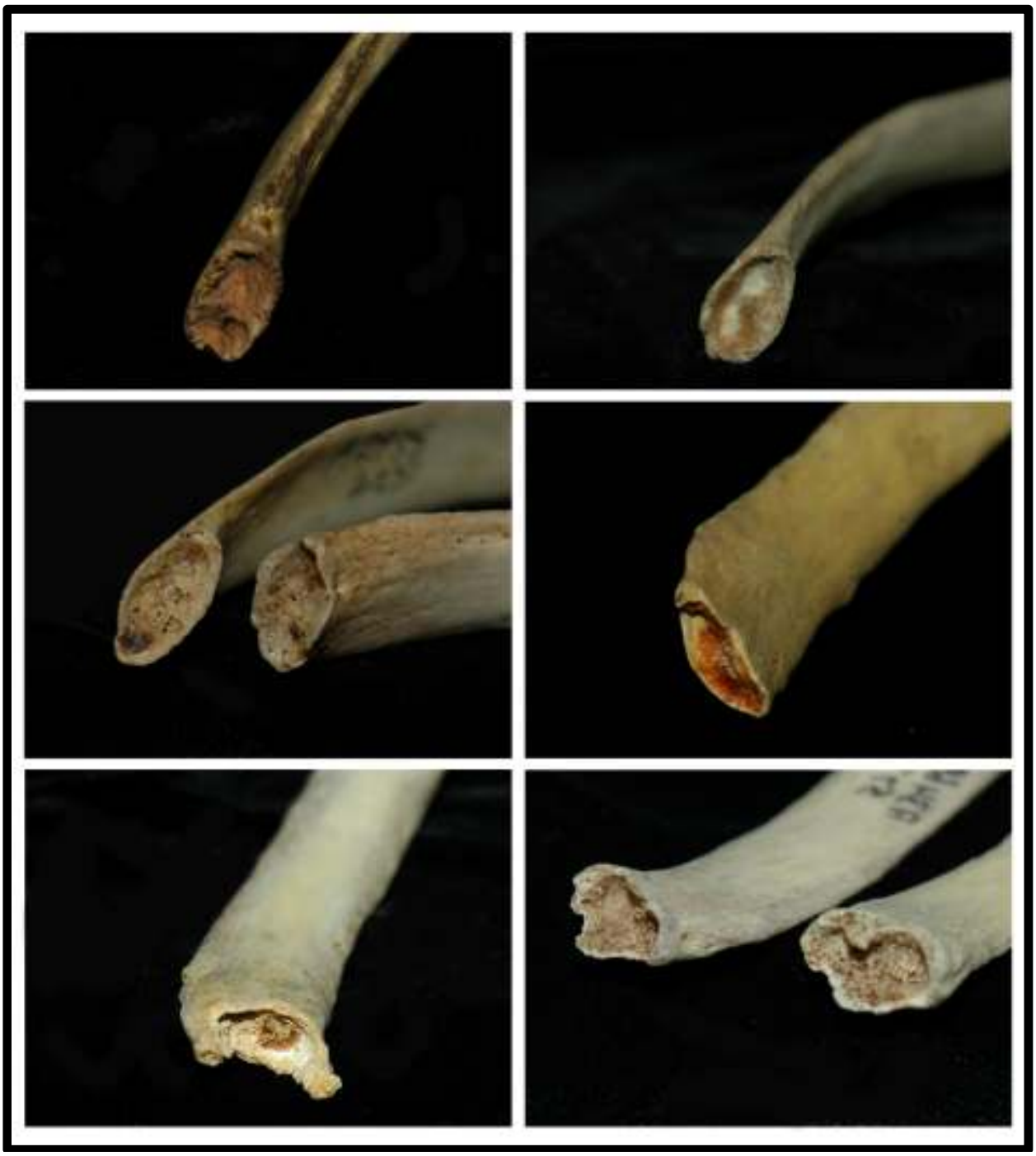


**Figure 5.1.** Variation in sternal rib ends for adult males.
From left to right, top to bottom: ages ranging from 35 to 49 years old.

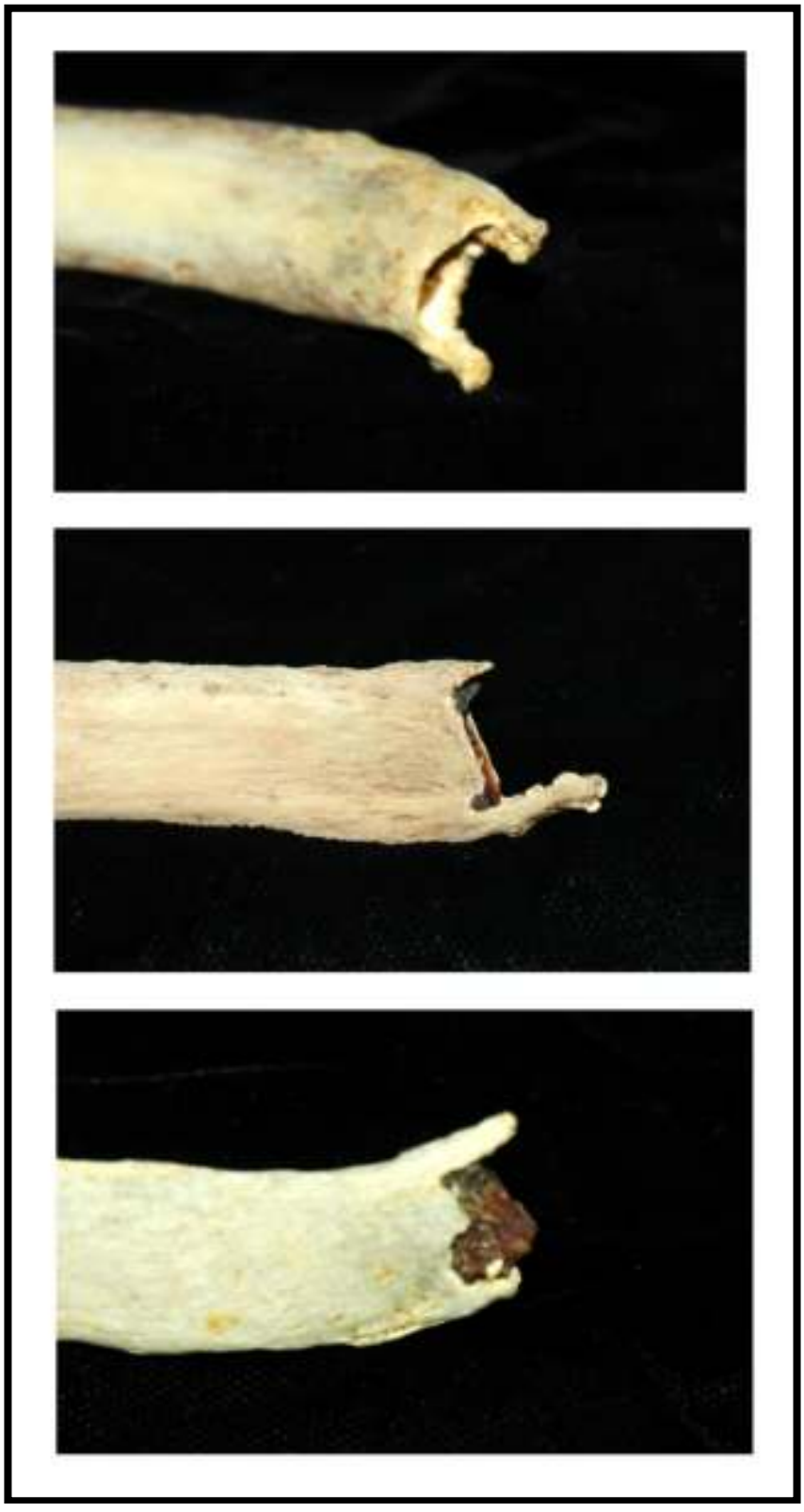


**Figure 5.2.** Variation in sternal rib ends for adult males. From top to bottom: age 45, 58, and 68 years.

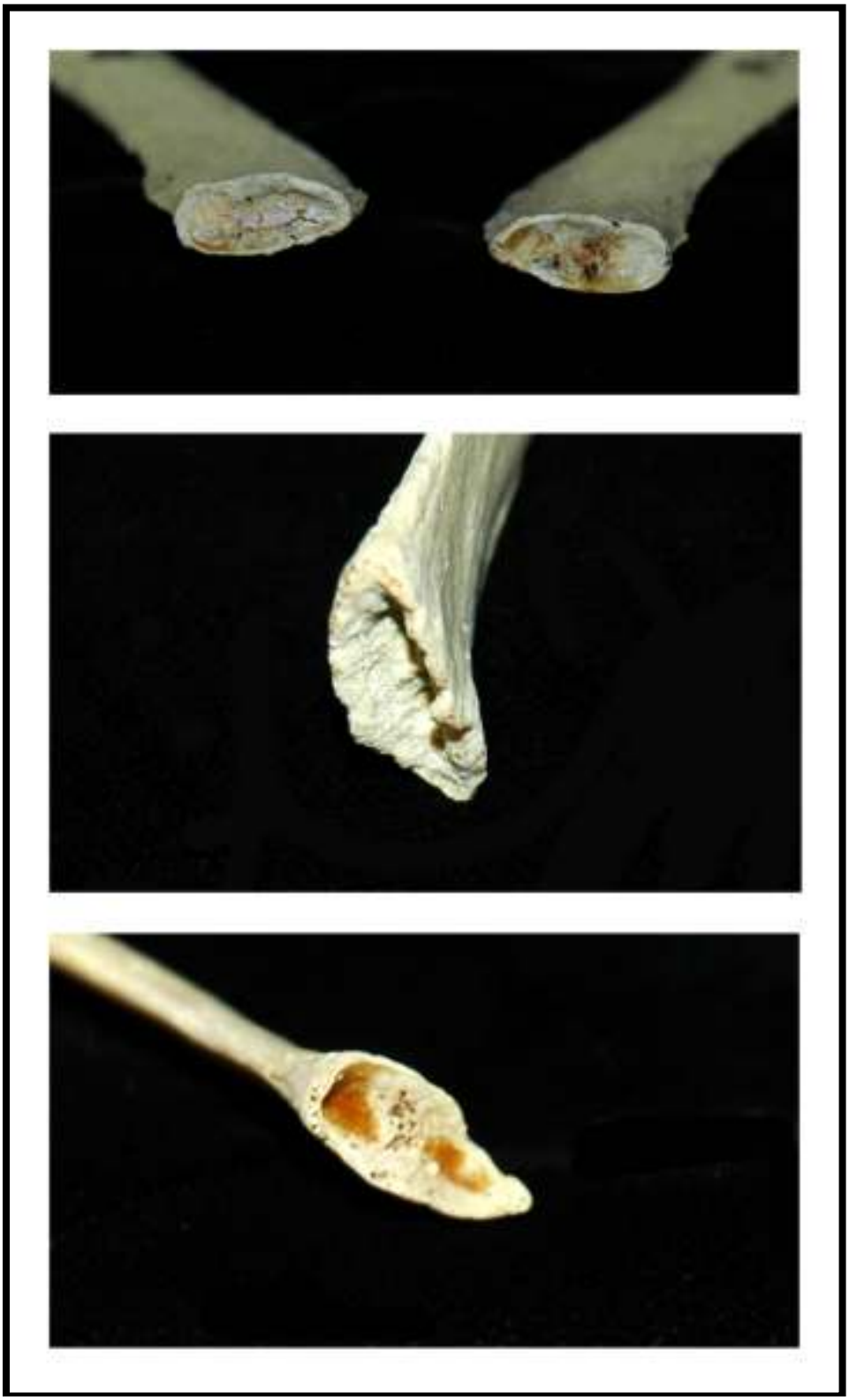


**Figure 5.3.** Variation in sternal rib ends for adult females.
From top to bottom: age 32, 40, and 48 years.

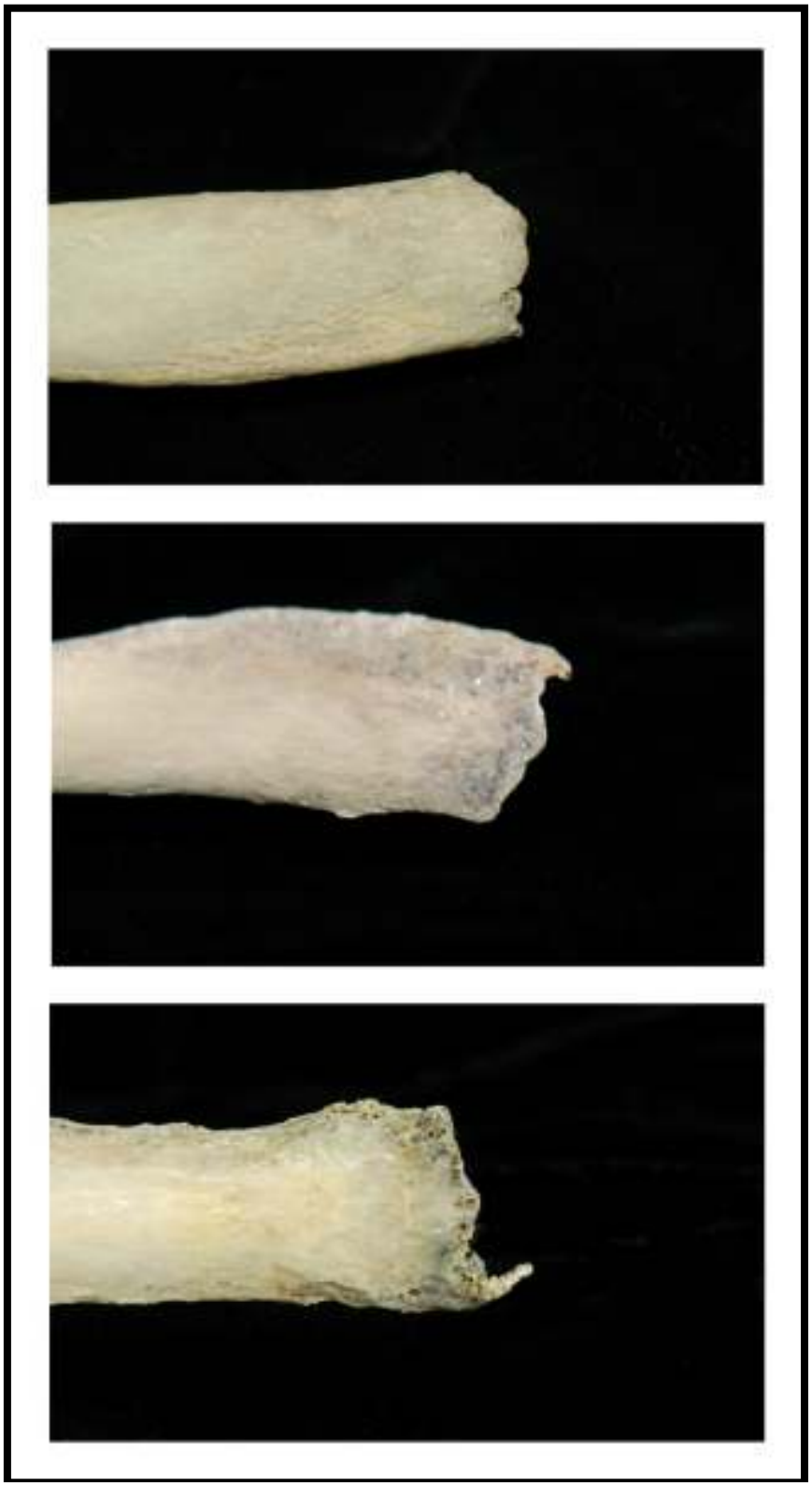


**Figure 5.4.** Variation in sternal rib ends for adult females. From top to bottom: age 27, 32, and 56 years.



**Figure 5.7.** Variation in pubic symphyses for adult males.
From left to right, top to bottom: age 36, 45, 49, and 58 years.

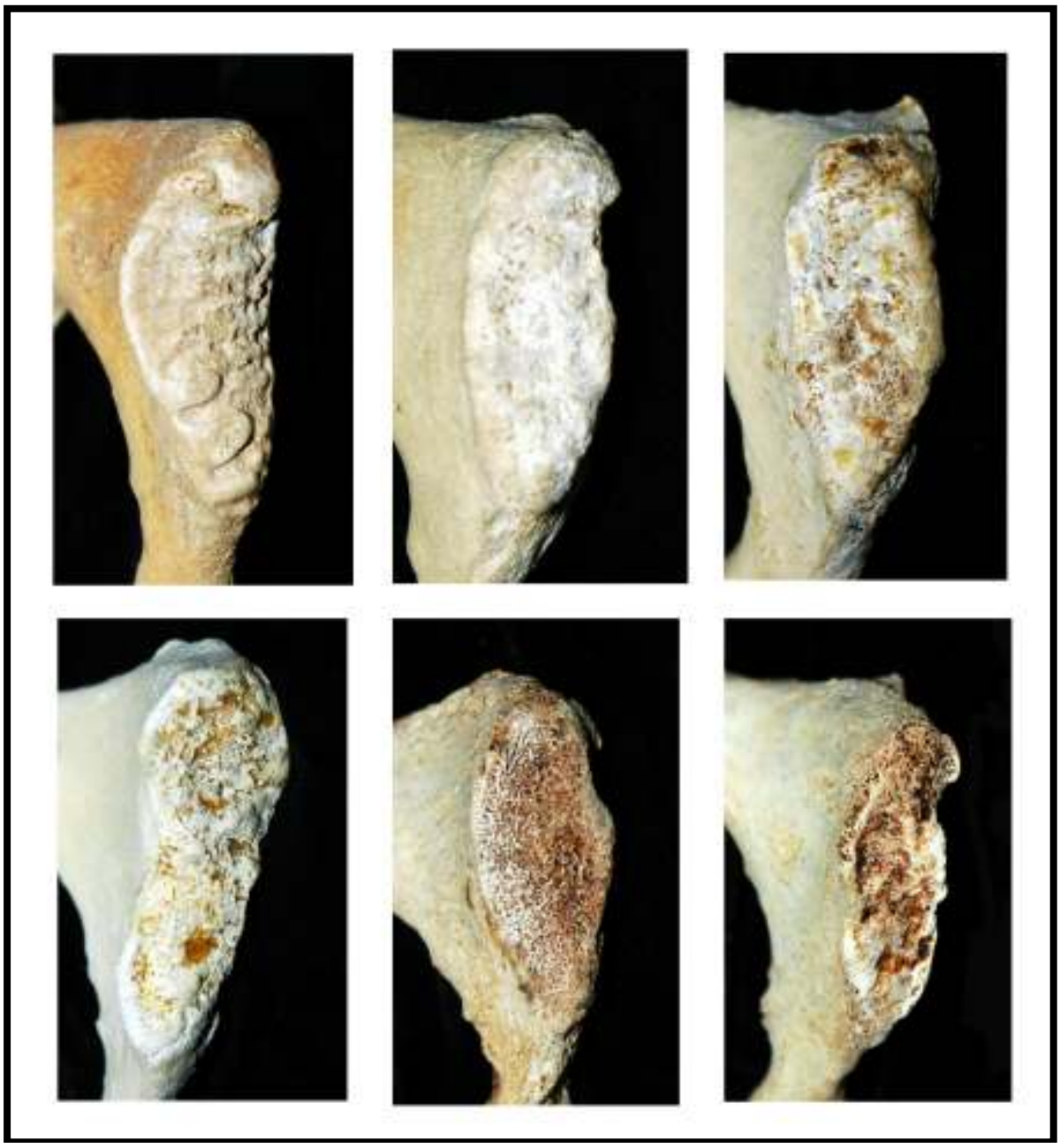


**Figure 5.8.** Pubic symphyses for adult females.
From left to right, top to bottom: age 20, 27, 32, 40, 50, and 65 years.

# Section 6:
# Osteological Markers of Nutritional and Metabolic Diseases




**Figure 6.1.** Cribra orbitalia present bilaterally in orbits of juvenile female from Mandingo, Cameroon (AMNH).



**Figure 6.2.** Examples of linear enamel hypoplasias in the form of horizontal bands across the tooth surface, labial view.
Both examples come from African American adult males (NMNH).

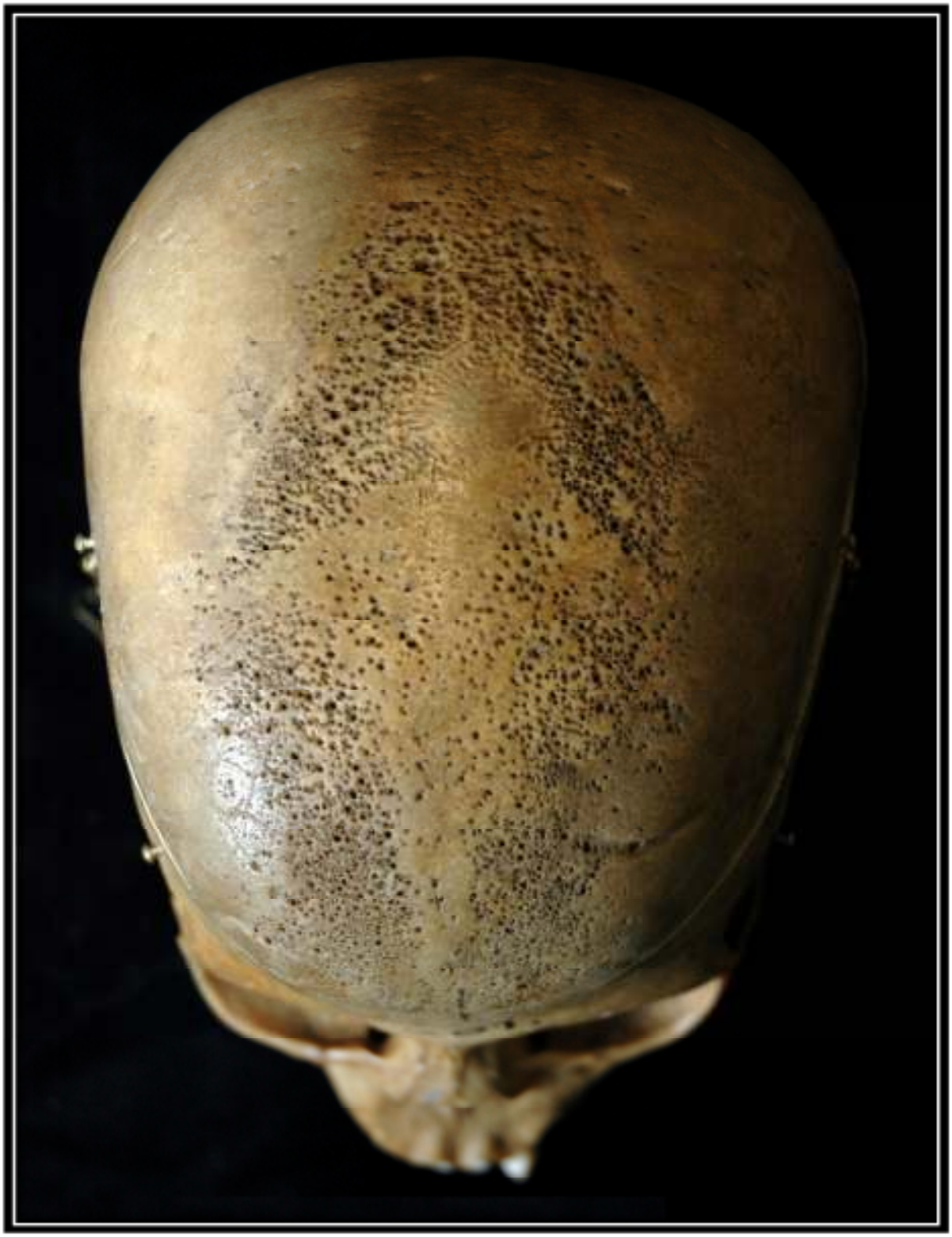


**Figure 6.3.** Skull of unknown juvenile from Elmina, Gold Coast, Ghana (AMNH), superior view. Note the presence of healed and active porotic hyperostosis.



**Figure 6.4.** Skull of juvenile from Elmina, Gold Coast, Ghana, posterior view. Note the presence of healed ectocranial porosis and the premature fusion of the sagittal suture.



**Figure 6.5.** Adult female from Calabar, Nigeria (AMNH), frontal view. Note the retention of the partially fused metopic suture and osteolytic lesion along the midsagittal plane on the frontal bone.



**Figure 6.6.** 33 year old female with ossification of the left stylohyoid ligament, Mozambique (Dart), oblique view.




**Figure 6.7.** Basilar view of adult female cranium from Calabar, Nigeria (AMNH). Note the abnormal shape (flatness) and porosity with eburnation on the occipital condyles due to osteoarthritis and activity-induced stress to the joint.



**Figure 6.8.** Right lateral view of first and second thoracic vertebrae of 60 year old female from Tswana, Botswana (Dart). Note the compression fracture in the vertebral body and the abnormal bone formation and fusion of the spinous processes, and vertebral bodies, possibly resulting from DISH (diffuse idiopathic skeletal hyperostosis).



**Figure 6.9.** Bilateral proximal ulnae with lipping along the entire joint surfaces. 60 year old female from Tswana, Botswana (Dart).



**Figure 6.10.** Healed fracture with osteomyelitis, myositis ossificans, and deformation due to misalignment of the fractured bone, anterior view. Proximal, right humerus of 50 year old female, Tswana, Botswana (Dart).