The Effect of Skeletal Completeness on Cranial Trauma Analyses

by

Kaela Parker
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Abstract

A trauma frequency analysis was undertaken on a skeletal sample (n = 75) from the skeletal collections of the medieval Augustinian Priory of St. Mary Merton and the post-medieval lower cemetery of St. Bride's Church. Fourty-four individuals exhibited trauma on one or more cranial elements. Cranial bones were arranged in different groupings for analysis: inclusive samples of 100% complete, at least 75% complete, at least 25% complete, entire sample; and independent samples of 100% complete, 75 - <100% complete, 25 - <75% complete, and <25% complete. Crania were categorized as 100% complete and incomplete. Four frequencies were calculated (frequency of lesions, of individuals with lesions, of individuals with multiple lesions, and the number of lesions per injured individuals) for each category and cranial element. The results illustrate a general trend towards a decrease in frequency as more fragmentary material is included, illustrating that including the more fragmentary material may bias the results towards underestimating trauma frequencies. However, Fisher's exact tests do not show statistically significant differences between frequencies in the independent samples analysis, except for individuals with lesions on the right nasal bone. Further research into the effect of fragmentation and poor preservation in skeletal research, cranial trauma research in particular, is required.

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Chapter 1: Introduction and Background Information

1.1 Introduction

Skeletal trauma has often been used as a proxy for understanding past lifestyles, especially where populations are suspected of having been violent or warlike. Skeletal trauma, along with grave goods and historical documents, can facilitate the understanding of the past but must be interpreted with caution. Skeletal preservation is a major limiting factor in skeletal research as poor preservation may lead to the misinterpretation or over- interpretation of skeletal evidence. As such, this project will focus on the issue of preservation in skeletal trauma analysis. The following research involves the examination of cranial lesions and the effect of different levels of completeness on the frequency of lesions found. Traumatic cranial lesions were documented by location, shape, and size. Using recording techniques employed in previous skeletal trauma research (Brasili et al. 2004; Djuric et al. 2006; Efran et al. 2009: Jiminez-Brobeil et al. 2009; Judd 2004, 2006; Kanz and Grossschmidt 2006; Jurmain 1999; Smith 2003; Torres-Rouff and Junqueira 2006; Walker 1989, 1997; Williamson et al. 2003; Wilkinson 1997), differences in frequency and appearance of skeletal lesions will be assessed.

Previously, much of the bioarchaeological research has ignored or overlooked issues of preservation, ultimately disregarding the fact that the information derived from an excavation may not be representative of the lifestyle or violent/warlike tendencies of a population due to poor preservation and incompleteness of the skeletal record. Klein and Cruz-Uribe (1984) describe five stages that a skeletal assemblage undergoes in order for it to survive into the archaeological record. The stages include:

1) The life assemblage, all of the living members of a population.

2) The death assemblage, which includes all of the dead individuals that are available for collection by people, carnivores, and any other destructive agents.

3) The deposited assemblage, where complete or partial carcasses come to rest at a site.

4) The fossil assemblage, which includes the material that survives at a site until excavation or collection.

5) The sample assemblage, the final stage, which encompasses the part of the fossil assemblage that is excavated or collected. If an entire sample is excavated the sample assemblage will be the same as the fossil assemblage.

Inferring the life, death, and deposited assemblages from the fossil or sample assemblage can be difficult and sometimes impossible (Klein and Cruz-Uribe 1984). The previous statement illustrates one of the significant issues surrounding the collection and analysis of archaeological bone. Osteologists and archaeologists use bone fragments and partial skeletal assemblages to make inferences about past populations, which can become problematic when researchers use multiple recording and analysis techniques to make their inferences.

The lack of standardization in trauma analysis research may make the comparison of trauma frequencies inaccurate. This issue has been addressed (Buikstra and Ubelaker 1994; Judd 2002; Judd and Roberts 1999; Walker 1997, 2001); however, no universally accepted solutions have, as yet, been presented (see Brasili et al. 2004; Djuric et al. 2006; Efran et al 2009: Jiminez-Brobeil et al. 2009; Judd 2004, 2006; Jurmain 1999; Kanz and Grossschmidt 2006; Smith 2003; Torres-Rouff and Junqueira 2006; Walker 1989, 1997; Williamson et al. 2003; Wilkinson 1997).

The primary focus of the current research is to demonstrate problems associated with skeletal analysis of samples with varying levels of skeletal preservation, thus illustrating the need for standardization in skeletal research.

The aim of this project includes examining the issues of preservation and completeness and their effect on trauma analysis. Poor preservation and incompleteness of skeletal material can be the result of a variety of factors ranging from the properties of soil to the techniques employed by excavators when exhuming skeletal remains. Regardless of the reason, poor skeletal preservation may seriously affect the results of skeletal analyses (Grauer and Roberts 1996). Depending on what elements are preserved trauma may be under- or over-represented in the archaeological record. For example, nasal bone fractures are considered highly indicative of interpersonal violence; however, as the nasal bones are thin and delicate they are rarely preserved in the archaeological record (Walker 1997). By assessing several different methods for recording cranial trauma this research will examine whether different levels of completeness significantly affect the number of lesions found per bone, the number of lesions per individual (both single and multiple), and the number of lesions per injured individual.

1.2 Palaeotrauma Research Aims

Palaeotrauma analysis attempts to evaluate the lifestyle, everyday activity, violence, and warfare in skeletal populations. Cranial and facial lesions are often used as indicators of interpersonal violence (Brasili et al. 2004; Djuric et al. 2006; Efran et al 2009: Jiminez-Brobeil et al. 2009; Judd 2004, 2006; Jurmain 1999; Kanz and Grossschmidt 2006; Smith 2003; Torres-Rouff and Junqueira 2006; Walker 1989, 1997; Williamson et al. 2003; Wilkinson 1997). Although variation does occur temporally and across populations in terms of where intentional trauma is inflicted, in most samples nasal bone fractures are the most common followed by traumatic lesions on the frontal bones and parietal bones respectively (Jurmain 1999; Walker 1997). The orbits and calvarium may also be fractured; however, such lesions occur less frequently as a result of interpersonal violence (Jurmain 1999). In both contemporary and archaeological contexts a significantly higher prevalence of injuries in males than females have been noted, and older individuals tend to exhibit more injuries than younger individuals. This may be a function of decreased bone density and/or simply an accumulation of injuries over time (Brasili et al. 2004; Jiminez-Brobeil et al. 2009; Judd 2004, 2006; Torres-Rouff and Junqueira 2006; Walker 1997).

Cranial lesions caused by hand-to-hand combat include zygomatic arch fractures, nasal bone fractures, loss of teeth, and mandibular fractures; however, such lesions may result from a variety of causes. It is important not to over interpret the skeletal evidence seen in any given sample; interpersonal violence can be assumed when several indicative lesions such as facial, rib, and digit fractures are seen in combination (Hershkovitz et al. 1996).

During analysis of skeletal samples representing past populations, the assumption that the material found in the skeletal record gives an accurate representation of past lifestyles is often inadvertently made; however, the notion that information is frequently destroyed due to taphonomic processes is often ignored or overlooked in bioarchaeological research. This is especially significant as many of the lesions associated with hand-to-hand combat are found on the face (Hershkovitz et al. 1996). The facial bones are relatively thin and therefore may not be present if the skeletal sample has been subjected to significant and/or long-term, taphonomic processes (Bello and Andrews 2006; Walker 1997).

1.3 Taphonomic Destruction of Bone

Preservation is an issue present in all skeletal research; it is particularly significant in skeletal trauma analysis as poor preservation may result in the over- or under-interpretation of trauma and may lead to the misidentification of a past population as violent or warlike. Over- or under-interpretation due to poor preservation and completeness can result from a number of taphonomic processes, from soil acidity to animal scavenging to poor recovery techniques (Boddington et al.1987; Stodder 2008; Von Endt and Ortner 1984).

The current study looks at the effect of an assemblage's cranial completeness on the frequency of cranial trauma found. In this study the terms preservation and completeness are used somewhat interchangeably. Buikstra and Ubelaker (1994) define cranial material as well preserved if at least 75% on the crania is present and poorly preserved if less than 25% of the crania is present. Employing these definitions in the current study is effective as the bones were buried and very little surface damage was present on the bones. It is important to note, however, that a bone can be well preserved and incomplete as well as complete and poorly preserved. As discussed in Section 1.3.2, some of the extrinsic factors that affect bone can damage the integrity of the outer cortex of bone without destroying the bone itself (Bello et al. 2006; Behrensmeyer 1978, 1991; Henderson 1987; Haglund 1997; Haglund and Sorg 2002; Von Endt and Ortner 1984).

Several taphonomic processes, both intrinsic and extrinsic to bone, can lead to poor preservation and the under-representation of certain skeletal elements.

1.3.1 Intrinsic Factors Affecting Bone Preservation

Although both the intrinsic and extrinsic factors that lead to bone destruction work in unison to destroy and decompose tissue, often making it impossible to understand what causes a bone's destruction, they all play an important role in the postmortem preservation of human remains. The intrinsic factors that often lead to postmortem bone loss include bone density, shape, size, the position of the element on the body, and the individual's health, age, and sex.

In a study of the Crow Creek Massacre victims, Willey and colleagues (1997) assess the correlation between bone mineral density (BMD) and the survival of bone elements. Using the skeletal sample from Crow Creek, the skeletal remains of approximately 500 individuals killed in a raid ca. 1350 in South Dakota, the authors analyzed the events that led up to the massacre at Crow Creek, the massacre, and the relative survivorship of bones. Analysis of the bones and the archaeological context from which they came indicated that the individuals were killed during a single attack. Cranial depressions, evidence of scalping, decapitation, and mutilation were apparent on many of the individuals interred in the mass grave excavated in 1978. After the raid the individuals killed at Crow Creek were left exposed on the surface of the ground where they were scavenged by the village dogs, coyotes, and wolves. It was also suggested that the raid took place in the winter implying that the bodies went through at least one freeze and thaw cycle before being buried. After burial, the bones were further disturbed by erosion and rodent tunneling. The accumulation of all the postmortem taphonomic processes left behind bones that were very poorly preserved (Willey et al. 1997).

The density of human long bone elements was measured using single photon absorptiometry (SPA) which provides an indication of the bone mineral content (BMC), bone width (BW), and BMD. The study found that, for all bone elements, the midshaft was more frequently represented than the epiphyseal and metaphyseal segments. The authors noted also that the right side elements were more highly represented than left side elements. The study found a statistical correlation between bone density and element survival. Denser elements and element segments were found to be more likely to survive (Galloway et al. 1997; Willey et al. 1997; see also Lyman 1984). Less dense elements have a higher cancellous to cortical bone ratio, making them easier to destroy and presenting more fat and nutrition to scavengers (Blumenschine and Marean 1993).

In a more recent study, Bello and Andrews (2006) examined skeletal remains from three medieval and three post-medieval collections, St. Estève Le Pont, Hauture, St. Maximin, Fédons, Observance, and Spitalfields, in order to determine if the intrinsic forces that play a role in preservation of bone could be quantified. Each bone was analyzed using an Anatomical Preservation Index (API) which assesses the quantity of osseous material present, and a Bone Representation Index (BRI), a ratio of the actual number of bones excavated and the number of bones that should be present according to the Minimum Number of Individuals (MNI). The results of the study illustrated that, while the cranium as a unit was generally well represented, the facial bones are often less well represented. Parietal bones were well represented, most likely due to their relatively high BMD, as well as the temporal and occipital bones. The mandible was usually partially preserved, however the area between the two mental foramina was generally better preserved than the rami. The authors found similar results when assessing the density of the post-cranial skeletons; denser bones were better represented than less dense, more cancellous bones (Bello and Andrews 2006).

The cranial bone elements that are usually the most well represented in burial sites are the dense, relatively heavy sections such as the petrous temporal, the mastoid process, and the mandible (Henderson 1987). Lam et al. (1999), in a comparative study of bovid, equid, and cervid species, noted that the petrous temporal was the most dense bone in the body. In human skeletal analyses, the petrous temporal is often used to identify the MNI in archaeological samples as it is commonly preserved (e.g. Willey et al. 1997).

As a unit, the skull is very susceptible to warping, crushing by soil pressure, and breakage during excavation (Henderson 1987). The trunk of the body is usually present for a longer period of time than the appendicular skeleton, and the more distal bones are less likely to be present in the skeletal record as are bones with low mineral density (Stodder 2008).

Apart from bone density, Bello and Andrews (2006) discuss the importance of size and shape in element survival. Small, light bones are more easily lost if a body is moved from a primary burial site to a secondary burial site. They note that during rituals that involve the transfer of a body to a secondary burial site the bones of the hands and feet, the patellae and the hyoid are often lost. Assuming that a burial occurs in situ, a higher frequency of large, robust bones and a lower frequency of lighter, smaller bones is still likely as smaller bones are also more easily carried off by animals. The authors do, however, point out that skeletal samples may or may not fit into the pattern they lay out, as mortuary ritual and funerary practices may alter the amount of, and way in which, an individual is buried (Bello and Andrews 2006).

Additionally, the size of a bone plays a role in its survival as smaller bones are often missed during excavation. As well as getting left behind during excavation small bones also decompose faster than larger bones. Smaller bones are more susceptible to destruction, decomposition, and transport both prior to and after burial (Guthrie 1967; Henderson 1987). In a study done by Von Endt and Ortner (1984) on a bovine tibia it was found that smaller bone fragments decayed and became porous more quickly than larger bone fragments in a controlled environment. In order to minimize the impact of any extrinsic factors the authors kept the bones in stagnant water that was kept at a constant temperature.

The age of the individuals at death, their health, and their sex may also affect the rate at which their bones decay. The bones of very young individuals, being smaller, will decay faster than those of adults, and the bones of very old individuals that exhibit signs of osteoporosis may decay faster as they are porous at death (Bello et al. 2006; Henderson 1987). The bones of the young are frequently under-represented, as they are softer and more nutritious than those of older individuals (Gifford-Gonzalez 1989). The presence of antemortem infections or injuries may also accelerate the decomposition process. Sex is another factor, as in many societies females and males are not treated in the same manner. This is often reflected in the burial rites that they are given. Different burial rites may accelerate or decelerate the process of decay causing an unrepresentative skeletal sample being left behind in the archaeological record (Bello et al. 2006; Henderson 1987).

Finally, the anatomical position of bones seems to have an effect on the survival of bones. In his assessment of the survival of bone from data collected during the excavation of the Roman-British site at West Tenter in London, Waldron (1987) found that distal bones seem to survive less often than proximal bones, and the anterior bones of the thorax tend to survive more often than the posterior bones. In his study, the phalanges, the carpals, and the coccyx were the least well represented along with the smaller tarsal bones. Waldron (1987) noted, however, that the talus, calcaneus, metacarpals, and metatarsals were relatively well represented. He also detected an under-representation of the anterior bones of the body, the sternum, coracoid and acromion processes of the scapulae, the pubis, and the patellae. Important for the current study is Waldron's (1987) observation that the petrous temporal, the mastoid processes, and segments of the mandible are the most resilient bone elements in the body along with the acetabulum and the sciatic notch of the pelvis, the proximal end of the ulna, and the middle metacarpal (see also Haglund 1997). It is important to note that areas surrounded by an abundance of meat would be more susceptible to animal scavenging and transport if the individual is not interred immediately after death than would areas where meat is limited (Guthrie 1967).

The intrinsic factors of bone combine to create the palette on which extrinsic factors can act. The density, shape, size, anatomical position, and the individual's age, sex, and health at death act in unison with the extrinsic factors discussed in Section 1.3.2 to decompose and disintegrate tissue after death.

1.3.2 Extrinsic Factors Affecting Bone Preservation

Extrinsic factors – the physical, chemical, and biological agents of the burial environment (for example, soil and water characteristics) – are also highly influential in the destruction of bone. Preservation is greatly enhanced by rapid burial or in the absence of decay and scavenging (Martin 1999; Wilson 1988). Animal destruction (trampling, transportation, collection, redeposition of bone, chewing, fracturing, and consuming body parts) accounts for a large amount of the incomplete skeletal, poorly preserved material unearthed in the archaeological record (Boddington et al. 1987; Martin 1999; Stodder 2008; Wilson 1988). Archaeologically, the smaller, more fragile bones, such as he carpals, the patellae, the metacarpals, the nasal bones, and the zygomatics, are often missing due to animal scavenging, weathering processes, and poor recovery techniques (Martin 1999). This raises questions about the foundation of frequency analyses in skeletal research of cranial trauma as several cranial elements are important in the assessing the cause of trauma. If they are not present, trauma frequencies may be inaccurately represented and interpreted.

Depending on the predators and scavengers that inhabit the area near a deposition site, disarticulation by predators and scavengers can occur within minutes of death, with the less meaty portions often persisting longer (Haglund 1997). Teeth, jaws, and foot elements are more likely to survive scavenging, as they are quite dense and of relatively little nutritional value (Behrensmeyer 1991). Carcasses submerged in water disarticulate, usually within weeks or months. On land, transport accounts for the majority of the taphonomic loss (Martin 1999; Wilson 1988).

The burial environment is extremely important in the breakdown of osseous material. For example, temperature has a direct relationship with the rate of bone breakdown. As temperature increases the rate at which protein is degraded accelerates, thus increasing the rate of decomposition (Bello et al. 2006; Henderson 1987; Von Endt and Ortner 1984). The oxygen in an environment also affects the rate of decomposition, as bacteria need oxygen to work. The less oxygen in an environment the slower the rate at which bacteria will break down bone. Water leaches minerals from bone, thus breakdown will occur faster in wetter environments. Additionally, the acidity of the soil is important in the decomposition of bone. Bone will break down much faster in acidic environments than in pH neutral or slightly alkaline environments. Finally, high salinity will increase the speed of the decomposition of bone (Bello et al. 2006; Henderson 1987). Corrosion and pitting occurs in environments with high salinity, low temperatures, and active bioturbation (the movement of sediments by organisms), whereas bioerosion (caused by boring, grazing, or shelter seeking organisms) leads to dissolution of bone (Haglund and Sorg 2002).

Aquatic environments are as diverse as those seen on land. They differ in temperature, depth, salinity, oxygenation, and current. Disarticulation in water occurs most rapidly for the hands, feet, and wrists, as well as the mandible and the crania, followed by the bones of the lower legs and forearms. Understanding disarticulation patterns may aid in finding skeletal material that was deposited in water and may allow an excavator to comprehend why certain bones are missing in specific environments. Generally, water tends to carry lighter bones, such as the bones of the foot, the vertebrae, and the ribs away from the point of deposition (Behrensmeyer 1991). Taphonomic loss is most severe in shallow-water marine remains (Martin 1999; Wilson 1988). In marine environments, destruction accounts for more taphonomic loss than transportation (Martin 1999; Wilson 1988). High currents and surf, in addition to rocky-bottomed water environments, may lead to breaks along planes of weakness in bone, potentially simulating blunt force or sharp force trauma when bones impact the rocky bottoms or shores of the aquatic environment (Haglund and Sorg 2002).

Weathering, another extrinsic taphonomic process, tends to affect different bones than animal scavenging or transportation, and leads to cracking and the eventual disintegration of bones. Where the lighter bones and the bones with a higher nutrient density are more susceptible to animal scavenging, bones with a high proportion of cortical bone and natural lines of weakness (jaws, ribs, and limbs) tend to be more susceptible to weathering than other bones. Porous bones are affected more often by roots, invertebrates, and leaching (Behrensmeyer 1991). According to Behrensmeyer (1978, 1991), the teeth do not follow any consistent weathering patterns; she found slightly weathered mandibles with severely cracked teeth as well as highly weathered mandibles with uncracked teeth. Behrensmeyer (1978) describes six weathering stages ranging from bones that show no signs of cracking or flaking to bones that show disintegrating in situ (see also Ubelaker 1997; Lyman and Fox 1997). Weathering follows the same pattern in all environments; however, the time frame varies significantly in different climates. Weathering can occur for multiple reasons and can be found in different stages within the same bone (Behrensmeyer 1978, 1991; Lyman and Fox 1997; Ubelaker 1997).

Taphonomic processes greatly affect the amount of skeletal material preserved in the archaeological record and using the skeletal material available, no matter the level of preservation, is often a reality in skeletal analyses. That being said, it is important to acknowledge that the use of skeletal samples that vary in preservation and completeness, and therefore are lacking certain elements, can be problematic. As the discussion of taphonomy has illustrated, good preservation in the archaeological record is rare. Furthermore, differential preservation of skeletal material makes the standardization of skeletal recording methods difficult and potentially ineffective. Preservation is an important issue in skeletal research as it questions the basis of much osteological research. That is, it forces us to contemplate the notion that what we find in the skeletal record may not be an accurate representation of past lifestyles or events.

1.4 Preservation Requirements In the Literature

Cranial trauma research has long been an influential aspect of skeletal research; however, as of yet, no universally accepted standards have been created for recording and assessing cranial trauma in archaeological and contemporary skeletal populations. Despite the fact that several protocols exist for assessing and reporting craniofacial palaeotrauma (e.g., Buikstra and Ubelaker 1994; Walker 1997), researchers adapt them in order to fit their research, and while the adaptation is necessary in dealing with different levels of preservation and completeness it leads to results that are incomparable and potentially misleading (Judd 2002). Due to the varying levels of completeness found in the skeletal record it is imperative that standardized guidelines for the recording and analyzing cranial trauma be implemented (Buikstra and Ubelaker 1994; Judd 2002; Walker 1997, 2001). Using samples with varying levels of preservation and completeness leads to inaccuracy as certain elements are more likely to survive and become fossilized, whereas other elements such as the nasal bones and the maxillae are less likely to survive (Behrensmeyer 1978, 1991). As the nasal bones and maxillae can be instrumental in identifying violence, interpersonal violence levels may be reduced as a result of their absence in the archaeological record. The purpose of this research is to examine the potential biases that might be introduced in cranial trauma analyses using different completeness conditions and illustrate the need, as argued by Buikstra and Ubelaker (1994), Judd (2002), Lovell (1997), and Walker (1997), for standardization in this type of skeletal research. Standardization in skeletal analysis will allow for more accurate and meaningful conclusions to be drawn from the skeletal record and will simplify cross-population analyses. Poor preservation is, for the most part, a fact in skeletal research. It is important to have standards and guidelines in place in order to best deal with the issues presented by poorly preserved, incomplete skeletal material.

In early palaeotrauma studies only complete skulls were examined, as the aim was collection of skeletal material rather than research. Many of the early cranial trauma recording methods employed in the literature were adapted from methods used to record long bone trauma. In their study of long bone fractures from a site in Ohio, Lovejoy and Heiple (1981) use only complete bones, both with evidence of trauma and without, as they argue that the inclusion of fragmentary material may skew the data in favour of the more poorly preserved material. The use of only complete crania and complete cranial elements is quite common in the cranial trauma literature (Djuric et al. 2006; Jimenez-Brobeil et al. 2009; Smith 2003; Torres-Rouff and Junqueira 2006; Walker 1989), especially in samples where preservation is good; however, good preservation is not common in archaeological samples and the use of this method is not feasible in highly fragmentary, poorly preserved samples. The lack of standardization in the field makes cross-sample comparison difficult and potentially inaccurate.

Walker (1997) created a method for recording trauma in his examination of cranial trauma of several archaeological samples from Asia, Europe, England, and the United States. Walker (1997) noted that the failure to systematically record the number of individuals examined in a sample decreases the effectiveness of the study, as it makes cross-cultural sample comparison impossible. In order to minimize this type of error in the future he formulated a new way of recording trauma where the cranium is split into two sections, the crania (in which he includes the facial bones, the cranial vault, and the cranial base) and the nasal bones. Each section is scored as either 0.5 or 1.0 based on its completeness. Elements that are only partially preserved are considered partial individuals and thus only contribute 0.5 to the final tally whereas complete, undamaged crania and nasal bones are counted as 1.0. The sum of the scores is tallied and the fracture frequencies of the samples calculated using the sum found. Other than in his own study, Walker's (1997) method has not been used in the literature, with the exception of Alvrus (1999) who applied the method to a fracture analysis of a fragmentary Nubian sample. Alvrus (1999) excluded crania that were less than 50% complete but included a summary of the percent completeness of each skeletal element in order to illustrate the potential biases.

For the most part, the contemporary literature on cranial trauma can be categorized into four broad approaches: those that use only 100% complete crania and cranial elements, those that allow for mild taphonomic damage but require ≥ 75% completeness, those that allow for some fragmentation but require ≥ 25% completeness, and those that allow for severe fragmentation by using all of the elements present regardless of fragmentation. The level of completeness dictates the amount of skeletal material that can be used in palaeotrauma analysis; ease in collecting, recording, and assessing data are also often a factor in the amount of material that will be assessed.

1.4.1 100% Completeness Required

Studies that assess cranial trauma using only complete crania (Efran et al. 2009; Jimenez-Brobeil et al. 2009; Smith 2003; Torres-Rouff and Junqueira 2006; Walker 1989) allow for ease in evidence gathering and recording; however, they also run the risk of skewing the results in favour of the individuals or skeletal elements that are better preserved thereby making the data incomparable to samples that are less well preserved (Judd 2002). For the purpose of this study this category includes all crania that are 100% complete regardless of whether they are articulated or unarticulated.

The recording method that requires 100% completeness is employed by Torres-Rouff and Junqueira (2006). Using 682 crania from six sites from San Pedro de Atacama, the authors assessed the changing pattern of interpersonal violence with respect to environmental and cultural stability. The sites examined are from a range of periods: the Early Intermediate period (200 BC-600 AD), the Middle Horizon (AD 600-950), the Late Intermediate (AD 950-1450), and the Late Horizon (AD 1400-1532). The authors hypothesized that the trauma would parallel the evidence of cultural and environmental stability and instability found in the archaeological record. The evidence in the archaeological record suggested that the frequency of traumatic lesions would be low in the Early Intermediate period as the population was small and resources were readily available, would remain low in the Middle Horizon period as the environment was good and there was an abundance of resources available, would increase drastically in the Late Intermediate period as there was a drought during this period and, would, finally, decrease in the Late Horizon period as the environmental conditions improved and resource stresses decreased. The skeletal analysis at San Pedro de Atacama confirmed the hypotheses of the authors with the exception of the frequency of violence in the Middle Horizon period. The frequency of traumatic skeletal lesions increased during this period, which may have been due to an increase in population density even though this was a time of prosperity in the region. In this study the authors defended their use of only the 100% complete crania arguing that the preservation was excellent and therefore the exclusion of fragmentary material was not a problem; however, as Walker's (1989) study demonstrates, evidence of trauma may be lost with the exclusion of fragmentary material and as such the interpretation provided by such studies of the past may be skewed.

Walker's (1989) paper using only complete crania was done on a sample excavated in the early 19th century and as such the sample contained only complete, well-preserved skulls. Walker (1989) is one of few authors who explains the reasoning behind the use of only complete crania, arguing that, in accordance with the excavation techniques of the time, only the well-preserved, complete crania were saved. According to Walker (1989), the inclusion of only complete crania may have biased in the results of the study. Walker (1989) examined evidence of traumatic injuries on 744 crania from archaeological sites on the Northern Channel Island and the adjacent mainland coast in Southern California. He found that middle-aged males had the highest frequency of lesions, that lesions in young individuals were rare, that the frontal and parietal bones were the most commonly fractured and the most commonly impacted during interpersonal violence, and that the residents of the island sites had a higher frequency of trauma. According to Walker (1989), the higher frequency of trauma on island sites could be attributed to increased resource stress on the island relative to the mainland. He recognized that there are several explanations for the trauma in the Southern Californian sites including accidents, interpersonal violence or warfare, and self-inflicted injury.

Walker (1989) argued that warfare and interpersonal violence are likely in this case as many of the wounds are the same relative size and shape indicating violence with a common or ritualistic weapon, although he does state that self-inflicted violence could also have resulted in some of the wounds seen in the sample. There are several ethnographic examples of self-inflicted trauma from these areas, mainly seen on the frontal bones where people have cut themselves in penance or for healing purposes. It is also important to note that the parietal and frontal bones are relatively thin and, as such, may not survive the process from deposition to discovery, which, as they are the most commonly fractured sites in the sample, may cause the actual fracture frequency to be under-represented.

Djuric et al. (2006) follow similar methods to the research discussed above. Their research analyzes only complete cranial bone elements but allowing elements of the skull to be missing. The authors documented and interpreted fractures from a sample of Late Medieval Serbians, focusing on the type of fracture and the mechanism of injury. The human remains of 1,071 individuals from six rural Late Medieval to Early Modern church cemeteries (11^{th}-19^{th} century AD) in Serbia were examined. Djuric and colleagues (2006) concluded that, based on the pattern of the fractures in the sample, the individuals examined were not victims of interpersonal violence and that the fractures were related to activity. Depending on the elements missing from the sample, which were not specified by the authors, the sample may over- or under-represent the frequency of skeletal trauma, as facial fractures are often interpreted as relating to interpersonal violence (Hershkovitz et al. 1996) and yet are also fragile and often missing in the archaeological record (Bello and Andrews 2006; Galloway et al.1997; Willey et al. 1997).

If the fragmentary material is ignored the amount of trauma presented may seem higher or lower than the actual rate. This could be especially prevalent in populations where burials differ based on social standing and/or sex. Individuals from lower classes may not have been given the same burials as those of higher standing which may lead to differential preservation and consequently inaccurate trauma frequencies. Additionally, this exclusion of highly fragmentary material in cranial trauma analysis may bias the research against any cranial trauma that severely damages the crania. This type of trauma may occur as a result of crushing blunt force trauma. The combination of radial and concentric fracture patterns, a common result of injuries caused by a blow to the head with a large blunt object or fall, can cause the crania to fracture into small pieces (Aufderheide and Rodriguez-Martin 1998; Bennike 2008, Berryman and Symes 1998; Byers 2008). This type of trauma can also result from gunshot wound (Bennike 2008; Berryman and Symes 1998; Byers 2008) and, in more contemporary populations, high intensity trauma, such as car crashes (Berryman and Symes 1998). This becomes more relevant when taphonomic issues are taken into consideration. As discussed in section 1.3 on taphonomy, smaller fragments disintegrate more rapidly than larger fragments and whole bones (Bello et al. 2006; Martin 1999; Von Endt and Ortner 1984).

1.4.2 At least 75% Completeness Required

Buikstra and Ubelaker (1994) consider cranial elements to be complete if ≥ 75% of the bone is present in palaeotrauma studies. In an attempt to avoid problems associated with including only complete material these guidelines have been implemented by several authors (e.g., Brasili et al. 2004; Judd 2004, 2006). Judd's (2004, 2006) work follows the Buikstra and Ubelaker (1994) guidelines, advocating for the inclusion of skeletal elements only if they are ≥ 75% complete.

Judd (2006) hypothesized that the nonlethal interpersonal violence related injuries would be similar between rural and urban samples of the same culture but that the accident-related injuries would be higher among the rural sample. Using all skull elements that were ≥ 75% complete and all long bone elements that were ≥ 80% complete, Judd analyzed the antemortem trauma on 55 adult skeletons from a rural Kerma sample and 223 skeletons from an urban Kerma sample. The results illustrated that females from the rural and urban samples were equally vulnerable to interpersonal violence regardless of their social standing and that male skeletons from the rural sample exhibited a higher number of indirect-force trauma that, according to Judd (2002), can be explained by their participation in more physically demanding activities. As hypothesized, the rural and urban samples showed similar frequencies of lesions associated with interpersonal violence (cranial trauma, parry fractures, and facial injuries) and the rural sample had a significantly higher frequency of accident related trauma. While including mostly complete material may allow for a degree of standardization, ignoring certain fragmentary elements may cause the trauma frequency to be underestimated and overlooks any fractures that may be present in fragmentary bone (Judd 2002). The most frequently fractured bones in the Kerma sample were the frontal and the parietal bones. Since the parietal and anterior portion of the frontal bones are thin relative to the dense occipital and petrous portion of the temporal, they may not be represented or may be highly fragmented in the skeletal sample that has undergone significant or long-term taphonomic processes and, thus, fracture evidence may be lost.

1.4.3 At least 25% completeness required

Certain studies state that due to the fragmentary nature of the samples being studied, all of the material should be analyzed; however in some cases severely fragmentary material is excluded as gaining information from it is seen as too difficult. Williamson et al. (2003), on a highly fragmentary sample from Ohio, studied the interpersonal violence between 18th century Native Americans and Europeans. The study was undertaken with the intention of proving or disproving witness accounts of the 1779 ambush on British soldiers by the First Nations people of the area. The evidence found in the study supported the witness accounts of scalping but accounts that the garrison was fired upon were not substantiated. While Williamson et al. (2003) do not specify a minimum preservation requirement for the inclusion of fragmentary material in their sample, they state that there were skulls that were not complete enough for examination. For the purpose of my research a separate category requiring ≥ 25% completeness was created in order to investigate the effect that including more fragmentary material would have on trauma frequency analyses.

1.4.4 The Inclusion of All Available Fragments

Using all elements present, as in the studies by Efran et al. (2009), Jordana et al. (2009), Jurmain and Bellifemine (1997), Kanz and Grossschmidt (2006), Meyer et al. (2009), Smith (2003), and Wilkinson (1997), eliminates much of the problem associated with overlooked trauma in archaeological remains, however, may make cross-population analysis impossible as different methods for recording trauma may lead to different trauma frequency results. While using all the available material may seem like the obvious solution to countering the under- or overestimation of skeletal trauma it is important to understand that, as the current research will illustrate, allowing the inclusion of a severely fragmented, incomplete skeletal material in any type of frequency analysis may also skew the final data. A severely fragmented, incomplete skeleton must still be counted as an individual and, depending on the portions of bone that are missing, traumatic lesions may be excluded, thus increasing the number of individuals while leaving the trauma count the same, creating a situation where the trauma frequency will be understated. Comparing skeletal samples with varying levels of preservation and completeness may lead to inaccurate results if one method over-represents the level of trauma while another under-represents it. The skeletal remains used in the following studies are highly fragmentary. The authors were, therefore, unable to accurately determine the number of individuals present at the site making fracture frequency analysis by individual unfeasible.

The cranial trauma literature analyzing all of the material present can be divided into two categories: those who know the number of individuals represented by the sample and those where the number of individuals represented is unknown. When the number of individuals is known or the minimum number of individuals (MNI) can be determined with relative certainty, frequency analysis can be undertaken. However, as the following study will illustrate, increased fragmentation may lead to the misrepresentation of trauma. The majority of studies that analyze all of the material available have a known MNI (see Efran et al. 2009; Jordana et al. 2009; Jurmain and Bellifemine 1997; Meyer et al. 2009). Jordana et al. (2009) analyzed the skeletal remains of Pazyryk warriors from two sites in the Bayan-Olgiy province of Mongolia. The aim of the analysis was to substantiate Herodotus' ancient historical accounts of the violent and warlike nature of the Pazyryk warriors. The excavation of the two sites unearthed 10 individuals: seven males, one female, and two children. The authors found 14 traumatic injuries on the remains, 12 of which, present on six individuals (86%), were interpreted as the result of interpersonal violence. Additionally, five of the ten individuals (50%) showed evidence indicating a violent death. The authors conclude that, despite the small skeletal sample, the descriptions of the Pazyryk warriors were corroborated (Jordana et al. 2009).

In studies where the number of individuals is not known or where fragmentation makes finding the MNI difficult, frequency analysis should be avoided as the likelihood of accurate results is low. Wilkinson (1997) describes evidence of interpersonal violence from a prehistoric cemetery at the Late Woodland site of Rivière Aux Vaux (AD 1000-1300). The skeletal material examined in this study included the very incomplete remains of between 220 and 350 individuals interred in 145 graves. Due to the fragmentary nature of the remains, age and sex were estimated using a combination of several different forensic techniques, and trauma was assessed on every available bone. The author found that females showed a significantly higher frequency of cranial trauma and that the parietal bones were the most frequently fractured, followed by the frontal bones. According to Wilkinson (1997) the high frequency of traumatic fractures and depressions on the skulls would most likely have been caused by the abduction or attempted abduction of women by neighboring populations. There is evidence from other populations in the area that women were routinely seized from one population and integrated into another. While interpretation can be dangerous as there is no way of concluding with any certainty whether an action occurred, Wilkinson (1997) describes several scenarios that could have resulted in the cranial trauma seen on the Rivière Aux Vaux sample. The notion of female warriors was discussed; the author dismissed this theory concluding that abduction was the most probable. The Wilkinson (1997) article is an example of why fracture frequencies may be inaccurate due to the fragmentary nature of the skeletal material available. The prevalence of trauma per individual and the population frequency would vary considerably depending on whether the authors used 220 or 350 as the number of individuals represented by the study and a misrepresentation of the frequency of trauma is also likely.

Kanz and Grossschmidt (2006) analyzed a mass gladiator grave and found that the cranial trauma on the gladiator sample was present solely on the frontal and parietal bones. Therefore, as discussed by Walker (1989) and Judd (2006), the trauma may be under-represented due to post-depositional factors.

White's (1992) analysis of the skeletal material from the Mancos 5MTUMR-2346 assemblage from southern Colorado provides an excellent example of an analysis where the entire sample was included in the analysis. The MNI of the assemblage was calculated; however, due to the fragmentary nature of the assemblage (only 34.2% of the specimens were identified), frequency calculations were undertaken with caution. White (1992) relies heavily on description and is careful to state the biases present. White (1992) gives a detailed description of the skeletal material including the fractures present, evidence of scalping, and postmortem taphonomic damage. Considering the highly fragmentary nature of many of the archaeological assemblages excavated today, description may be more informative than attempted frequency calculations. Attempting fracture frequency calculations on assemblages where the number of individuals is unknown could bias and misinterpret the frequency of trauma represented.

In order to understand the problems associated with the loss of information due to issues surrounding preservation and completeness and the inclusion or exclusion of material, this research will examine the differences in trauma frequencies when different methods of recording trauma based on varying levels of cranial completeness are employed. The proposed research will assess cranial trauma frequencies using several different methods of recording and evaluating cranial trauma that allow for varying levels of completeness in order to discover whether the cranial completeness affects the frequency of trauma found.

1.5 Preservation and Osteological Research

In order to test whether preservation affects trauma analysis results Judd (2002) tested five methods for recording long bone trauma in order to observe whether or not the use of different recording techniques led to statistically meaningful differences in the frequency of fractures. This article formed the foundation of the current research. Judd's (2002) study involved 55 individuals from the Kerma Period (2500-1750 BC) of ancient Nubia. According to Judd (2002), although several protocols exist for reporting palaeotrauma, researchers adapt protocols in order to fit their research and, while the adaptation is necessary in dealing with different levels of preservation and completeness, it leads to potentially misleading results that are incomparable to data from other samples. Judd (2002) analyzed five different recording techniques. She examined several long bones, recording them multiple times using different preservation and completeness criteria. Each category was divided into two subsections: subsection (a) and subsection (b). Subsection (a) laid out the preservation requirement for the recording method and subsection (b) combined all of the traumatically fractured bones with the requirements of (a).

The categories included:

1 – (a) all of the undamaged, complete bones, (b) all undamaged bone (1a) and all other fractured bones (no matter the level of preservation);

2 – (a) bones where all five segments of bone were present (the diaphysis was separated into three segments: proximal, middle, and distal, and the two epiphyses) but minor taphonomic damage was tolerated, (b) all bone where the five segments were present (2a) and all other fractured bone (no matter the level of preservation);

3 – (a) all of the bones with slight taphonomic damage and allowed one segment of the bone to be absent, (b) all bones that had at least four of the five segments preserved (3a) and all other traumatized bone (no matter the level of preservation);

4 – (a) bones exhibiting severe taphonomic damage and allowed for two of the five segments of the bone to be absent, (b) all bones that that possessed at least three of the five segments preserved (4a) and all other traumatized bone (no matter the level of preservation);

5 – a tally of each segment type for its respective bone element (segment frequency = segments with fractures/segments observed).

Judd (2002) found that each method possessed both advantages and disadvantages depending on the preservation level of each bone. While statistically significant differences were not observed between the different recording methods, when the recording method employed studied only undamaged bone as in Method 1a five of the partial bones excluded from the study showed accident-associated fractures causing the prevalence of violence-related fractures to seem higher. Thus Judd argues that the choice of recording method should be based on the overall preservation of the skeletal material. The conclusions that Judd (2002) arrived at reinforce the possibility that the skeletal record provides a biased representation of past lifestyles or events. Unfortunately, Judd is not able to propose a solution to the problem as preservation varies drastically from site to site and from population to population.

1.6 Research Goals

The aim of this research is to assess differences in cranial trauma frequencies when the criteria for the level of completeness required for inclusion of cranial material in an analysis differs. Studies in the cranial palaeotrauma literature use various recording techniques in order to minimize problems associated with preservation of individual samples; however, the use of different recording techniques in studies may lead to potentially inaccurate or incomparable results (Judd 2002; Lovell 1997; Walker 1997). Cranial and facial lesions are often used as indicators of interpersonal violence, especially fractures of the nasal, zygomatic, frontal, and parietal bones (Brasili et al. 2004; Djuric et al. 2006; Efran et al. 2009; Jimenez-Brobeil et al. 2009; Judd 2004, 2006; Jurmain 1999; Kanz and Grossschmidt 2006; Smith 2003; Torres-Rouff and Junqueira 2006; Walker 1989, 1997; Wilkinson 1997; Williamson et al. 2003). However, it is important to note that facial fractures can occur accidentally (Jurmain 1999; Walker 1997, 1989). As such it is important to make the interpretations as accurate as possible and to avoid the over- or under-interpretation of trauma. The research examines whether poor preservation and completeness lead to the over- or under-interpretation of cranial trauma.

1.6.1 Medieval and Post-Medieval England

The current study was undertaken on 75 individuals from two British cemeteries, the medieval cemetery of the Augustinian priory of St. Mary Merton and the post-medieval lower cemetery of St. Bride's Church. The Medieval period in England ranges from 1066 to 1547, from the Norman Conquest until the Reformation. Medieval England is described as a time of increasing population density and is often depicted as a time when the standard of living decreased and morbidity increased (Roberts and Cox 2003). The medieval period began with a trend toward improved living conditions and life expectancy; as the period evolved and the size and population density of urban centers increased, quality of life decreased and illness became rampant; diseases such as leprosy and the Black Death were introduced (Roberts and Cox 2003). As the period progressed social stratification became more apparent, especially in the urban context. Housing in the medieval period ranged from multi-level, multi-roomed houses in the wealthier areas to single-room dwellings without water or waste management systems on the poorer end of the scale (Museum of London Group 2008; Roberts and Cox 2003).

With the decline in the standard of living, violence, both legalized and not, became increasingly central to British society. Judicial sentences were often on the harsher side, as harsh punishment was believed to be more of a deterrent. Mutilation was often used as a form of punishment in medieval England. The eyes, nose, hands, feet, and testicles were removed as punishment for petty crime, such as pick pocketing. While wife-beating was not legally approved of in the medieval period, it was often seen as normal. A wife was akin to property, much as oxen, and as such could be treated similarly (MyGlynn 2008). On a grander scale, the medieval period as a whole saw a substantial amount of warfare, from battles to skirmishes over land claims (Roberts and Cox 2003).

Accidental trauma increased during the medieval period paralleling the trend towards industrialization in Britain. Many of the industries of the medieval period were dangerous and involved high personal risk. Fracture rates and repetitive strain injuries increased during the industrialization of Britain (Roberts and Cox 2003).

The post-medieval period in England dates from 1547 to the present day. During the post-medieval period Britain saw rapid population growth, industrialization, and urban expansion. As industrialization evolved, individuals from rural populations flocked to the urban centers in search of work. Overcrowding and poor sanitation became a problem and, as a result, infectious diseases proliferated. With urban expansion came waste management problems. Large cities such as London became divided by socio-economic status with an area for the wealthier classes and one for the poorer workers. And, as in the medieval period, the living conditions of the two halves of society differed greatly (Museum of London Group 2008; Roberts and Cox 2003). As in the medieval period, harsh punishment for even minor offences was the norm. Public hangings were common during the post-medieval period. Basilar skull fractures, skeletal trauma often seen in association with hanging victims, are evident in the sample from St. Bride's lower cemetery (Waldron 1996). The post-medieval period was also a time of warfare, in which Britain engaged in several wars with other European powers (Roberts and Cox 2003).

1.6.2 Hypotheses

Using the medieval and post-medieval material from the two British cemeteries, the overarching hypothesis that important information is lost and the frequency of trauma is under-represented when fragmentary material is excluded from the analysis was tested. Thus, the hypotheses tested in this study include:

Hypothesis 1: the overall frequency of trauma increases when less complete cranial elements are included in the analysis.

Hypothesis 2: the frequency of lesions per individual increases as more fragmentary material is included.

Hypothesis 3: the number of lesions per injured individual increases as fragmentary material is included.

Hypothesis 4: the frequency of individuals with more than one injury increases as more fragmentary material is included

Chapter 2: Materials and Methods

2.1 The Research Samples

Two samples were examined for cranial trauma in the current study. The samples come from the medieval cemetery of the Augustinian Priory of St. Mary Merton and the post-medieval lower cemetery of St. Bride's Church, in the United Kingdom, housed at the Centre of Human Bioarchaeology at the Museum of London. The samples were ideal for the project as they met the completeness criterion of mixed fragmentation. The samples were chosen specifically for their range of highly fragmentary, poorly preserved cranial material to well preserved, complete cranial material. The samples are comprised of five females and 25 males from the medieval cemetery from the site of the Augustinian Priory of St. Mary Merton (n = 30) and 12 females and 33 males from the post-medieval lower cemetery of St. Bride's churchyard (n = 45). In both cemeteries the individuals were buried individually; comingling was not an issue. The sample consists of all the crania that showed signs of trauma (n=44) and 31 other skulls chosen at random to complete the sample of 75 individuals. The sample was created to artificially mirror an archaeological sample with a variety of complete and fragmentary material, with an emphasis on the individuals with traumatic lesions, by combining the 75 individuals from the two samples. The two samples were combined in order to create one sample that was large enough, with a high enough incidence of trauma, to analyze.

2.1.1 The Augustinian Priory of St. Mary Merton

The Department of Greater London Archaeology excavated the cemetery of the Augustinian Priory St. Mary Merton between 1976 and 1990, unearthing the skeletal remains of 738 individuals (Mikulski 2007; Miller and Saxby 2007). The St. Mary Merton Church, founded in

1140, was one of the earliest Augustinian priories in England until it was demolished in 1540 (Waldron 1985), although the cemetery was in use between 1117 and 1598 (Mikulski 2007). The individuals buried at St. Mary Merton are believed to be a mixture of lay and clerical people in the northern cemetery, canons and older privileged individuals in the south-east cemetery, and higher status individuals including women and children from a wealthier background in the inner cemetery (Miller and Saxby 2007).

The Merton Priory sample was included in the research as it presented a mixture of well preserved and poorly preserved skeletal material. After the demolition of the Church in 1540 the site was reused several times, first in the late eighteenth century when a trench for bleaching calico was dug through the site and then later in the nineteenth century when part of the site was used for dyeing industrial materials (Waldron 1985). Finally, in 1868 a railway line was built across the site. It was removed in 1975 before the beginning of the excavation (Waldron 1985). The multiple disturbances at the site of the Merton Priory are a probable reason for the range of fragmentary to complete skeletal material. Of the two cemeteries examined in this study the Merton Priory sample was the more poorly preserved.

2.1.2 The Lower Cemetery of the St. Bride's Church

The Department of Urban Archaeology and the Museum of London Archaeology Service excavated the lower cemetery of St. Bride's Church in 1990. The excavation unearthed the skeletal remains of 606 individuals (Kausmally 2008). The entire cemetery at St. Bride's Church dates to between the seventeenth and nineteenth centuries; however, as an overflow cemetery, the lower cemetery is believed to have been in use mostly after the eighteenth century

(Kausmally 2008). The majority of the skeletons (83%) buried in the lower cemetery have been dated to between 1800 and 1852 (Knüsel and Bowman 1996; Steele 1962).

The St. Bride's Lower sample was ideal for this study as the cemetery presented a relatively high percentage of individuals with trauma (especially nasal fractures) and a range of fragmentation. The Great Fire of London destroyed much of the city in 1666 and many of the buildings, including St. Bride's Church, required rebuilding (Museum of London 2008; Steele 1962). However, the skeletal material from St. Bride's Lower cemetery was more intact than that from St. Mary Merton, thus offsetting the Merton Priory sample and creating a sample that had a mixture of all levels of completeness. The majority of the individuals buried in the lower cemetery are individuals from the Bridewell workhouse and the Fleet Prison. These individuals were of low socioeconomic status, even compared to those buried in the main cemetery (Kausmally 2008). Information about the cemetery is known from church records. The church kept documentation of the cause of death, age, and sex of the individuals buried in the cemetery; however, as a cemetery for the poor, coffin plates were rarely erected and thus the information on the records does not relate to specific individuals (Kausmally 2008).

2.2 Data Collection

2.2.1 Cranial Completeness Data Collection Method

In order to test the hypotheses, the skeletal material was examined using non-invasive, non-destructive, visual techniques. The cranial material was examined as a unit and by skeletal element. The cranial elements incorporated in the analysis include frontal bones, parietals, temporals, occipitals, nasal bones, maxillae, zygomatics, and mandibles. The sphenoid, ethmoid, palatines, and vomer were excluded from the study. As bones of the interior of the skull they are infrequently fractured and, as thinner, more fragile bone, are rarely preserved in the archaeological record (Galloway et al. 1997; Willey et al. 1997). Each skeletal element was analyzed for the level of completeness and was recorded according to the standard guidelines (Buikstra and Ubelaker 1994) as well preserved (≥ 75% of the bone is present), partial (between 25% and <75% is present), or poorly preserved (< 25% is present). The percent completeness was estimated as an exact percent would be difficult to quantify, especially for severely fragmented material. A fourth category was created to differentiate 100% complete skeletal elements from those that are ≥ 75% complete. The categories were recorded separately in order to account for the recording techniques that use only complete bone elements.

The completeness data were recorded on a Cranial Completeness Recording Spreadsheet. The Cranial Completeness Recording Spreadsheet is made up of multiple columns, each for a specific bone or the crania. Each row represents an individual. The archaeological context number was recorded in column 1. During data collection, each bone was rated from 0 - 4; 0 denotes a missing bone, 1- a bone that is less than 25% complete, 2- a bone that is between 25 and <75% complete, 3- a bone that is between 75 and <100% complete, and 4- a bone that is 100% complete. Bones were recorded based on completeness; therefore, bones were recorded, regardless of level of fragmentation, based on the amount of the bone present. Crania were scored as either complete (1) or incomplete (0). For the Data Collection Template for Cranial Completeness see appendix A.

2.2.2 Presence or Absence of Lesions Data Collection Method

All antemortem and perimortem lesions (sharp force trauma and blunt force trauma: both healed and unhealed) that were non-pathological in nature were assessed for location, side, size, and shape. As the cause of lesions is often impossible to identify, lesions were included in the sample unless they were obviously of pathological origin, rather than traumatic. As such, the assumption is being made that all of the lesions included in the study were caused by trauma (either interpersonal or accidental), thus it is important to note that the frequency of trauma being used in this study is inclusive and may over-represent the actual trauma frequency of the tested samples. For the trauma criteria see appendix D.

The lesion data were recorded on a Presence or Absence of Lesion Spreadsheet, again, comprised of multiple columns, each for a specific bone or the cranium. Each row represents an individual. The archaeological context number is recorded in column 1. Each lesion was recorded as 0, Absent, or 1, Present, in the column for the bone on which the lesion occurs. A recording of 2 or greater denotes the number of lesions present on each skeletal element. For each individual, the size and shape of the lesion was noted as well as its location. The shape, size, and side of the lesion were documented (columns 2-5 of the Presence or Absence of Lesions Recording Spreadsheet) and described. In cases where description was difficult the lesion was sketched onto the Skull Recording Form (For the template see appendix C). The size of each lesion was measured using electronic calipers. Linear lesions were measured from one end to the other, while the maximum length of the circular and depressed lesions or cutmarks and healing calluses were measure both widthwise and lengthwise. The left- and right-sided elements (parietals, temporals, zygomatics, maxillae, and nasals) were recorded and analyzed separately. For the Presence or Absence of Lesions Data Recording Sheet template see Appendix B.

The location of the cranial lesion was then noted on a skull recording form, which was adapted from Buikstra and Ubelaker's (1994) *Standards for the Data Collection from Human*

Skeletal Remains. The form was created by combining 4 views of the skull (anterior, posterior, and right and left lateral views), making the lesions and completeness of each cranium simple to sketch. For the Skull Recording Form template see Appendix C.

2.2.3 Data Analysis Method

Modifying the methodology put forward by Judd (2002), the data were documented in multiple ways.

1: Data were recorded on all 100% complete crania.

A tally of all the 100% complete crania was made and the lesions present were recorded as absent (0), present (1), or the number of lesions present if more than one (≥ 2) as well as according to size, shape, and side.

2: Data were recorded on all incomplete crania.

A tally of all the incomplete crania was made and the lesions present were recorded as absent (0), present (1), or the number of lesions present if more than one (≥ 2) as well as according to size, shape, and side.

3: Data were recorded on all 100% complete undamaged bone by skeletal elements.

A tally of all the 100% complete skeletal elements was made and the lesions present were recorded as absent (0), present (1), or the number of lesions present if more than one (≥ 2) as well as according to size, shape, and side.

3: Data were recorded for all bones that are between 75 and <100% complete.

A tally of all the bones that are ≥ 75% complete skeletal elements was made and the lesions present were recorded as absent (0), present (1), the number of lesions present if more than one (≥ 2) as well as according to size, shape, and side.

4: Data were recorded for all bone that is between 25 and <75% complete.

A tally of all the bones that were ≥ 25% complete skeletal elements was made and the lesions present were recorded as absent (0), present (1), or the number of lesions present if more than one (≥ 2) as well as according to size, shape, and side.

5: Data were recorded for all bone and bone fragments that are less than 25% complete.

A tally of all of the skeletal elements was made and the lesions present were recorded as absent (0), present (1), or the number of lesions present if more than one (≥ 2) as well as according to size, shape, and side.

The data were analyzed in two separate ways. Initially, the data were combined into the four inclusive categories (the entire sample, ≥ 25% complete, ≥ 75% complete, and 100% complete). The frequencies of skeletal trauma were calculated and compared for each skeletal element (frontals, parietals, temporals, occipitals, zygomatics, maxillae, nasals, and mandibles) as well as complete crania among the recording method categories. For the purpose of the analysis, each bone element analyzed was used to represent the individual being tested; therefore, the terms bone element and individual are used interchangeably. The following were calculated:

1: $$\text{Frequency of lesions by element} = \frac{\text{Number lesions on Element A}}{\text{Number of fragments of Elements A}} \times 100$$

2: $$\text{Frequency of individuals with lesions} = \frac{\text{Fragments of Element A with Lesions}}{\text{Number of Fragments of Element A}} \times 100$$

3: $$\text{Number of lesions per injured bone element} = \frac{\text{Number of Lesions}}{\text{Number of Fragments with Lesions}}$$

4: $$\text{Frequency with multiple lesions} = \frac{\text{Fragments of Element A with >1 lesion}}{\text{Number of Fragments of Element A}} \times 100$$

For the purpose of this study, the data analyzed in this way will be referred to as the inclusive data and will be described descriptively. In order for Fisher's exact tests to be applied to a sample, the categories being analyzed must be independent. The inclusive categories created in this research are nested within one another. For example, the individuals that fall into the 100% complete category are also ≥ 75% complete. The individuals that are ≥ 75% complete are also ≥ 25% complete and so on. As the inclusive samples are not independent, they cannot be analyzed statistically. Comparisons were made for each sampling method by bone element and level of completeness. The results for each method of trauma recording were compared in order to assess the frequency difference when elements with varying levels of preservation are included.

As stated earlier, it is hypothesized that as more fragmentary material is included:

- a higher frequency of traumatic lesions would be observed,
- the frequency of lesions per individual would increase,
- the number of lesions per injured individual would increase,
- the frequency of individuals with more than one lesion would increase.

2.3 Data Analysis

2.3.1 Data Recording and Storage

During the research, data were recorded in a coil notebook and on data recording template sheets (Appendix A, B, and C). After returning from London the data were entered into Microsoft Excel (Microsoft 2008) and was subsequently analyzed using descriptive statistical analysis techniques and SAS version 4.2 (SAS 2008) for statistical analysis.

2.3.2 Statistical Data Analysis

As the skeletal material included in the frequency of traumatic lesion calculations was not independent, descriptive statistics were applied. The inclusive categories were described in detail, outlining where lesions were excluded and where the inclusion of highly fragmentary material lowered the trauma frequency.

In order to test statistical significance for the frequencies, the samples were recorded again independently. The data recorded in this way will be referred to as independent data. The frequency of individuals with lesions as well as the frequency of individuals with multiple lesions was recalculated using the recorded categories (<25%, 25 - <75%, 75 - <100%, and 100%) and analyzed inferentially.

Fisher's exact test was applied to the independent samples in order to deduce whether there are any statistically significant differences between the frequencies of individuals with traumatic lesions (both single and multiple) in each completeness category. The Fisher's exact test is used to examine the relationship between two discrete variables and thus evaluates whether an observed frequency (in this case the frequency of individuals with one or more traumatic lesions) in one completeness category significantly differs from that of another completeness category (Elliot and Morrell 2010; Garner 2005; Madrigal 1995). The analysis in this case tested whether the frequency of traumatic lesions differs with relation to bone completeness. This analysis allowed for an evaluation of the most representative way of analyzing skeletal trauma to be undertaken.

Chapter 3: Results

3.1 Completeness

The Museum of London specimens were chosen on the basis of their completeness. The sample analyzed in this study was artificially created by selecting skeletal material that fit the completeness criteria. The 75 crania were chosen to represent a wide range of fragmentation, from fragmentary to complete. The overall cranial completeness ranged from severely fragmentary to 100% complete between the individuals chosen from the two samples, St. Mary Merton and St. Bride's lower. In order to quantify the number of lesions per bone with respect to completeness, each bone element was initially categorized by completeness. Table 3.1 outlines the preservation of the crania and Table 3.2 summarizes the preservation by skeletal element from the two samples included in this study.

Of the 75 individual crania analyzed, only ten crania were 100% complete. It is also important to note that four skulls, scored as incomplete, exhibited only minor damage, such as a broken mastoid process, slight ectocranial damage, or damaged nasal bones. In a trauma analysis study requiring completeness these four individuals would most likely have been included in the sample but, for the purpose of this study, they were scored as incomplete. The decision to score the crania this way was made because, for the purposes of this study, fixed categories had to be set. The category set for the complete crania was 100% completeness. Using this criterion any crania less than 100% complete had to be scored as incomplete.

As with the crania there were five individual cranial bones that exhibited only minor damage and would most likely have been included as complete bones in a trauma analysis study; for the purpose of this study were entered into the well preserved (75 - <100%) category. These bones included two frontal bones, a right parietal bone, and two left temporal bones. Any fragments that were too small to identify to a skeletal element were excluded.

Table 3.1 - 100% Complete versus Incomplete Crania.

Completeness level	Number of crania
100% Complete	10
Incomplete	65

Table 3.2 - Completeness of the skeletal elements.

Skeletal element	Poorly preserved (<25%)	Partial (25 - <75%)	Well preserved (75 - <100%)	Complete (100%)
Frontal	8	12	20	30
Parietal (R)	3	14	17	36
Parietal (L)	4	15	16	35
Temporal (R)	6	7	20	36
Temporal (L)	2	10	27	30
Zygomatic (R)	1	5	2	42
Zygomatic (L)	2	2	5	43
Maxilla (R)	16	11	8	21
Maxilla (L)	16	16	4	19
Nasal (R)	0	9	5	21
Nasal (L)	1	7	5	21
Occipital	1	17	27	25
Mandible	1	12	26	29

3.2 Presence/Absence of Lesions

Traumatic lesions were relatively abundant on the cranial material of the 75 individuals sampled. Table 3.3 presents the presence/absence of lesion data for the crania while Table 3.4 outlines the presence/absence of lesions data for each skeletal element based on the independent data completeness categories.

Table 3.3 - Presence/Absence of lesions on the crania.

Cranial Preservation	Total number of lesions	Individuals with 1 lesion	Individuals with multiple lesions	Individuals with no lesions	Total Individuals
Complete Crania	10	6	2	2	10
Incomplete Crania	77	23	10	32	65

Table 3.4 - Presence/Absence of lesions by skeletal element and completeness.

Skeletal Element	Total number of lesions	Individuals with 1 lesion	Individuals with multiple lesions	Individuals with no lesions	Total Individuals
Frontal (100%)	3	1	1	28	30
Frontal (75 - <100%)	14	1	3	15	19
Frontal (25 - <75%)	1	1	0	11	12
Frontal (<25%)	0	0	0	9	9
Right Parietal (100%)	6	4	1	31	36
Right Parietal (75 - <100%)	2	2	0	15	17
Right Parietal (25 - <75%)	4	0	2	12	14
Right Parietal (<25%)	0	0	0	3	3
Left Parietal (100%)	5	3	1	31	35
Left Parietal (75 - <100%)	2	2	0	14	16
Left Parietal (25 - <75%)	3	3	0	12	15
Left Parietal (<25%)	1	1	0	3	4
Right Temporal (100%)	2	2	0	33	35
Right Temporal (75 - <100%)	0	0	0	21	21

Right Temporal (25 - <75%)	0	0	0	7	7
Right Temporal (<25%)	0	0	0	6	6
Left Temporal (100%)	0	0	0	30	30
Left Temporal (75 - <100%)	2	0	1	26	27
Left Temporal (25 - <75%)	1	1	0	9	10
Left Temporal (<25%)	0	0	0	2	2
R Zygomatic (100%)	0	0	0	42	42
R Zygomatic (75 - <100%)	0	0	0	2	2
R Zygomatic (25 - <75%)	0	0	0	5	5
R Zygomatic (<25%)	0	0	0	1	1
Left Zygomatic (100%)	0	0	0	42	42
Left Zygomatic (75 - <100%)	0	0	0	5	5
Left Zygomatic (25 - <75%)	0	0	0	2	2
Left Zygomatic (<25%)	0	0	0	2	2
Right Maxilla (100%)	1	1	0	19	20
Right Maxilla (75 - <100%)	0	0	0	8	8
Right Maxilla (25 - <75%)	0	0	0	11	11
Right Maxilla (<25%)	0	0	0	16	16
Left Maxilla (100%)	1	1	0	18	19
Left Maxilla (75 - <100%)	0	0	0	4	4
Left Maxilla (25 - <75%)	0	0	0	16	16
Left Maxilla (<25%)	0	0	0	16	16
Right Nasal (100%)	13	13	0	8	21
Right Nasal (75 - <100%)	1	1	0	4	5
Right Nasal (25 - <75%)	1	1	0	8	9
Right Nasal (<25%)	0	0	0	0	0
Left Nasal (100%)	12	12	0	9	21
Left Nasal (75 - <100%)	1	1	0	4	5
Left Nasal (25 - <75%)	1	1	0	6	7
Left Nasal (<25%)	0	0	0	1	1
Mandible (100%)	6	1	1	26	28
Mandible (75 - <100%)	1	1	0	26	27
Mandible (25 - <75%)	0	0	0	12	12
Mandible (<25%)	0	0	0	1	1
Occipital (100%)	18	1	2	22	25
Occipital (75 - <100%)	0	0	0	27	27
Occipital (25 - <75%)	3	3	0	14	17
Occipital (<25%)	0	0	0	1	1

3.3 Data Summary by Completeness and Bone Element

The following tables (Table 3.5 – 3.12) summarize the data for the frequency of traumatic lesions (f_l = total lesions/total elements X 100), individuals with traumatic lesions (f_i = individuals with lesions/total individuals X 100), individuals with multiple traumatic lesions (f_{ml}=individuals with multiple lesions/total individuals X 100), and the number of lesions per injured individuals (*n.o.l* = number of lesions/injured individuals X 100). The tables are separated into inclusive sample data, where the preservation categories are separated into four inclusive categories (the entire skeletal sample, skeletal material that is ≥ 25% complete, skeletal material that is ≥ 75% complete, and skeletal material that is 100% complete) for the cranial bones and complete versus the entire sample for the crania as a unit, and separately into four different independent categories that allow for statistical analysis (< 25% complete, 25 - <75% complete, 75 - <100% complete, and 100% complete) for the cranial bones and complete versus incomplete for the crania as a unit.

Table 3.5 - Frequency of traumatic lesions for the inclusive samples by completeness and element.

	Entire sample			25% +			75% +			100%		
Element	n[1]	N[2]	f_I[3]	n[1]	N[2]	f_I[3]	n[1]	N[2]	f_I[3]	n[1]	N[2]	f_I[3]
Frontal	18	70	25.71	18	62	29.03	17	50	34.00	3	30	10.00
Parietal –R	12	70	17.14	12	67	17.91	8	53	15.09	6	36	16.67
Parietal – L	11	70	15.71	10	66	15.15	7	51	13.73	5	35	14.29
Temporal – R	2	69	2.90	2	63	3.17	2	56	3.57	2	36	5.56
Temporal – L	3	69	4.35	3	67	4.48	2	57	3.51	0	30	0
Zygomatic – R	0	50	0	0	49	0	0	44	0	0	42	0
Zygomatic – L	0	52	0	0	50	0	0	48	0	0	43	0
Maxilla –R	1	56	1.79	1	40	2.50	1	29	3.45	1	18	5.56
Maxilla – L	1	55	1.81	1	39	2.56	1	23	4.35	1	19	5.26
Nasal - R	15	35	42.89	15	33	45.5	14	26	53.84	13	21	61.90
Nasal – L	15	34	44.12	15	33	45.5	14	26	53.84	12	21	57.14
Occipital	21	70	30.00	21	69	30.43	18	52	34.62	18	25	72.00
Mandible	7	68	10.29	7	67	10.45	7	55	12.73	6	29	20.69
Crania	87	75	116	-	-	-	-	-	-	10	10	100

1. n = the number of lesions present on the bones
2. N = the number of individuals represented in each category.
3. f_I = n/N * 100

Table 3.6 - Frequency of traumatic lesions for the independent samples by completeness and element.

	<25%			25 - <75%			75 - <100%			100%		
Element	n[1]	N[2]	f_I[3]	n[1]	N[2]	f_I[3]	n[1]	N[2]	f_I[3]	n[1]	N[2]	f_I[3]
Frontal	0	9	0	12	62	19.35	14	18	77.78	3	30	10.00
Parietal –R	0	3	0	4	14	28.57	2	17	11.76	6	36	16.67
Parietal – L	1	4	25.00	3	15	20.00	2	16	12.50	5	35	14.29
Temporal – R	0	6	0	0	7	0	0	21	0	3	33	9.09
Temporal – L	0	2	0	1	10	10.00	2	27	7.41	0	30	0
Zygomatic – R	0	1	0	0	5	0	0	5	0	0	42	0
Zygomatic – L	0	2	0	0	2	0	0	5	0	0	43	0
Maxilla –R	0	16	0	0	11	0	0	8	0	1	18	5.56
Maxilla – L	0	16	0	0	16	0	0	4	0	1	19	5.26
Nasal - R	0	0	0	1	9	11.11	1	5	20.00	13	21	61.90
Nasal – L	0	1	0	1	7	14.29	1	5	20.00	12	21	57.14
Occipital	0	1	0	3	17	17.65	0	27	0	18	25	72.00
Mandible	0	1	0	0	12	0	1	27	3.70	6	29	20.69
Crania	77	65	119	-	-	-	-	-	-	10	10	100

1. n = the number of lesions present on the bones
2. N = the number of individuals represented in each category.
3. f_I = n/N * 100

Table 3.7 - Frequency of individuals with traumatic lesions for the inclusive samples by completeness and element.

	Entire sample			25% +			75% +			100%		
Element	n[1]	N[2]	f_i [3]	n[1]	N[2]	f_i [3]	n[1]	N[2]	f_i [3]	n[1]	N[2]	f_i [3]
Frontal	7	70	10.00	7	62	11.29	6	50	12.00	2	30	6.67
Parietal –R	9	70	12.86	9	67	13.43	7	53	13.21	5	36	13.88
Parietal – L	10	70	14.29	9	66	13.64	6	51	11.76	4	35	11.43
Temporal – R	2	69	2.90	2	63	3.17	2	56	3.57	2	35	5.71
Temporal – L	2	69	2.90	2	67	2.99	1	57	1.75	0	30	0
Zygomatic – R	0	50	0	0	49	0	0	44	0	0	42	0
Zygomatic – L	0	52	0	0	50	0	0	48	0	0	43	0
Maxilla –R	1	56	1.79	1	40	2.50	1	29	3.45	1	20	5.00
Maxilla – L	1	55	1.82	1	39	2.56	1	23	4.35	1	19	5.26
Nasal - R	15	35	42.86	15	35	42.86	14	26	53.85	13	21	61.90
Nasal – L	15	34	44.12	15	33	45.45	14	26	53.85	12	21	57.14
Occipital	6	70	8.57	6	69	8.70	3	52	5.77	3	25	12.00
Mandible	3	68	4.41	3	67	4.48	3	55	5.45	2	29	6.90
Crania	41	75	54.67	-	-	-	-	-	-	8	10	80.00

1. n = the number of bone fragments exhibiting lesions.
2. N = the number of individuals represented in each category.
3. f_i = n/N * 100

Table 3.8 - Frequency of individuals with traumatic lesions for the independent samples by completeness and element.

	< 25%			25 - <75%			75 - <100%			100%		
Element	n[1]	N[2]	f_i [3]	n[1]	N[2]	f_i [3]	n[1]	N[2]	f_i [3]	n[1]	N[2]	f_i [3]
Frontal	0	9	0	1	12	8.33	1	19	5.26	2	30	6.67
Parietal –R	0	3	0	2	14	14.29	2	17	11.76	5	36	13.89
Parietal – L	1	4	25.00	3	15	20.00	2	16	12.50	4	35	11.43
Temporal – R	0	6	0	0	7	0	0	21	0	2	35	5.71
Temporal – L	0	2	0	1	10	10.00	0	27	0	0	30	0
Zygomatic – R	0	1	0	0	5	0	0	2	0	0	42	0
Zygomatic – L	0	2	0	0	2	0	0	5	0	0	43	0
Maxilla –R	0	16	0	0	11	0	0	8	0	1	21	4.76
Maxilla – L	0	16	0	0	16	0	0	4	0	1	19	5.26
Nasal - R	0	0	0	1	9	11.11	1	5	20.00	13	21	61.90
Nasal – L	0	1	0	1	7	14.29	1	5	20.00	12	21	57.14
Occipital	0	1	0	3	17	17.65	0	27	0	3	25	12.00
Mandible	0	1	0	0	12	0	1	27	3.70	2	28	7.14
Crania	23	65	35.38	-	-	-	-	-	-	8	10	80.00

1. n = the number of bone fragments exhibiting lesions.
2. N = the number of individuals represented in each category.
3. f_i = n/N * 100

Table 3.9 - Frequency of Individuals with multiple lesions for the inclusive samples by completeness and element.

	Entire sample			25% +			75% +			100%		
Element	n[1]	N[2]	f_{ml} [3]	n[1]	N[2]	f_{ml} [3]	n[1]	N[2]	f_{ml} [3]	n[1]	N[2]	f_{ml} [3]
Frontal	4	70	5.71	4	62	6.45	4	50	8.00	1	30	3.33
Parietal –R	3	70	4.29	3	67	4.48	1	53	1.89	1	36	2.78
Parietal – L	1	70	1.43	1	66	1.52	1	51	1.96	1	35	2.86
Temporal – R	0	69	0	0	63	0	0	56	0	0	36	0
Temporal – L	1	69	1.45	1	67	1.49	1	57	1.75	0	30	0
Zygomatic – R	0	50	0	0	49	0	0	44	0	0	42	0
Zygomatic – L	0	52	0	0	50	0	0	48	0	0	43	0
Maxilla –R	0	56	0	0	40	0	0	29	0	0	21	0
Maxilla – L	0	55	0	0	39	0	0	23	0	0	19	0
Nasal - R	0	35	0	0	35	0	0	26	0	0	21	0
Nasal – L	0	24	0	0	33	0	0	26	0	0	21	0
Occipital	2	70	2.86	2	69	2.90	2	52	3.85	2	25	8.00
Mandible	1	68	1.47	1	67	1.49	1	55	1.82	1	29	3.45
Crania	12	75	16.00	-	-	-	-	-	-	2	10	20.00

1. n = the number of bone fragments exhibiting multiple lesions.
2. N = the number of individuals represented in each category.
3. f_{ml} = n/N * 100

Table 3.10 - Frequency of individuals with multiple lesions for the independent samples by completeness and element.

	< 25%			25 - <75%			75 - <100%			100%		
Element	n[1]	N[2]	f_{ml} [3]	n[1]	N[2]	f_{ml} [3]	n[1]	N[2]	f_{ml} [3]	n[1]	N[2]	f_{ml} [3]
Frontal	0	9	0	0	12	0	3	19	15.79	1	30	3.33
Parietal –R	0	3	0	2	14	14.29	0	17	0	1	36	2.78
Parietal – L	0	4	0	0	15	0	0	16	0	1	35	2.86
Temporal – R	0	6	0	0	7	0	0	21	0	0	35	0
Temporal – L	0	2	0	0	10	0	1	27	4	0	30	0
Zygomatic – R	0	1	0	0	5	0	0	2	0	0	42	0
Zygomatic – L	0	2	0	0	2	0	0	5	0	0	43	0
Maxilla –R	0	16	0	0	11	0	0	8	0	0	21	0
Maxilla – L	0	16	0	0	16	0	0	4	0	0	19	0
Nasal - R	0	0	0	0	9	0	0	5	0	0	21	0
Nasal – L	0	1	0	0	7	0	0	5	0	0	21	0
Occipital	0	1	0	0	17	0	0	27	0	2	25	8.00
Mandible	0	1	0	0	12	0	0	27	0	1	28	3.57
Crania	10	65	15.38	-	-	-	-	-	-	2	10	20.00

1. n = the number of bone fragments exhibiting multiple lesions.
2. N = the number of individuals represented in each category.
3. f_{ml} = n/N * 10

Table 3.11 - Number of lesions per injured individual for the inclusive samples by completeness and element.

	Entire sample			25% +			75% +			100%		
Element	n[1]	N[2]	*n.o.l*[3]	n[1]	N[2]	*n.o.l*[3]	n[1]	N[2]	*n.o.l*[3]	n[1]	N[2]	*n.o.l*[3]
Frontal	18	7	2.57	18	7	2.57	17	6	2.83	3	2	1.50
Parietal –R	12	9	1.33	12	9	1.33	8	7	1.14	6	5	1.20
Parietal – L	11	10	1.10	10	9	1.11	7	6	1.17	5	4	1.25
Temporal – R	2	2	1.00	2	2	1.00	2	2	1.00	2	2	1.00
Temporal – L	3	2	1.50	3	2	1.50	2	1	2.00	0	0	0
Zygomatic – R	0	0	0	0	0	0	0	0	0	0	0	0
Zygomatic – L	0	0	0	0	0	0	0	0	0	0	0	0
Maxilla –R	1	1	1.00	1	1	1.00	1	1	1.00	1	1	1.00
Maxilla – L	1	1	1.00	1	1	1.00	1	1	1.00	1	1	1.00
Nasal - R	15	15	1.00	15	15	1.00	14	14	1.00	13	13	1.00
Nasal – L	15	15	1.00	15	15	1.00	14	14	1.00	13	13	1.00
Occipital	21	6	3.50	21	6	3.50	18	3	6.00	18	3	6.00
Mandible	7	3	2.33	7	3	2.33	7	3	2.33	6	2	3.00
Crania	87	41	2.12	-	-	-	-	-	-	10	8	1.25

1. n = the number of lesions present on the bones.
2. N = the number of individuals exhibiting lesions.
3. *n.o.l* = n/N

Table 3.12 - Number of lesions per injured individual for the independent samples by completeness and element.

	<25%			25 - <75%			75 - <100%			100%		
Element	n[1]	N[2]	*n.o.l*[3]	n[1]	N[2]	*n.o.l*[3]	n[1]	N[2]	*n.o.l*[3]	n[1]	N[2]	*n.o.l*[3]
Frontal	0	0	0	1	1	1.00	14	4	3.50	3	2	1.50
Parietal –R	0	0	0	2	1	2.00	2	2	1.00	6	5	1.20
Parietal – L	1	1	1.00	3	3	1.00	2	2	1.00	5	4	1.25
Temporal – R	0	0	0	0	0	0	0	0	0	2	2	1.00
Temporal – L	0	0	0	1	1	1.00	2	1	2.00	0	0	0
Zygomatic – R	0	0	0	0	0	0	0	0	0	0	0	0
Zygomatic – L	0	0	0	0	0	0	0	0	0	0	0	0
Maxilla –R	0	0	0	0	0	0	0	0	0	1	1	1.00
Maxilla – L	0	0	0	0	0	0	0	0	0	1	1	1.00
Nasal - R	0	0	0	1	1	1.00	1	1	1.00	13	13	1.00
Nasal – L	0	0	0	0	0	0	1	1	1.00	13	13	1.00
Occipital	0	0	0	3	3	1.00	0	0	0	18	3	6.00
Mandible	0	0	0	0	0	0	1	1	1.00	6	2	3.00
Crania	77	41	1.88	-	-	-	-	-	-	10	8	1.25

1. n = the number of lesions present on the bones.
2. N = the number of individuals exhibiting lesions.
3. *n.o.l* = n/N

3.4 Data Analysis by Bone Element

3.4.1 Frontal Bones

The frequency of traumatic lesions (f_l) was calculated (f_l=total lesions/total elements X 100) for each inclusive sample (the entire sample, ≥ 25% complete, ≥ 75% complete, 100% complete) and while the frequency of trauma did vary slightly between the categories, it was only in the category requiring 100% completeness that the frequency of lesions showed any significant variation. Between the more fragmentary material and the 100% complete material the frequency of traumatic lesions decreased from between 25 - 35% to 10%. As more fragmentary material is included the frequency of trauma decreases: 100% complete bone: f_l = 10.00%; ≥ 75% complete bone: f_l = 34.00%; ≥ 25% complete bone: f_l = 29.03 %; Entire sample: f_l = 25.71%. Figure 3.1 illustrates the difference for the frequency of trauma on the frontal bone.

When analyzing the frequency of lesions, fifteen lesions were excluded when 100% completeness was required; one lesion was excluded when the category included only individuals that were ≥ 75% complete; no additional lesions were found on the material that was less than 25% complete. Eight individuals made up the < 25% category and an additional twelve individuals are between 25 - <75% preserved; therefore, frequency analyses may become problematic on samples where the population is highly fragmentary as one would expect that the frequency would remain the same for all of the categories (see the statistical analysis for further examination).

The frequencies of individuals with traumatic lesions (f_i) relative to those with multiple traumatic lesions (f_{ml}) are summarized in Figure 3.2. There was only a small disparity between the results found in each category; however, the summary of the frequencies mirrors the results found in the previous calculation. The frequency of individuals with lesions (f_i=elements with lesions/total elements X 100), as well as the frequency of individuals with multiple lesions (f_{ml}=elements with multiple lesions/total elements X 100) were calculated by completeness category. There is an increase in the frequency of individuals with traumatic lesions, a measure of those individuals with one or more lesions, between the 100% complete and the ≥ 75% complete category and a subsequent decrease for the more fragmentary material. As more fragmentary material is included the frequency of individuals with traumatic lesions decreases after an initial increase.

With the requirement of 100% completeness, five of the frontal bones with lesions were excluded leaving only two individuals with lesions out of a total of thirty in the sample. When the sample included the entire sample that was ≥ 75% complete, all the individuals with traumatic lesions were included except one, which was then included in the sample that required ≥ 25% completeness. No additional trauma was found on the individuals that were > 25% complete. The frequency of individuals with multiple lesions (f_{ml}) follows a slightly different pattern, one that corresponds more closely to the hypothesis. As more fragmentary material is included in the analysis the frequency of individuals with multiple lesions increases; however, the frequency decreases again when the extremely fragmentary material (< 25% complete) is included. The frequency of individuals with multiple traumatic lesions first increases and then decreases as more fragmentary material is included. The analysis shows, as with the other calculations, that it is the 100% complete category that is most incongruous with the other categories, presenting a significantly lower frequency than those found in the other categories.

The final calculation, the number of lesions per injured individual (*n.o.l* = number of lesions/fragments with lesions), follows a different pattern. Only the category requiring 100% completeness shows discrepancy with 1.50 lesions per individual, while the other categories range between 2.57 - 2.83 lesions per individual. Figure 3.3 outlines the traumatic lesions per injured individual.

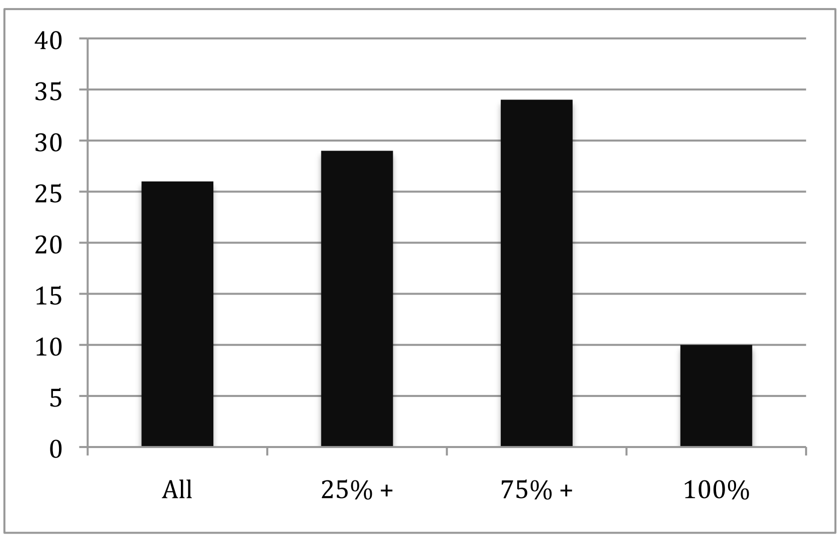

Figure 3.1. Frequency of traumatic lesions by completeness for the frontal bone (f_l = n/N X100, where n = the number of lesions and N = the number of frontal bones) for each inclusive preservation category.

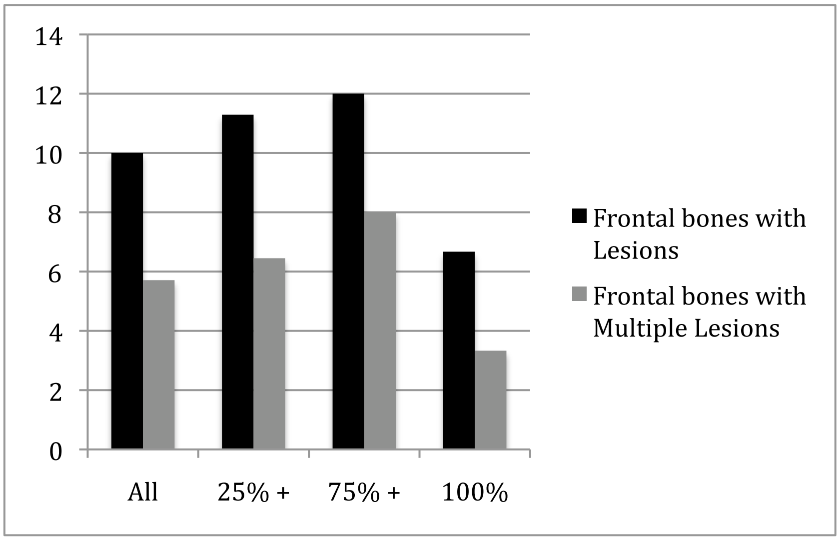

Figure 3.2 Frequency of individual with traumatic lesions ($f_i = i_n/N \times 100$, where i_n = the number of frontal bones with traumatic lesions and N = the number of frontal bones) and frequency of frontal bones with multiple lesions ($f_{ml} = i_m/N \times 100$, where i_m = the number of frontal bones exhibiting multiple injuries and N = the total number of individuals) for each inclusive completeness category of the frontal bone.

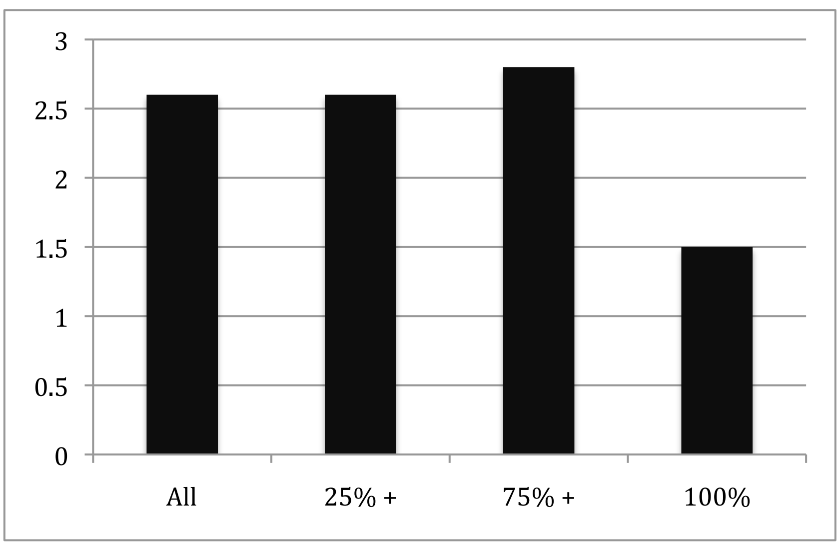

Figure 3.3 Number of traumatic lesions per injured individual ($n.o.l = n/N' \times 100$, where n = the number of lesions and N' = the number of injured frontal bones).

3.4.2 Parietal Bones

The frequencies of traumatic lesions per bone (f_l) were analyzed for the left and right parietal bones. The trauma frequency calculations did not vary significantly between the categories for either the right or left parietal bones. The frequency did not increase or decrease as more fragmentary material was included, ranging from 15-18% for the right parietal bone and 14-15% for the left parietal bone. As more fragmentary material is included the frequency of traumatic lesions varies for both the right and left parietal bones. Figure 3.4 outlines the frequency of trauma on the parietal bones.

Using the same categories, the frequency of individuals with lesions (f_i), the frequency of individuals with multiple injuries (f_{ml}), and the number of lesions per injured individuals (*n.o.l*) were calculated. As summarized in Figure 3.5, there was little difference found between the results in each category. For the right parietal bones, the number of individuals with lesions decreases, from f_i = 13.89% for the 100% complete category when the preservation criteria allows for minor damage, but remains relatively constant (f_i= 12.86 - 13.43%) when more fragmentary material is included. Minor variation is present between the preservation categories for the left parietals.

The number of individuals with multiple lesions shifts between 1.43 - 4.48% as the completeness requirements change. As shown in Figure 3.5, slight variations occur between the completeness categories as more fragmentary material is included. Here a caveat must be presented. Out of the right parietal bones showing evidence of trauma, none of the bones were < 25% complete, only two of the individuals were represented in the 25 - <75% complete category, and two others were in the 75 - <100% category. The majority of the lesions on the right parietal bones were found on the 100% complete bones. This may account for the higher frequency found in the 100% complete category. Only three right parietals from the sample showed multiple traumatic lesions; it is important to note that two of these individuals would have been excluded by both the 100% complete and the ≥ 75% complete requirements.

There is no visible linear pattern for the individuals with traumatic lesions (f_i) or multiple traumatic lesions (f_{ml}). Only three right parietals from the sample showed multiple traumatic lesions; yet, it is important to note that two of these individuals would have been excluded by both the 100% complete and the ≥ 75% complete requirements. It may also be noteworthy to mention that, as a more durable bone, the number of parietal bones that are 100% complete is almost double that of any other category (see Table 3.2).

The analysis of the number of lesions per injured individual (*n.o.l*) does not show deviation between the groups. As shown in Figure 3.6, the lesions per injured individuals all range between 1.10 and 1.33. The number of lesions per injured individual is comparable among the categories but, as shown in Figure 3.6, there is a steady decline for the left parietal bones as more fragmentary material is included. No linear pattern is discernable for the right parietal bones.

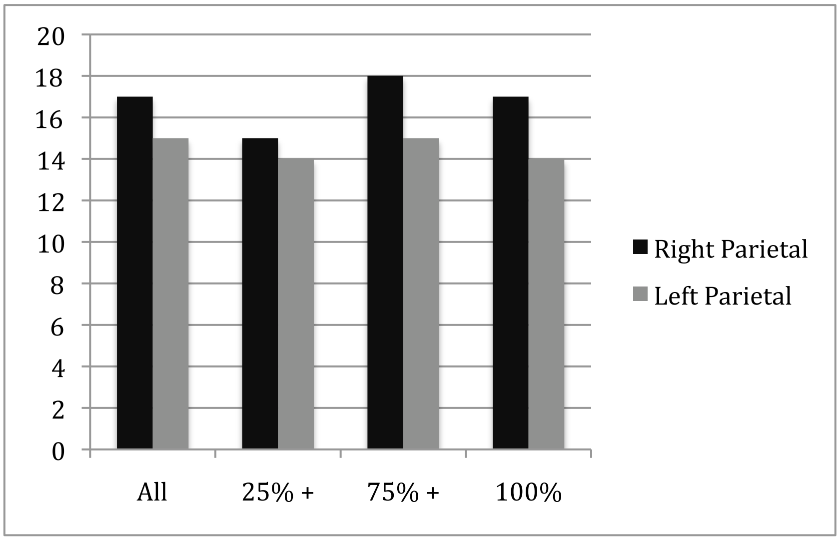

Figure 3.4 Frequency of parietal lesions (f_l = n/N X 100, where n = the number of lesions and N = the number of parietal bones) for each inclusive completeness category on both the right and left parietal bones.

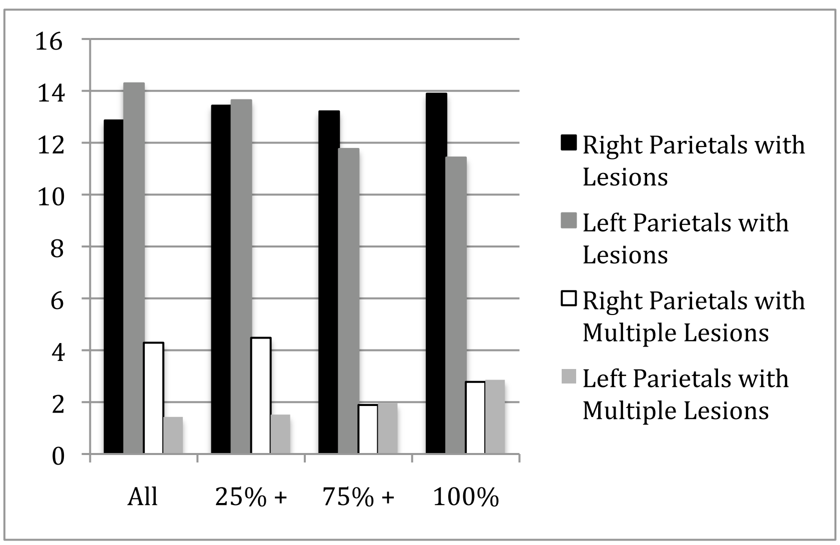

Figure 3.5 Frequency of individual with traumatic lesions (f_i = i_n/N X 100, where i_n = the number of parietal bones with traumatic lesions and N = the number of parietal bones) – shown in black and light grey - and the frequency of parietal bones with multiple lesions (f_{ml} = i_m/N X 100, where i_m= the number of parietal bones exhibiting multiple injuries and N = the total number of parietals) – shown in grey and white - for each inclusive completeness category for both the right and left parietals.

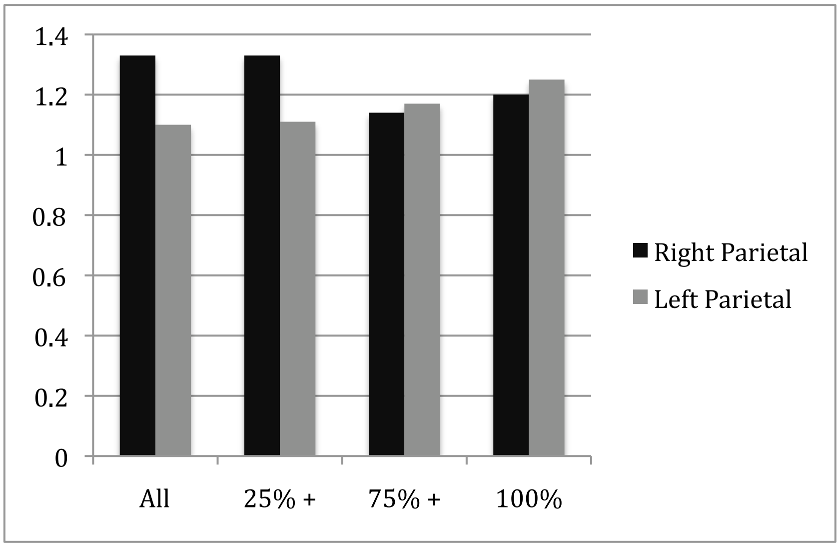

Figure 3.6 Number of traumatic lesions per injured individual (*n.o.l* = n/N', where n represents the number of lesions and N' represents the number of injured individuals) for both the right and left parietal bones.

3.4.3 Temporal Bones

The traumatic lesion frequency (f_l) for the temporal bones was calculated. The right temporal bones exhibited only two lesions, both of which were found on temporal bones that were 100% complete, and the left temporal bones exhibited only three lesions, one on bone that was between 75 - <100% complete and two on bone between 25 - <75% complete. Analysis on such small numbers is difficult; the numbers were analyzed and the results showed a decline in frequency for the right temporal but not the left. The frequency of traumatic lesions decreases as more fragmentary material is included for the right temporal bones and remains constant for the left temporal bones except for the category requiring 100% completeness, where the frequency of traumatic lesions found is 0%. Figure 3.7 outlines the frequency of trauma on the temporal bones.

Calculations on the frequency of individuals with traumatic lesions (f_i) produced similar results. The frequency of individuals with traumatic lesions increases as more fragmentary material is included for the left temporal bone but decreases for the right temporal bones. Figure 3.8 summarizes the results of the frequency of individuals with traumatic lesions. The frequency of individuals with multiple injuries (f_{ml}) was not calculated for the right temporal bone as none of the right temporal bones exhibited multiple trauma; only one left temporal bone (75 - <100% complete) had multiple lesions present.

As seen in Figure 3.9, the number of lesions per injured individual (*n.o.l*) remains constant for the right temporal bones (*n.o.l* = 1.00) regardless of the recording category; however, for the left temporal bones, the inclusion of only the 100% complete bones excludes all of the traumatic lesions and the ≥ 75% complete category may over represent the actual number of lesions if the analysis of the more fragmentary material is taken at face value (100% complete bone: *n.o.l* = 0; ≥ 75% complete bone: *n.o.l* = 2.00; ≥ 25% complete bone: *n.o.l* = 1.50; Entire sample: *n.o.l* = 1.50).

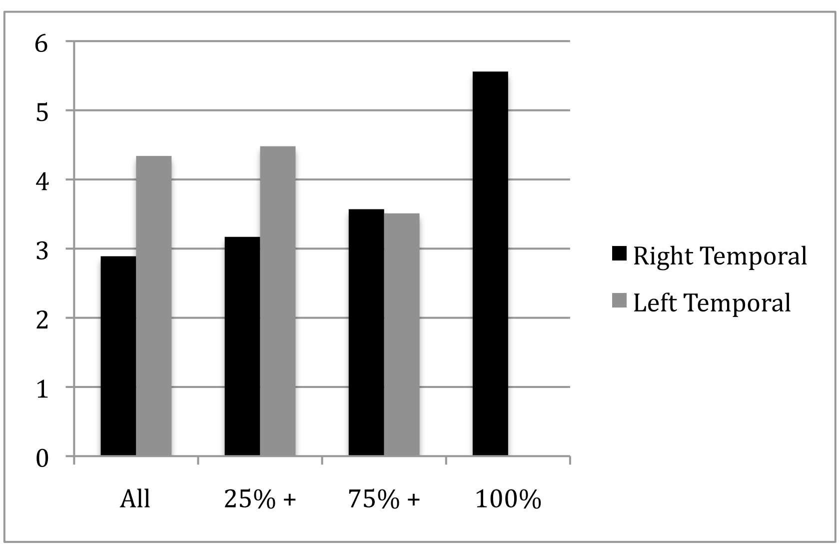

Figure 3.7 Frequency of trauma (f_l = n/N X 100,where n = the number of lesions and N = the number of temporal bones) for each inclusive completeness category of the right and left temporal bone.

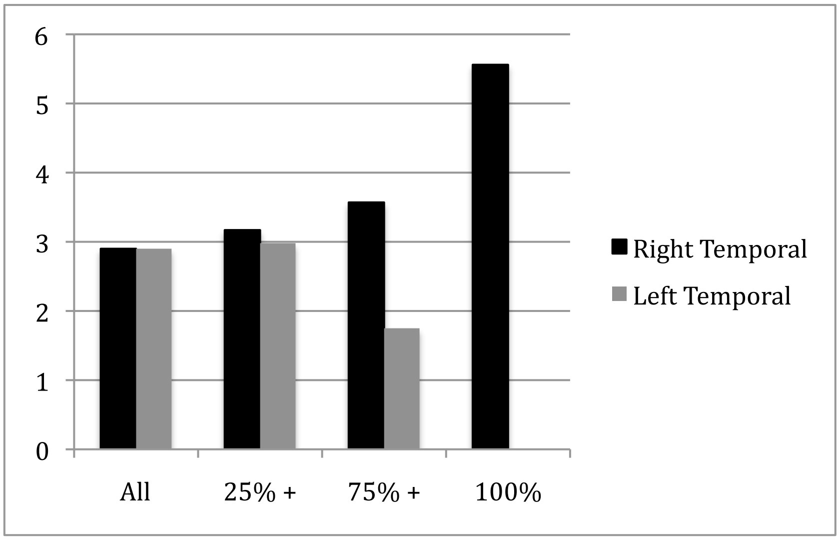

Figure 3.8 Frequency of temporal bones with traumatic lesions ($f_i = i_n/N$ X100, where i_n = the number of temporal bones with traumatic lesions and N = the number of temporal bones) for each inclusive completeness category of the right and left temporal bones.

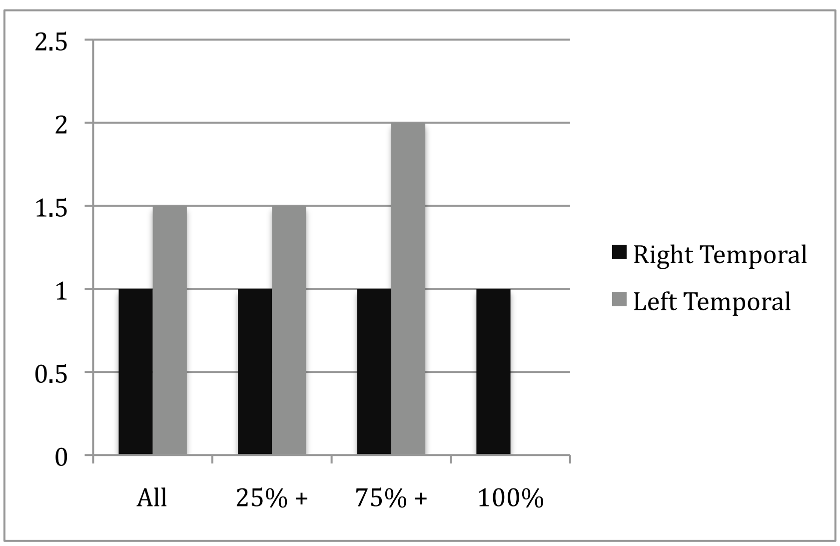

Figure 3.9 Number of traumatic lesions per injured temporal bone (*n.o.l* = n/N', where n represents the number of lesions and N' represents the number of injured individuals) for both the right and left temporal bones.

3.4.4 Zygomatic Bones

No trauma was observed on the zygomatic bones and therefore they were excluded from the analysis.

3.4.5 Maxillae

The maxillae from the sampled specimens were fairly fragmentary. Only fifty-six individuals were represented by the right maxillae and fifty-five by the left maxillae. The frequency of trauma (f_l) was examined, and for both the right and left maxillae, as more fragmentary bone was included in the calculations, the frequency of trauma decreased (see Figure 3.10). The right and left maxillae each presented only one bone with evidence of lesions. Both bones were 100% complete, explaining the decrease in frequency as less complete material is included in analysis.

Figure 3.11 summarizes the frequency of maxillae with traumatic lesions (f_i) of both the right and left maxillae. As only one lesion is present, similar results to the previous analysis are found. There is a decrease in the frequency of individuals with lesions as less well preserved, fragmentary material was incorporated. No evidence of multiple lesions was found on this bone (on either the right or left side).

Finally, the number of lesions per injured individuals (*n.o.l*) was analyzed. The only maxilla exhibiting a traumatic lesion, both on the right and left side, fell into the 100% complete category and thus was included in all the other samples, making the number of lesions per injured individuals one for every category the same (*n.o.l* = 1.00).

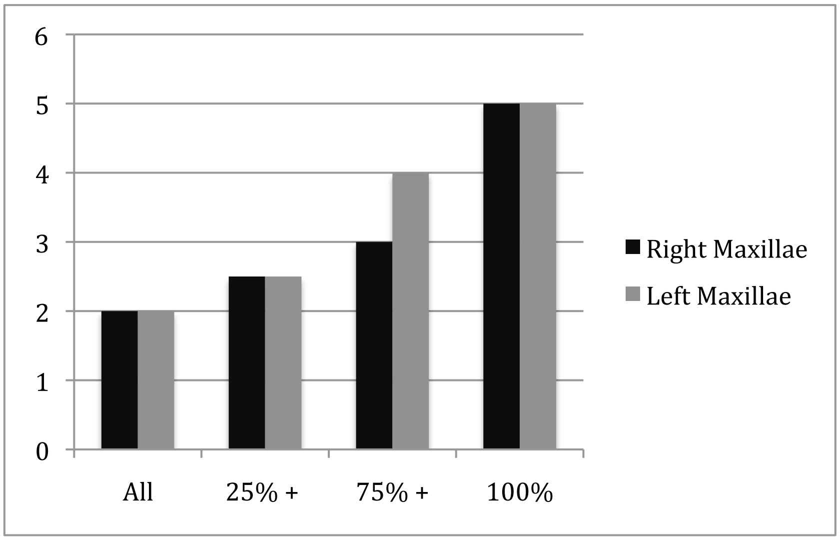

Figure 3.10 Frequency of traumatic lesions (f_l = n/N X 100, where n = the number of lesions and N = the number of maxillae) for each completeness category of the right and left maxillae.

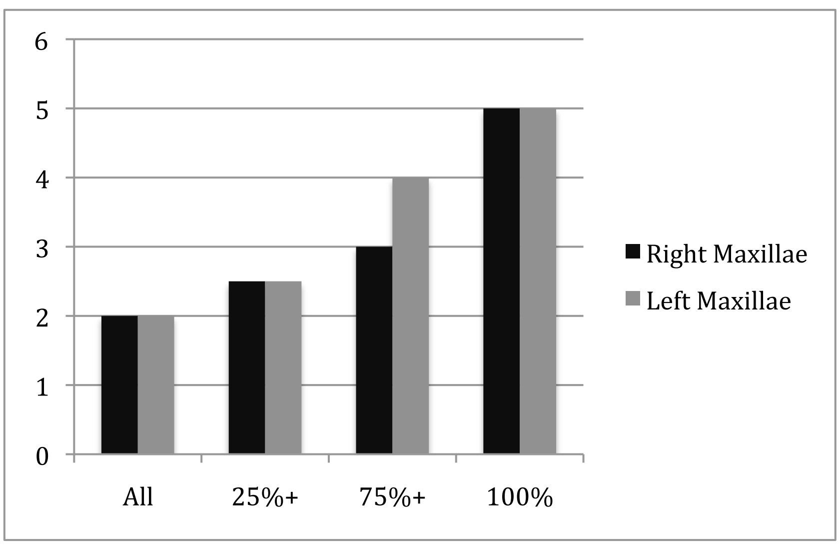

Figure 3.11 Frequency ($f = i_n$/N X100, where i_n = the number of maxillae with traumatic lesions and N = the number of maxillae) for each inclusive completeness category of the right and left maxillae.

3.4.6 Nasal Bones

Of the 75 individuals represented in the sample tested in this study, only approximately half of the individuals had nasal bones in any stage of preservation (n(r) = 35; n(l) = 34). The analysis of the frequency of trauma for the nasal bones is summarized in Figure 3.12. The traumatic lesion frequency (f_l) calculation results showed a decrease for both the right and left nasal bones as more fragmentary material is included.

The frequency of nasal bones with traumatic lesions (f_i) was analyzed using the completeness criteria specified earlier. The results for the frequency of individuals with traumatic lesions for both the right and left nasal bones were analyzed; the results are outlined in Figure 3.13. A decrease is seen in the frequency for both the right and left nasal bones as more fragmentary material is included in the analysis. The results for the frequency of individuals with trauma are the same as the frequency of trauma, as none of the individuals presented multiple traumatic lesions on either the right or left nasal bone. There were no nasal bones with multiple traumatic lesions; the frequency calculation (f_{ml}) was excluded from this study.

The number of lesions per injured individuals (*n.o.l*) was analyzed. Each injured individual had only one lesion, making the number of lesions per injured individual one in every category (*n.o.l* =1.00).

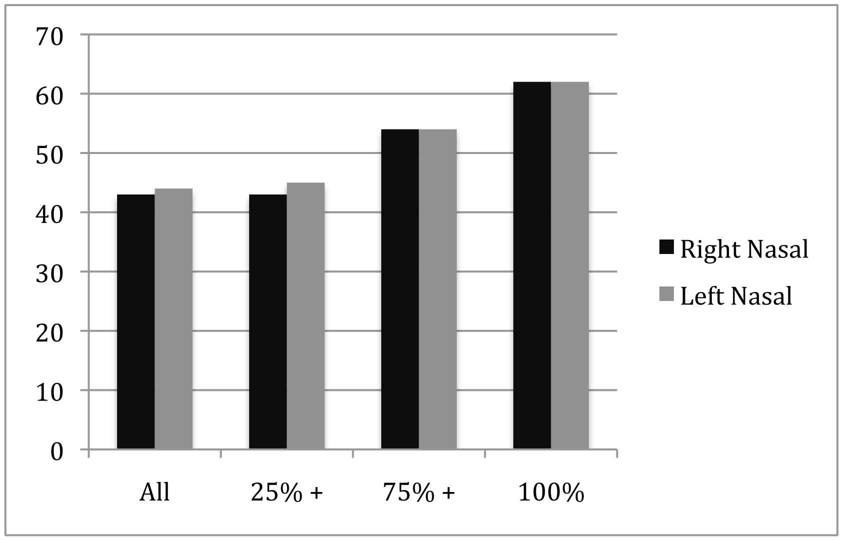

Figure 3.12 Frequency of traumatic lesions (f_i = n/N X 100, where n = the number of lesions and N = the number of nasal bones) for each inclusive completeness category of the right and left nasal bones.

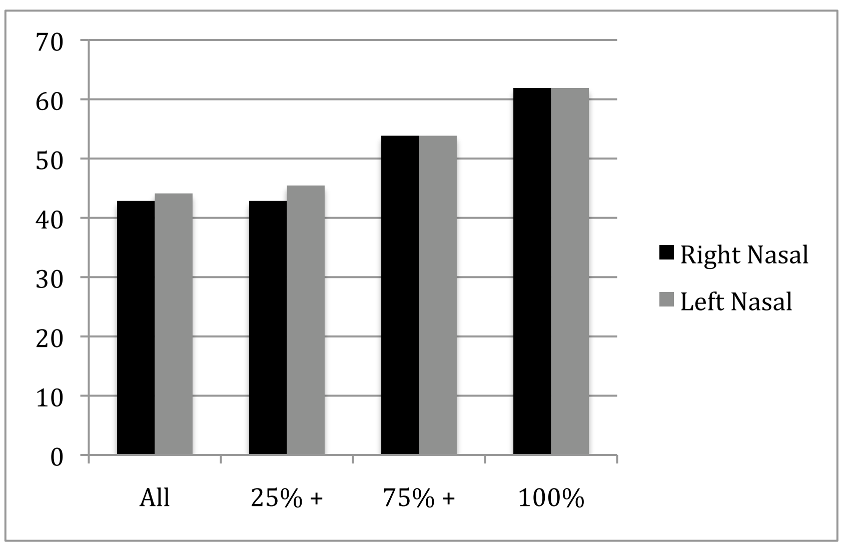

Figure 3.13 Frequency of injured nasal bones (f_i = i_n/N X 100, where i_n = the number of nasals with traumatic lesions and N = total number of nasals) for each inclusive completeness category for the right and left nasal bones.

3.4.7 Occipital Bones

Of the 75 individuals sampled in this study, only five were missing the occipital bone completely and only one occipital bone fell into the < 25% complete category. There is a high frequency of lesions (f_l) found when the completeness requirement is 100% (f_l = 72.00%) and then there is a significant decrease in the frequency for the more fragmentary material (≥ 75% complete bone: f_l = 34.61%; ≥ 25% complete bone: f_l = 30.43%; entire sample: f_l = 30.00%), significantly lower than the frequency found when using only the 100% complete bones. As more fragmentary material is included the frequency of trauma decreases. Figure 3.14 outlines the difference for the frequency of trauma on the occipital bones as the completeness requirements change. When analyzing the trauma frequencies from the occipital bone it is important to note that 18 of the 21 lesions were found on occipital bones that were 100% complete. One of the 100% complete occipital bones presented 15 lesions and may have skewed the data in favour of more complete bones. The other three lesions were found on bones that were between 25 - <75% complete. This accounts for the significant drop in frequency at the 75 - <100% complete category.

As summarized by Figure 3.15, the frequency of individuals with traumatic lesions (f_i) decreases between the 100% complete category (f_i = 12.00%) and the ≥ 75% complete category (f_i = 5.77%) and increases again as more fragmentary material is included (≥ 25% complete: f_i = 8.70%; Entire sample: f_i = 8.57%). The same is not true for the number of individuals with multiple lesions. There is a steady decline in the number of individuals with multiple injuries (f_{ml}) as more fragmentary material is included.

The analysis of the number of traumatic lesions per injured individual (*n.o.l*) shows the number almost doubling as increasingly fragmentary material is excluded. In this case, the inclusion of the more fragmentary material lowers the lesion per injured individual count. Figure 3.16 illustrates the decline in the number of lesions per injured individual as more fragmentary material is included in the analysis of the occipital bone.

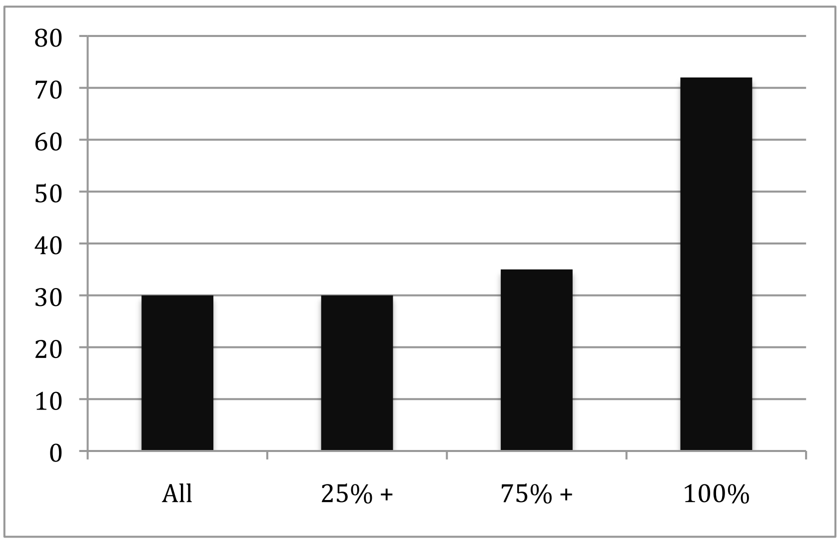

Figure 3.14 Frequency of traumatic lesions (f_l = n/N X 100, where n = the number of lesions and N = the number of occipital bones) for each inclusive completeness category for the occipital bones.

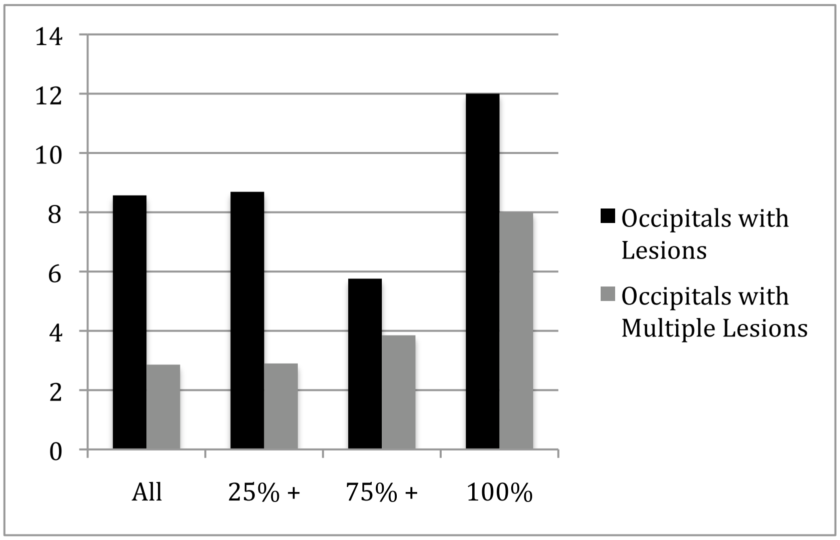

Figure 3.15 Frequency of occipital bones with traumatic lesions ($f_i = i_n/N \times 100$, where i_n = the number of occipital bones with traumatic lesions and N = the total number of occipital bones) and the frequency of occipital bones with multiple traumatic lesions ($f_{ml} = i_m/N \times 100$, where i_m= the number of occipital bones exhibiting multiple injuries and N = the total number of occipitals) for each inclusive completeness category for the occipital bones.

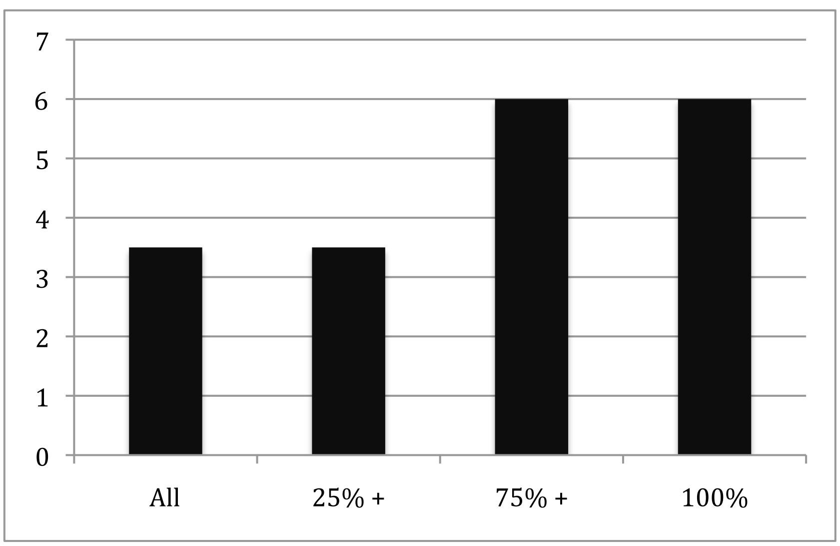

Figure 3.16 Number of traumatic lesions per injured individual ($n.o.l = n/N'$, where n represents the number of lesions and N' represents the number of injured occipital bones) for each completeness category of the occipital bone.

3.4.8 Mandibles

Of the 75 total individuals analyzed in this study, 68 had a mandible in some level of completeness. The frequency of traumatic lesions (f_l) decreased as more fragmentary material was included in the analysis. Figure 3.17 summarizes the frequency of trauma results for the mandibles. Only one traumatic lesion was excluded from the calculations with the exclusion of the < 100% complete material. Only one lesion was present on the bones that were 75 - <100% complete were included, and no lesions were excluded on when more fragmentary bones were not included in the analysis. However, the sample size almost doubled when analyzing the bones that were ≥ 75% complete (n = 55) versus the 100% complete (n = 28) bones and several more bones were included when the less fragmentary material was incorporated in the analysis (n(25% +) = 12; n(entire sample) = 1), causing a significant drop in the frequency as more fragmentary material was included (f_l (100%) = 20.69%; f_l (≥ 75%) = 12.72%; f_l (≥ 25%) = 10.45%; f_l (entire sample) = 10.29%).

Analysis of the frequency of individuals with lesions (f_i), the frequency of individuals with multiple lesions (f_{ml}), and the number of lesions per injured individual (*n.o.l*) was undertaken using the same categories. Figure 3.18 outlines the frequency of individuals with traumatic lesions, illustrating a decline after the 100% complete category (f = 6.90%) and relative stasis and slight decline in the more fragmentary categories (≥ 75% complete bone: f = 5.45%; ≥ 25% complete bone: f = 4.48%; Entire sample: f = 4.41%). The frequency of individuals with multiple traumatic lesions follows a similar pattern (Figure 3.18).

The number of lesions per injured individuals (*n.o.l*) decreases as fragmentary material is included, as the data outlined in Figure 3.19 illustrates. As shown, the lesions per injured individuals decrease between the 100% complete category (*n.o.l* =3.00) and the ≥ 75% complete category (*n.o.l* =2.33) and remain constant for the more fragmentary material (*n.o.l* =2.33).

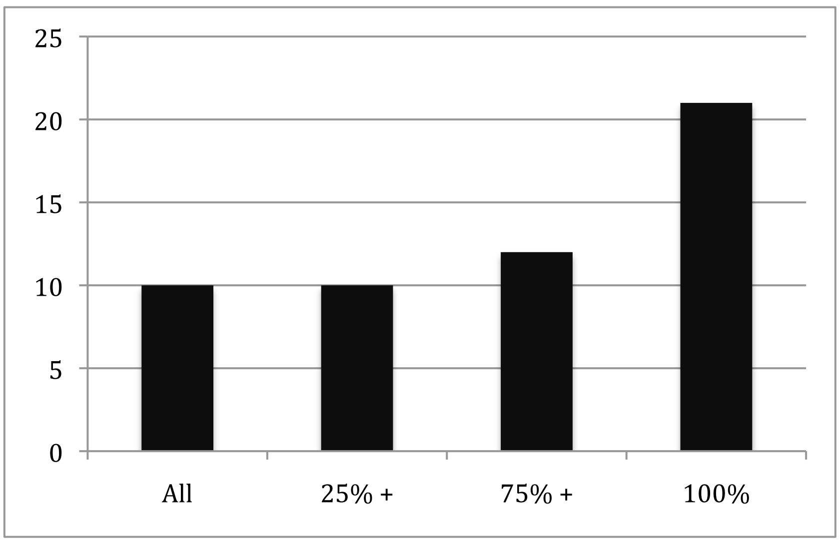

Figure 3.17 Frequency of traumatic lesions (f_l = n/N X 100, where n = the number of lesions and N = total number of mandibles) for each inclusive completeness category for the mandible.

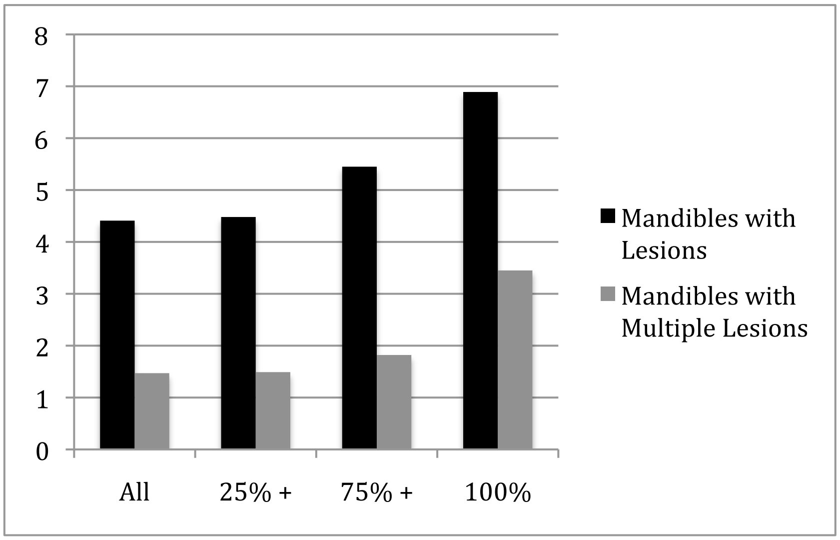

Figure 3.18 Frequency of mandibles exhibiting traumatic lesions and the frequency of mandibles with multiple traumatic lesions. The graph shows the frequency of mandibles with traumatic lesions ($f_i = i_n/N \times 100$, where i_n = the number of mandibles with traumatic lesions and N = the total number of mandibles) and the frequency of mandibles with multiple traumatic lesions ($f_{ml} = i_m/N \times 100$, where i_m= the number of mandibles exhibiting multiple injuries and N = the total number of mandibles) for each inclusive completeness category for the mandible.

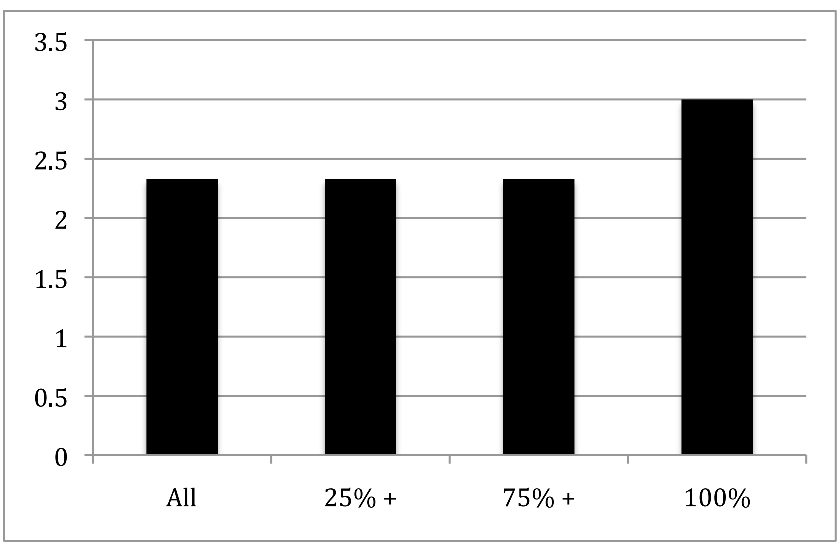

Figure 3.19 Number of traumatic lesions per injured mandible (*n.o.l* = n/N', where n represents the number of lesions and N' represents the number of injured mandibles) for each completeness category of the mandible.

3.4.9 Crania

The crania were analyzed in a slightly different way than the individual bones. Using the two categories, 100% complete crania and the entire sample, the frequency of traumatic lesions was tested. The results illustrated a decrease in frequency as more fragmentary material was included. Figure 3.20 delineates the number of traumatic lesions per cranium (f_l = total lesions/total crania) results for the crania. The sample sizes of the two groups may have skewed the result as the 100% complete category contained only ten crania, eight of which presented ten lesions (f_l = 1), whereas the total number of crania analyzed was 75, on which 87 lesions were present, (f_l = 1.16). When only 100% complete crania were analyzed 77 lesions were excluded from the frequency calculation.

The frequency of individuals with lesions (f_i) and the frequency of individuals with multiple lesions (f_{ml}) was analyzed for 100% complete crania versus the entire sample. A decline is observed between the results when only complete crania are used versus when the entire sample is included. Thirty-three individuals exhibiting evidence of trauma are excluded when the analysis criterion was set at 100% completeness and ten individuals with multiple lesions were left out of the calculation of individuals with multiple injuries. The frequency of individuals with multiple traumatic lesions also decreases with the inclusion of fragmentary material. The results are summarized in Figure 3.21.

The number of lesions per injured individual (*n.o.l*) increases as fragmentary material is included. The data is outlined in Figure 3.22, which clearly illustrates an increase in the number of lesions per injured individual when all of the material is included versus when only complete crania are used. The number of lesions per injured individual doubles from the 100% complete category (*n.o.l* =1.25) to the category where all of the cranial material was analyzed (*n.o.l* =2.12).

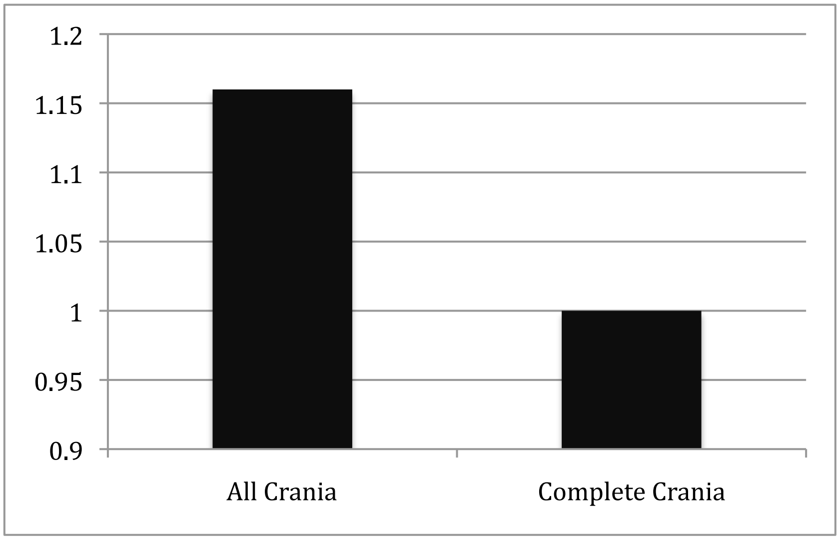

Figure 3.20 Number of traumatic lesions per individual (f_l = n/N, where n = the number of lesions and N = total number of crania) for the complete crania and the entire cranial sample available.

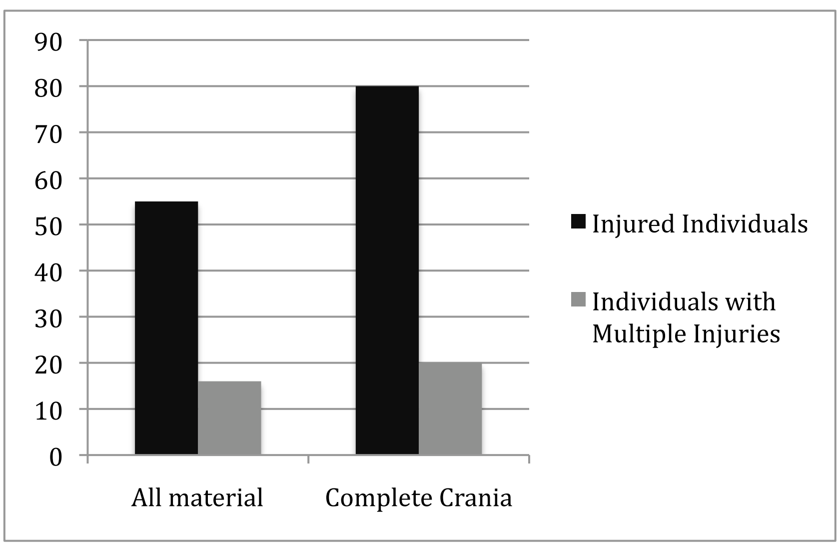

Figure 3.21 Frequency of individuals with traumatic lesions ($f_l = i_n/N \times 100$, where i_n = the number of crania with traumatic lesions and N = the total number of crania) and the frequency of individuals with multiple traumatic lesions ($f_{ml} = i_m/N \times 100$, where i_m= the number of crania exhibiting multiple injuries and N = the total number of crania) for both the complete crania and all cranial material.

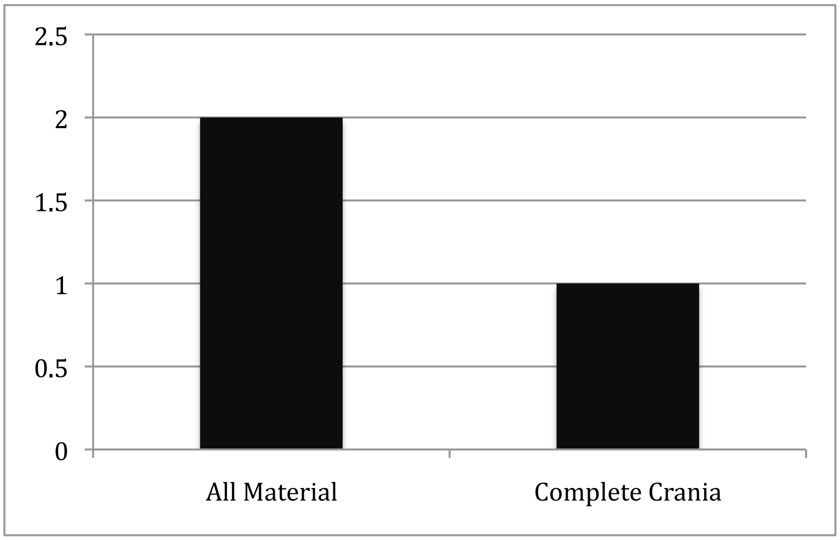

Figure 3.22 Number of traumatic lesions per injured individual (*n.o.l* = n/N', where n represents the number of lesions and N' represents the number of injured crania) for the complete crania and all of the cranial material present.

3.4.10 Statistical Analysis

To test the hypothesis that information is lost and trauma frequency is under-represented as fragmentary material is excluded, the skeletal material was separated into independent categories and Fisher's exact tests were utilized to test for significant differences in the frequencies of elements (or crania) with traumatic lesions among the completeness categories. The individuals with lesions versus individuals without lesions were analyzed for statistical significance. The data were analyzed in order to note if there was a significant difference in the frequency found in each of the independent completeness categories (100% complete, 75 - <100%, 25 - <75%, and <25%). The data for individual skeletal elements are summarized in Table 3.13 and the complete crania data in Table 3.14.

Only the individuals with traumatic lesions on right nasal bone showed statistical significance ($P = 0.02$). The significant difference in the right nasal bones results arise from the large disparity in the results from the 100% complete category and the results from the other categories. The frequency of trauma decreases dramatically between the 100% complete category ($f = 61.90\%$) and the entire sample category ($f = 20.00\%$). As more fragmentary material is included the frequency of individuals with lesions is increasingly under-represented.

Statistical significance was not found when Fisher's exact test was run on the occipital bone data as a whole; however, when a Fisher's exact test is conducted on the occipital bone using only the skeletal material from the 25 - <75% complete category and the 75 - <100% complete data, the results are significant (P=0.05). The frequency of individuals with lesions increases from 0% to 17.65% between the two categories. The incomplete versus complete cranial material showed no significant difference between the individuals with lesions and those without lesions (Table 3.14).

The number of individuals with one lesion was analyzed against the number of individuals with multiple lesions. As shown in Table 3.15, none of the elements showed statistically different frequencies regardless of completeness category examined (only bones with multiple lesions were examined; the nasals, zygomatic, maxillae, right parietals, and right temporal bones were excluded). No statistical significance was found when complete crania with one lesion versus those with multiple lesions were analyzed against incomplete crania (see Table 3.16).

Table 3.13 - Results of Fisher's exact test for comparison of preservation categories by element for the number of individuals with lesions versus the number of individuals without lesions.

	< 25%		25 - <75%		75 - <100%		100%		Fisher's Exact Value	P Value *
Element	**Lesions**	**No Lesions**	**Lesions**	**No Lesions**	**Lesions**	**No Lesions**	**Lesions**	**No Lesions**		
Frontal	0	9	1	11	4	12	2	28	0.11	1.00
R Parietal	0	3	2	12	2	15	5	31	0.07	1.00
L Parietal	1	3	3	12	2	14	4	31	0.03	0.63
R Temporal	0	6	0	7	0	21	3	33	0.25	0.69
L Temporal	0	2	1	9	1	26	0	30	0.01	0.17
R Maxilla	0	16	0	11	0	8	1	19	0.38	1.00
L Maxilla	0	16	0	16	0	4	1	18	0.35	1.00
R Nasal	0	0	1	8	1	4	12	9	0.00	**0.02**
L Nasal	0	1	1	6	1	4	12	9	0.01	0.10
Occipital	0	1	3	14	0	27	3	22	0.01	0.13
Mandible	0	1	0	12	1	26	2	26	0.20	1.00

*__bold__ indicates significance at α=0.05

Table 3.14 Results of Fisher's Exact test for comparison of preservation for the crania.

	Incomplete		Complete		Fisher's Exact Value	P Value*
	Lesions	No Lesions	Lesions	No Lesions		
Crania	33	32	8	4	0.06	0.10

Table 3.15 - Individuals with one lesion versus individuals with multiple lesions by bone.

	> 25%		25 - <75%		75 - <100%		100%		Fisher's Exact Value	P Value *
Element	1 Lesion	>1 Lesion	1 Lesion	>1 Lesion	1 Lesion	>1 Lesion	1 Lesion	>1 Lesion		
Frontal	0	0	1	0	1	3	1	1	0.23	0.66
R Parietal	0	0	0	2	2	0	4	1	0.56	1.00
L Parietal	1	0	3	0	2	0	1	0	0.40	1.00
L Temporal	0	0	1	0	0	1	0	0	0.50	1.00
Occipital	0	0	0	3	0	0	1	2	0.20	0.40
Mandible	0	0	0	0	1	0	1	1	0.67	1.00

Table 3.16 - Individuals with one lesion versus individuals with multiple lesions for the crania.

	Incomplete		Complete		Fisher's Exact Value	P Value*
	1 Lesions	>1 Lesions	1 Lesion	>1 Lesion		
Crania	23	10	6	2	0.33	1.00

Charter 4: Discussion

4.1 Introduction

Craniofacial trauma is often used as an indication of the violent or warlike nature of past populations in skeletal analyses (Brasili et al. 2004; Djuric et al. 2006; Efran et al. 2009; Jiminez-Brobeil et al. 2009; Judd 2004, 2006; Jurmain 1999; Kanz and Grossschmidt 2006; Smith 2003; Torres-Rouff and Junqueira 2006; Walker 1989, 1997; Wilkinson 1997; Williamson et al. 2003) and used to compare the frequencies of violence between past populations (Brickley and Smith 2006; Jurmain 1999; Walker 1997). Some cranial injuries, however, are indicative of accident related trauma (Judd 2004). The scope of this project does not allow for an analysis of the cranial lesions used as indicators of violence or those used to indicate accidents, or to analyze the issues surrounding these interpretations. Whether used as an indicator of violence and warfare or accidental injury, cranial trauma is an important line of evidence in palaeoanthropological and contemporary skeletal analyses. The argument presented by this study is that, although fragmentation of skeletal material in the archaeological and contemporary skeletal record, due to varying levels of preservation and completeness, is an ever-present issue in skeletal trauma analysis, standardization could minimize the inconsistency between studies and increase the accuracy of cross sample analyses.

4.2 Preservation Issues and Skeletal Research

Preservation issues have plagued osteology from its inception; however, with a few exceptions (e.g., Wood et al. 1992), preservation issues have not been adequately considered in palaeotrauma and palaeopathological analysis (Judd 2002). In an attempt to increase standardization, this study employs Buikstra and Ubelaker's (1994) completeness categories (complete if ≥ 75% of the crania is present and poor completeness if < 25% of the crania is present), acknowledging that a bone can be well preserved and incomplete as well as complete and poorly preserved (Behrensmeyer 1978, 1991; Haglund 1997; Haglund and Sorg 2002).

Issues of taphonomic preservation are accentuated in skeletal trauma research by the lack of standardization between research studies (Buikstra and Ubelaker 1994; Walker 1997). The frequency of trauma in a population is used, depending on whether the lesions are taken to reflect violence or accident, as a line of evidence for either the interpersonal violence within a population or the danger in everyday activities undertaken by the population. The lack of standardization in the field makes any inter-sample analysis problematic. If two populations that were recorded and analyzed in different ways are compared there is an elevated chance that the information that is being compared is not compatible. The current study presents the results found when an artificially created sample (n = 75) from the medieval cemetery of Augustinian Priory of St. Mary Merton and the post-medieval lower cemetery of St. Bride's Church, England, was tested for trauma frequencies. The frequency of traumatic lesions, the frequency of individuals with single or multiple traumatic lesions, and the number of lesions per injured individuals were calculated for four distinct completeness categories for individual bones (100% complete bones, ≥ 75% complete bones, ≥ 25% complete bones, and the entire sample) and in two separate categories for the crania as a unit (100% complete and the entire sample).

4.3 Completeness and Trauma Frequencies

It was hypothesized that a trend towards the loss of information would be seen as more fragmentary material was excluded. In order to test this hypothesis four frequency calculations were tested: the frequency of lesions per skeletal element (f_l = total lesions/total elements X 100), the frequency of individuals with lesions (f_i = individuals with lesions/total individuals X 100), the frequency of individuals with multiple lesions (f_{ml} = individuals with multiple lesions/total individuals X 100), and the number of lesions per injured individual (*n.o.l* = number of lesions/injured individuals). Originally, it was hypothesized that the frequencies would increase as more fragmentary material was included. However, the overall trend seems to be a decrease in the frequency and number, contradicting the initial hypothesis of this study.

4.3.1 Frequency of Traumatic Lesions

When the frequency of trauma was analyzed the predominant outcome seen for most of the skeletal elements was that as more fragmentary material was included, a resulting decrease in trauma frequency was observed. Table 4.1 outlines the frequency (%) of traumatic lesions.

There were a few exceptions to this pattern. The frontal bones, the parietal bones, and the left temporal bones follow distinctive patterns. An increase in trauma frequency was noted for the frontal bones when ≥ 75% complete bone was included and a subsequent decrease was observed as more fragmentary material was included. This discrepancy was caused by the considerable number of lesions found on the frontal bones that were between 75 - <100% complete. The parietal bones showed no linear trend toward either an increase or decrease in frequency of trauma, and the trauma frequency increased for the left temporal bone. The few fractures found on the left temporal bone occur on the bones that were between 25 - <100%

complete, explaining the initial increase and subsequent stasis of the trauma frequency.

Table 4.1 - The trauma frequency (%) for each completeness category by bone.

	100%	75% +	25% +	All
Frontal	10.00	34.00	29.00	26.00
Right Parietal	16.67	15.10	17.90	17.00
Left Parietal	14.29	13.70	15.20	16.00
Right Temporal	5.56	3.57	3.17	2.90
Left Temporal	0	3.51	4.48	4.30
Right Maxilla	4.76	3.45	2.50	1.80
Left Maxilla	5.26	4.35	2.56	1.80
Right Nasal	61.90	53.80	42.90	43.00
Left Nasal	61.90	53.80	45.50	44.00
Occipital	72.00	34.60	30.40	30.00
Mandible	20.69	12.70	10.40	10.00
Crania	116.00	X	X	100.00

4.3.2 Individuals with Lesions

A similar trend to that found for trauma frequency is found when analyzing the frequency of individuals with traumatic lesions. A decrease is observed in the frequency (f_i) as more fragmentary material is included and the same interpretations as to the cause of this decrease apply. Table 4.2 summarizes the patterns for the frequency of individuals with lesions.

The exceptions occur again on the frontal bones, parietal bones, and left temporal bones. The frequency of individuals with lesions for the frontal bone increases initially with the inclusion of ≥ 75% complete material and then drops incrementally as more fragmentary material is included. For the right parietal bones, there is no linear pattern (increase/decrease/increase) for the f_i; the f_i of the left temporal bone increases as more fragmentary material is included.

Statistical analysis of the frequency of individuals with lesions revealed no statistical significance between the samples tested, with the exception of the lesions on the right nasal bone. This is not surprising as, when divided into independent units, the samples were small and the incidences of trauma were low. A statistically significant difference was found only for the number of right nasal bones exhibiting trauma ($P = 0.02$). The right nasal bones were the most commonly lesioned bone in this sample, which gives rise to the question of whether the smaller sample size is the reason for statistical insignificance and whether a sample that presented larger numbers of lesioned individuals would show statistical significance for more bones.

Table 4.2 - The frequency (%) of individuals with lesions for each completeness category by bone.

	100%	**75% +**	**25% +**	**All**
Frontal	6.67	12.00	11.29	10.00
Right Parietal	13.89	13.20	13.43	12.86
Left Parietal	11.43	11.75	13.63	14.29
Right Temporal	5.56	3.57	3.17	2.90
Left Temporal	0	1.75	3.00	2.90
Right Maxilla	4.76	3.45	2.50	1.79
Left Maxilla	5.26	4.35	2.56	1.82
Right Nasal	61.90	53.85	42.86	42.86
Left Nasal	61.90	53.85	45.45	44.12
Occipital	12.00	5.77	8.70	8.57
Mandible	6.90	5.45	4.48	4.41
Crania	80.00	X	X	54.67

4.3.3 Individuals with Multiple Lesions

When analyzing trends in the frequency of individuals with multiple lesions (f_{ml}) only six bone elements could be analyzed, the frontals, the right and left parietals, the left temporals, the occipitals, and the mandibles, as well as the complete crania. The overall analysis of frequency for individuals with multiple lesions showed no linear trend. The most common result observed was a decrease in frequency as more fragmentary material was included; however, this was only perceived for the mandibles and the crania. There was no consensus between the results observed for the other bones. An initial increase and then decrease when the entire sample was examined was noted on the frontal bones; the right and left parietal bones and the occipital bones illustrated no linear pattern. The pattern of the f_{ml} is summarized in Table 4.3.

When statistically analyzed, the frequency of individuals with multiple lesions showed no statistical significant differences between the completeness categories for any bone. This may be the result of small sample size or simply an indication that the level of completeness included in trauma analysis does not affect the frequency results. There were no exceptions to this observation.

Table 4.3 - The frequency (%) for individuals with multiple lesions for each completeness category by bone.

	100%	**75% +**	**25% +**	**All**
Frontal	3.33	8.00	6.45	5.71
Right Parietal	2.78	1.89	4.48	4.28
Left Parietal	2.86	1.96	1.51	1.43
Left Temporal	0	1.75	1.49	1.45
Occipital	8.00	3.85	2.90	2.86
Mandible	3.45	1.81	1.49	1.47
Crania	20.00	X	X	16.00

<u>4.3.4 Lesions per Injured Individual</u>

As an overall trend, the number of lesions per injured individuals remains constant; however, this is only when the small bones are included. Due to their size many of these bones show only one injury. When the small bones are excluded there is a trend towards a decreasing number of lesions per injured individual as more fragmentary material is included, echoing the results found in the other calculations. Table 4.4 outlines the number of lesions per injured individual by bone. Exceptions to this trend include an initial rise in the number of injured individuals for the frontal and left temporal bones followed by a decrease, no linear pattern for the right parietal bones, and an increase in number for the crania.

Table 4.4 - The number of lesions per injured individual by bone for each completeness category.

	100%	**75% +**	**25% +**	**All**
Frontal	1.50	2.83	2.57	2.57
Right Parietal	1.20	1.17	1.33	1.33
Left Parietal	1.25	1.17	1.11	1.10
Right Temporal	1.00	1.00	1.00	1.00
Left Temporal	0	2.00	1.50	1.50
Right Maxilla	1.00	1.00	1.00	1.00
Left Maxilla	1.00	1.00	1.00	1.00
Right Nasal	1.00	1.00	1.00	1.00
Left Nasal	1.00	1.00	1.00	1.00
Occipital	6.00	6.00	3.50	3.50
Mandible	3.00	2.33	2.33	2.33
Crania	1.25	X	X	2.12

<u>4.4 Variation in the Trauma Frequencies between Completeness Categories</u>

The general trend for all of the trauma calculations was that of decreasing frequency as more fragmentary material was included. There are several explanations for the overall trend towards decreasing frequencies. These include:

1) The more complete, well preserved crania or cranial bones possessed more traumatic lesions;
2) The arbitrary way in which the sample was created biased the results.
3) Lesions that were present on the more complete material, hypothetically, were not preserved in the archaeological record as the bone degraded and became more fragmented;

Interpretation 1 is, in my opinion, unlikely. If interpretation 1 is valid, one would expect that the less dense, more fragile bones - the bones that are less likely to be preserved in the archaeological record, (Blumenschine and Marean 1993; Galloway et al. 1997; Lyman 1984; Willey et al. 1997) such as the nasals, maxillae, and the squamous portion of the temporals - would show comparable rates of trauma to the denser, less fragile bones. The trauma frequencies calculated in this study show the opposite effect. The frequency of trauma does not differ greatly by completeness for the maxillae as very few well-preserved, complete maxillae were available for analysis. The nasals, however, show the highest frequency discrepancy between the samples, ranging from 61.90% of individuals with lesions from the 100% complete category to 42.89% of individuals with lesions for the category where all fragments were included. The occipital bone shows a significant decline when trauma frequency was taken between the category requiring 100% completeness (f_1 = 72.00%) and the entire sample

(f_i = 30.00%). However, most of the traumatic lesions that account for the decrease are attributed to a single 100% complete occipital bone. When the frequency of individuals with traumatic lesions was calculated the decrease in frequency was negligible (f_i (100%) = 12.00%; f_i (All) = 8.57%). Additionally, the chance of traumatized bone being preferentially preserved over un-traumatized bone is slim. The skeletal material from the sample studied was subjected to similar taphonomic processes and thus would most likely have degraded at comparable rates.

This interpretation cannot be fully excluded, however, as the more highly traumatized bones came from the St. Bride's lower cemetery, the more complete, well preserved of the two samples, meaning that for many elements the trauma was, in fact, more abundant on the more complete material. The disturbances to the site of the Augustinian Priory of St. Mary Merton, the wealthier and more fragmentary of the two samples, coupled with the highly traumatized and less fragmentary material from the St. Bride's lower cemetery, make it impossible to completely exclude this interpretation and puts forth an alternative explanation for the frequency inconsistency: Interpretation 2, which states that the way in which the sample was created was biased.

The sample used in the current research (n=75) was selected by combining all of the crania which showed evidence of lesions (n= 44) with 31 other unlesioned skulls chosen at random from the cemetery of St. Mary Merton and St. Bride's lower cemetery collections. Of the 44 crania presenting traumatic lesions 29 were taken from the lower cemetery of St. Bride's Church. The material from the Augustinian Priory of St. Mary Merton presented less evidence of traumatic lesions, as would be expected with a British medieval sample of higher socioeconomic status (Roberts and Cox 2003) and, as was stated earlier, this sample was more fragmentary and poorly preserved. This could have biased the sample towards the St. Bride's material as it presented more evidence of trauma as well as better preservation and completeness. The individuals buried in the lower cemetery of St. Bride's Church were of lower socioeconomic status, mostly from the Bridewell workhouse and Fleet prison (Kausmally 2008). Not surprisingly, as poorer individuals were forced to work and live in dangerous, unsafe conditions where accidents were common (Roberts and Cox 2003), a higher number of the traumatic lesions were found on the St. Bride's material, as opposed to the St. Mary Merton material. The skeletal material from the Priory of St. Mary Merton was included for its fragmentary nature in order to limit the bias presented by the more traumatized, more complete St. Bride's material and offer a more inclusive representation of preservation and completeness often found in archaeological samples. Conducting the analysis on only the St. Bride's material would have reduced this bias. However, the samples in each completeness category would be too small, would have included too many complete, well preserved skulls, and would not provide enough evidence for the more fragmentary, poorly preserved material, biasing the results towards the more complete material.

Whether the discrepancy in trauma frequency is, in fact, a true representation of the trauma from the population or an effect of the poor preservation cannot be discerned without further research. However, as the actual trauma frequency for the population is not known, the frequencies found by this study cannot be tested against a known frequency. If the trauma frequency were known, it would provide a better understanding of which completeness requirement is more accurate. However, if the results of this analysis are taken as accurate, which they would be in a trauma analysis on an archaeological population, a discrepancy in the results is noted, meaning that the trauma frequencies found on the more fragmentary material are under-representative of the actual trauma frequency.

Interpretation 3 – lesions that would have been present on the more complete material, hypothetically, were not preserved in the archaeological record as the bone degraded and became more fragmented – is, in my opinion, the most likely. Logically, the trauma frequency found in each completeness category should be the same. If the sample is representative of the population, the frequency should remain constant as more fragmentary material is included. It is unlikely that the drop in frequency represents an accurate picture of the trauma from the sampled population or that the traumatized material was preferentially preserved over the unlesioned material, as the material was exposed to similar taphonomic forces. In addition, the chance of finding a lesion on a bone decreases as more of the bone is degraded. The problem that arises is that, without knowing the actual trauma frequency of the population, our understanding of the most accurate method for recording trauma is limited. While the trauma frequency on the living population cannot be known, the conclusion that can be drawn from the results presented in this study is that including the more fragmentary material (< 75% complete) in analyses does not add information to the results and may, in fact, under-represent the trauma frequency. In other words, using the more complete material allows us to see the true trauma pattern. The exclusion of the more fragmentary material may allow for a more accurate picture of the trauma pattern, while the inclusion of more fragmentary material is unnecessary and potentially problematic.

4.5 Meaning for Previous Research.

The overarching hypothesis tested in this study was that information is lost, or that trauma is under-represented, when fragmentary material is excluded from the analysis. This hypothesis was not corroborated. The inclusion of increasingly fragmentary material generally lowered the overall frequencies of trauma. Without knowing how these frequencies relate to the actual frequency of trauma in this sample, it is impossible to know with certainty whether information is missing in the more fragmentary samples. However, taking the information presented by the fragmentary samples as accurate, the frequencies found should be comparable in all categories. This was not the case in this research. The frequency of trauma declined as more material was included. This finding is an argument against the inclusion of the more fragmentary material. If a bone is only slightly preserved (< 25% complete) there is a greater chance that the lesions that were present on the hypothetically complete bones at the time of death have been taphonomically removed or destroyed and no longer available for analysis. In the current study the frequencies differ considerably between 100% complete material and highly fragmentary material. Interpreting the results of this study led to the conclusion that frequency calculations done on cranial material that is ≥ 75% complete is representative of the frequency of the population being studied. However, until a trauma analysis coupled with a preservation study can be undertaken on a sample where the actual trauma frequency is known, the most accurate method for recording and analyzing trauma cannot be determined. This issue would be accentuated when whole skeletons are considered, as less complete individuals would bias the study more significantly than the analysis of solely cranial material would. And, unfortunately the likelihood of having several well preserved, 100% complete skeletons in a sample is low. The use of only 100% complete cranial material is a problematic requirement for cranial trauma analyses. The requirement of ≥ 75% completeness for a bone to be considered complete, which was put forward by Buikstra and Ubelaker (1994) and later used by Judd (2002), is the most viable solution for the standardization problem, at least until further research on the subject can yield a better alternative.

The next question that arises is whether or not accurate trauma analyses can be undertaken on fragmentary skeletal samples. Again, without knowing the precise trauma frequency the actual accuracy of each method cannot be determined. It would seem that, statistically speaking, the difference between the frequencies found using the different completeness categories is dismissible. However, as the descriptive analysis suggests, the use of different categories creates misleading and ambiguous results, especially when compared with trauma frequencies that may have been recorded in a different way. To echo the previous research, in order for accurate inter-sample trauma comparisons to be undertaken, skeletal trauma should be recorded in the same way; standardization is necessary (Buikstra and Ubelaker 1994; Judd 2002; Walker 1997, 2001). While I am not advocating for the exclusion of all fragmentary material in skeletal trauma research, researchers should undertake frequency analyses with caution, taking into account potential biases they may face. Trauma analysis must be undertaken with care when fragmentation is an issue. When fragmentation is problematic, description of traumatic lesions may be more informative than attempting trauma frequency analyses. Until usable standards can be put into effect, researchers should explicitly state the method in which trauma was recorded, allowing other researchers to use the data for comparative studies and thereby minimizing potential bias.

This is not to say that analyzing fragmentary skeletal samples has no value. The main theme of the arguments presented in this study emphasizes the need for caution when interpreting trauma in the archaeological record (Judd 2002; Jurmain 1999; Walker 1997, 2001). Previously, osteological trauma research has been divided into four main categories: skeletal research using only complete crania or cranial elements (see Efran et al. 2009; Jimenez-Brobeil et al. 2009; Torres-Rouff and Junquiera 2006; Smith 2003; Walker 1989), skeletal research allowing for minor damage but requiring 75% completeness (see Judd 2004, 2006; Brasili et al. 2004), skeletal research done on entire samples but excluding the highly fragmentary material (<

25% complete) (see Williamson et al. 2003), and skeletal research done on all of the available material (see Jordana et al. 2009; Meyer et al. 2009; Efran et al. 2009; Kanz and Grossschmidt 2006; Smith 2003; Jurmain and Bellifemine 1997; Wilkinson 1997). There are arguments supporting and opposing the use of each technique. The use of only 100% complete material allows for ease and accuracy in gathering and recording skeletal trauma data and does not require an in-depth knowledge of the cranial bones, as complete crania and cranial elements are more easily identifiable than cranial bone fragments. However, as all of the fragmentary material is ignored the results will favour the individuals who were more complete (Judd 2002) and would bias the results against any cranial trauma that severely damages the skull, for example blunt force trauma with a large weapon. The frequencies found when using only 100% complete material were the most inconsistent for many of the bones analyzed in the current study. The use of only complete crania would become increasingly problematic when analyzing skeletal material from stratified societies where burial rituals may not have been the same for all members of the society. The frequency of traumatic lesions on the occipital bones decreases from 72.00% when only 100% complete occipital bones were included in the analysis to 34.62% with the inclusions of ≥ 75% complete material, 30.43% when ≥ 25% material was considered, and decreases only slightly to 30.00% when the entire sample was analyzed. The frontal bone frequencies also vary notably between the 100% complete category and the more fragmentary categories (f_l (100%) = 10.00%; f_l (≥75%) = 34.00%; f_l (≥25%) = 29.03%; f_l (entire sample) = 25.71%).

Tolerating minor bone damage, such as in the ≥ 75% complete category, retains much of the recording and analyzing ease but allows for the inclusion a larger range of preservation and completeness, thus ridding the analysis of some of its bias. The use of the entire sample in the archaeological record permits the inclusion a wider range of preserved material, thus a larger sample to analyze; however, frequency analysis becomes more difficult. The increasing inclusion of fragmentary material caused, in this analysis, a decrease in frequency of trauma, which suggests that the under-interpretation of trauma becomes more significant as more skeletal material is included in the analysis. Whether this is true for other samples requires further investigation. The problem is exacerbated when a sample is highly fragmentary and the number of individuals represented may be difficult to assess, potentially furthering the inaccuracy of frequency analyses. Trauma analysis using all of the fragmentary material may underestimate trauma frequencies, especially on highly fragmentary samples where the MNI is difficult to estimate. Even when the number of individuals represented in a sample is known, difficulty may arise when assessing fracture frequencies in a population as a partial individual must still be recorded as an individual and, depending on the bony portion preserved, fractures may be missing from the more fragmentary individuals. The likelihood of missing traumatic lesions increases as the bone becomes increasingly fragmentary. The need for standardization is clear; however, the diversity of skeletal preservation and completeness in the archaeological record causes difficulty in creating a universally functional methodology.

The results of the study illustrate that, for most bones, very little difference is seen in the frequencies calculated. There is, however, an obvious decline in the frequencies as more material is included. Statistically speaking, no significance was found for the independent samples (0 - <25%, 25% - <75%, 75 - <100%, 100%), with the exception of lesions on the right nasal bone (Fisher's exact value = 0.00; $P = 0.02$). This would suggest that the fragmentary nature of a sample can dictate the recording method without sacrificing accuracy. However, the values resulting from the calculations on the inclusive samples show obvious discrepancy. For example, the traumatic lesion frequency and the frequency of individuals with traumatic lesions for the nasal bones, which in the case of the nasal bones were equivalent, range from 61.90% for the 100% complete category to 42.86% when the entire sample is included, arguably a significant difference. This is especially problematic as fractures of the nasal bones are often taken as an indication of violence in past populations (Walker 1989, 1997; Hershkovitz *et al.* 1996). The violent tendencies of a population could easily be over interpreted in studies where only complete crania or cranial elements are examined.

4.5.1 A Zooarchaeological Approach to Preservation Issues

Many of the same issues are encountered in zooarchaeological research. As in osteological research, animal bone "modification studies are … hindered by: 1) lack of standardized descriptive nomenclature; 2) dearth of comparative case studies; 3) data sets scattered and in dire need of synthesis; 4) existing knowledge based on limited data sets; 5) workers from different fields lacking knowledge of many studies in areas outside their special areas of interest" (Marshall 1989:7). The same weathering and chemical processes affect animal bones as human bones. The same postmortem conditions must be met in order for animal bones to appear in the archaeological record for analysis and as such the employment of some of the cutmark analysis methodology would be beneficial in trauma analysis research. The analysis of cutmarks and postmortem bone modification is used by archaeologists to assess the origin of meat eating, butchery and dismemberment techniques, and to determine the animal carcasses used in antiquity. Examination of the marks can substantiate claims about past tool use, diet, hunting strategies, and animal butchering techniques (see Abe et al. 2002; Fisher 1995; Selvaggio 1994; Brewer 1992; Marshall 1989). The scope of this project does not allow for an in-depth analysis of surface modification of animal bones, an in depth review of the cutmark frequency research in the zooarchaeological literature, or an analysis of human bone using the zooarchaeological techniques. However, as zooarchaeologists are faced with similar frequency quantification issues, it is important to touch on how these issues have been addressed, bringing to light where development can be made in future osteological research. (For a more in-depth review of the cutmark frequency literature see Abe et al. 2002).

Issues around the partial representation of skeletal assemblages in cutmark analyses are circumvented by expressing an assemblage's completeness as a *percentage representation* or a *percentage survival* ratio. *Percentage representation* is the quantification of the ratio (NISP/MNI) or number of identified specimens (NISP) to the minimum number of individuals (MNI). The resulting ratio is an estimate of the skeletal completeness of a faunal assemblage. Alternatively, the *percentage survival* ratio*,* quantified by the ratio of minimum number of elements (MNE) to expected number of elements (ENE), displays the relative frequency of various bones that exist in an assemblage (Marshall 1989). These calculations can then be used to assess cutmark frequencies when faunal assemblages are fragmentary (Lyman 1992; see also Speth 1983). White (1992) uses zooarchaeological methodology in his assessment of the Mancos 5MTUMR-2346 skeletal assemblage to assess MNI and NISP, numbers with which he can assess frequencies.

Otarola-Castillo (2010) analyzed the change in cutmark patterns between well preserved and highly fragmentary faunal assemblages by simulating the butchering of deer long bones using ArcGIS 9.1 software. The purpose of the study was to examine the effects of fragmentation on cutmark-count when using the number of identified specimens (NISP) versus the minimum number of elements (MNE). The study illustrated that the cutmark frequency varied significantly from a control sample as fragmentation increased. The discrepancy was greatest when cutmark frequency was analyzed using NISP, but was still significant, but not as considerably, when MNE was employed. The author concluded that using MNE as the quantitative unit in cutmark analysis was more representative than using NISP (Otarola-Castillo 2010; see also Abe et al. 2002).

As in the osteological literature, methodology varies between authors and debate arises over the most accurate techniques; however, there is a general consensus throughout the literature that standardization is necessary (Abe et al. 2002; Lyman 1992; Fisher 1995; Brewer 1992; Marshall 1989). There are two basic techniques employed in the literature for analyzing cutmark frequency. In one method the frequency of individual specimens with cutmarks can be analyzed. In this technique, the number of bones with and without evidence of cutmarks is tallied. A ratio of specimens showing evidence of butchery to the total number of specimens examined is then calculated and the result is the cutmark frequency for that assemblage. This method is analogous to the method used in trauma frequency analyses on human skeletal material. Alternately, analysts calculate the frequency of cutmarks on a given element or area. This is done by tallying the number of cutmarks in an assemblage and the number of individuals or elements and then calculating the ratio (Abe et al. 2002; Otarola-Castillo 2010; Lyman 1992; Binford 1981). As in trauma frequency analyses, the more fragmentary a sample the more difficult it is to assess the total number of individuals represented (Lyman 1992). In an assessment of butchery marks on Nunamiut faunal assemblages, Binford (1981) calculated cutmark frequency by dividing the number of bones with cutmarks (MKD) by the minimum number of elements (MNE). Thus the frequency calculation was f = MKD/MNE.

In order to account for the taphonomic processes that often destroy bone in the archaeological record, Lyman (1992), in his study analyzing seal and sea-lion butchering practices, tallies the total number of surfaces that have the potential of displaying butchery-related marks and the number of surfaces where butchery-related marks are seen, as well as the number of external surfaces of the bones that have been modified through non-butchery-related processes. The frequency of butchery marks is then calculated by dividing the surfaces calculated for each anatomical area that showed butchering by the total number of surfaces with the potential for showing cutmarks. In an example provided by Lyman (1992:251), he notes "20 distal medial fragments may be in the sample, but 3 are heavily weathered and 2 have been gnawed by rodents, leaving only 15 with the potential to display butchery marks. If 5 display such marks then 33 percent is the proportional frequency of specimens with the potential to display butchery marks that in fact display such marks".

In his unpublished PhD dissertation, Rapson (1990) came up with a surface area correction for fragmentation, where the frequency of cutmarks is calculated by unit area. This calculation is done by multiplying the total number of cutmarks per specimen by 1,000 and then dividing by the specimen area. The resulting number is the frequency of cutmarks per 1,000 mm^2. Overall frequency can then be calculated by taking the mean surface area and the mean frequency of cutmarks per unit area (mean $f = f/mm^2 \times SA$). Abe et al. (2002) take this a step further arguing that, by using image-analysis software (they suggest GIS), frequency can be analyzed with higher precision. Using GIS software, cutmarks can be analyzed by percent surface area as the computer can more easily calculate MNI and can accurately calculate the *percentage survival* ratio. There is still little consensus over the most accurate method for analyzing cutmarks in faunal assemblages. However, as more research has been done on analyzing cutmarks than on trauma analysis, it may be beneficial to employ some of the techniques used in the zooarchaeological literature. This is the reason that considering the methods and examples presented by Binford (1981), Lyman (1992), and others is important. Future trauma frequency research could examine whether the accuracy of trauma frequency analyses increases when preservation is quantified by percentage or frequency by unit area, or by employing Lyman's (1992) cutmark potential method.

4.6 Possible Changes to the Current Research

Were this study to be repeated, a few adjustments should be made. Firstly, choosing a larger sample that presented a wider range of traumatic lesions would allow for statistical analysis to be undertaken with more accuracy. Statistically speaking, the size of the sample in this study was problematic as there were very few individuals with traumatic lesions in each preservation category when the samples were divided into independent data components. Furthermore, creating more preservation categories would broaden our understanding of the effect of preservation on trauma analyses. Thus including an '≥ 50% complete' category and applying this to the crania as well as to the bone elements would be beneficial.

4.7 Variation in Frequency Analysis Results between Completeness Categories

The results presented in this study illustrate a decline in trauma-related frequencies as more fragmentary material is included in the analysis. The results indicate that the way in which cranial trauma is recorded and analyzed currently is effective, statistically speaking, however when descriptive analyses were undertaken on the results, notable discrepancies were found. The results indicated that the inclusion of incomplete material (< 75% complete) is unnecessary and potentially problematic, as the lesion frequency decreases significantly for many of the cranial bones. Inter-sample analysis should not be attempted unless recording and analysis is done in the same way. Frequency analysis should be undertaken with extreme caution, and the interpretation of trauma frequency may be problematic for fragmentary samples. The observed decrease in frequency as more fragmentary material is included in an analysis complicates the issue of calculating trauma frequencies. Further research into the effect of completeness on cranial trauma analyses where the actual trauma frequency for a population is known is necessary. The need for a standardized methodology for recording and analyzing trauma is obvious, yet without further research in this area accurate standards may be difficult to implement. Until concrete standards can be put into effect, researchers should be meticulous about stating their methods and the potential biases that may be presented by the skeletal material in their samples.

Chapter 5: Conclusions and Future Research

5.1 General Conclusions

The aim of this research was to examine whether information is lost when fragmentary cranial material is excluded from cranial trauma analyses. The study tested cranial trauma frequencies commonly employed in trauma analyses of archaeological samples. The frequencies examined included the overall trauma frequency, the frequency of individuals with trauma, the frequency of individuals with multiple traumatic lesions, and the number of lesions per injured individuals, using set completeness criteria. The analysis was conducted in two separate ways. Initially, the calculations were undertaken using the following inclusive preservation criteria: the entire sample, all cranial material that was ≥ 25% complete, all cranial material that was ≥ 75% complete, and all cranial material that was 100% complete. The inclusive data were analyzed descriptively as the samples were not independent and statistical analysis could not be performed. The results of these analyses clearly show a general decrease in all of the trauma frequency calculations as more fragmentary material is included. The most likely interpretation of this decrease is that trauma frequency decreases due to the taphonomic loss of the lesions that would have been present on complete, well-preserved bone. In other words, using the more complete cranial material is more representative of a population's trauma frequencies than calculations done using an entire sample regardless of cranial completeness.

In order to test whether the discrepancy in frequencies was statistically significant, the cranial material was reanalyzed using independent categories (< 25% complete, between 25% complete and < 75% complete, between 75% complete and < 100% complete, and 100% complete). The results demonstrated a lack of statistical significance for all of the bones except for the frequency of right nasal bones with lesions ($P = 0.02$). While the statistical analysis illustrated little significance in the results, it is important to note that the use of statistical means to test the current hypothesis – that the trauma frequencies are under-represented as increasingly fragmentary material is included in cranial trauma analyses - may be problematic. As a statistical analysis could not be carried out on the inclusive samples, there may be no accurate statistical means of testing the hypotheses related to trauma frequency by skeletal preservation, meaning that the statistical results found in this study are potentially negligible and the descriptive results are the more instructive of the two, especially when the small sample sizes of the independent samples are taken into consideration.

The inclusive results presented in this study illustrated a decline in trauma-related frequencies as more fragmentary material is included in the analysis. All of the trauma data should be collected as they may be useful in identifying patterns in the trauma location but the results indicated that the inclusion of fragmentary material (< 75% complete) in frequency analysis is unnecessary and potentially problematic. The fracture frequency decreases significantly for many of the cranial bones. This contradicts the initial hypothesis that information is missed as more fragmentary material is ignored. As more fragmentary material is included more of the evidence of trauma that would have been present in the, hypothetically, complete bones is lost.

5.2 Implications for Previous Research

In cranial trauma research to date there are no universally accepted standards for recording and analyzing cranial trauma. Researchers choose the amount of skeletal material to include in their research based on the ease of recording and the level of preservation of the material available. Problematically, the use of different categories creates misleading and ambiguous results, especially when compared with trauma frequencies that may have been recorded in a different way. To echo previous research, in order for accurate inter-sample trauma comparisons to be undertaken, skeletal trauma should be recorded in the same way; standardization is necessary (Buikstra and Ubelaker 1994; Judd 2002; Walker 2001, 1997). While not advocating for the exclusion of all fragmentary material in skeletal trauma research, the results found in this research suggest that researchers should undertake frequency analyses with caution, taking into account potential biases they may face. Trauma analysis must be undertaken with caution when fragmentation is an issue. When severe fragmentation is an issue, description of trauma may be more instructive than attempted trauma frequency analyses. Until usable standards can be put into place, researchers should base the minimum skeletal preservation requirements on the level of preservation in their research sample. This being said, authors should explicitly state the method in which trauma was recorded, allowing other researchers to use the data for comparative studies and thereby minimize potential bias. Additionally, the use of previous research for comparison should be avoided if fragmentary material was included in the sample or the research was recorded or analyzed in a different way.

The current research provides a starting point for the formulation of a standard set of guidelines in cranial trauma research. The variation in preservation and completeness in the archaeological record makes creating a universal set of guidelines difficult; however, if the current research was expanded to include several samples and similar results were found, then, arguably, a standard could be set for cranial trauma frequency analysis for the inclusion of material that is ≥ 75% complete and the exclusion of material < 75% complete. The guidelines could stipulate that ignoring the more fragmentary material is not necessary in a descriptive analysis of the trauma found on a population; however, the more fragmentary material should be excluded when frequencies are being calculated. If the same methodology is applied to multiple samples with the same result, then an accurate and implementable standard could be put into place.

The analysis of fragmentary material can still be beneficial for descriptive analyses of the trauma in a population; however, the results found in this study suggest that including the more fragmentary material in frequency calculations increases the likelihood of underestimating the amount of trauma in a population. For example, the traumatic lesion frequency and the frequency of individuals with traumatic lesions for the nasal bone, which were the same for each calculation as each nasal bone only presented one lesion, ranges from 61.90% for the 100% complete inclusion requirement to 42.86% when all of the material is included, arguably a notable difference. This problem becomes more important when researchers attempt to evaluate differences in percentages between samples or populations. For many bones, the use of only 100% complete crania is equally problematic. The frequency calculations on the occipital and frontal bones illustrate the discrepancy. The frequency of trauma found using only 100% complete occipital bones was 72.00%, whereas when the more fragmentary material was included the frequency ranges from between 35 and 30% ($f_l(\geq 75\%) = 34.60\%$; $f_l(\geq 25\%) = 30.40\%$; $f_l(\text{entire sample}) = 30.00\%$). The frequency of lesions on the frontal bone illustrates a different pattern; however, a notable discrepancy is still seen between the 100% complete category and the less well preserved material ($f_l(100\%) = 10.00\%$; $f_l(\geq 75\%) = 34.00\%$; $f_l(\geq 25\%) = 29.00\%$; $f_l(\text{entire sample}) = 26.00\%$). For this reason the use of Buikstra and Ubelaker's (1994) guidelines for completeness – a bone is complete if ≥ 75% of the bone is present – should be applied to cranial trauma frequencies and frequency calculations should be done on skeletal material that is ≥ 75%.

The inclusive, descriptive analysis values resulting from the calculations on the inclusive samples show obvious discrepancy. When comparing samples for which lesion frequencies were recorded in different ways the results may not be viable. This is especially problematic as fractures of the nasal bones are often taken as an indication of violence in past populations (Hershkovitz et al. 1996; Walker 1989, 1997). The violent tendencies of a population could easily be over-interpreted in studies in which only complete crania or cranial elements are examined.

5.3 Further Research

Further research is needed to understand whether this phenomenon of decreasing trauma frequencies as fragmentary material is included is evident for other samples or is simply true for the sample tested in this study. If there were a tendency toward decreasing fracture frequencies with the inclusion of more fragmentary material in other samples, it would seem that there is a significant issue with comparing samples that had different preservation and completeness criteria, further illustrating the need for standardization in trauma analysis research (Buikstra and Ubelaker 1994; Walker 1997). Gathering trauma frequency data from a range of samples and analyzing it according to multiple preservation categories would allow for a more precise understanding of the effects of preservation on trauma frequencies and would allow for accurate standards to be created.

Furthermore, it would be beneficial for an analysis of complete skeletons to be undertaken, taking into consideration the potential causes and implications attached to trauma. This type of trauma analysis would be more representative of actual research as trauma analyses for archaeological samples often consider the whole skeleton when interpreting and creating narratives about the population being studied. Interpretation of trauma is being scrutinized in the literature as the cause of trauma is often difficult and, in some cases, impossible to ascertain (Jurmain 1999; Walker 1997).

Additionally, trauma analysis research would benefit from a study similar to the current research with a taphonomic component. A taphonomic study on an assemblage exhibiting fractures and an analysis of the difference in fracture frequency over time (as fragmentation increases using the presented preservation criteria) would add to our understanding of preservation issues. Drawing on the zooarchaeological research on cutmark analysis, fracture frequency could be calculated using *percentage representation* and *percentage survival* ratios akin to those put forward by Marshall (1989) or using Rapson's (1990) surface area correction for fragmentation (mean $f = f/\text{mm}^2 \text{ X } SA$). A computer simulation of trauma using a known fracture frequency and using GIS software to analyze the change in frequency as simulated postmortem bone degeneration occurs could potentially enhance our knowledge of how fracture frequencies change with increased fragmentation.

Further research into the effect of completeness on cranial trauma analyses is necessary. The need for a standardized methodology for recording and analyzing trauma is obvious, yet without further research in this area accurate standards may be difficult to implement. Until concrete standards can be put into effect, researchers should be meticulous about stating their methods and the potential biases that may be presented by the skeletal material in their samples.

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Appendix A. Data Collection Template for Cranial Completeness.

CRANIAL COMPLETENESS

#	CONTEXT	CRANIA	FRONTAL	PARIETAL		TEMPORAL		OCCIPITAL	ZYGOMATIC		MAXILLA		NASAL		MANDIBLE
				R	L	R	L		R	L	R	L	R	L	

FOR CRANIA

*0= INCOMPLETE; 1= 100% COMPLETE

FOR BONE ELEMENTS

*0=ABSENT; 1= LESS THAN 25% COMPLETE; 2= 25-75% COMPLETE; 3= ≥ 75% COMPLETE; 4= 100% COMPLETE

Appendix B. Data Collection Template for Presence of Lesions.

LESIONS (PRESENCE ABSENCE) PAGE 1

#	CONTEXT	LESION SIZE	LESION SHAPE	FRONTAL	PARIETAL		TEMPORAL		ZYGOMA	
					R	L	R	L	R	L

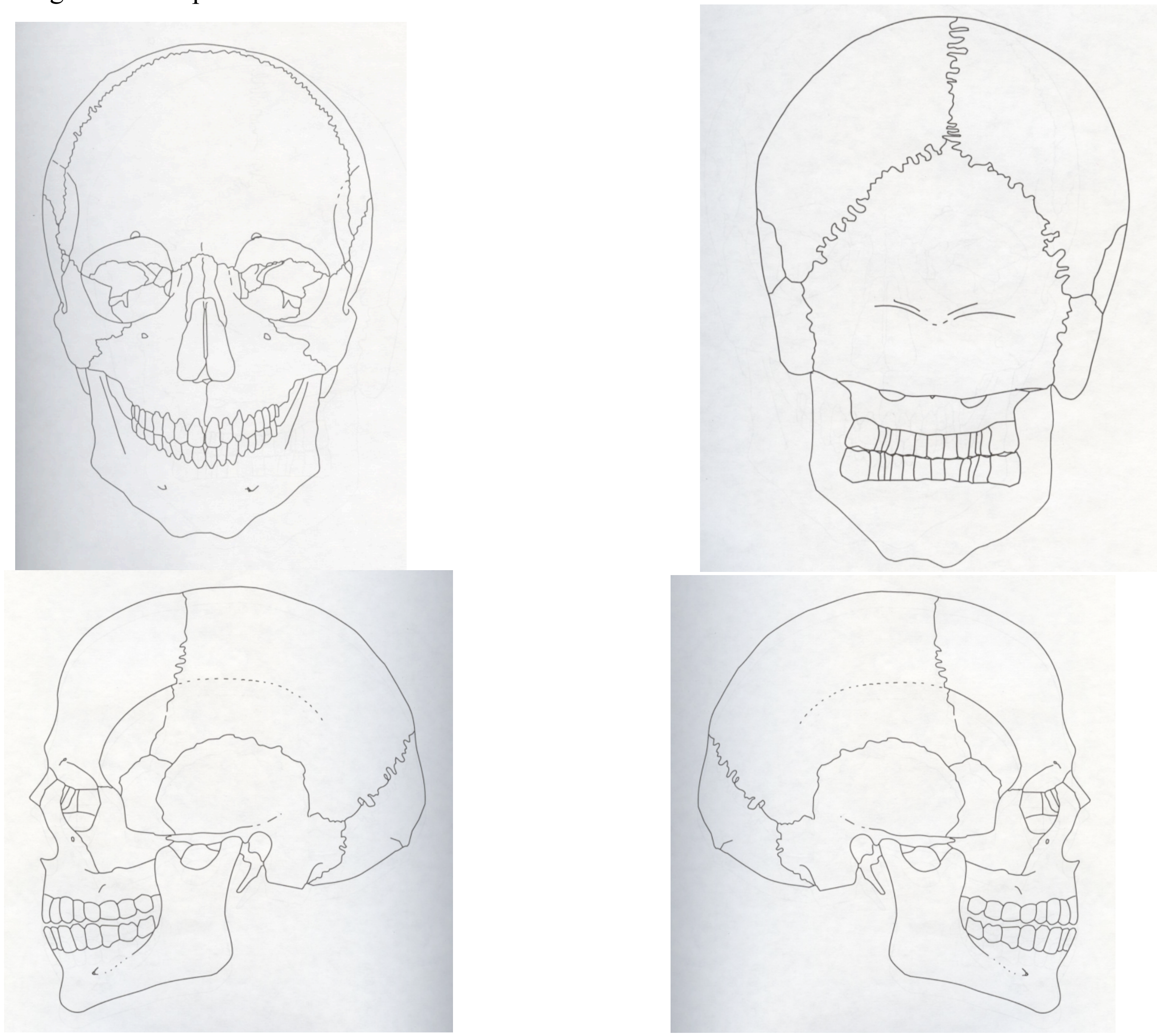
*0=NO LESION; 1=LESION PRESENT; 2 (AND UP) REPRESENT THE NUMBER OF LESIONS PRESENT ON THE BONE ELEMENT

LESIONS (PRESENCE ABSENCE) PAGE 2

#	CONTEXT	OCCIPITAL	MANDIBLE	MAXILLA		NASAL		TOTAL # OF LESIONS
				R	L	R	L	

*0=NO LESION; 1=LESION PRESENT; 2 (AND UP) REPRESENT THE NUMBER OF LESIONS PRESENT ON THE BONE ELEMENT

Appendix C. Skull Recording Form Template.



CONTEXT:

Appendix D. Criteria For Assessing Lesions.

Antemortem and perimortem lesions that were not pathological in nature were analyzed in this study. The criteria used to classify the lesions is as follows:

Antemortem Trauma Classification:
- Lesion displaying evidence of healing (callus formation; rounded edges).

Perimortem Trauma Classification:
- Lesions displaying broken ends that are similar in colour to the bone surface.
- Fractures at oblique angles. Fractures that occur in bones of living or recently dead individuals tend to form acute angles to the bone surface (Walker 2001).
- Sharp force lesions, distinguished from other lesions by their regular, defined edges.

Postmortem Damage Classification:
- Fractures where the edges are a different colour, usually lighter, than the bone surface.
- Fractures are at a right to the bone's surface. Due to the postmortem breakdown of collagen in bone, bone becomes more brittle and tends to break at a right angle to the surface of the bone (Walker 2001).

(Buikstra and Ubelaker 1994; Walker 2001)