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Investigating Patterns of Interpersonal Violence Using Frequency Distributions of Cranial Vault Trauma

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INVESTIGATING PATTERNS OF INTERPERSONAL VIOLENCE USING FREQUENCY DISTRIBUTIONS OF CRANIAL VAULT TRAUMA

by

Armando Anzellini

A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Anthropology
in the College of Sciences
and in The Burnett Honors College
at the University of Central Florida
Orlando, Florida

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Thesis Chair: Dr. J. Marla Toyne

Abstract

Violence has been found ubiquitously across human societies and throughout time. An act of violence can be defined as purposeful harm brought upon one individual as a direct or indirect result of the actions of another. The purpose of this research is to develop a quantitative approach to examining lethality using frequency distributions for location of trauma on the cranium in order to model patterns of interpersonal violence. This is accomplished through the study of a skeletal sample, from the prehispanic Chachapoya (existing around A.D. 800 – 1535), discovered at the site of Kuelap in the northern Peruvian Andes. Metric data were gathered from 81 individuals including males, females, and subadults. The data consisted of precise location of traumatic injury measured from anatomical landmarks in each of five two-dimensional views of the cranium as well as estimated diameter of impact for all lesions. The lesions were separated between perimortem (lethal) and antemortem (non-lethal) in order to explore patterns of lethality that correlate with location of injury. A statistical difference ($p > 0.05$) in location could not be determined when the distributions were compared in five standard two-dimensional views or between the sexes. Statistical significance ($p > 0.05$), however, was encountered when the entire cranium was used for the distribution. This distribution showed that perimortem injuries tend to occur more frequently on the posterior aspect of the cranium while antemortem injuries tend to occur more frequently on the anterior for this sample. These results show that a quantitative approach to location of injuries to the cranial vault can reveal new patterns of violent interactions and aid in the study of violent behavior.

Dedication

To my parents for providing all the support I needed throughout my life for whatever crazy goal I wanted to achieve at the time, and to Jessica Purvis for being understanding and supportive through every stressful step of this process – hopefully only the first of many.

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I would like to thank Dr. Marla Toyne for all of her support and all of the opportunities she has given me during the time we have worked together. This thesis would not be possible without her guidance, encouragement, and willingness to share her knowledge and her data. I would also like to thank my committee members, Dr. Schultz and Dr. Corzine for their insightful suggestions during the process of writing this thesis. I would like to thank the University of Central Florida for their commitment to improving undergraduate research by creating and maintaining the Honors in the Major program. Lastly, I would like to thank the Burnett Honors College for providing the funding for this project through the HIM Scholarship.

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Chapter 1: Introduction

1.1 Purpose

The purpose of this thesis is to investigate evidence of violent human behavior and add to our understanding of patterns associated with the timing of physical trauma by using a quantitative approach in addition to the standard qualitative method. The main objective of anthropology is furthering our understanding of human behavior across cultures in the present and the past. One aspect of humanity that has extraordinary implications for our understanding is the prevalence of violence between two or more individuals (i.e. interpersonal violence). This form of violence is evident in almost every culture, every time period, and every region of the world (e.g. Riches, 1986; Ember and Ember, 1994; Ferguson, 1997; Walker, 1997, 2001; Judd, 2004; Brickley and Smith, 2006; Andrushko and Torres, 2011), and many times those acts of violence are associated with issues of economics, territory, morality, religion, and even gender; therefore, the study of violence plays an important role in the evolution of human societies (Riches, 1986; Walker, 2001). While most people think of warfare and militarism when they think of violence, the study of violence can give anthropologists a broader perspective, one that encompasses all facets of daily life. One can only really grasp a more complete understanding of violence through the study of the physical remains of those that once lived and died within the culture that we seek to understand (Walker, 2001). Bioarchaeology examines human remains within the historical, cultural, technological, and ideological context in order to gain a more clear appreciation of the life of the people via direct evidence left on the skeleton (Walker, 2001).

Unfortunately, the interpretation of the physical remains can be difficult in cases associated with violence.

The most complex aspect of studying violence through skeletal remains is the distinction between injuries caused by accident from those caused deliberately by another human being. Studying such a distinction and reconstructing the conditions in which violence occurred are challenging due to the qualitative nature of interpreting fracture patterns and affected regions of the body (Lovell, 1997; Sauer, 1998; for an alternative see Novak, 2006). This methodology has led to problems of both over-reporting and under-reporting of violence-related trauma in many archaeological contexts. It is clear that the most effective way to mitigate these inaccuracies is to create a working quantitative model which, when applied to similar cultures, will result in a statistically significant certainty of interpretation.

This thesis looks to develop that quantitative approach by using *frequency distributions* of location of weapon-related trauma on the cranial vault in order to model patterns of interpersonal violence. Through the study of cranial remains from a sample from the archaeological site of Kuelap, Chachapoyas, Peru, I expect that a quantitative approach utilizing frequency distributions will improve our understanding of interpersonal violence and the pattern of blunt force trauma injuries to the cranial vault.

1.2 Violence in Anthropology

Anthropology seeks to understand and explain human behavior from as many perspectives and in as many situations as possible. This is especially true when concerning violent behavior, due to its universal existence in human society (Knauft, 1991; Krohn-Hansen,

1994). As with any attempt at a cross-cultural study, the definition and connotations of terms can lead to confusion and misunderstanding. The term violence conjures up ideas of illegitimacy in Western Society that may not be perceived equally in other cultures because the term is relative (Riches, 1986; Krohn-Hansen, 1994; Walker, 2001), thus it must be defined explicitly in order to be properly studied. Violence has been defined by David Riches (1986) and Phillip Walker (2001) as purposeful harm brought upon an individual as a direct or indirect result of the actions of another. When most people in the Western World imagine violence, they will most likely picture organized military warfare and physical conflict. While not mistaken, this definition falls within the more refined term of interpersonal violence usually restricted to a select group of individuals in many societies; however, violence comes in many forms and leaves behind many traces. As with most human behaviors, violence is meaningful, symbolic, social, and cultural (Krohn-Hansen, 1994).

1.2.1 Performance of Violence

Acts of violence, both overt and symbolic, are culturally specific (Brickley and Smith, 2006), acts of aggression are universal in both humans and our closest evolutionary relatives, the great apes (Riches, 1986; Knauft, 1991; Ember and Ember, 1994; Krohn-Hansen, 1994). They can be acts of passion, expressions of power, defenses of resources, or even vengeful retaliations, but the one connecting factor is the possibility of causing traumatic injuries or death to both individuals and communities when physical violence is “expressed” (Knauft, 1991; Walker, 1997, 2001). Riches (1986) explains that all acts of violence are performances intended to achieve a goal, either 'symbolic' or 'practical', that there is a message ciphered in the act. That

message is not always intended for the victim, but might also be a 'warning' to any person that has witnessed the act or its results (Riches, 1986). In cases of direct interpersonal violence, the intent of the perpetrator and the reactions of the victim will define the patterns of injury, including location, size, and severity (Brink et al., 1998).

1.2.2 Violence in the Past

History is fraught with interpersonal violence, but it is not always the expected set-piece, medieval style warfare that has been popularized by our Western history and lore. Acts of violence in the past tended to be either raids and skirmishes designed to minimize the possibility of injury to the perpetrators or intimate acts of aggression between two individuals in the same group (intergroup versus intragroup violence) (Ember and Ember, 1994; Krohn-Hansen, 1994; Walker, 1997, 2001; Knüsel and Boylston, 2000; Palkovich, 2012).

Examples from European archaeology and history offer evidence of prehistoric warfare in England (Ferguson, 1997), Neolithic raiding in Scandinavia (Fibiger et al., 2013), and even violence for sport in Rome (Kanz and Grossschmidt, 2006). Bioarchaeology has uncovered just as much information on traumatic injury and violence in places like Kerma, the Canary Islands, Pakistan, and other ancient centers of population in both Africa and Asia (Judd, 2004; Owens, 2007; Robbins Schug et al., 2012). The history of the Americas is not much different.

While many people believe that the pre-Columbian (before European contact) American societies were pacifistic or at least relatively non-violent, there is much evidence to the contrary (Walker, 2001). Although it is true that European contact brought new technology and tactics of violence to the Americas (Murphy and Gaither, 2010; Gordón and Bosio, 2012), there seems to

have been little increase in the number of violent intragroup interactions (Gaither, 2012). From the expanse of the North American Southwest, to the achievements of the Aztecs and the Maya in Central America, and the Inca and the Wari in the Andes, the evidence for warfare, raiding, militaristic empires, and ritual violence exemplifies that violence in both large and small scales was not reserved to the metal weapons and firearms of the Old World (Tung, 2007; Toyne, 2011; Andrushko, 2011; Tiesler and Cucina, 2012; Palkovich, 2012).

Clearly, violence has been ever present in human societies, it is a part of our species, it is an expression of our culture. For an anthropologist, the study of violence is essential in understanding the culture in which the act is perpetrated whether from the point of view of the perpetrator or the victim. The unique, broad, cross-cultural, and historical perspective used by the anthropologist can yield great insights into the factors that shape violence in both ancient and contemporary settings (Walker, 2001).

1.3 Methodological Framework

1.3.1 Bioarchaeological Approach to Violence

The specialization of bioarchaeology has an advantageous position from which to analyze violence, past and present. As previously discussed, bioarchaeology is a multidisciplinary field that seeks to understand the human past through the physical human remains and the cultural contexts in which these remains are found (Walker, 2001). Skeletal remains provide direct evidence of interpersonal violence, and while the written records and iconographic media can help support interpretations, the results of interpersonal violence are visible to all and are not subject to the bias of scribes or lords (Walker, 2001). As with all human knowledge, it has gaps

that need to be filled, such as mechanism of injury, or the distinction of the timing of fractures: whether they are antemortem (before the time of death), perimortem (around the time of death), or postmortem (after the time of death, usually due to burial environment and natural processes) (Sauer, 1998).

1.3.2 Observations of Trauma

Traumatic injuries to the skeleton can occur in many distinct patterns depending on the force of impact, direction of said force, and the structural integrity of the affected bone (Gurdjian et al., 1950; Lovell, 1997; Galloway, 1999). In order to analyze skeletal trauma, one must first understand the biomechanics of bone fracture. In terms of material analysis, fresh bone is a plastic medium, meaning that when a section of bone comes under stress, it will encounter two stages before fracture. First is the elastic stage, in which the bone will return to its original shape once the stress is removed. Second is the plastic stage, in which the bone will become malleable, deforms and does not return to its original shape. Once the stress crosses the plastic threshold, the bone will fracture in a variety of ways depending on the direction, mechanism, and amount of stress applied (Berryman and Haun, 1996; Lovell, 1997; Galloway, 1999).

In a living individual, fractures will result in a bodily response that begins with a hematoma, continues with the formation of woven bone, later becoming a hard/bony callous, and finally to the creation of cortical bone from a few days to a few months after the traumatic event (Sauer, 1998; Galloway, 1999). This bony response is a clear indicator that the trauma was survived for some period of time, as most physiological reactions of osseous remodeling can be seen an average of thirteen days after the injury if the individual is still alive (Sauer, 1998).

Finding bone remodeling to an injury indicates that it is antemortem (Lovell, 1997; Sauer, 1998; Galloway, 1999).

While recognizing antemortem trauma is relatively straightforward, the distinction between perimortem and postmortem is more challenging (Galloway, 1999). This is due to the fact that fracture patterns will only change once the organic component in bone has significantly decomposed, which may take anywhere from 14–57 days to fully occur depending on the mortuary environment, during which time any fracture will appear as 'fresh' (Wieberg and Wescott, 2008). Extension or contraction of the estimated perimortem interval (PMI) can be caused by levels of humidity and acidity in the soil, the feeding activity of insects and other scavengers, as well as the temperature of the surrounding environment (Wieberg and Wescott, 2008; Karr and Outram, 2012).

Perimortem injuries refer to any injuries sustained while the bone was still fresh and malleable. This causes a problem when discussing the perimortem interval since as previously discussed, bone can be considered fresh long after the person has been deceased depending on the burial environment (Galloway, 1999; Sauer, 1998; Lovell, 1997; Ubelaker and Adams, 1995; Wieberg and Wescott, 2008; Karr and Outram, 2012). Fortunately, there are certain patterns that can be used to distinguish perimortem from postmortem.

Due to the plastic nature of bone, perimortem fractures will often exhibit beveling of the surface outward in the direction of the force applied, especially on the laminar bones of the cranial vault, which will exhibit linear, comminuted, or puncture fractures with similar beveling (Lovell, 1997). This plastic deformation of the vault can only be caused by blunt force impact trauma (Wieberg and Wescott, 2008). The edges of a perimortem fracture will also appear

irregular since fresh bone will flex and pieces will remain attached (Sauer, 1998). Finally, fractures of the cranial vault, depending on the force of impact, will include radiating and possibly concentric fractures that will stop upon reaching an open suture or fracture line (Berryman and Haun, 1996).

Unfortunately for bioarchaeologists, the burial environment, as well as any activity performed on the remains after the deposition and initial decomposition process of the body, can cause what is defined as postmortem modifications or taphonomy, which can also damage or fracture skeletal remains (Galloway, 1999; Sauer, 1998; Lovell, 1997). As a result of this dilemma, we must consider taphonomic indicators when interpreting fracturing and fragmentation of skeletal remains. Since bone is dry and brittle once the collagen has decomposed, the bone is more likely to shatter into small fragments (Sauer, 1998), but if the injury occurs while bone is fresh this may not appear, therefore other assessments must be made. The color of the fracture can be a useful indicator of postmortem damage (Ubelaker and Adams, 1995; Calce and Rogers, 2007; Wieberg and Wescott, 2008). A fracture line that appears lighter in color than the surrounding bone is likely to have been incurred after decomposition had occurred or the remains have spent considerable time in the burial environment. Evidence for scavengers and rodents will also point to exposure and taphonomic changes (Sauer, 1998), and signs of erosion due to water, wind, sun, or other natural process will also lend further support for taphonomic processes being at work (Ubelaker and Adams, 1995; Galloway, 1999; Calce and Rodgers, 2007). Ultimately, only the observational skills and experience of the researcher in the field can lead to higher accuracy in determining the timing of injury, but certain meaningful factors can be included in the analysis that lead to an acceptable level of certainty. It is important

for the researcher to identify individuals exhibiting patterns consistent with taphonomic processes in order to establish standards of comparison and ultimately report findings clearly and consistently.

1.3.3 Intentionality and Lethality

Just as deciphering if a fracture is perimortem or postmortem, distinguishing between accidental injuries and intentional injuries can be difficult. The importance of such a distinction lies in the fact that detailed analysis of both intentionality and lethality could explain a great deal about the specific culture being studied and their patterns of behavior. Attempts have been made to standardize and quantify the distinctions, each relying on observation and qualitative deductive reasoning (Berryman and Haun, 1996; Lovell, 1997; Walker, 1997, 2001; Brink et al., 1998). The location and "force of impact" can give the bioarchaeologist a great deal of information regarding the intentions of the attacker (Walker, 2001; Fibiger et al. 2013). For example, an attack to the head with enough force to puncture the cranial vault was likely intended to kill the individual. Such a blow will also leave perimortem damage that extends beyond the impact including radiating and concentric fractures that weaken the cranial vault and possibly result in a larger puncture. Healed depressed cranial fractures, on the other hand, signal that the intent may not have been to exterminate the other individual or that there were other behavioral factors, such as dodging the incoming attack, which contributed to the possibility of survival (Worne et al., 2012). Due to healing of such an impact, even if it does puncture the cranial vault, the healing will reduce the apparent size of the injury. In the case of location, Jurmain et al. (2009) and Fibiger et al. (2013) discuss the location of injury and its correlation

with sex and lethality. They both show that females tend to receive more injuries to the posterior aspect of the head due to the societal expectation, for females, of fleeing from a violent conflict. On the other hand, males receive more anterior injuries due to the societal expectation of fighting back, face-to-face, when threatened. It is then expected that all cranial injuries, lethal and non-lethal, will be correlated to location depending on the behavior during the reception of such an injury. While intent is difficult to discern, the effect of the action is what is of interest to the bioarchaeologist.

1.3.4 Bioarchaeological Methods

The current methodology in most bioarchaeological studies generally uses qualitative descriptions of the skeletal modification or lesion to infer whether an injury is interpersonal or accidental trauma (e.g. Berryman and Haun, 1996; Quatrehomme and Isçan, 1999; Judd, 2004; Brickley and Smith, 2006; Murphy and Gaither, 2010). Although effective, this qualitative method lacks a statistical certainty that is recommended in many aspects of understanding violence, and attempts have been made to quantify these patterns (e.g. Novak, 2006; Fibiger et al., 2013).

Since it is difficult to say with certainty that a traumatic injury is a result of interpersonal violence in the archaeological record, due to the postmortem history of the individuals under study, a few useful definitions and methods can be borrowed from forensic anthropology. In forensic contexts there is a difference between manner of death and cause of death, that is to say under what circumstances the person died versus what caused the person's ultimate demise

(Sauer, 1998). It is essential to acknowledge that in the archaeological context we cannot define cause of death, but must instead discuss the manner of death to define behavioral patterns.

Forensic anthropology aids us in acknowledging that many intrinsic variables apply when analyzing trauma, especially on the cranium, such as vault thickness, buttressing, direction of impact, and pathology that may reduce bone resistance, etc. and may lead to complications of interpretation (Gurdjian et al., 1950; Berryman and Haun, 1996; Quatrehomme and Isçan, 1999).

There is currently a lack of consistent quantitative data analysis in the bioarchaeological study of violence. While studied by Tung (2007), Jurmain et al. (2009), and Andrushko and Torres (2011) have used statistical analysis to improve their interpretations, there needs to be a standardization of methodology. Therefore, I propose in this thesis a working model for such investigations. Using a statistical analysis applied to multiple variables in a data set, I will create a set of frequency distributions of cranial trauma comparing antemortem (assumed or modeled as non-lethal) injuries to perimortem (lethal) injuries in order to model patterns of interpersonal violence. This method will then be tested against the current methodology of qualitative description to determine its efficacy. I propose that this quantitative method will add to the prediction and revelation of patterns of weapon-related violence when combined with the current qualitative methodology. It is clear that a more direct approach to total counts of injuries will be more accurate in predicting violence than the current method of presence or absence.

1.3.5 Distinction of the Cranium in Studies of Violence

The head is an excellent location of the body for observations of violent interpersonal trauma. The majority of fractures occurring on the cranium are a result of direct trauma (e.g., a

blow to the head) rather than indirect trauma (e.g., torsion, rotation), and studies have shown that the cranium is the most likely area to be attacked using blunt weapons during individual, face to face conflict, making it the preferred skeletal element for studies relating to interpersonal violence (Lovell, 1997; Brink et al., 1998; Novak, 2006). The propensity for the cranium to maintain a record of traumatic injury is also useful for this study, as it will consistently show evidence of perimortem trauma as well as antemortem trauma even if it is well healed (Walker, 1997). The last factor in studying crania is the propensity for lethal blows to strike the cranial vault. It is not only vulnerable, but there is also a clear psychological propensity for violence to be directed there (Walker, 1997; Brink et al., 1998). Fortunately, there is a large quantity of complete and partial crania available for this study from the Chachapoya site of Kuelap.

1.4 Study Goals, Questions, and Hypotheses

This study aims to create a spatial distribution model that will aid in the bioarchaeological analyses of trauma. By looking at the patterning of weapon-related cranial impacts and testing for statistical significance I aim to demonstrate that such a method can bring add statistical significance to the interpretation of osteological material being analyzed and should therefore be emulated in further studies of violence and trauma. The current literature on the topic of violence and patterning of trauma suggests that certain patterns exist in traumatic injuries to the cranium, thereby creating the following expectations:

1. That there is a significant difference in frequency of perimortem and antemortem trauma between five standard views of the cranial vault.

2. That there is a significant difference in distribution of perimortem and antemortem

trauma within each of the five standard views.

3. Since size of impact (measured by the diameter of the perforation of the vault in perimortem injuries and the area of healed lesion in antemortem injuries) can be a proxy for force of impact (Gurdjian et al., 1950), I expect that there is a significant difference in diameter of impact between perimortem and antemortem trauma.

4. That there is a significant difference in the frequency of perimortem and antemortem trauma between the sexes with males having a higher frequency of antemortem.

5. That there is a significant difference in the location of perimortem and antemortem trauma between the sexes with males receiving more impacts anteriorly and left and females receiving more impacts posteriorly and right.

6. That there is a significant difference in frequency of perimortem and antemortem trauma between adults and subadults (those not skeletally mature, under 19 years of age), with adults exhibiting more antemortem trauma.

These expectations are built on the qualitative analysis of other archaeological, clinical, and forensic samples, and thus with them in mind I plan to answer the following questions:

1. Does the addition of a quantitative approach to osteological analysis give a more complete representation of the sample than a purely qualitative approach?

2. What information can be gathered through the use of a quantitative approach that cannot be gathered through a purely qualitative analysis?

3. Can the use of precise location and approximate size of impact lead to a more accurate

interpretation of lethality and manner of death?

4. Is there variation in location of traumatic injuries that correlates and predicts lethality?

The main purpose of this study is to discover if a statistically intensive quantitative approach can give bioarchaeologists more complete and precise interpretations of patterns of cranial trauma. Within that purpose, this study also hopes to examine if there is a correlation between lethality and location of cranial trauma for the sample population. If there is no correlation between location and perimortem injury then it may be possible to assume that the circumstances surrounding the injury play a stronger role in lethality. The method here proposed will allow me to quantify and test said assumptions and explore with statistical certainty said correlations. I expect that the quantitative approached described in the Materials and Methods chapter of this thesis will not only provide more certain interpretations of patterns but will also lead to discovery of patterns not previously examined.

1.5 Organization of Thesis

I will begin this thesis by looking at the skeletal material available for study and the methods of data collection and analysis in Chapter Two. In Chapter Three I will present the results of my analysis through the six expectations described in the introductory chapter. I will continue my analysis in Chapter Four with a detailed discussion of the findings and implications of the results. Finally, in Chapter Five, I will conclude this thesis with a discussion on the validity or invalidity of my hypothesis and suggestions for further study. I will examine how the use of quantitative models and the results found through this study will add to our understanding of violence and patterning of weapon-related trauma in the ancient world.

Chapter 2: Materials and Methods

2.1 Introduction

This section covers the skeletal material explored in this study as well as the methods of data collection and statistical analysis used in the investigation of patterns of weapon-related cranial trauma. This begins with background information on the Chachapoya culture of the high-altitude rainforests of Peru. It will then go on to explain the skeletal collection available for study including total numbers and demographics. Next, I will describe the methods of data collection, both primary and secondary, and the use of two-dimensional coordinate visual grid systems. Finally, I describe the methods of statistical analysis used to further understand the patterns that occur within the data, and explain why the use of such methodology is important.

2.2 The Chachapoya of Ancient Peru

Although with few historical records and having limited archaeological studies, what is known about the Chachapoya, or "Warriors of the Clouds," makes them the perfect candidate population to study both non-lethal and lethal cranial injuries. The classic Chachapoya culture existed between AD 800 and 1470 in the highland rainforests of northern Peru (Church, 2006). Figure 2.1 shows the strategic location of their territory; nestled in the Andes mountain range with access to both Amazonian and highland resources, it was likely a hotspot of trade in the region even with connections to the Pacific coast (Church and Hagen, 2008). Little is known of their sociopolitical organization before the Inka conquest in AD 1470, but current interpretations place the Chachapoya in various chiefdoms, or *curacazgos*, led by local chiefs and in which power was directly correlated with availability of resources (Church, 2006). They were

renowned as competent warriors and were said to have fended off highland Wari and Inka attempts at conquest and constantly rebelled against later Inka occupation. The weapon of choice for the Chachapoya was a star shaped mace, made of ground stone and hafted on wood (Figure 2.2). With high incidence of trauma for the skeletal remains recovered at fortified sites, the Chachapoya clearly had experience with violence (de Murua, 2008 (1616); Church and Hagen, 2008; Toyne and Narváez, 2013). Their environment on the eastern slopes of the Peruvian Andes, however, also lent itself to accidents of falls and rock slides that may have left evidence as non-violent skeletal injuries (Church and Hagen, 2008). The Chachapoya appear to have been connected by a cultural tradition rather than existing as a centralized political unit leading to instability and continuous hostilities in the region (Church and Hagen, 2008; Nystrom, 2009).

Although scarce information exists on the political structure of the Chachapoya, it is clear that the fortified citadel of Kuelap was an important site for the region and the culture (Narváez, 1988; Church, 2006). Narváez (1988) has argued that Kuelap, being a massive walled platform with over 400 round buildings covering the 20 meter high human-made plateau, including a towering structure known as the *Torreón* in which a virtual arsenal of sling stones was found, and seems to have been intended as an important place of defense in the region.

As was typical in the Chachapoya culture, burial practices in urban centers included interments within walls and beneath floors (Ruiz Estrada, 2008; Toyne and Narváez, 2013). In 2007, a unique archaeological context was discovered at the southern end of the site on an elevated circular platform. The bodies of multiple individuals were discovered on the floors and walkways between 8 buildings that had been toppled on them around the time of death. All exhibited clear evidence of perimortem trauma to the head (Toyne, 2009; Toyne and Narváez,

2013). Since these are distinctly lethal, weapon-related cranial injuries, this sample is consistent with evidence of interpersonal violence, giving us a perfect population for this study. There are two clear mortuary samples at this site: those which exhibit evidence for intentional blunt force trauma in what appears to be a single event (a possible massacre), and those which exhibit evidence of typical death and burial within the Chachapoya culture.

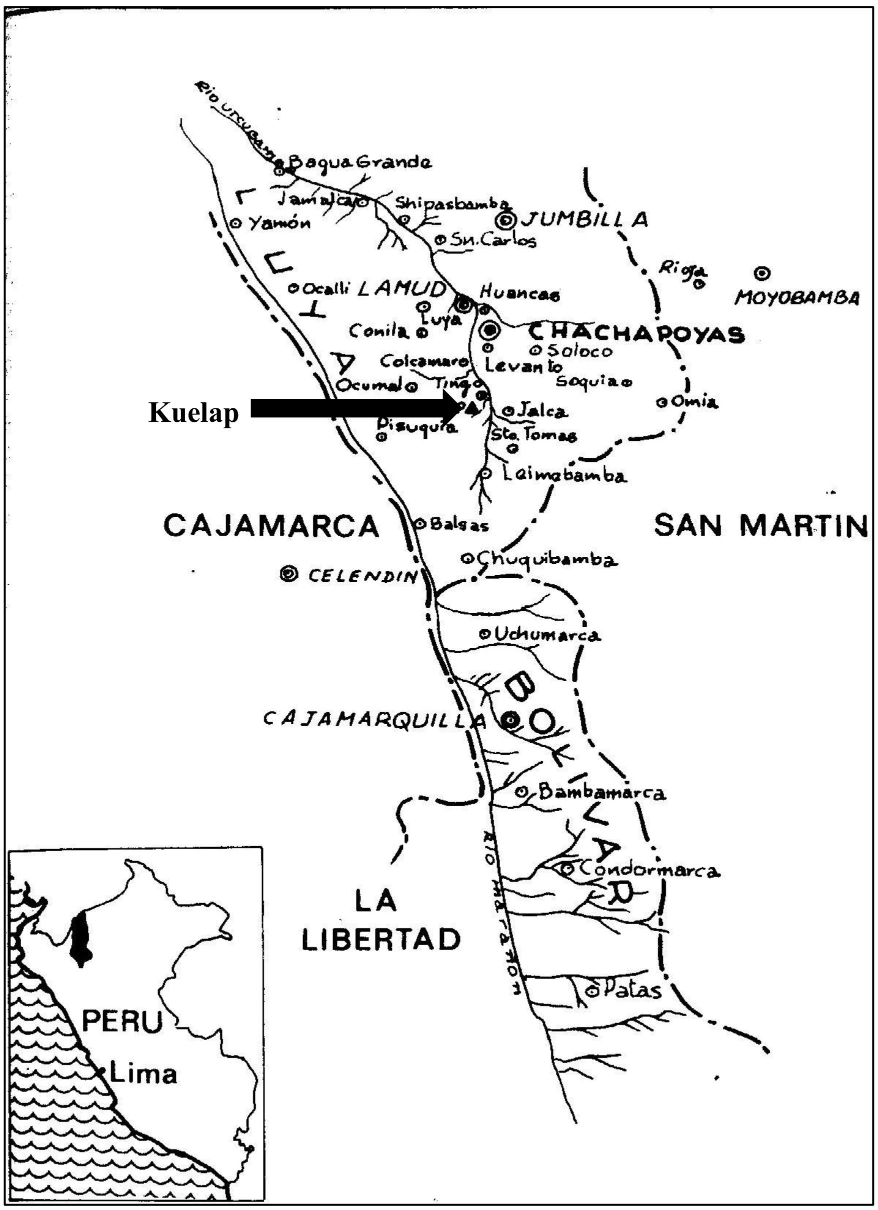


Figure 2.1: Territory of the Chachapoya and known archaeological sites in the area (After Narváez, 1988)

Figure 2.2: Example of Star Shaped Mace

2.3 The Skeletal Collection

The entire skeletal sample at Kuelap encompasses a total of 588 individuals including adult males, females and subadults. The massacre sample includes 106 individuals subdivided into 64 males, 12 females, and 61 subadults. They were found at one end of the Kuelap complex apparently left where they died with the stone walls of the buildings toppled over them, interpreted as likely victims of a massacre (Toyne and Narváez, 2013). The rest of the individuals in this study were found in typical burials under floors and inside walls of various buildings within the site. All individuals are housed in the storage facilities of the Kuelap Archaeological complex and have fair to good preservation. For the purposes of this study, some of the individuals found in typical burials have been analyzed, but only those that exhibited cranial trauma.

2.4 Quantification of Trauma

In order to conduct this study, the first step was to carry out total counts of perimortem and antemortem injuries to the individual crania in the collection. Once the total number of injuries was recorded, they were classified and separated into 1) antemortem fractures with evidence of healing reflecting non-lethal violence, and 2) perimortem fractures, occurring at or around the time of death, consistent with lethal interpersonal violence. Since correlations between sex, age, and injury patterns have been previously encountered (Walker, 1997; Novak, 2006; Fibiger et al., 2013), the data were also separated into antemortem and perimortem injuries sustained by males, females, and subadults, including timing of said injuries. Location and timing of injuries had been previously collected through detailed illustrations including measurements, descriptions, and corresponding images. Dr. J. Marla Toyne, utilizing a standard data collection method (Buikstra and Ubelaker, 1994), and through first hand observations of skeletal material at Kuelap, collected this information in separate field seasons from 2004 to 2011. While direct observation of skeletal material is ideal, the skeletal remains are currently housed in a storage facility at the Kuelap Archaeological complex, near Chachapoyas, Peru, and time and funds did not allow for first hand observations. The illustrations of the individuals included the predicted impact location on each cranial vault bone, fracture patterns (i.e. radiating and concentric fractures), approximate size of impact (in mm), and timing of injuries to the cranial vault each on five separate standard views given by Buikstra and Ubelaker (1994): anterior, superior, posterior, lateral left and lateral right (Appendices A-E). Only falls from a great height will compress the spine and fracture the basilar portion of the cranium (Lovell, 1997) and it is highly unlikely that an attacker will strike the cranium from below, thus the

inferior/basilar view yields no significant data for the purpose presented here. All individuals had associated photographs depicting the cranium in the standard views and the lesion from both the inner and outer tables. These images were used in conjunction with the illustrations in order to assess the extent of the damage for both perimortem and antemortem lesions. Due to the availability of images I was able to include individuals that had not been illustrated.

I began by exploring the broad location of injuries by dividing the standard skull into anterior and posterior aspects using anatomical landmarks. Then, in order to ascertain precise location in millimeters per each standard view, a two-dimensional coordinate grid system was created, aligned to anatomical landmarks, and printed on transparency sheets to later superimpose this grid system onto the original illustrations. The anatomical landmarks used for these measurements were as follows: for the anterior view, the nasion (point where nasal bones and frontal bone unite); for the superior view, the bregma (point where the sagittal and coronal sutures meet); for the posterior view, the lambda (point where the lambdoidal and sagittal sutures meet); and for both lateral views, the pterion was used (the point where the coronal suture meets with the parietal bone at the sphenoidal angle) (Appendix A-E). The estimated center of impact was measured in millimeters, with respect to the anatomical landmarks previously mentioned, in x and y coordinates followed by the measurement of the diameter (Figure 2.3). In order to estimate the diameter of oblong and oddly shaped impacts, the longer axis was measured allowing for a standard measurement of diameter for both perimortem and antemortem. Once the data was collected as metric points, it was plotted to include the area of impact per injury (defined from the diameter given for ease of visualization) as well as accurately scaled distance from the anatomical landmarks.

Each standard view has two separate plots, one for perimortem and one for antemortem. Timing of the injuries is differentiated by coloring with perimortem as black and antemortem as light gray, with each having some transparency in order to avoid obscuring impacts.

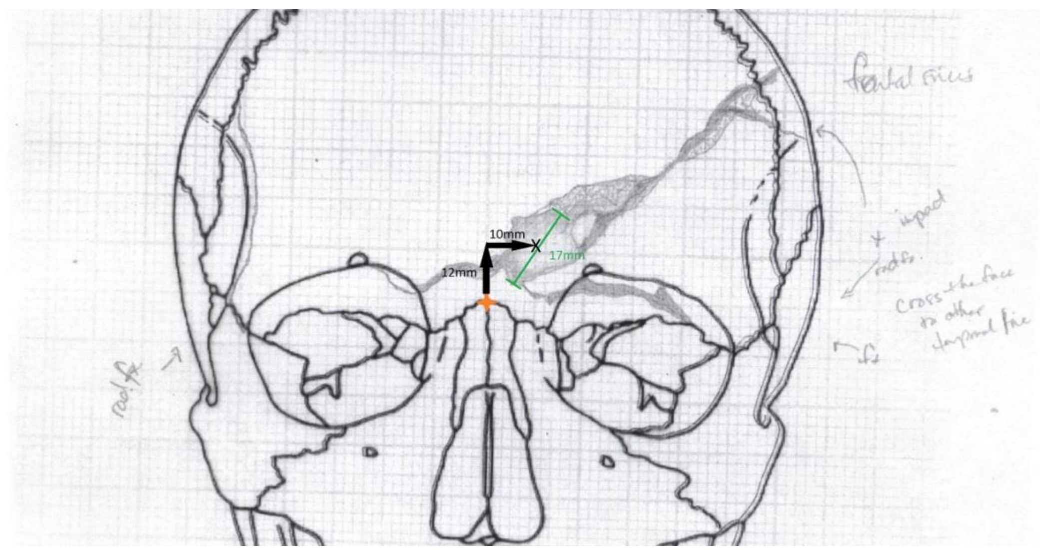


Figure 2.3: Example of method for measurement of location and estimated diameter

Visual systems like this have been used by other researchers to visualize/identify location of injuries per individual, but by then overlapping individual points of data, this creates collective patterns of the sample based on 2-D standardized views (e.g. Walker, 2001; Tung, 2007). This method has also been used to understand patterns with respect to location in the field of biology by also including heatmaps/density plots with contour lines leading to precise data analysis of frequencies and population densities in three dimensions from which inferences about distribution of species and patterns of landscape have been successfully supported (Chandler and

Royle, 2011; Gu et al., 2012; Eberhardt et al., 2013; Zarco-Gonzales et al., 2013). While there are problems with heatmaps and density plots brought up by Bojko (2009), there are precautions that can be taken to improve the efficacy of such models. While Bojko (2009) focuses on eye-tracking heatmaps, some of the same suggestions can be applied in this context. One of the main criticisms is the possible lack of focus, an idea of plotting just to see what happens. This is why a question must always be proposed and the heatmap/density plot only used as a tool in answering said question. The rest of the suggestions given by Bojko (2009) can be condensed for topics outside of eye-tracking into two simple suggestions: 1) using density plots/heatmaps as tools and visualization aids rather than making them the main machinery for data analysis, and 2) be clear to the audience when explaining both the data shown and its significance since the simplicity of a heatmap/density plot can lead to speculation and misunderstanding of the data. To fulfill these purposes, the data has been visualized as contour plots rather than density maps, and statistically sound analytical methods create the bulk of the results.

2.5 Statistical Analysis of Location of Traumatic Injuries

After observations were collected in a spreadsheet, several frequency distributions of injury were created in order to explore if a correlation exists between the locations of perimortem (lethal) trauma and antemortem (non-lethal) trauma. The frequency distributions include: 1) distributions per view, 2) distributions for posterior and anterior, 3) distributions for males versus females, and 4) distributions for adults versus subadults. Due to the lack of precedent for this method, once the measurements had been properly recorded, I created a program using the Enthought Programming package (see www.enthought.com) for the Python language in order to

analyze and plot a three-dimensional array of the data including location on an x-axis and a y-axis as well as estimated diameter of impact. While correlation analysis is possible without creating a brand new program, its use allows me to explore the spatial relationships created in the three-dimensional plots of the data including precise (in millimeters) location and diameter of impact. Using this custom software, it is possible to analyze and plot a three-dimensional scatter of the data and, in much simpler fashion than conventional analysis, use standard tests of correlation, such as the Student's t-test or Fisher's Exact test, to understand the data at a statistically significant level. After the raw data was plotted, the mean, standard deviation, and the Pearson product-moment correlation coefficient (ρ) were calculated for each plot. Using this information the data were normalized by creating a random Gaussian distribution from the previously calculated information and then plotted to visualize clustering and patterning. One limitation with normalizing the data in this way is that there is an inherent assumption of the data fitting a normal distribution, but this assumption is supported by the Central Limit theorem (Rice, 1995). Using the raw metric data for the statistical tests and only using the normalized data for simplified visualization is a simple way to mitigate the possible errors in such an assumption. In order to discover if there is a statistically significant difference between the location of perimortem injuries and the location of antemortem injuries, a Student's t-test for independent variables was used on continuous data (e.g. location, diameter) and a Fisher's Exact test was used on categorical data (e.g. counts per sex, counts per age), expecting that a $p < 0.05$ (as is convention) would dictate a significant difference.

2.6 Summary

The skeletal collection of the Chachapoya at Kuelap is excellent material for this statistically based study of violence. They not only exhibit notable quantities of violent cranial trauma but are also a large enough sample of individuals to give statistically significant results. The method of recording metric data for location of injury to the cranium presented here allows for a more precise collection and a more direct transformation of said data into statistical analysis. Using visualization of both the raw data and the normalized contour plots allows for better presentation of the results while direct statistical analysis can give us true significance in comparisons between the different distributions here presented. The Student's t-test will be used when the data being analyzed is metric and continuous (e.g. precise location of injury) while a Fisher's Exact test will be used when the data set is categorical (e.g. perimortem versus antemortem in males and females). This combination of both numerical and observational analysis is expected to be certain and efficient when encountering patterns in cranial trauma.

Chapter 3: Results

3.1 Introduction

In this chapter I will present the results of the statistical analysis of each of the frequency distributions. First I will describe the results given by the separation into five standard views. This analysis led to a surprising revelation about differences between injuries to the posterior aspect of the skull and those to the anterior aspect, and those results will be discussed. I will explain the results of studying the diameter of impacts. Finally, I will state the results of sex differentiation and age differentiation in the current skeletal collection.

3.2 Crania Used for Study

Although the collection at Kuelap includes many skeletons, several could not be used in this study. Of the total individuals with crania available only 81 were suitable for this study due to many reasons including lacking clear traumatic injuries and more importantly lacking cranial remains (Appendix F inventories the individuals used in the analysis and rough location of trauma). The total number associated with the massacre reaches 106 individuals, but unfortunately the amount of postmortem damage to the crania does not allow for precise measurement of trauma on 76 of the individuals and therefore those individuals could not be included in this analysis. 61 of the individuals in that sample were used in this study while the remaining 20 individuals came from typical burials excavated throughout the site. Of the 81 sampled there were 42 males (M), 8 females (F), one indeterminate adult, and 30 subadults (SA). There were 51 adults (A) subdivided into 3 age ranges with 30 young adults (20-35 years old) (YA), 18 middle adults (35-50 years old) (MA), and 2 older adults (50 +) (OA), while one adult

was of undetermined age. All ages and sexes were determined using standards given by Buikstra and Ubelaker (1994). Table 3.1 shows the number of individuals with perimortem (PM) and the number with antemortem (AM) separated by sex and age.

Table 3.1: Number of individuals with trauma divided by age and sex (some had both PM and AM)

Demographic	# with PM	# with AM	% PM	% AM
M:	31	21	59.62%	40.38%
F:	5	3	62.50%	37.50%
SA:	30	0	100.00%	0.00%
A:	44	24	64.71%	35.29%
YA:	27	11	71.05%	28.95%
MA:	16	11	59.26%	40.74%
OA:	1	1	50.00%	50.00%

3.3 Qualitative Assessment

A large portion of the skeletal sample had extensive postmortem damage and fragmentation. While some individuals had evidence of perimortem injuries, from the toppled buildings, it was best to be cautious when describing injuries and those lesions that could not be observed or measured precisely were not used for the study. All perimortem injuries used in this study were clear impacts from star shaped maces in order to avoid confusion. The extent of postmortem damage may have been due to the fact that the perimortem injuries encountered included extensive radiating and concentric fractures indicating a high amount of force and also possibly weakening the structural integrity of the cranial vault after burial (Gurdjian et al., 1950; Berryman and Haun, 1996). The perimortem injuries were often complete circular punctures of the cranial vault (perforating both outer and inner tables, Figure 3.1) usually associated with a

neighboring puncture (creating a side by side double circles) as would be expected from a star shaped mace (the most common weapon in the ancient Chachapoya region) (Toyne, 2009). On the other hand, the antemortem lesions found on the sample from Kuelap generally include only depressed cranial fractures with little signs of associated radiating or concentric fracturing and only some showing a minor degree of damage to the inner table of the cranial vault (Figure 3.2).

Figure 3.1: Typical perimortem injuries encountered (photograph by Dr. Marla Toyne)

Figure 3.2: Typical antemortem injuries encountered (photograph by Dr. Marla Toyne)

3.4 Perimortem versus Antemortem in the Five Standard Views

In order to get a better picture of differences in location between perimortem and antemortem trauma it is important that the sample remain together regardless of sex and age differences. Combining the different distributions when simply comparing location of perimortem and antemortem mitigates variables that might otherwise skew the results of comparison. The total counts of traumatic impacts show a greater number of perimortem trauma versus antemortem trauma overall in this skeletal sample with 263 total perimortem injuries and 28 total antemortem injuries. The total values are shown in Table 3.2, where they have also been subdivided into their respective five standard views. Fisher's Exact testing was used to compare each sample per view to the total ratio of perimortem to antemortem injuries and found no statistically significant difference between the five different views ($p > 0.05$) (Table 3.2). Anterior and posterior views had the closest values to statistically significant with the anterior p-value = 0.08 and the posterior p-value = 0.11, two views which also had the highest number of perimortem injuries. The anterior view also had the largest number of antemortem injuries. It is also interesting to note that the p-value for lateral left is 1, meaning it is the same distribution as the total counts.

Table 3.2: Total counts divided by location and Fisher's Exact test results

Location	PM	% PM	AM	% AM	P-values
Anterior:	56	82.35%	12	17.65%	***0.08***
Superior:	39	82.98%	8	17.02%	0.13
Posterior:	80	96.39%	3	3.61%	0.11
Lateral Left:	45	91.84%	4	8.16%	***1.00***
Lateral Right:	43	97.73%	1	2.27%	0.14
Total:	263	90.38%	28	9.62%	-

When it comes to precise location of the injuries, a Student's t-test was performed to examine if the means of the two samples (perimortem and antemortem locations) per view were significantly different from each other using the sample standard deviation for each distribution. The testing was performed separately in the x and y axes in order to get more refined significance testing and avoid clouding values that could possibly be significant. Table 3.3 shows the mean and standard deviation of each view as well as the correlation coefficient (ρ). The abbreviation system used in this table corresponds to PM as perimortem and AM as antemortem with the third letter indicative of one of the five standard views: A for anterior, S for superior, P for posterior, L for lateral left, and R for lateral right. As can be seen by the 0 value for every ρ, the x and y values are not correlated, supporting the separation of the axes in further tests. The raw metric data are shown in Figures 3.3 – 3.13 separated by views and timing (perimortem and antemortem). For ease of visualization and comparison, the data on perimortem and antemortem location have been normalized and binned to create contour plots showing areas of high frequency per each view (Figures 3.14-3.20). These contour plots were made by taking the mean and standard deviation of each distribution and creating a two-dimensional Gaussian distribution with the same values to show areas of high concentration and how frequencies diminish over distances from the mean. Three of the five views for antemortem data (Posterior, Lateral Left, and Lateral Right) have been omitted due to low total counts leading to uncertain normalized plots. The results for the Student's t-test are given in Table 3.4 including the calculated t-statistic and the corresponding p-value. The lateral right view only had 1 impact for the antemortem data, and therefore a comparison using a Student's t-test resulted in unreal values (shown as "-" in the table). None of the p-values are significant ($p > 0.05$), but both the x-value in the lateral left view

and the y-value in the superior portion are close enough to significance to merit further inquiry. By looking at the means in the lateral left and superior views in Table 3.3 we can discern a pattern in which perimortem trauma tend posteriorly and antemortem trauma tends anteriorly.

Table 3.3: Mean and standard deviations of metric data separated by view

View and Timing	Mean (x)	Std Dev (x)	Mean (y)	Std Dev (y)	ρ (cov)
PMA	1.68	24.63	30.36	19.23	0
AMA	14.67	25.18	30.33	17.44	0
PMS	3.90	26.09	13.13	40.31	0
AMS	3.25	24.40	-13.38	26.79	0
PMP	-0.09	26.42	-23.95	25.70	0
AMP	9.67	31.33	-2.00	2.16	0
PML	45.50	31.10	14.85	17.35	0
AML	17.50	47.63	18.75	21.32	0
PMR	-46.65	36.58	5.60	24.77	0
AMR	26	0	5	0	0

Table 3.4: Results from Student's t-test on metric data

View	t-statistic (x)	p-value (x)	t-statistic (y)	p-value (y)
Anterior	-1.63	0.11	0.00	1.00
Superior	0.06	0.95	1.74	***0.09***
Posterior	-0.62	0.54	-1.46	0.15
Lateral Left	3.62	0.11	-0.41	0.68
Lateral Right	-	-	-	-

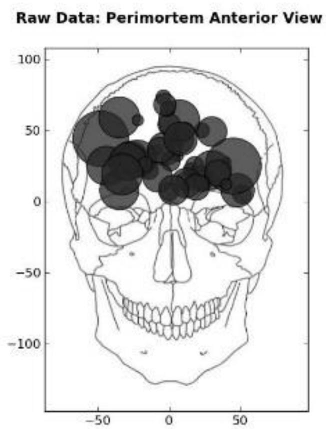


Figure 3.3: Raw data Perimortem Anterior

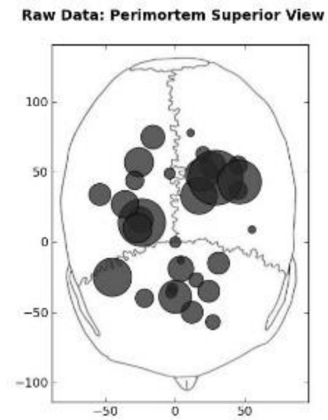


Figure 3.4: Raw data Perimortem Superior

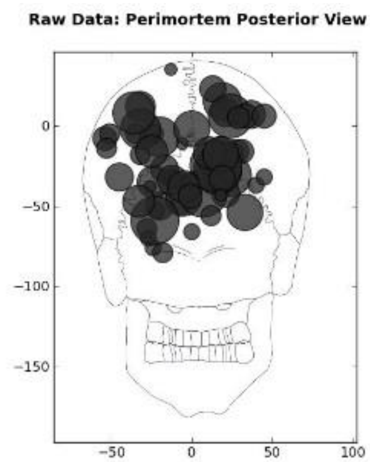


Figure 3.5: Raw data Perimortem Posterior

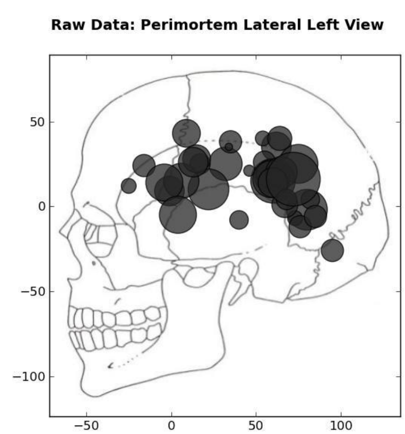


Figure 3.6: Raw data Perimortem Lateral Left

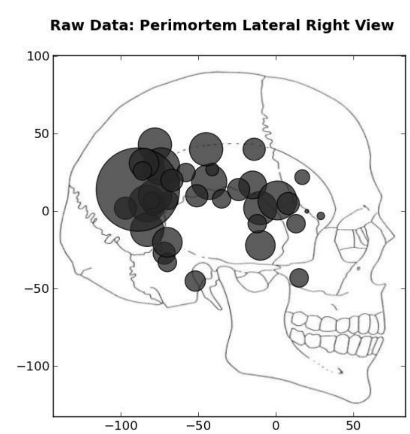


Figure 3.7: Raw data Perimortem Lateral Right

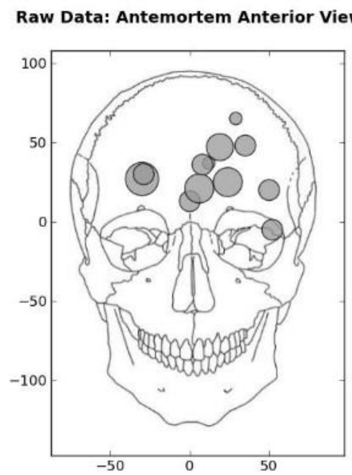


Figure 3.8: Raw data Antemortem Anterior

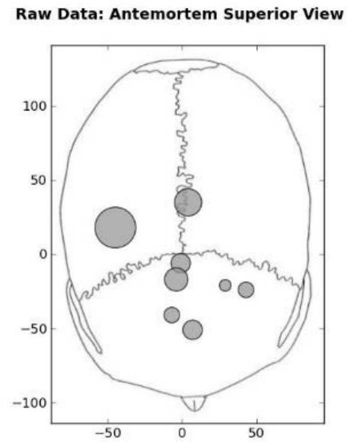


Figure 3.9: Raw data Antemortem Superior

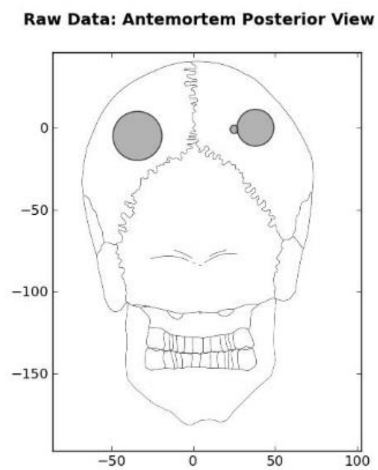


Figure 3.10: Raw data Antemortem Posterior

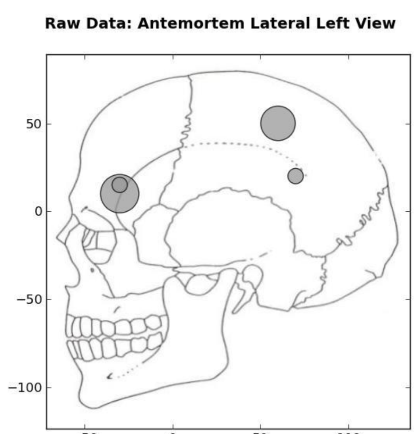


Figure 3.11: Raw data Antemortem Lateral Left

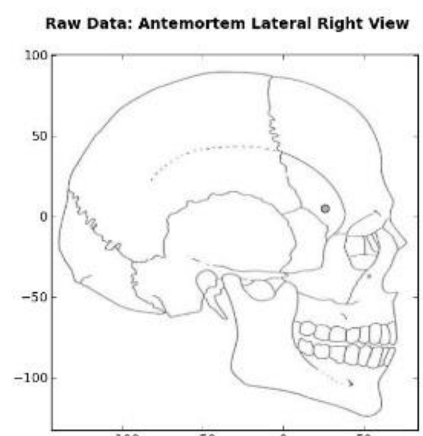


Figure 3.12: Raw data Antemortem Lateral Right

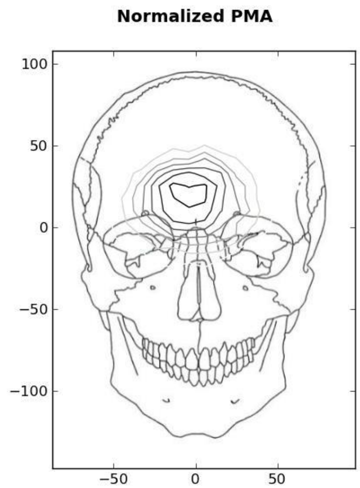


Figure 3.43: Contour Perimortem Anterior

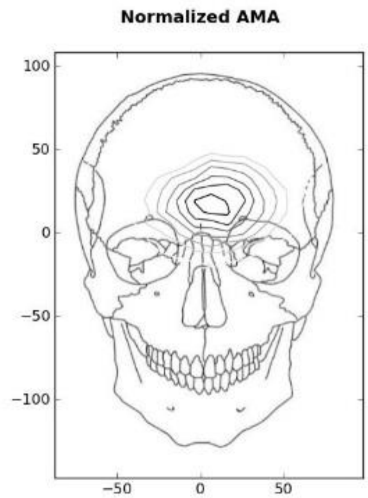


Figure 3.14: Contour Antemortem Anterior

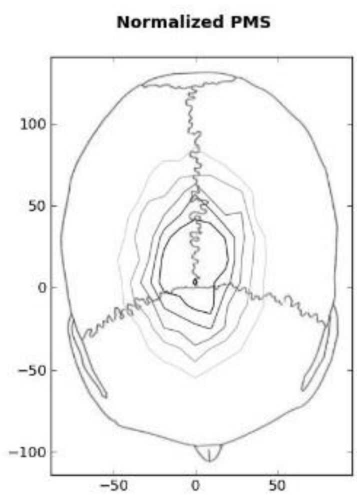


Figure 3.15: Contour Perimortem Superior

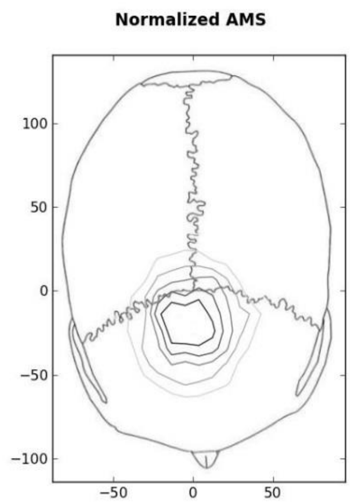


Figure 3.56: Contour Antemortem Superior

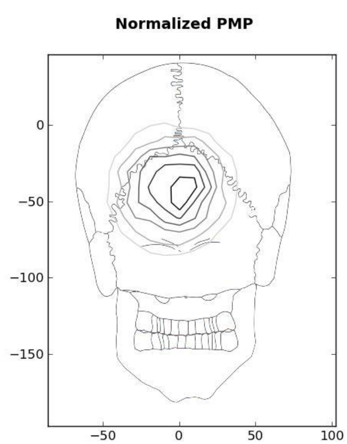


Figure 3.17: Contour

Perimortem Posterior

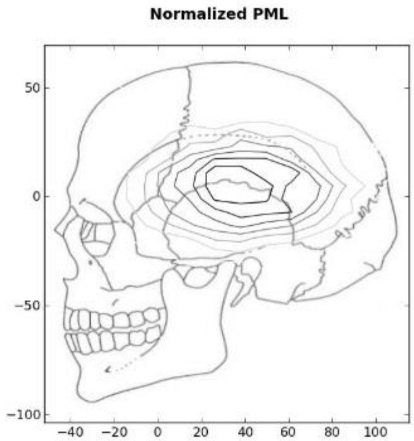


Figure 3.18: Contour Perimortem Lateral Left

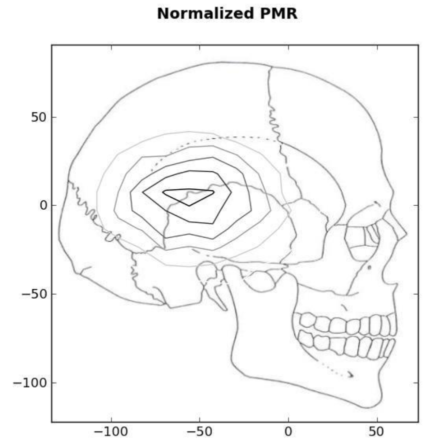


Figure 3.19: Contour Perimortem Lateral Right

3.5 Posterior versus Anterior

As suggested from the location analysis, it was necessary to investigate the difference between injuries recorded anteriorly and those recorded posteriorly across the entire cranium. The same anatomical landmarks used for the precise location analysis of the superior and lateral views were used to divide the cranium into anterior and posterior portions (bregma and pterion) (Figures 3.20 and 3.21). A Fisher's Exact test was conducted on the raw count values to investigate if there was a significant difference in frequency of antemortem and perimortem injuries between the anterior and posterior portions of the cranial vault (see Table 3.5 for total counts). The testing showed that overall there was a significant difference in frequencies ($p = 0.01$) with antemortem occurring more frequently on the anterior aspect and perimortem occurring more frequently on the posterior aspect across the entire cranium.

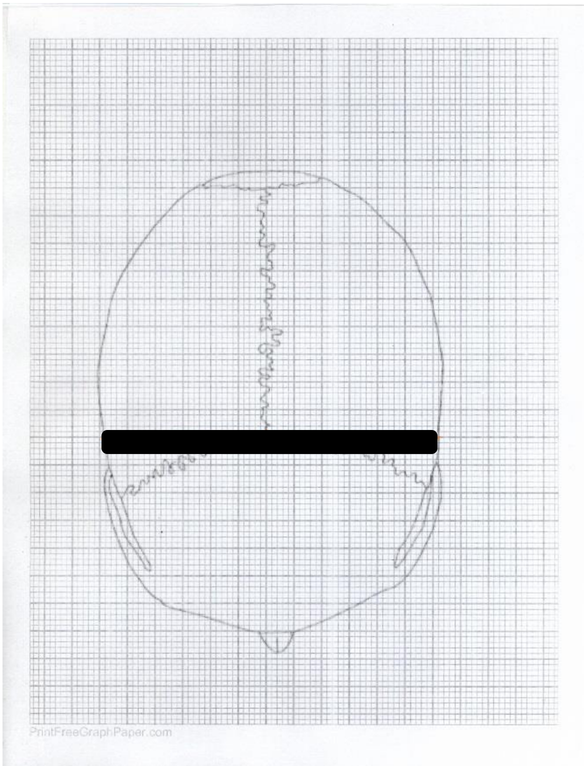


Figure 3.20: Posterior/Anterior division on Superior view

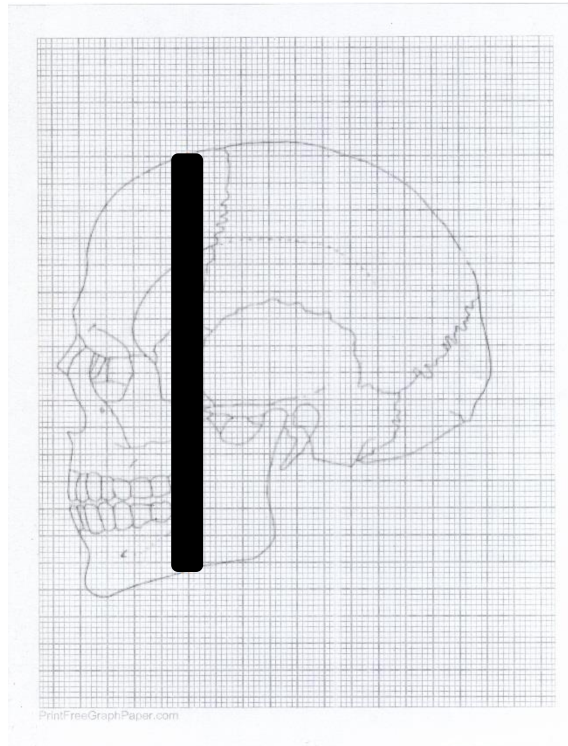


Figure 3.21: Posterior/Anterior division on Lateral Left view (same for Lateral Right)

Table 3.5: Total counts of injuries encountered on the posterior and anterior aspects of the cranium

Location	PM	% PM	AM	% AM	Total
Anterior:	93	84.55%	17	15.45%	110
Posterior:	170	93.92%	11	6.08%	181
Total:	263	90.38%	28	9.62%	582

3.6 Diameter of Impact

In Appendices G and H a zero in the "size column" indicates either a linear fracture pattern (there was no size to measure or specific impact point), the impact has been obscured by missing fragments due to postmortem damage, or indeterminate size due to the impact location being approximated through the associated radiating and concentric fractures. Since I am predicting that the diameter of impact could be a proxy for the force applied, it was important to investigate if there were significant differences between perimortem injuries (lethal) and antemortem injuries (non-lethal). Average size of impact across the entire cranium was 11.31 mm with a standard deviation of 7.18 mm. Table 3.6 gives the mean and standard deviation values for diameter of both perimortem and antemortem injuries in each of the five views. Notably, the means and standard deviations for perimortem are more consistent due to the larger sample size when compared to antemortem. A Student's t-test was performed in six separate comparisons in order to discover if there was a significant difference in diameters as follows: 1) a difference between perimortem and antemortem injuries per each of the five views (Table 3.6), 2) a difference between perimortem and antemortem in the anterior portion ($p = 0.83$), 3) a difference between perimortem and antemortem in the posterior portion ($p = 0.21$), 4) a difference in perimortem injuries between the anterior and posterior portions ($p = 0.75$), 5) a difference in antemortem injuries between the anterior and posterior portions ($p = 0.42$), and 6) an overall difference between perimortem and antemortem injuries across the entire cranium ($p = 0.37$). No significant difference was found in any of the cases described ($p > 0.05$).

Table 3.6: Means, standard deviations, and results from Fisher's Exact test for estimated diameter of impact

View	Mean (PM)	Std Dev (PM)	Mean (AM)	Std Dev (AM)	P-value
Anterior	11.41	7.73	10.75	2.92	0.77
Superior	10.44	7.59	11.13	4.40	0.81
Posterior	10.81	6.71	15.33	8.38	0.27
Lateral Left	11.76	7.52	13.50	5.55	0.66
Lateral Right	12.18	7.51	4.00	0	-

3.7 Sex Difference in Location and Timing

In order to test the hypothesis of sex differentiation of injuries a Fisher's Exact test was conducted on the total count of perimortem and antemortem injuries separated by sex. While total counts in Table 3.4 clearly show that overall males have a higher incidence of injuries since they are more represented in this sample with 42 males versus 8 females, it is also important to note that the percentages of timing of injuries versus total injuries suffered are very similar. The results of the Fisher's Exact test gave a p-value of 1, meaning there is no difference between males and females in the number or timing of injuries received in this sample.

In testing a difference in location of injuries for males and females, the number of injuries received by females was too small to further separate into five views and remain significant, therefore the comparisons were done on with a broader distribution (anterior versus posterior). In this sample included 30 males with anterior injuries and 22 with posterior injuries, while in females 6 had anterior injuries and 3 had posterior injuries. Injuries to the posterior and anterior aspects are not mutually exclusive, meaning a single individual may have injuries to both the anterior portion and the posterior portion of their cranium; therefore, those individuals have been

counted twice for the purpose of this analysis. Fisher's Exact testing for this sample yielded no significant difference in location of injury (anterior versus posterior) between the sexes with a p-value of 0.45. In this sample there is no clear statistical difference between males and females in either timing or location of injuries.

3.8 Age Difference

With the total counts given by Table 3.1 it is clear that statistical testing for age differentiation of injuries is not only unnecessary but inefficient since values would not be valid. 100% of subadults exhibit perimortem injury (0% antemortem injury) while in adults 67% exhibit perimortem and 33% adult exhibit antemortem.

3.9 Summary

Using statistical analysis, the results were as follows:

1. There is no significant difference in frequency of perimortem and antemortem trauma between the five views.
2. There is no significant difference in precise location of perimortem and antemortem trauma within each of the five views.
3. There is a statistically significant difference between the frequency of perimortem and antemortem injuries when the cranium is divided into anterior and posterior aspects with antemortem occurring more frequently anteriorly and perimortem posteriorly.
4. There is no statistically significant difference in approximate (estimated) diameter of antemortem and perimortem injuries.

5. There is no statistically significant difference in timing of injuries between males and females.
6. There is no statistically significant difference in location of injuries between males and females when the cranium is divided into anterior and posterior aspects.
7. There is a statistically significant difference between adults and subadults in the timing of injuries received.

Chapter 4: Discussion

4.1 Introduction

In this chapter I will explore the significance of the results in each of the distributions presented with regard to the use of a quantitative method rather than a purely qualitative approach. I begin with a discussion on the distribution of the five standard views comparing the precise quantitative approach to previous qualitative methods, I continue on to examine the results of the broad testing of posterior versus anterior and the significance of flexibility in the method used, then investigate the results of diameter of impact, followed by an exploration of sex and age differentiation.

4.2 Perimortem versus Antemortem in the Five Standard Views

Without enough antemortem traumatic injuries to study precisely, neither the total counts nor the more precise metric location data show any significant difference between the five views in the frequency of perimortem versus antemortem trauma. This may be due to the fact that the total counts for antemortem trauma are about one-tenth of those for perimortem. Although this may seem a barrier for the quantified method, the utility and certainty of such a method is only diminished slightly by such counts. Observational methods utilizing higher percentages of non-lethal trauma have found certain patterns that are not supported by this study. Brink et al. (1998) found that significantly more injuries seen in a modern emergency room (mostly non-lethal) are found on the anterior portion of the cranium. While in this study I found that this pattern holds true for antemortem injuries, perimortem injuries seem to be found significantly more often on the posterior aspect. Studies by both Tung (2007) and Andrushko and Torres (2011) suggest that

interpersonal violence can be determined by location of injuries on the cranium. They, as well as others, propose that injuries due to interpersonal violence occur more frequently on the anterior and lateral left aspects of the cranium due to most attackers being right handed. This study found no such correlation since antemortem and perimortem injuries were both clearly results of interpersonal violence and the injuries seem to cluster by timing anteriorly and posteriorly with no significant difference in frequency between the lateral right and lateral left aspects of the cranium. Studies using a qualitative approach may also find a distinction between the perimortem and antemortem location of injuries when there really might be none. This is demonstrated by the use of the contour plots displayed in the Results chapter. When the mean location of injuries separated by timing is examined visually using the contour plots, a difference seems to appear in both the anterior and superior aspects of the cranium. Human bias towards patterns might recognize such a small difference and make inferences. Unfortunately, when such a pattern is tested, that difference is found to be statistically insignificant and therefore no certain inference can be made from such data. It might be that this method of taking precise measurements in five standard views, when employed with few points of data, may be too narrow of a perspective to gather useful information, but the flexibility of the qualitative method proposed in this study allows a simple change in the parameters that can lead to more conclusive patterns.

4.3 Posterior versus Anterior

When using the quantification method with more broadly defined regions, a significant result was found. There is a statistically significant difference between the frequency of

perimortem and antemortem injuries when the cranium is divided into anterior and posterior aspects with antemortem occurring anteriorly and perimortem posteriorly. Another important result in this sample is the lack of antemortem injuries to the lateral right portion of the head (only 1) and the comparatively low numbers of antemortem injuries to the posterior and lateral left portions (3 and 4 respectively) whereas superior and anterior antemortem injuries happened much more frequently (8 and 12 respectively). When looking at perimortem, however, this trend is reversed, with 80 perimortem injuries occurring on the posterior portion and 56 occurring on the anterior portion. This suggests that lethality in this sample is correlated with posterior attacks. Such attacks are emblematic of raids and attacks that were unexpected to the victims (Ember and Ember, 1994). It also suggests that non-lethal attacks occur more often anteriorly, which is more typical of reciprocal violence, between face-to-face opponents. Brink et al. (1998) studied contemporary violent trauma and discovered that most injuries occurred anteriorly, but most were also non-lethal (1 death of 63 individuals with cranial trauma). It may be, as Walker (2001) and Tung (2007) suggest, that attacks to the anterior portion of the cranium may be due to more ritualized forms of violence and therefore there are societal and cultural limitations to the lethality of such an act. Another possibility, however, is that a face-to-face attack allows the victim to dodge the perpetrator in order to prevent injury. Even if unsuccessful at avoiding the strike, any movement might not allow the attacker to use full force when striking the cranium therefore resulting in less damaging impacts. On the other hand, when an attacker is behind their victim, the victim might not have the chance to move, they might not even see their attacker, and therefore, while the victim is unaware of their attacker, the full force behind the blow might strike the cranium and cause the extensive damage that leads to death. This result seems to

suggest predictability in the behavior of both the attacker and the victim surrounding an event. Ember and Ember (1994) examines behavior of raiding versus traditional warfare explaining that during a raid all possible victims flee, leaving the posterior aspect of the cranium open for attack. It is possible that other contexts exhibiting perimortem trauma could be examined using this method and predict whether the trauma is a result of raiding or traditional warfare.

4.4 Diameter of Impact

While a difference in diameter between perimortem and antemortem injuries was expected, there was no statistically significant difference found. The assumption was that a lethal blow must have been made with more force relative to a non-lethal blow, but it is possible that the lethality of the injuries is correlated with damage to the inner table due to a difference in human behavior during impact or even bone response at the site of injury. Most of the antemortem injuries found were depressed cranial fractures, with little damage to the inner table, whereas the blunt force perimortem injuries were more extensive crushing not only the outer table but a shattering of the inner table and subsequent radiating and concentric fractures. In some cases the weapon used actually created a circular puncture in the vault (Toyne, 2009; Toyne and Narváez 2013). The lack of a size difference in the impacts (puncture versus circular depressed fracture) could be explained by the use of a similar blunt instrument in creating both the vault puncture wounds and the circular compression fractures. The difference could then lie in the behavior surrounding the attack or the force behind the attack. Greater force during a deadly attack and lesser force during a survivable attack could, once again, suggest a raid or unexpected attack for the former and expected or anticipated attack for the latter.

4.5 Sex Difference

Studies conducted by Fibiger et al. (2013) and Brink et al. (1998) as well as the review by Walker (2001) had encountered a significant difference between males and females in both location and frequency of cranial trauma. Fibiger et al. (2013) encountered a higher presence of antemortem trauma on males but equal frequencies of perimortem trauma on both sexes for a pair of Neolithic Scandinavian settlements. Brink et al. (1998) studied contemporary trauma in a modern emergency room and found the same pattern of females being struck posteriorly significantly more often than men. While my study has concurred with the findings of perimortem trauma, the results have also indicated no difference between the sexes when it comes to incidence of antemortem trauma. Walker (1997), Brink et al. (1998), and Fibiger et al. (2013) also encountered a difference in location of injuries between the sexes with females receiving more impacts to the posterior aspect of the cranial vault and males receiving more craniofacial injuries. Two expectations came about from this literature: 1) that there is an expected difference in the frequency of perimortem and antemortem trauma between the sexes with males having a higher frequency of antemortem, and 2) that there is an expected difference in the location of perimortem and antemortem trauma between the sexes with males receiving more impacts anteriorly and females receiving more impacts posteriorly. However, in the current study neither expectation was met. There was no statistically significant difference in timing of injuries between males and females nor in location of injuries between males and females when the cranium was divided into anterior and posterior aspects. For this sample at Kuelap, males and females showed no difference in the ration of antemortem to perimortem injuries, but with fewer females in the study it is difficult to make inferences. However, there is also no difference in

location of traumatic injury between the sexes. This finding not only contradicts the studies previously mentioned, but it also goes against the assumption that females are more likely to be fleeing from their attacker and males are more likely to face their attacker. This could suggest that differences in the patterns of cranial trauma between the sexes are culturally dependent, that there were too few females in the sample, or it might be an indication of the manner of death (an inferred massacre) of a large number of these studied individuals.

For Andean populations, Andrushko and Torres (2011) also had very few females in their sample and those females also exhibited trauma across the cranium with no tendency posteriorly. Tung (2007) on the other hand clearly encountered a pattern of females being struck posteriorly while males were more often struck anteriorly. This difference once again points to a cultural factor. Where Andrusko and Torres (2011) examined Inca remains, Tung (2007) examined Wari remains. Tung (2007) even found a distinction within the culture itself, with females of higher status being more protected from injury than those of lower status. A stratified society will encounter such differences, but a lack of information on the Chachapoya prevents such inferences on stratification of society and protection of the elite.

4.6 Age Difference

The expectations for the difference in patterns of trauma between adults and subadults were clearly met; there is a statistically significant difference between adults and subadults in the timing of injuries received. Subdaults encountered only perimortem trauma while adults had a ratio of about three-to-two perimortem versus antemortem injuries. The more refined age categories were not tested since there was a lack of older adults in this context. Many variables

contribute to lower counts of older adults, and inferences on such data require greater certainty on life expectancy for that population. When it comes to adults versus subadults, Glencross (2011) describes the notion that an older individual has had more years to accumulate non-lethal trauma than a younger individual, they also have a higher possibility of injury recidivism due to more time spent in situations that could lead to trauma. Judd (2004) gives a contemporary example of this in a study on traumatic injury in the ancient Egyptian city of Kerma. Another important factor is that the force of an impact causing antemortem damage to an adult might be enough to cause death to a child. Osifo et al. (2012) showed that in a modern population of children, the majority (56%) died due to cranial trauma.

4.7 Method Review

The variation in location of traumatic injuries does correlate and predict lethality but not exactly as originally expected. I expected the differences to appear in the narrow, two-dimensional standard views, and that was not the case. But the correlations between anterior and antemortem injuries and posterior and perimortem injuries do, in fact, allow for a prediction of lethality. That prediction is that lethal attacks are significantly more likely to occur on the posterior aspect of the cranium while non-lethal attacks are more likely to occur on the anterior portion. While the original scope of the quantitative methodology might have proved too narrow for significant results, there is flexibility and certainty in using this method. The flexibility comes in the ability to change test parameters with simple changes to the program. The certainty comes in the use of statistical analysis to test the significance of possible patterns encountered.

By combining the visual approach with the quantitative methods patterns can be perceived and tested for significance with very little difficulty and inferences can have greater certainty. The program I have created can easily be adjusted for sets of data and a grid pattern could be included in the original illustration of the injury in order to simplify and standardize the collection of data.

4.8 Summary

When using the precise metric method on the five standard views, there are no significant results. However, when such a method is applied more broadly (posterior versus anterior) there is a clear significance in the results, which allows for more certainty in the analysis of patterns across the cranium. In this sample there appeared to be no difference in estimated diameter of injuries between the perimortem and the antemortem lesions. There was also no statistically significant difference between males and females, which, when compared to studies by other bioarchaeologists, can be inferred as cultural differences. The differences in patterns of injury between the adults and subadults can be explained by the idea of injury recidivism and the higher probability of having been struck as you become older just by having lived more years. Overall the visual quantitative method proposed for this study has yielded significant results with great flexibility and simplicity. It has been shown to avoid observational bias by using statistical certainty but also allows for observer input when patterns are examined more closely by the researcher. The method here proposed seems effective, simple, and repeatable.

Chapter 5: Conclusions

5.1 Research and Limitations

The study violence in bioarchaeology is an important aspect of understanding past cultures and their behavior. Violence is ubiquitous in human societies and further research into patterns in traumatic injury can yield inferences not only of the violent behavior being studied, but also of the culture that serves as context for the behavior. While the distinction between antemortem, perimortem, and postmortem injuries has been well established in bioarchaeology, the distinction in patterning between perimortem and antemortem injuries has lacked depth. Through a combination of qualitative analysis and a quantitative approach to comparisons, I have encountered patterns of trauma that have been previously dismissed or over-reported.

By creating a custom program to compile the data, create tables, and analyze the patterns, the research not only becomes simpler, but the inferences become more certain and the parameters of study can be manipulated with greater flexibility in order to examine both expected and unexpected patterns. Programs already exist to do statistical analysis, but no program out there will read the data, analyze the patterns and also allow for as much user input as will a personally tailored data analysis system.

Through the use of this custom program, I was able to examine the expectations originally set forth by this research and answer the questions raised. This method has its limitations: 1) a lack of programming experience can make the use of a tailored program more difficult than for someone with such experience and 2) the data must be collected and recorded in a very specific manner in order to allow the program to read and analyze the data correctly. With

respect to the experience, the program is rather simple and easy to use, with only some instruction any researcher has the opportunity to learn and use such a program. Collection of the data must be done on gridded standard images. If a gridded and scaled pattern is added to the standard illustrations by Buikstra and Ubelaker (1994) then the collection of data becomes simple. For recording such data, the only limitations are the order and organization of the spreadsheets used for data collection so that the program may read the coordinates and diameters correctly and without mistake since a mistake in the reading of the data can cause errors with the program. Even with these limitations, the use of such a program is simple and easily repeatable. And if the use of such a program is unlikely for the researcher, just the combination of qualitative and quantitative analysis will not only simplify their analysis but also lead to more significant inferences.

This method has revealed the possibility to continue the study of inaccessible skeletal collections. By using standard collection methods such as those found in Buikstra and Ubelacker (1994) in combination with detailed photographs a researcher may carry on studying remains that have been repatriated or reburied and still make a significant contribution. The method has also shown the possibility for a researcher to make statistically significant predictions about violent behavior by quantitatively studying patterns of trauma on skeletal remains; predictions that aid in the study of victim and perpetrator alike.

5.2 Future Considerations

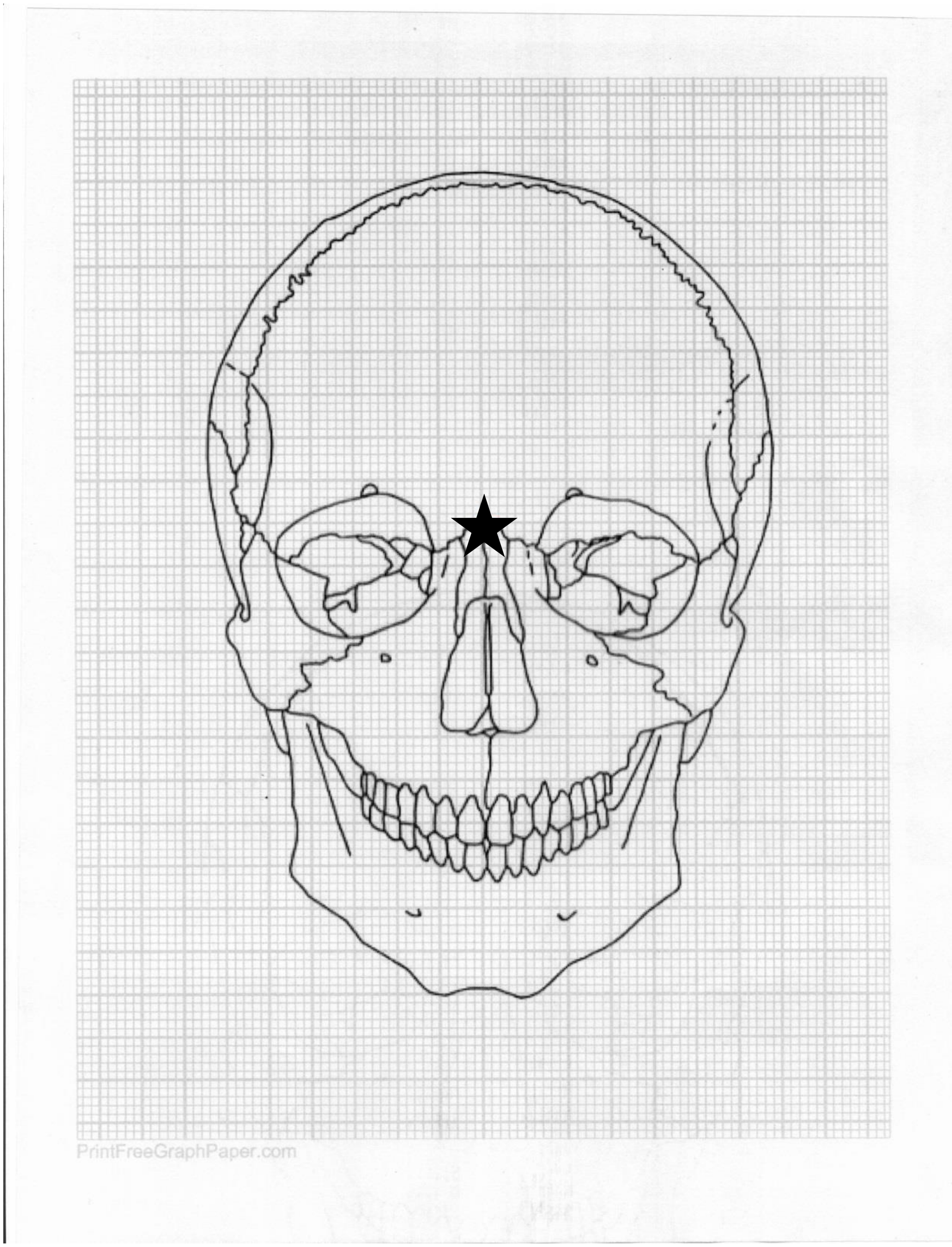
This research is a stepping stone for further inquiries into violence and patterns of cranial trauma. Future research on other samples from different cultures will dictate if the conclusions

here drawn can be applied cross-culturally and continue to predict behavior and manner of death. Although I used two-dimensional views to divide the crania, I suggest that future study use three-dimensional modeling such as ArcGIS or laser scanning techniques to more accurately represent the cranium, the shape of fractures, and the distribution of injuries. In a more narrow sense, research needs to continue on the violent lives of the Chachapoya to answer not only questions about patterns, but to also try to discern the how and why such patterns seem to exist in this ancient population and region.

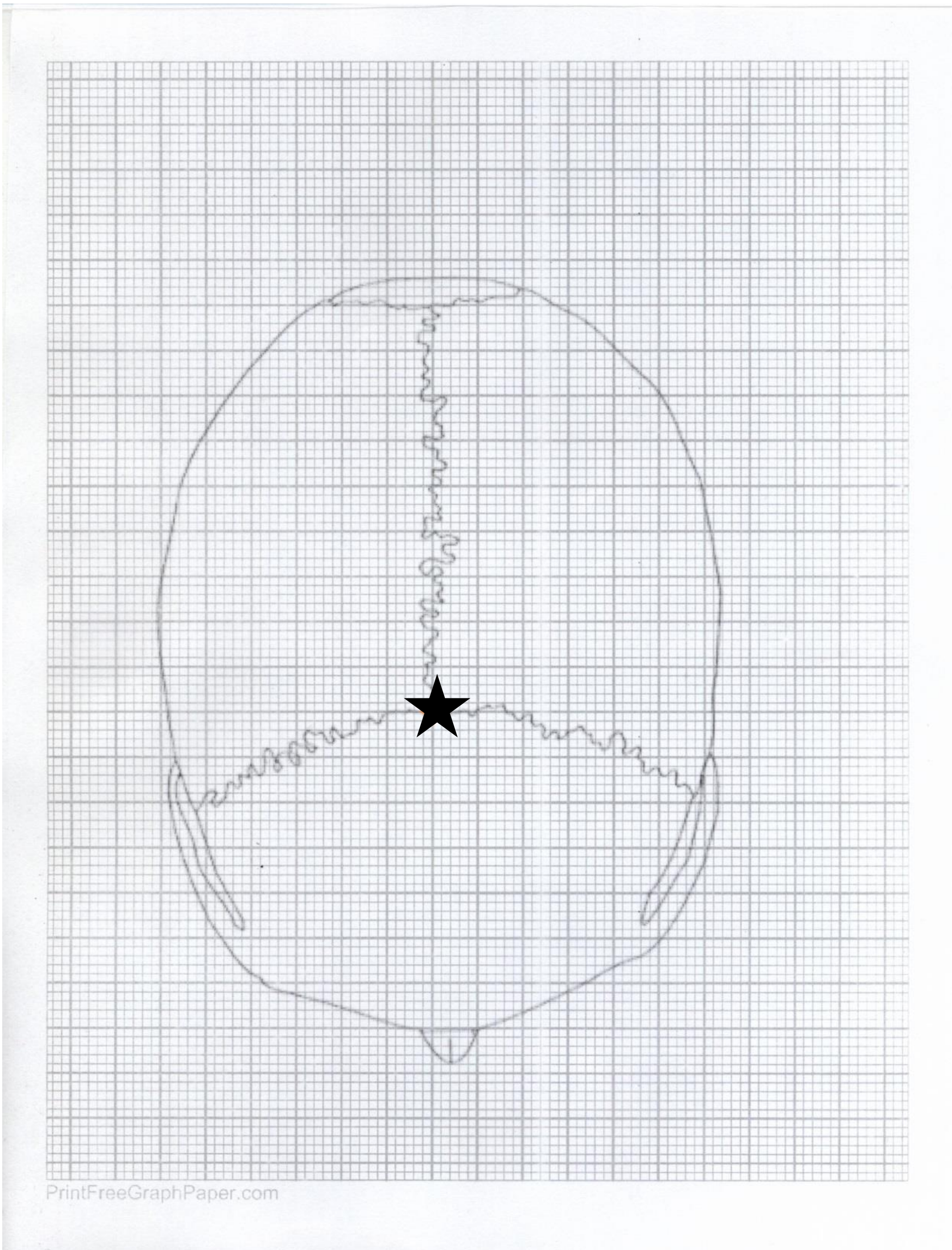
Bioarchaeology is already turning to more detailed and statistically based analysis (Wright and Yoder, 2003). Bioarchaeology is borrowing from the hard sciences to improve our interpretations in the social sciences. The combination of the human ability to perceive patterns and the accuracy of statistical analysis can lead to more precise inferences and results that will be more broadly trusted. Not only was such a method able to discover a correlation between lethality and location of trauma, the entire thesis was able to show that statistical significance can break down expectations and raise new questions which may not have become obvious previously. To use this method in future studies the entirety of the cranium needs to be assessed, avoiding further dividing the skull and narrowing the scope of analysis. These practices lead to less statistical certainty. The goal of this thesis was to support the use of a more quantitative approach in the analysis of cranial trauma, and while problems may still exist with such a method, the benefits of statistical significance outweigh the difficulties with its implementation.

Appendices

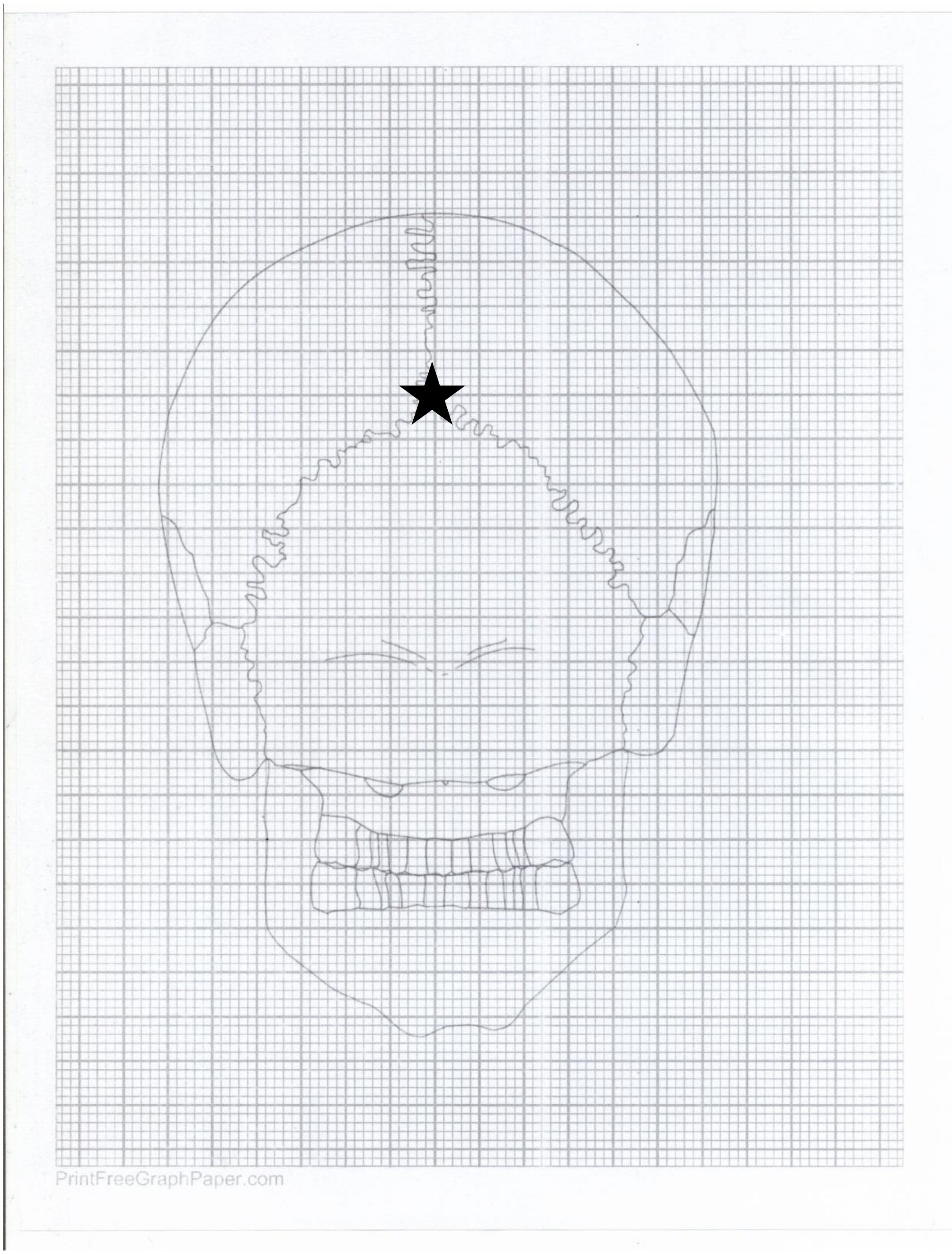
Appendix A: Anterior view of the skull indicating nasion



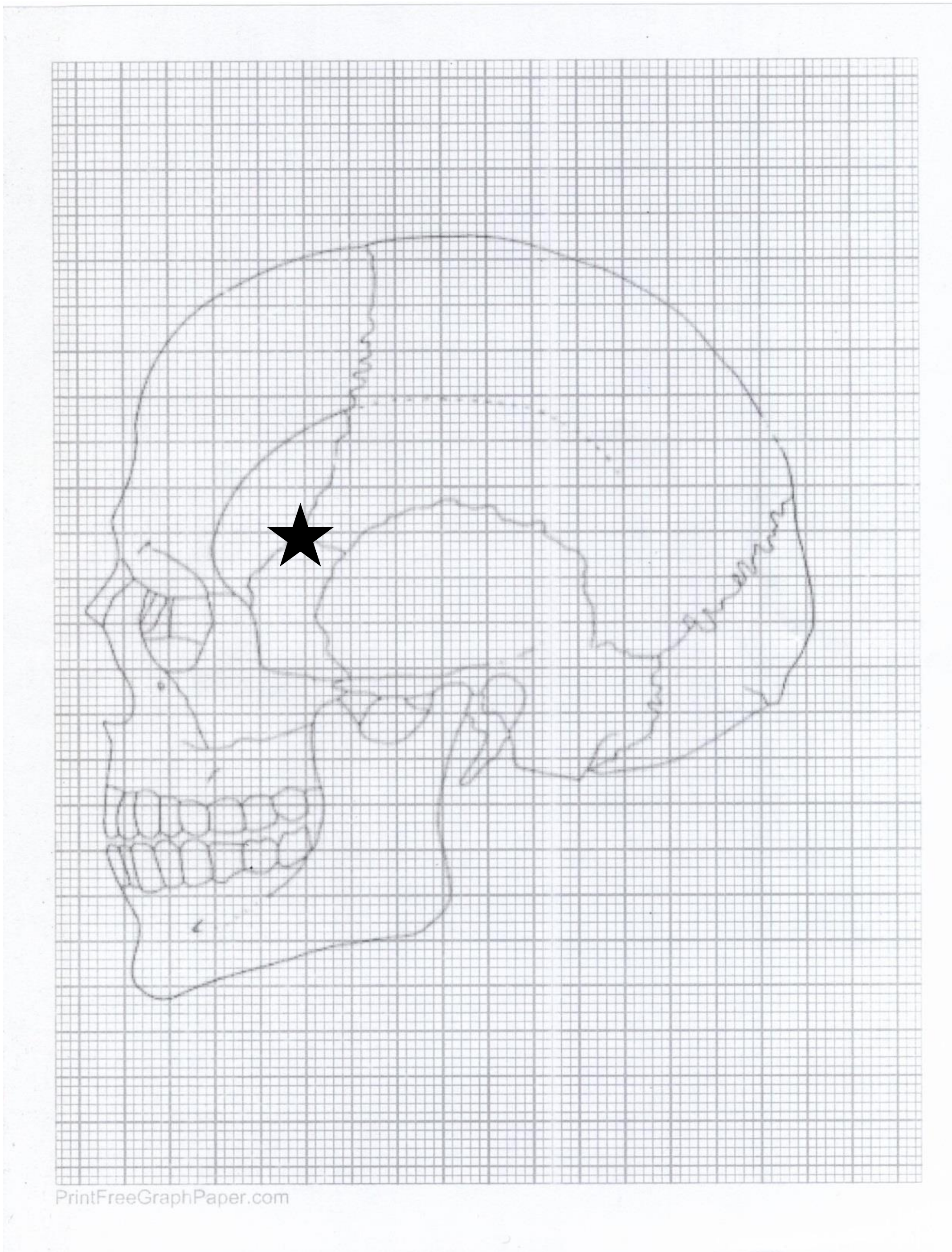
Superior view of the skull indicating bregma



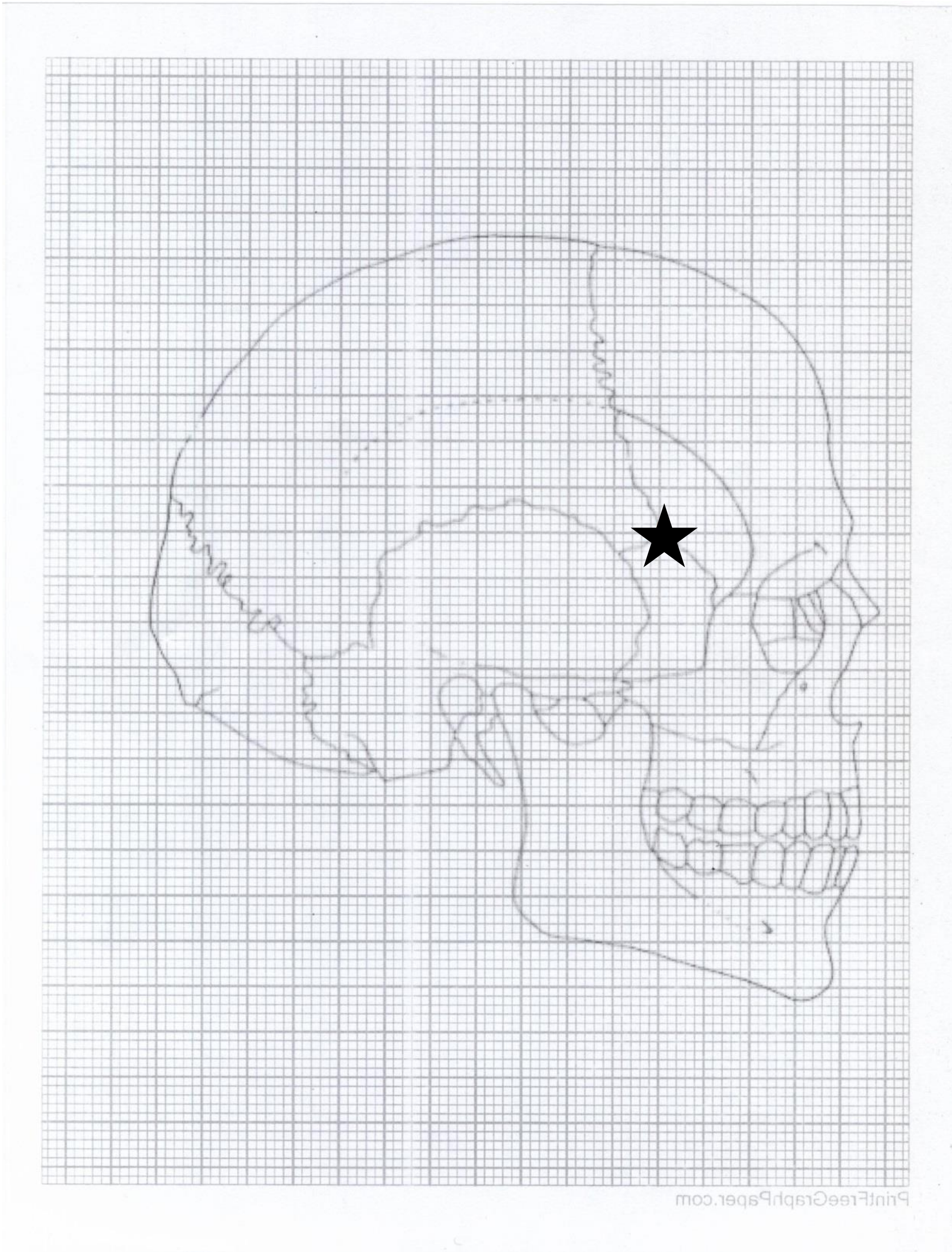
Appendix C: Posterior view of the skull indicating lambda



Appendix D: Lateral Left view of the skull indicating pterion



Lateral Right view of the skull indicating the pterion



Appendix F: Spreadsheet of Skeletal Sample

Individual	Sex	Age	Ant			Sup			Post			Lat. L			Lat. R		
			P	**A**	**B**	**P**	**A**	**B**	**P**	**A**	**B**	**P**	**A**	**B**	**P**	**A**	**B**
KSPlatC E6 Ent86	M	A								x							
KSPlatC E6 Ent70a	M	MA						x	x								
KSPlatC E6 Ent84	M	MA		x			x										
KSPlatC E6 Ent87	M	MA					x									x	
KSPlatC E4 Ent48	I	SA							x								
KSPlatC E4 Ent50	I	SA							x			x			x		
KSPlatC E4 Ent63	M	MA					x										
KSPlatC E3 Ent40	M	MA	x									x					
KSPlatC E4 Ent47	I	SA							x			x					
KSPlatC E3 Ent31	I	SA	x												x		
KSPlatC E3 Ent32	M	YA												x	x		
KSPlatC E3 Ent33	I	SA				x						x					
KSPlatC E3 Ent34	M	YA	x						x								
KSPlatC E3 Ent35a/b	M	YA							x								
KSPlatC E3 Ent36	M	YA	x														
KSPlatC E3 Ent41	M	YA													x		
KSPlatC E2 Ent5	M	YA		x					x								
KSPlatC E2 Ent10b	I	SA	x														
KSPlatC E2 Ent12a	M	MA							x								
KSPlatC E2 Ent14	M	MA	x			x						x			x		
KSPlatC E2 Ent7	M	MA				x			x								
KSPlatC E2 Ent9a	M	YA							x								
KSPlatC E2 Ent11	M	MA				x						x			x		
KSPlatC E2 Ent15	M	YA				x				x		x			x		
KSPlatC E2 Ent16a	I	SA							x								

KSPlatC E2 Ent17a	I	SA							x								
KSPlatC E2 Ent19a	M	YA													x		
KSPlatC E2 Ent20a	M	YA	x						x						x		
KSPlatC E2 Ent21	M	YA													x		
KSPlatC E2 Ent22	I	SA	x						x						x		
KSPlatC E2 Ent23	M	YA	x			x			x			x					
KSPlatC E2 Ent26	I	SA	x			x											
KSPlatC E2 Ent27b	I	SA	x														
KSPlatC E2 Ent28	M	YA							x								
KSPlatC E3 Ent39a	F	MA	x									x					
KSPlatC E4 Ent54	M	MA	x						x								
KSPlatC E4 Ent55	I	SA							x						x		
KSPlatC E4 Ent56	I	SA	x												x		
KSPlatC E4 Ent58	I	SA							x			x			x		
KSPlatC E4 Ent59	I	SA										x					
KSPlatC E4 Ent60	I	SA										x					
KSPlatC E4 Ent61	I	SA													x		
KSPlatC E4 Ent62	I	SA													x		
KSPlatC E4 Ent64	M	MA	x					x									
KSPlatC E4 Ent66b	M	MA				x			x								
KSPlatC E6 Ent68	I	SA				x			x								
KSPlatC E6 Ent73	I	SA							x								
KSPlatC E6 Ent74	M	YA	x														
KSPlatC E6 Ent81	M	YA		x													
KSPlatC E6 Ent83	M	YA										x					
KSPlatC E6 Ent85	F	OA	x														
KSPlatC E6 Ent88	M	YA			x												
KSPlatC E6 Ent90b	M	MA	x														
KSPlatC E6 Ent93a	M	YA	x														
KSPlatC E6 Ent75	I	SA	x			x			x								
KSPlatC E6 Ent76	I	SA							x						x		

KSPlatC E6 Ent77	I	SA							x			x			x		
KSPlatC E6 Ent78a	I	SA	x									x					
KSPlatC E6 Ent79	F	YA	x						x								
KSTin E2 -VIx Ent1	I	SA	x			x						x					
KSTin E2 -VIx Ent2	I	SA	x			x						x					
KSTin E2 -VIx Ent3	I	SA				x			x			x			x		
KSTerrazas E22 -IIIx Ent1a	M	YA	x			x			x			x			x		
KSTerrazas E22 -IIIx Ent1b	I	YA							x			x					
KSTin E19 -IIv Ent11	F	MA		x													
KSTin E19 -IIv Ent8	F	YA	x														
KSPlatC E9 Osario Grupo1	M	YA	x														
KSPlatC E9 Osario Cra5	M	MA			x			x									
KSPlat2 E12 -IIr Ent1	I	SA	x						x			x					
KSPlat2 E8 -IIIr Ent1	M	MA							x								
KSPlat2 E1 -IIIegne Ent2	F	YA					x										
KSPlat2 E1 -IIIegne Ent1	M	YA											x				
KSPlat1 IIIegne Ent4	I	SA										x					
KSSubplat2 E5 Ent3	M	YA							x			x			x		
KSSubplat2 E5 Ent1	M	YA							x			x			x		
KPACMO E1 Ent2 Cra1	M	YA	x														
KPACMO E2 Ent4	M	YA					x										
KPASMO Rel. Ent70	M	YA		x													
KPASMO Rel. Ent59	F	OA		x													
KPASMO Rel. Ent26	I	SA							x			x					
KPAC E2 Ent1c	F	MA								x							

Appendix G: Spreadsheet of Metric Data – Perimortem

Anterior			
Individual	**X (in mm)**	**Y (in mm)**	**Size (in mm)**
KSPlatC E3 Ent40	22	16	14
KSPlatC E3 Ent31	-6	4	0
KSPlatC E3 Ent34	11	14	10
KSPlatC E3 Ent34	15	22	8
KSPlatC E3 Ent34	6	32	6
KSPlatC E3 Ent34	-14	22	10
KSPlatC E3 Ent34	-9	36	6
KSPlatC E3 Ent34	-28	27	8
KSPlatC E3 Ent34	6	44	8
KSPlatC E3 Ent34	40	28	5
KSPlatC E3 Ent36	-15	40	0
KSPlatC E2 Ent10b	-3	37	18
KSPlatC E2 Ent10b	-48	44	30
KSPlatC E2 Ent20a	-25	29	16
KSPlatC E2 Ent20a	18	25	10
KSPlatC E2 Ent20a	23	50	8
KSPlatC E2 Ent20a	0	54	12
KSPlatC E2 Ent20a	-4	73	8
KSPlatC E2 Ent22	-44	25	21
KSPlatC E2 Ent23	26	35	0
KSPlatC E2 Ent23	-23	15	0
KSPlatC E2 Ent26	-27	30	19
KSPlatC E2 Ent27b	-22	30	20
KSPlatC E3 Ent39a	1	28	10
KSPlatC E3 Ent39a	30	22	21
KSPlatC E4 Ent56	56	17	0
KSPlatC E4 Ent64	-6	36	14
KSPlatC E4 Ent64	8	43	14
KSPlatC E4 Ent64	30	49	16
KSPlatC E6 Ent74	0	7	10
KSPlatC E6 Ent74	51	5	10
KSPlatC E6 Ent85	12	13	16
KSPlatC E6 Ent88	-14	86	0
KSPlatC E6 Ent90b	-35	8	21
KSPlatC E6 Ent93a	4	-10	0
KSPlatC E6 Ent93a	-26	21	0
KSPlatC E6 Ent75	48	8	18
KSPlatC E6 Ent78a	7	57	22
KSPlatC E6 Ent78a	45	25	30

KSPlatC E6 Ent79	-29	28	20
KSPlatC E6 Ent79	-35	59	22
KSTin E2 -VIx Ent1	-8	17	16
KSTin E2 -VIx Ent1	34	20	14
KSTin E2 -VIx Ent1	11	49	10
KSTin E2 -VIx Ent2	-5	18	0
KSTin E2 -VIx Ent2	-1	40	0
KSTin E2 -VIx Ent2	-1	65	8
KSTin E2 -VIx Ent2	23	13	8
KSTerrazas E22 -IIIx Ent1a	19	10	14
KSTerrazas E22 -IIIx Ent1a	40	12	6
KSTin E19 -IIv Ent8	-22	57	6
KSPlatC E9 Osario Grupo1	-17	26	8
KSPlatC E9 Osario Cra5	-3	68	12
KSPlat2 E12 -IIr Ent1	3	8	16
KSPlat2 E12 -IIr Ent1	8	44	18
KPACMO E1 Ent2 Cra1	-33	19	22
Superior			
Individual	**X (in mm)**	**Y (in mm)**	**Size (in mm)**
KSPlatC E6 Ent70a	-2	-33	6
KSPlatC E6 Ent70a	-54	34	12
KSPlatC E3 Ent33	0	40	0
KSPlatC E3 Ent33	23	73	0
KSPlatC E2 Ent14	-25	16	14
KSPlatC E2 Ent14	-24	58	0
KSPlatC E2 Ent7	15	-27	8
KSPlatC E2 Ent11	20	63	8
KSPlatC E2 Ent15	0	0	6
KSPlatC E2 Ent15	-26	57	16
KSPlatC E2 Ent20a	-24	14	26
KSPlatC E2 Ent23	27	55	14
KSPlatC E2 Ent23	-29	44	10
KSPlatC E2 Ent26	-3	3	0
KSPlatC E2 Ent26	18	24	0
KSPlatC E4 Ent64	17	33	20
KSPlatC E4 Ent64	19	48	18
KSPlatC E4 Ent66b	-3	-36	6
KSPlatC E4 Ent66b	12	-50	12
KSPlatC E4 Ent66b	24	-35	12
KSPlatC E4 Ent66b	31	-15	12
KSPlatC E6 Ent68	-36	27	15

KSPlatC E6 Ent68	45	37	10
KSPlatC E6 Ent68	45	55	10
KSPlatC E6 Ent75	29	46	30
KSPlatC E6 Ent75	46	43	24
KSTin E2 -VIx Ent1	55	9	4
KSTin E2 -VIx Ent1	27	-57	8
KSTin E2 -VIx Ent2	-4	49	6
KSTin E2 -VIx Ent2	4	-13	4
KSTin E2 -VIx Ent2	0	-39	18
KSTin E2 -VIx Ent2	-5	-48	0
KSTin E2 -VIx Ent2	25	-42	0
KSTin E2 -VIx Ent2	-16	75	13
KSTin E2 -VIx Ent3	-27	10	16
KSTin E2 -VIx Ent3	-45	-25	21
KSTin E2 -VIx Ent3	-22	-40	10
KSTerrazas E22 -IIIx Ent1a	11	78	4
KSPlatC E9 Osario Cra5	4	-19	14
Posterior			
Individual	**X (in mm)**	**Y (in mm)**	**Size (in mm)**
KSPlatC E6 Ent70a	-17	-27	14
KSPlatC E4 Ent48	-24	-5	10
KSPlatC E4 Ent48	-35	-5	10
KSPlatC E4 Ent48	-11	-34	10
KSPlatC E4 Ent48	0	-41	10
KSPlatC E4 Ent48	12	-36	10
KSPlatC E4 Ent48	21	-30	10
KSPlatC E4 Ent48	18	-13	10
KSPlatC E4 Ent48	26	-17	10
KSPlatC E4 Ent50	24	-31	21
KSPlatC E4 Ent47	-32	12	15
KSPlatC E3 Ent34	19	14	7
KSPlatC E3 Ent34	40	8	0
KSPlatC E3 Ent35a/b	-10	-40	0
KSPlatC E3 Ent35a/b	-52	0	0
KSPlatC E2 Ent5	-8	-78	0
KSPlatC E2 Ent5	-27	-70	8
KSPlatC E2 Ent5	-31	-54	0
KSPlatC E2 Ent12a	-7	-50	10
KSPlatC E2 Ent12a	-26	-22	0
KSPlatC E2 Ent7	0	-66	8
KSPlatC E2 Ent7	-20	-50	14

KSPlatC E2 Ent9a	40	-37	8
KSPlatC E2 Ent9a	-24	-76	8
KSPlatC E2 Ent9a	-18	-79	10
KSPlatC E2 Ent16a	-22	-53	8
KSPlatC E2 Ent17a	-20	-7	20
KSPlatC E2 Ent17a	-24	-35	16
KSPlatC E2 Ent20a	19	15	19
KSPlatC E2 Ent22	13	23	13
KSPlatC E2 Ent23	28	5	8
KSPlatC E2 Ent28	28	-16	12
KSPlatC E2 Ent28	45	-32	8
KSPlatC E2 Ent28	-32	-18	10
KSPlatC E4 Ent54	21	8	14
KSPlatC E4 Ent54	31	-16	12
KSPlatC E4 Ent54	-6	-11	6
KSPlatC E4 Ent54	-12	-33	10
KSPlatC E4 Ent55	-5	-45	18
KSPlatC E4 Ent55	21	-42	14
KSPlatC E4 Ent58	0	-2	18
KSPlatC E4 Ent58	-32	-2	20
KSPlatC E4 Ent58	-26	-38	6
KSPlatC E4 Ent66b	24	6	22
KSPlatC E4 Ent66b	37	7	14
KSPlatC E6 Ent68	16	-28	24
KSPlatC E6 Ent68	34	6	12
KSPlatC E6 Ent73	0	-41	0
KSPlatC E6 Ent73	27	-54	0
KSPlatC E6 Ent73	34	24	0
KSPlatC E6 Ent73	45	13	0
KSPlatC E6 Ent75	7	-42	24
KSPlatC E6 Ent75	-12	-34	15
KSPlatC E6 Ent76	-28	-64	10
KSPlatC E6 Ent77	12	-22	14
KSPlatC E6 Ent79	15	-25	26
KSTin E2 -VIx Ent3	-23	-59	24
KSTerrazas E22 -IIIx Ent1a	11	-17	16
KSTerrazas E22 -IIIx Ent1a	-25	-16	16
KSTerrazas E22 -IIIx Ent1a	-13	35	6
KSTerrazas E22 -IIIx Ent1b	19	5	0
KSTerrazas E22 -IIIx Ent1b	-1	-34	8
KSTerrazas E22 -IIIx Ent1b	35	-26	0
KSTerrazas E22 -IIIx Ent1b	33	-54	18

KSPlat2 E12 -IIr Ent1	14	-25	0
KSPlat2 E12 -IIr Ent1	-16	-26	0
KSPlat2 E8 -IIIr Ent1	18	-18	18
KSPlat2 E8 -IIIr Ent1	-5	-38	16
KSSubplat2 E5 Ent3	-1	-44	12
KSSubplat2 E5 Ent3	12	-56	10
KSSubplat2 E5 Ent3	-54	-8	12
KSSubplat2 E5 Ent3	-45	-32	14
KSSubplat2 E5 Ent3	-33	-47	16
KSSubplat2 E5 Ent3	29	5	11
KSSubplat2 E5 Ent3	45	6	12
KSSubplat2 E5 Ent1	19	-33	13
KSSubplat2 E5 Ent1	18	-43	6
KSSubplat2 E5 Ent1	-51	-5	10
KSSubplat2 E5 Ent1	-53	-14	10
KPASMO Rel. Ent26	-36	8	21
Lateral Left			
Individual	**X (in mm)**	**Y (in mm)**	**Size (in mm)**
KSPlatC E4 Ent50	46	5	0
KSPlatC E4 Ent50	32	25	18
KSPlatC E4 Ent50	80	-2	22
KSPlatC E3 Ent40	9	43	15
KSPlatC E3 Ent40	17	25	11
KSPlatC E4 Ent47	-1	9	16
KSPlatC E3 Ent33	22	10	22
KSPlatC E2 Ent14	6	15	19
KSPlatC E2 Ent14	73	-7	8
KSPlatC E2 Ent11	76	-12	12
KSPlatC E2 Ent15	62	35	16
KSPlatC E2 Ent23	82	4	10
KSPlatC E2 Ent23	54	40	8
KSPlatC E2 Ent23	35	38	12
KSPlatC E2 Ent23	-16	24	12
KSPlatC E3 Ent39a	40	-8	10
KSPlatC E4 Ent58	75	25	21
KSPlatC E4 Ent59	-4	23	0
KSPlatC E4 Ent59	94	0	0
KSPlatC E4 Ent60	-4	14	20
KSPlatC E4 Ent60	15	28	15
KSPlatC E4 Ent60	60	15	24
KSPlatC E6 Ent83	64	40	13

KSPlatC E6 Ent77	58	17	16
KSPlatC E6 Ent78a	55	26	12
KSPlatC E6 Ent78a	62	17	8
KSTin E2 -VIx Ent1	34	35	4
KSTin E2 -VIx Ent1	-25	12	8
KSTin E2 -VIx Ent2	-2	55	0
KSTin E2 -VIx Ent2	46	21	6
KSTin E2 -VIx Ent3	13	26	16
KSTin E2 -VIx Ent3	47	18	0
KSTin E2 -VIx Ent3	95	-26	12
KSTerrazas E22 -IIIx Ent1a	59	19	16
KSTerrazas E22 -IIIx Ent1a	70	-1	0
KSTerrazas E22 -IIIx Ent1b	41	31	0
KSTerrazas E22 -IIIx Ent1b	55	14	0
KSPlat2 E12 -IIr Ent1	59	16	20
KSPlat2 E12 -IIr Ent1	67	1	14
KSSubplat2 E5 Ent3	65	20	17
KSSubplat2 E5 Ent3	85	-6	12
KSSubplat2 E5 Ent3	88	-30	0
KSSubplat2 E5 Ent1	60	14	16
KSSubplat2 E5 Ent1	68	4	11
KPASMO Rel. Ent26	72	16	29
KSPlat1 IIIegne Ent4	4	-5	20
Lateral Right			
Individual	**X (in mm)**	**Y (in mm)**	**Size (in mm)**
KSPlatC E4 Ent50	-43	19	19
KSPlatC E4 Ent50	-83	5	20
KSPlatC E3 Ent31	-41	27	7
KSPlatC E3 Ent31	-68	20	10
KSPlatC E3 Ent31	-83	-12	18
KSPlatC E3 Ent32	-35	8	10
KSPlatC E3 Ent41	13	-8	10
KSPlatC E3 Ent41	-10	2	18
KSPlatC E3 Ent41	-15	17	15
KSPlatC E3 Ent41	-69	7	10
KSPlatC E3 Ent41	-79	4	11
KSPlatC E2 Ent14	-52	-45	11
KSPlatC E2 Ent11	20	0	2
KSPlatC E2 Ent15	-77	33	8
KSPlatC E2 Ent19a	-79	27	12
KSPlatC E2 Ent19a	-78	10	18

KSPlatC E2 Ent20a	-2	-82	0
KSPlatC E2 Ent20a	-72	-27	12
KSPlatC E2 Ent20a	15	-43	10
KSPlatC E2 Ent21	-97	2	12
KSPlatC E2 Ent21	-78	43	18
KSPlatC E2 Ent22	-74	29	20
KSPlatC E2 Ent22	-70	-33	10
KSPlatC E4 Ent55	-24	14	12
KSPlatC E4 Ent55	-80	0	0
KSPlatC E4 Ent56	-72	25	0
KSPlatC E4 Ent56	-45	40	18
KSPlatC E4 Ent58	-80	7	9
KSPlatC E4 Ent61	-89	14	45
KSPlatC E4 Ent61	-10	-22	16
KSPlatC E4 Ent62	-70	-20	16
KSPlatC E6 Ent76	-51	10	12
KSPlatC E6 Ent76	-85	31	16
KSPlatC E6 Ent77	-58	25	10
KSTin E2 -VIx Ent3	1	7	21
KSTin E2 -VIx Ent3	17	22	8
KSTin E2 -VIx Ent3	-14	40	12
KSTin E2 -VIx Ent3	-61	5	0
KSTin E2 -VIx Ent3	29	-3	4
KSTerrazas E22 -IIIx Ent1a	8	5	12
KSSubplat2 E5 Ent3	-67	20	12
KSSubplat2 E5 Ent3	-86	26	10
KSSubplat2 E5 Ent1	-12	-8	10

Appendix H: Spreadsheet of Metric Data – Antemortem

Anterior

Individual	X (in mm)	Y (in mm)	Size (in mm)
KSPlatC E6 Ent84	0	13	10
KSPlatC E6 Ent84	52	-5	10
KSPlatC E2 Ent5	12	37	6
KSPlatC E6 Ent81	-30	27	16
KSPlatC E6 Ent88	6	21	14
KSTin E19 -IIv Ent11	19	47	13
KSPlatC E9 Osario Cra5	8	36	10
KSPlatC E9 Osario Cra5	29	65	6
KPASMO Rel. Ent70	24	25	14
KPASMO Rel. Ent70	35	48	10
KPASMO Rel. Ent70	-29	30	10
KPASMO Rel. Ent59	50	20	10

Superior

Individual	X (in mm)	Y (in mm)	Size (in mm)
KSPlatC E6 Ent70a	-1	-6	10
KSPlatC E6 Ent87	-7	-41	8
KSPlatC E4 Ent63	43	-24	8
KSPlatC E4 Ent64	4	35	14
KSPlatC E9 Osario Cra5	7	-51	10
KSPlatC E9 Osario Cra5	29	-21	6
KSPlat2 E1 -IIIegne Ent2	-45	18	21
KPACMO E2 Ent4	-4	-17	12

Posterior

Individual	X (in mm)	Y (in mm)	Size (in mm)
KSPlatC E2 Ent15	25	-1	4
KPAC E2 Ent1c	-34	-5	24
KPAC E2 Ent1c	38	0	18

Lateral Left

Individual	X (in mm)	Y (in mm)	Size (in mm)
KSPlatC E6 Ent86	-30	10	20
KSPlatC E3 Ent32	-30	15	8
KSPlatC E3 Ent32	70	20	8
KSPlat2 E1 -IIIegne Ent1	60	50	18

Lateral Right

Individual	X (in mm)	Y (in mm)	Size (in mm)
KSPlatC E6 Ent87	26	5	4

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