

PUTTING FRACTURE REDUCTION ON REPEAT: AN ANALYSIS OF
THE LONG-TERM HEALTH CONSEQUENCES OF DIFFERENTIAL
TREATMENT IN INDUSTRIAL-ERA LONDON

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Derek A. Boyd

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ABSTRACT

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Traumatic injury is the leading cause of mortality in over ten percent of all deaths worldwide, and is becoming a major global issue. Treatment can prevent injury-related mortality, but access to it is constrained by culture. Further, those that survive the injury event may develop long-term health conditions, including subsequent injury. To understand how culture might constrain access to treatment in the present, and why such a constraint might have long-term health consequences, this study investigated patterns of treatment and subsequent injury in two socioeconomically disparate communities from Industrial-era London (AD 1700-1850).

It was hypothesized that the quality of treatment received (1) was unevenly distributed among the population, and (2) influenced the likelihood of subsequent injury. Fractures and their complications were recorded for forty-six individuals curated at the

Museum of London Centre for Human Bioarchaeology, thirteen individuals from the high-status Chelsea Old Church sample, and thirty-three individuals from the low-status St. Bride's Lower Churchyard sample. The prevalence of fracture complications, including fracture deformity and non-union, were first compared between samples, and then between individuals with single and multiple fractures.

The results suggest that (1) socioeconomic status did not deter individuals from seeking treatment for their injuries in either community, and (2) the quality of treatment received did not influence the likelihood of subsequent injury. These results highlight the importance of considering the avenues for treatment available in a given cultural context, and demonstrate that other factors beyond the complications surrounding a prior injury may influence lived experiences with future injury. Further, this research calls attention to the problems inherent in making inferences about treatment in the archaeological record. Limitations aside, it has the potential to inform the discourse on industrialization and its influence on access to treatment.

CHAPTER I

INTRODUCTION

Unequal distributions of disease, undernutrition, trauma, and biological adaptation are the products of human action and interest rather than natural and inevitable stressors equally born by all members of a society. (Zuckerman et al. 2012:50)

Accidental and inflicted injuries constitute some of the most common pathological conditions found on archaeological, historical, and contemporary human skeletal remains, and may contribute to mortality as either a primary cause, a comorbidity of another insult, or a chronic debilitation (Glencross and Stuart-Macadam 2001; Kilgore et al. 1997). In the present, trauma is the leading cause of mortality in over ten percent of all deaths worldwide, and is rapidly becoming a formidable, global pandemic (Leppäniemi 2004). Recent trends in globalization have facilitated exposure to new environments and, consequently, new forms of trauma for many individuals around the world.

The current infrastructures of most developed and developing countries favor individuals from high-income households (Leppäniemi 2004). They are buffered from the negative health consequences associated with traumatic injury, including infection, biomechanical instability, subsequent injury, and, ultimately, mortality, among others, due to their ability to afford the time and money necessary for proper treatment and recovery (Roberts and Manchester 2005). Most of the world's population, however, lives

in low-income households and suffers high mortality due to lack of effective medical treatment, which, to most, explains why trauma is becoming a major global issue (Leppäniemi 2004).

What most people do not realize, however, is that trauma has always been a threat to the human species. Throughout history, humans have been exposed to changing sociocultural and physical environments, and have sought innovative ways to adapt to these changes through culture (Buzon 2012; Ortner 2003). An exploration of the ways in which human cultures have adapted to trauma in the past might prove useful in identifying some of the biological and social factors that influence variation in treatment and its long-term health consequences in the present. This thesis seeks to do so using England as the backdrop for analysis, as it was the first country to embrace industrialization (Roberts et al. 2009).

The Industrial Revolution in the 18th and 19th centuries altered England's sociocultural and physical environment (Roberts and Cox 2003; Roberts et al. 2009). Rapid population growth created a rising demand for food, which put pressure on rural agricultural communities to increase productivity (Roberts et al. 2009). Urbanization associated with the movement and transformation of small farms from rural areas into large, powerful factories, mining operations, and quarries instigated increases in population density, the prevalence of workplace injuries, and interpersonal violence associated with social conflict (Roberts and Cox 2003). These sociocultural circumstances likely instigated increases in the prevalence and diversity of traumatic injuries, which would have created a rising demand for effective treatment.

Anthropological studies of treatment in the post-Medieval period, however, are largely absent from the literature. Historians of medicine suggest that avenues for treatment of traumatic injuries during this time period were numerous (e.g., Wear 1995; Risse 1993). Individuals of varying socioeconomic status could seek help from bonesetters, clergymen, surgeons, physicians, and even family and friends. There is, however, little discussion amongst historians of the potential for variation in the quality of treatment received, which is unfortunate. Complications following injury, including malalignment or deformity, joint damage, and infection are more likely to develop when an individual experiences inadequate care (Roberts and Manchester 2005; Kilgore et al. 1997). These additional health insults can induce long-term physiological stress that accumulates over time and predisposes the injured to future health insults, including subsequent injury (Klaus 2014). Together, this kind of information could lend valuable insight into patterns of cultural and structural violence as potential by-products of development, which may lead to a better understanding of quality of life in developed and developing countries.

Research Questions and Hypotheses

In relation to the concerns mentioned previously, this thesis seeks to address the following research questions:

- Were there socioeconomic status differences in access to treatment for traumatic injuries?
- What role, if any, did differences in socioeconomic status, and rural and urban life play in the quality of treatment received?

□ Did the quality of treatment received influence the likelihood of subsequent injury?

This thesis aims to address these questions by testing two major hypotheses. The first hypothesis was that the quality of treatment received, if any, was unevenly distributed among the population. If this was the case, then the expectation is that there will be a higher prevalence of post-traumatic complications in individuals from the lower classes than in individuals from the upper classes. The second hypothesis was that the quality of treatment received influenced the likelihood of subsequent injury. If so, then the expectation is that there will be a statistically significant association between the level of treatment received and the prevalence of individuals with one or more traumatic injuries.

Research Design

Human skeletal remains from two well preserved, but socioeconomically disparate cemetery collections housed by the Museum of London Centre for Human Bioarchaeology (CHB) were analyzed for evidence of trauma and its comorbidities. The Chelsea Old Church cemetery sample (AD 1700-1850) included a rural upper class community from the town of Chelsea. The St. Bride's Lower Churchyard cemetery sample (AD 1770-1849), in contrast, included an urban lower class community from St. Bride's Parish. Estimates of age and sex were co-opted from the Wellcome Online Research Database due to time constraints. Although both males and females were considered for this study, all individuals under the age of 18 were included.

Organization of Thesis

Chapter II outlines and describes the theoretical orientation used in this thesis. It begins with an introduction to bioarchaeological and paleopathological theory. Following this introduction is a breakdown of the theoretical framework employed in this study into three fundamental parts: (1) traumatic injuries record hazardous human-environmental interactions; (2) treatment is a cultural response to injury, but is ultimately constrained by culture; and (3) cultural constraints on treatment may have long-term health consequences.

Chapter III provides the historical background necessary to contextualize treatment for traumatic injuries and its possible long-term consequences. It is divided into four sections. The first section provides an overview of the Industrial Revolution in Britain. The second section delves into the presence of medical plurality in Britain's Industrial period and the development of the medical profession. The third section discusses some of the sociocultural circumstances that might have contributed to the development of injury recidivist behaviors. The last section identifies and discusses pertinent background information about the samples used in this thesis.

Chapter IV reviews the methods of data collection implemented in this thesis. First, the sampling strategy is described. Then, methods for estimating sex and age at death are outlined. Following this, methods for identifying single and multiple traumata, and assessing fracture deformity and non-union are discussed. This chapter ends with an outline of the statistical framework used to evaluate the research hypotheses under investigation.

Chapter V provides the results of this study. It is divided into four main sections. The first section includes the results of an analysis of the age and sex structures of both cemetery samples. The second section provides a breakdown of the distribution of fractures in each cemetery sample by location, type, and mechanism of injury. The third section provides the results of analyses pertinent to address the first research hypothesis. The last section of this chapter provides the results of analyses necessary to address the second research hypothesis.

Chapter VI discusses the results of this study. It is divided into two sections. The first section evaluates the quantitative results of this study that are associated with the first hypothesis that the quality of treatment received, if any, was unevenly distributed among the population. The last section evaluates the results associated with the second hypothesis that differential treatment influenced the likelihood of subsequent injury.

Chapter VII details the conclusions of this study. It is comprised of three parts. The first and second parts of this chapter provide the conclusions and potential considerations associated with the first and second research hypotheses, respectively. The third part of this chapter identifies and discusses the general limitations of this study, and suggests potential avenues for future research. The chapter ends with a summary of the findings of this thesis and their implications for the study of treatment for traumatic injuries in contemporary and archaeological skeletal populations.

CHAPTER II

THEORETICAL ORIENTATION

Introduction

This chapter outlines and describes the theoretical orientation used in this thesis. It begins with an introduction to bioarchaeological and paleopathological theory, specifically the application of the biocultural approach to the study of archaeological skeletal remains. Following this introduction is a breakdown of the theoretical framework employed in this study into three fundamental parts. The first part argues that traumatic injuries record hazardous human-environmental interactions. The second part posits that treatment is a cultural response to injury, but it is ultimately constrained by culture. The last part proposes the idea that cultural constraints on treatment may have long-term health consequences, including subsequent injury.

Bioarchaeology, Paleopathology, and the Biocultural Approach

The human skeleton is a physical record of life experiences (Sofaer 2006). Physical anthropologists, particularly bioarchaeologists, are interested in studying these experiences for the purposes of gaining insight into the human past. Bioarchaeology is the study of human skeletal remains from archaeological contexts. It combines method and theory from archaeology, cultural and physical anthropology, history, and medicine, among others, to rigorously interpret human skeletal variation at a given point in time

(Buzon 2011). Paleopathology, an important research topic in bioarchaeology, is concerned with the study of ancient disease (Grauer 2011). Skeletal trauma, while not technically a disease, is considered a pathological condition, and is, therefore, within the purview of paleopathology. Because the focus of this thesis is skeletal trauma, bioarchaeological and paleopathological theory, specifically the biocultural approach, can be used to analyze and interpret patterns of injury and treatment in London's archaeological record.

The biocultural approach to studying ancient disease was born out of ecological anthropology and processual archaeology in the 1960s and 1970s, around the time that bioarchaeology emerged as a subdiscipline of physical anthropology and archaeology (Goodman and Leatherman 1998; Buzon 2011). This approach posits that there is a dynamic interaction between humans and their physical and cultural environments. In other words, an individual's socioeconomic status, religious affiliation, living environment, and occupation, among others, impacts their biology and behavior, and *vice versa* (Zuckerman et al. 2011). Proponents of the biocultural approach often argue that human culture is an adaptive mechanism; it is used to buffer against the biological consequences of daily life (Zuckerman and Armelagos 2010). In this study, traumatic injuries are considered to be the outcomes of hazardous human-environmental interactions, and treatment is considered to be a cultural adaptation, as it has been shown to significantly decrease injury-related mortality in the present (Leppäniemi 2004). In the following sections, this theoretical framework is expanded upon and discussed using relevant literature.

Traumatic Injuries

Skeletal Trauma Analysis in Paleopathology

Traumatic injuries to the human skeleton, clinically and anthropologically referred to as skeletal traumata, are bodily wounds or focal areas of damaged biological tissue that are produced by the physical interaction between the body and an external force (Roberts and Manchester, 2005; Ortner 2003; Lovell 1997). Paleopathologists generally recognize four categories of skeletal trauma: (1) fractures, (2) dislocations and avulsions, (3) disruption of vascular and nervous supply, and (4) cultural modification. Of these four categories of skeletal trauma, fractures provide the most intuitive insight into treatment for traumatic injuries, particularly because they often, but not always, require a combination of reduction, splinting, and immobilization to facilitate remodeling with minimal complications (Roberts and Manchester 2005). For this reason, only fractures were analyzed for evidence of treatment in this thesis.

A fracture is defined as a discontinuity, disruption, or break in bone resulting from the intrusion of an external force (Lovell 1997). It can be classified as either complete or incomplete. Fractures can also be classified as open or closed. Open fractures, or fractures that expose the bone to the external environment through open tears in the integument, often result in infection unless antibiotic treatment is sought out (Ortner 2003). It is difficult to diagnose a fracture on archaeological bone as either open or closed, since the soft tissue is usually absent. Instead, the presence or absence of infection – usually osteomyelitis or periosteal new born formation – is considered indicative of an open fracture (Lovell 1997).

Fractures are also classified based on the mechanism of injury (i.e., direct, indirect, pathological, stress). A direct fracture (e.g., transverse) occurs at the point of impact. Indirect fractures (e.g., oblique, spiral), in contrast, occur at locations other than the point of impact (Lovell 1997). Pathological fractures occur when preexisting pathological conditions (e.g., osteoporosis, osteosarcoma) present on bone alter the biomechanical stability of the affected element and increase its susceptibility to fracture. Stress fractures (e.g., hairline fractures) are produced by exposure to repeated stress and strain. Direct, indirect, and pathological fractures were included in this study. Stress fractures were excluded, because they are less likely to require reduction or splinting, and are, therefore, less likely to lend insight into treatment for traumatic injuries in the archaeological record (Raasch and Hergan 2006).

In addition to identifying fracture type and the mechanism of injury, the paleopathologist is interested in estimating whether the ultimate cause of a particular fracture was either a violent altercation or an accident. The ultimate causes for some fractures (e.g., sharp force, projectile) are easier to estimate than others (e.g., fractures to the forearm) (Ortner 2003; Lovell 1997). Paleopathologists typically associate most fractures to the skull, posterior ribs, and hands and feet with violent altercations (e.g., Grauer and Roberts 1996; Lovell 1997). Researchers should be cognizant, however, of the potential for misidentifying the ultimate cause of a traumatic injury, particularly when using fracture names or eponyms instead of purely descriptive terms.

Some of the clinical eponyms given to commonly occurring fractures (e.g., parry fracture) should be used with caution, because they often imply causation (Judd 2008). Mixed with an inadequate understanding of fracture characteristics, the improper

use of fracture eponyms has the potential to impede proper identification of accidental and inflicted injuries. Unfortunately, eponyms cannot be avoided, because they are useful for associating observed fractures with the clinical literature concerning treatment. As a result, they are necessary for the current study. Regardless, paying careful attention to fracture characteristics and their distribution throughout both the individual skeleton and the entire skeletal sample can facilitate the construction of well-informed inferences about the ultimate causes of injuries (Lovell 1997).

Biosocial Predictors of Injury

Data concerning fractures, their characteristics, and their proximate and ultimate mechanisms of injury are important for informing theories and hypotheses about human biological and cultural adaptations to specific environments. According to the biocultural approach described above, traumatic injuries record hazardous human-environmental interactions; they are one of the many biological consequences of daily life. By reconstructing lived experiences with injuries through the analysis of skeletal trauma, more can be learned about the biosocial variables that affect their distribution within and between human populations.

Some of the biosocial variables known to influence the distribution of skeletal trauma within and between populations include intrinsic factors, such as age and biological sex, and extrinsic factors, such as living environment, activity patterns, and social status (Buzon 2011). Exposure to the hazardous physical and social environment increases with age. Therefore, researchers should expect to see a higher prevalence of skeletal traumata in older populations. If this pattern is not observed, it is an indication that another variable may be influencing risk of injury in a given sample or population.

In addition to age, biological sex plays an important although more ambiguous role in the distribution of traumatic injuries within a community or population (Redfern 2006). Males and females may be treated differently based on their positions within their culture. The sexual division of labor, for example, may produce observable sex differences in the prevalence and distribution of traumatic injuries, because it exposes males and females to different environmental hazards.

Extrinsic factors, such as the living environment (e.g., rural versus urban) and associated activity patterns also influence lived experiences with traumatic injuries. Judd and Roberts (1999), for example, studied the patterning and prevalence of long bone fractures within the Raunds Furnells cemetery sample, a Christian Saxon cemetery located in the Nene Valley, UK, that was occupied between A.D. 900-1100. The results of their study were compared to one rural and two urban cemetery samples with similar temporal and spatial components. While there were similarities in the prevalence of traumatic injuries between the Raunds Furnells cemetery sample and the comparative rural sample, and between the two comparative urban samples, they found that the differences between medieval rural and urban living environments had a significant effect on the prevalence of long bone fractures. Subsequent archival research suggested that urban peoples were more commonly employed in comparatively less labor intensive occupations than rural peoples. In contrast, Djuric and colleagues (2006) found a lower prevalence of traumatic injuries in a rural late medieval Serbian sample, which demonstrates the importance of considering cultural context.

Although residency patterns clearly impact lived experiences with disease, this thesis is concerned with the role that social status plays in the distribution of

traumatic injuries within and between populations. Contemporary and historic human societies are far removed from their prehistoric egalitarian ancestors. Individuals within and between societies are organized hierarchically based on a variety of factors, including income, religious beliefs, political affiliation, ethnicity, and sex and gender, among others (Zuckerman et al. 2011; Babic 2005). Social status is used to illustrate an individual's relative position within the social hierarchy using these various interacting biosocial factors. To reconstruct social status in the archaeological past, Bioarchaeologists primarily consider the burial context (e.g., grave goods, burial position) and any individualizing biohistorical data available.

While burial context can give insight into an individual's position in the social hierarchy, it often cannot be used to represent the entirety of one's social status. As a result, researchers often incorporate archival, historical, and ethnographic research into their assessments of social status when possible, and remain sensitive to it when generating conclusions about the archaeological past. Murphy (2004) and Powell (2008), for example, utilized a combination of burial context and ethnohistoric accounts to examine status differences in the prevalence of traumatic injuries at the cemetery of Puruchuco-Huaquerones in Peru, and the Chucalissa Mississippian community in Tennessee, US, respectively. Murphy (2004) examined 207 skeletons comprising the upper, middle, and lower social echelons for evidence of skeletal trauma. Their hypothesis was that there would be status-related differences in the prevalence of injuries associated with a change in the distribution of political power in the Incan Empire between A.D. 1476-1532. They found a higher prevalence of injury among the middle and lower social classes, but the association was not statistically significant. A possible

explanation for these findings is that the inclusion of the middle class could have introduced uncontrolled heterogeneity in health-related experiences into the study sample, as it tends to moderate the differences between the extremes (e.g., upper and lower classes) (Jose 2013). For this reason, the current study only considers individuals from London's upper and lower social echelons.

Powell (2008) examined several Mississippian communities for evidence of status-related differences in the prevalence of traumatic injuries. They hypothesized that elite individuals, particularly males, would exhibit a higher prevalence of traumatic injuries than non-elites, because they were more likely to engage in warfare with neighboring communities. Of the five major Mississippian communities studied, only the Chucalissa and, tentatively, the Moundville communities supported their hypothesis. Findings from the King site, in contrast, suggested that non-elites were more likely to suffer traumatic injuries than elites. The skeletal samples from the Dallas/Hixon and Etowah sites were poorly preserved or incomplete, and were excluded from analysis. Together, these two studies show that social status has a variable effect on the prevalence of traumatic injuries within and between communities and whole cultures. Future research should consider incorporating as many lines of evidence (e.g., mortuary archaeology, ethnohistory, archival documentation) into assessments of social status prior to analyzing its impact on human health.

In this thesis, social status is defined as one's position within the larger social hierarchy that is directly affected by their occupation and consequent level of income. A more parsimonious term for this definition would be socioeconomic status, which is a derivative of social status. Although this is but one aspect of an individual's social

identity, there is historical evidence that suggests that social status in London and the rest of Great Britain, particularly in the industrial period, was largely influenced by income (Roberts et al. 2009). These findings, therefore, support its utility in this thesis as a potential predictor of the patterning and distribution of traumatic injuries and treatment in industrial London.

In sum, traumatic injuries record hazardous human-environmental interactions. These interactions are dictated by one's position along the physical and cultural landscape. Intrinsic factors, such as age and sex differentially expose people to injury, as do extrinsic factors, like living conditions, activity patterns, and social status, among others. Social status, in particular, is an inherently complex concept that is difficult to define, but has been shown to exert a considerable yet highly variable influence on risk of injury within and between communities and whole cultures, both in the present and in the past.

Treatment for Traumatic Injuries

Anthropologists can link the past to the present using the biocultural approach by examining how changing cultural circumstances impacted human health. However, fundamental to this approach is the concept of adaptation, which, when applied to studies of trauma, implies a degree of resiliency. In other words, humans cannot adapt to changing cultural and physical environments without surviving the traumatic events themselves. Therefore, it is necessary to study how they responded to traumatic injuries both biologically and culturally by examining patterns of fracture healing.

Fracture Healing

Following a traumatic injury that does not result in immediate mortality, the body instigates an intricate healing process whose goal is to restore proper structure and function to affected element(s). While there is consensus within the paleopathological community as to the process of healing, different researchers classify the stages of fracture healing differently. Ortner (2003) and Lovell (1997), for example, refer to a five-stage process, while Roberts and Manchester (2005) outline a three-step process. For this discussion, emphasis will be placed on the process of fracture healing rather than the number of stages or steps associated with it.

In general, the process of fracture healing involves the formation of a hematoma, followed by the development of a fibrous callus that is replaced by a primary bony callus, and, ultimately, a secondary bony callus that is remodeled until the affected element regains its biomechanical stability (Ortner 2003; Roberts and Manchester 2005; Lovell 1997). Hematoma formation occurs within the first 24 hours of an injury event following the rupture of the bone's vascular supply. Within three weeks of the injury event, osteoblastic activity at the periosteal and endosteal surfaces of the fracture site produces and deposits a matrix of fibrous connective tissue (e.g., osteoid). This granular tissue permeates and displaces the fracture hematoma, producing a temporary fibrous callus that, although unmineralized, provides a framework upon which the primary bony callus can form. This fibrous callus is composed of three components: the endosteal, intermediate, and periosteal calluses. The endosteal callus bridges the traumatized marrow cavity, the intermediate callus connects the fracture margins, and the periosteal callus bridges the periosteum.

With time, each component of the fibrous callus is replaced first by woven bone (e.g., primary bony callus), and then by lamellar bone (e.g., secondary bony callus) (Ortner 2003; Roberts and Manchester 2005; Lovell 1997). Replacement occurs through three separate but simultaneous processes: woven and subsequent lamellar bone is apposed to the periosteal and endosteal surfaces of the fibrous callus; granular tissue is broken down through osteoclastic activity; and osteons are remodeled internally. Following the formation of both primary and secondary bony calluses, remodeling continues in the form of callus reduction until the traumatized bone regains most if not all of its biomechanical stability.

Timing of Injury

While the process of fracture healing is consistent and predictable, the rate at which it occurs is highly variable (Ortner 2003). Factors that affect the rate of healing include the location and severity of a fracture, the degree of apposition and stability of the fractured ends, and the individual's age and nutritional status. While the timing of the initial stages of fracture healing is generally consistent, accuracy in the estimation of the age of an injury severely decreases over time following the initial stages of callus formation between six and nine weeks (Lovell 1997). This is especially the case with archaeological remains, as only the periosteal callus is directly observable unless the researcher has access to radiographs (Roberts and Manchester 2005).

Even with access to radiographs, it is nearly impossible to estimate the age of an injury without detailed biohistorical documentation. Therefore, to remain objective and minimize error, paleopathologists commonly classify fractures as either antemortem (AM) or perimortem (PM). AM refers to an injury that occurred some time prior to death,

whereas PM is used to describe an injury that occurred at or around the time of death (Lovell 1997). AM injuries will exhibit evidence of fracture healing, including the presence of rounded fracture margins, and in more remote fractures, the presence a primary or secondary bony callus. These characteristics are absent in injuries considered to be PM.

Fractures to the bone that occur after death (i.e., the postmortem interval) are common in archaeological remains. Post-mortem damage (PMD) to human skeletal remains is often ignored in paleopathological studies, because it does not provide any insight into past human cultures; rather, it records the biotic and abiotic aspects of the burial context, which are often products of the biogeochemical processes inherent in the physical landscape. However, researchers need to take into consideration the presence of PMD, because it can be difficult to separate from AM and PM injuries (Ortner 2003). The characteristics of the fracture margins and other areas of the bone, however, can be used to distinguish between the two (Lovell 1997). For example, oblique edges are considered to be indicative of AM/PM injuries, while squared edges suggest PMD. Additionally, uniform soil staining along the fracture margins and the external surface of the bone suggests AM/PM injury, while variation in soil staining between these two surfaces indicates PMD.

Complications of Traumatic Injuries

As with most pathological conditions, traumatic injuries may be accompanied by comorbidities, or complications of the injury event. These complications include infection, tissue damage (e.g., avascular necrosis, nerve damage), fracture deformity, delayed union, non-union, secondary osteoarthritis, atrophy, ankylosis, traumatic *myositis*

ossificans, and, ultimately, mortality (Ortner 2003). They can occur for a variety of reasons commonly associated with the location, type, and severity of the injury.

However, most injuries, particularly to the appendicular skeleton, can be effectively treated to minimize or prevent entirely the development of these comorbidities (Roberts and Manchester 2005).

Infection and subsequent vascular and nervous tissue damage can accompany a fracture (Ortner 2003; Lovell 1997). Open wounds, in particular, maintain an elevated risk of infection, because the fractured bone and surrounding soft tissue may become exposed to external pathogens through a tear in the integument. Infection has the potential to disrupt the fractured bone's blood supply, causing necrosis of the osseous tissue surrounding the fracture site. Necrosis, however, can also be caused by other aspects of an injury, including its location, severity, and relation to adjacent soft tissue. Nerve damage can accompany bone necrosis, as nervous tissue is often positioned adjacent to the body's vascular supply; however, it can also occur without the presence of bone necrosis. While infection can be prevented or treated with antibiotics, vascular and nervous tissue damage may be more difficult to prevent and treat.

Another complication that may accompany a fracture is malalignment or deformation of the traumatized element (Lovell 1997). It is most often caused by powerful muscle contractions adjacent to the injured element (Ortner 2003). These contractions force the fractured ends together, causing the distal segment to deviate from its normal position. An individual presenting with fracture deformity might exhibit angulation or rotation of the distal segment, poor apposition of the fractured ends, or overlap and consequent shortening (Grauer and Roberts 1996).

A fracture in the process of healing exhibits angulation when the distal fragment deviates linearly from its natural longitudinal axis. It may also exhibit rotational deformity when the distal end is medially or laterally rotated about the same axis. When the muscular contractions are strong enough, the distal segment may also extend into or overlap the proximal segment. In instances where the fractured ends do not overlap, they may exhibit a variable degree of reunion, referred to as apposition. The presence of any of these types of deformity or any other complication may ultimately cause shortening of the affected element.

Shortening can also be caused by the failure of the fractured ends to reunite (Lovell 1997; Roberts 1988). This is referred to in the paleopathological and clinical literature as non-union. Non-union is thought to occur as a result of repeated disruption of the fracture callus, which causes hyaline cartilage to form instead of osteoid (Schinz et al. 1951). Alternatively, non-union may also occur when soft tissue, such as muscle, is interposed between the fractured ends (Resnick et al. 1995).

It is difficult to determine whether a fracture was complicated by a non-union or a delayed union, particularly in archaeological individuals (Ortner 2003). Delayed union, which is different than non-union, occurs when the rate at which the element is healing is slower than expected in a clinical setting for any given injury (Lovell 1997). Eventually, a case of delayed union may be reclassified as a non-union. However, identifying whether an archaeological case of non-union is truly non-union or just a delayed union is impossible. The presence of sealed but separate medullary cavities on the fractured ends is generally considered to be highly suggestive of non-union.

It may also be difficult to distinguish between non-union and pseudoarthrosis in archaeological bone. A pseudoarthrosis is a potential outcome of non-union. Due to repetitive loading and disruption of the fibrous fracture callus, hyaline cartilage formation proliferates (Ortner 2003). With a pseudoarthrosis, a cleft develops at the fracture site, permitting the formation of a synovial fluid-filled sac; it thus approximates a true joint. Without evidence of a synovial capsule, it may become incredibly difficult to tell pseudoarthrosis apart from non-union.

Premature or secondary osteoarthritis (OA) may develop either in association with another fracture complication, or as an inevitable comorbidity of intraarticular fractures (Ortner 2003; Buckwalter and Brown 2004). Fracture complications, like deformity, ultimately disrupt and even prevent the complete restoration of biomechanical stability. As a result, the articular surfaces of the traumatized elements and, in some cases, their contralateral counterparts may undergo abnormal biomechanical loading. Over time, abnormal stress on joints erodes the articular cartilage, causing eburnation and bony proliferation at the joint margins (Waldron 2009; Ortner 2003). Secondary OA almost always accompanies intraarticular fractures, as the blood vessels damaged by the injury event deposit blood into the adjacent joint spaces (Buckwalter and Brown 2004). However, secondary OA may not develop despite the presence of fracture complications, and Roberts and Manchester (2005) note the difficulties inherent in being able to identify whether or not the OA was present prior to the injury event.

Atrophy and traumatic *myositis ossificans* may also develop following fracture (Ortner 2003). Atrophy of the affected or adjacent element may result following long-term disuse. It may be facilitated by intense pain and/or loss of innervation and

blood supply in the affected elements. Fractures may also be accompanied by traumatic *myositis ossificans*, a condition in which injured muscle tissue ossifies following formation of a muscle hematoma. Traumatic *myositis ossificans* need not always accompany a fracture, and it may also be a temporary phenomenon.

Most of the complications of traumatic injury mentioned above are observable in the archaeological record, and can be mitigated or prevented through the same basic three-step process of treatment (Ortner 2003; Roberts 1988; Boehler 1935). First, the fractured ends should be repositioned and realigned (i.e., reduced). Then, the injured element should be temporarily immobilized through splinting, or internal or external fixation. Finally, the element or limb and surrounding soft tissue should be exercised carefully to maintain circulation and muscle tone (c.f., physical therapy).

At any point in the process of treatment, a complication can develop. For example, failed reduction or immobilization may produce fracture deformity or non-union and consequent secondary OA (Roberts 1988). In most cases, either the quality of the treatment received, an individual's agency in caring for his or her own injury, or a random accident may be the ultimate cause for why treatment failed (Roberts and Manchester 2005). Unfortunately, most of this information is lost in the archaeological record. Indeed, only the outcome of the healing process is observable on archaeological bone when biohistorical documentation is absent. Therefore, it is difficult to make inferences about treatment for traumatic injuries in the human past. Despite this issue, Roberts (1988), and Judd and Redfern (2011) posit that a multidisciplinary approach to studying treatment that integrates clinical, ethnographic, historical, and osteological data

may facilitate the development of stronger inferences about treatment in the archaeological record.

Fracture Treatment in the Archaeological Record

Consistently observed in the ethnographic record is the three-step process of treatment for traumatic injuries mentioned above: fracture reduction, immobilization, and subsequent physical therapy. That this phenomenon exists in aboriginal populations suggests that some form of treatment was likely available to the injured in the past (Roberts 1988). While the process of treatment is relatively consistent, the quality of treatment received varies within and between populations (Lovejoy and Heiple 1981). That considerable variation in treatment exists between extant cultures today has recently led archaeologists to investigate culture-specific treatment practices in the human past (Roberts 1988; Tilley and Oxenham 2011).

Lovejoy and Heiple (1981) provided one of the first systematic studies of skeletal trauma using the Libben population from the Late Woodland period (AD 500-1000). In it, they not only systematically assessed the prevalence and distribution of fractures and other traumata among individuals of all ages and sexes; they also examined patterns of fracture healing, and made inferences about the treatment received. That none of the 450 individuals analyzed exhibited marked angulation or shortening suggested that these Late Woodland peoples had sufficient knowledge of the therapeutic practices associated with fracture treatment. This landmark study arguably laid the foundation for future studies of treatment by providing a methodological framework for trauma analysis,

and a baseline for the development of biocultural theories tied to treatment in the archaeological record (Judd and Redfern 2011).

Following this research, several studies have yielded important insight into treatment for traumatic injuries in the archaeological record (e.g., Trinkhaus and Zimmerman 1982; Roberts 1988; Grauer and Roberts 1996; Hawkey 1998; Mitchell 2004; Dupras et al. 2010; Redfern 2010; Tilley and Oxenham 2011; Lessa 2011; Dougherty 2011). Together, these studies have demonstrated that traumatic injuries and their treatment reflect the biocultural circumstances associated with human-environmental interactions and the cultural adaptations that mitigate their biological consequences (Buzon 2011). Community and population-level research specifically focused on treatment, however, remains sparse (Judd and Redfern 2011). Fortunately, much like this thesis, several of these studies have explored treatment in England's archaeological record (e.g., Roberts 1988; Redfern 2010; Grauer and Roberts 1996).

Roberts (1988) provided the first extensive examination of treatment in England's archaeological record. They macroscopically and radiologically examined patterns of fracture healing on a combined total of 5,954 skeletons from the Romano-British (AD 43-410), Anglo-Saxon (AD 410-1066), and Medieval periods (AD 600-1485) who were associated with several cemetery samples from multiple archaeological sites in England. They wanted to know whether or not, and during what time period knowledge of fracture treatment was acquired and utilized. Based off of an analysis of the prevalence of fracture complications within and between time periods, the author found that people from the Romano-British and Anglo-Saxon periods exhibited better fracture

healing than those from the Medieval period. Unfortunately, this study did not assess the relationship between socioeconomic status and treatment.

Grauer and Roberts (1996) examined patterns of traumatic injuries and their treatment in a low socioeconomic status medieval community from St. Helen-on-the-Walls in York, England (AD 1100-AD 1550). They utilized macroscopic and radiologic methods to identify, analyze, and interpret patterns of fracture healing on 1,104 adult long bones. They found that, of those individuals with fractures (n=30), most injuries were well-healed and properly aligned. These results suggested that, unlike earlier peoples, individuals of low status medieval communities may have received effective treatment for their injuries.

More recently, Redfern (2010) examined patterns of treatment for skeletal trauma in Dorset, England, in the Iron Age (500 BC-AD 100) and in the Romano-British Period (AD 100-AD 400), the latter of which experienced immense sociocultural change following Roman conquest in AD 43. Focusing specifically on evidence for AM trauma and surgical intervention, the author examined 190 subadults and 270 sexed adults. They found that, as early as the Iron Age, individuals suffering traumatic injuries were able to receive effective medical treatment from skilled professionals, and that, in doing so, they were able to minimize their risk of developing fracture complications. However, the author also found that access to skilled medical care was largely contingent on socioeconomic status, and that those individuals who were unable to afford these services would have likely developed fracture complications.

These three studies have both a theoretical and methodological impact on this thesis. From a theoretical standpoint, they suggest that socioeconomic status, when

assessed, played a variable role in the distribution of treatment within and between archaeological communities in England. More broadly, these studies inform biocultural theories about health and disease by demonstrating that, although treatment represents a cultural response to injury, it is ultimately constrained by culture. From a methodological standpoint they provide a multidisciplinary framework upon which this thesis is constructed. This thesis, however, differs methodologically from these studies in three ways. First, radiographs were not examined, as the resources necessary to do so were unavailable. Second, a non-parametric statistical framework was implemented since a sufficient sample size was obtained. Lastly, fracture deformity and non-union were the only fracture complications considered for analysis due to time constraints.

Fracture deformity and non-union are more intuitive than other fracture complications in terms of their relationship to the process of fracture treatment. Fracture deformity most often occurs due to failed or unattempted reduction, although it can happen at another point in the healing process (Marsh 1998). Non-union most often occurs following poor immobilization, although it is also found in individuals with complex injuries, poor nutrition, limited blood supply, and when soft tissue is interposed between the fractured ends (Ortner 2003; Lovell 1997; Resnick et al. 1995). Other fracture complications, such as infection, necrosis, and osteoarthritis, can occur for a variety of reasons unrelated to the treatment process, and may therefore provide less reliable evidence of it in the archaeological record (Ortner 2003).

In sum, following a hazardous interaction with the physical and social environment that leaves the individual with a fracture, the body initiates an intricate healing process whose goal is to restore biomechanical stability to the affected element.

A variety of biological and cultural factors may impact the healing process by slowing it down and/or instigating the development of fracture complications, such as fracture deformity and non-union. Evidence of these comorbidities on human skeletal remains therefore reflects the biocultural circumstances surrounding the healing process, including access to treatment, which has sparsely been studied at the community and population level. By examining patterns of fracture complications, and by inference treatment, in the archaeological record, anthropologists can learn more about the role of treatment as a buffer to injury-related mortality, and the impact that culture has on its distribution among archaeological and contemporary populations.

Subsequent Traumatic Injury

It is clear from previous sections that the healing process is governed by the biological and cultural factors that manifest themselves on the skeleton through the comorbidities of injury. It is also clear that treatment can only be indirectly inferred in the archaeological record through an analysis of the outcomes of the healing process. What is unclear is the effect that variation in the healing process has on the distribution of individuals with single and multiple traumatic injuries. This is particularly the case with archaeological populations, although there is a dearth of clinical literature on this topic as well. One of the main purposes of this thesis is to examine this relationship, as it may help explain the distribution of individuals with single and multiple traumatic injuries in the archaeological record.

As with many aspects of paleopathological research, bioarchaeologists have relied heavily on the clinical and forensic literature to understand exhibited pathologies

on archaeological bone (Ortner 2003; Lovell 1997). Fundamental to the development of biocultural theories surrounding skeletal trauma in the archaeological record was a clinical study conducted by Sims and colleagues (1989) that challenged the previously held idea that traumatic injuries were randomly distributed among populations. While this study paved the way for the development of many of the concepts described in previous sections, it also contributed to the development of the concept of injury recidivism first among forensic anthropologists and clinical researchers, and then among bioarchaeologists (Judd 2002). For the latter, this idea provided a framework upon which researchers could analyze and interpret the distribution of individuals with single and multiple traumatic injuries among archaeological populations.

An injury recidivist is defined as an individual who has accumulated multiple traumatic injuries over their lifetime (Judd 2002). Injury recidivists maintain a unique relationship with their environment. These individuals are victims (or perpetrators) of their sociocultural circumstances, which predispose them to subsequent injury (Dougherty 2011; Judd 2002). In clinical studies, injury recidivists are men of low socioeconomic status who frequently become involved in agonistic interactions, are exposed to occupational hazards associated with poor working conditions, and cannot afford the time or money to treat their injuries (Sims et al. 1989; Reiner et al. 1990; Goins et al. 1992; Smith et al. 1992; Poole et al. 1993; Hedges et al. 1995; Madden et al. 1997; Williams et al. 1997; Kaufmann et al. 1998).

Judd (2002) provided some of the first insight into potential injury recidivism in the archaeological past. They studied a combined total of 266 rural and urban Sudanese Nubians from the Kerma Period (2500-1500 BC) for evidence of demographic

patterning in the distribution of individuals with single and multiple accidental and inflicted traumatic injuries. To do this, they grouped individuals by sex, age, and archaeological site. The author then further divided up individuals based on the number of traumatic injuries they exhibited (i.e., zero, one, and two or more). Afterwards, they analyzed the prevalence data, and found that most of the individuals with multiple traumatic injuries mirrored the typical characteristics of modern injury recidivists. They ended their study with a call for future research into injury recidivism in the archaeological record.

Redfern (2006) applied the methodological framework developed by Judd (2002) to a sample of 270 individuals living in Dorset, England. The skeletal remains came from 21 archaeological sites in the area that dated to the Iron Age and Romano-British periods. Although only part of their dissertation research, Redfern found that there was a decrease in recidivism from the Iron Age to the Romano-British periods. They posited that an overall decrease in violence associated with the Romanization of Dorset likely explained the decrease in recidivism, as most of the individuals exhibiting subsequent traumatic injury tended to suffer from inflicted rather than accidental injuries.

In their dissertation, Dougherty (2011) provided a cautious analysis of patterns of single and multiple traumatic injuries exhibited by 985 impoverished occupants of the Milwaukee County Institutional Grounds cemetery, Milwaukee, Wisconsin, which was in use from AD 1882-1925. They applied a much more conservative methodological framework based on Judd (2002), and remained even more conservative in their conclusions concerning the presence of injury recidivism in the study sample. The author found that injury recidivism was a potential reality for adult

males living in Milwaukee in the early twentieth century, but recognized that the true prevalence of recidivism was likely underestimated due to the absence of soft-tissue injuries, the context in which the individuals were buried, and to nature of the archaeological record.

Important in Dougherty (2011)'s discussion of recidivism, and what is considered to be of fundamental importance to this thesis, is that clinical research identifies prior injury as an important predictor of future injury. Madden and colleagues (1997) found in their sample of 34,378 individuals that, regardless of ethnicity, gender, or age, all patients presenting with a prior injury were at a higher risk of suffering a future injury, particularly if the previous injury was suffered within the last year. In their study of 2,511 identified recidivists, Brooke and colleagues (2006) found that individuals with a prior injury were at a higher risk of suffering a future injury of the same type (e.g., penetrating injury).

More recently, Fulton and colleagues (2014) conducted a literature review of several clinical studies involving the relationship between previous injury and subsequent injury. A majority of the literature reviewed indicated that previous injury, particularly to the lower extremities had a remarkable impact on the likelihood of suffering an injury in the future. In their discussion of their findings, Fulton and colleagues posited that several different neuromuscular alterations, including deficits in strength, balance, and ease of motion often follow an injury event. These deficits were argued to contribute to a loss of joint stability simultaneous with altered sensorimotor control, leading to compromised motion, and, ultimately, an increased risk of future injury.

These clinical and archaeological studies highlight the realities of recidivism and the mechanisms – both biological and cultural – that influence its manifestation in clinical and forensic contexts, and in the archaeological record. What these studies do not explicitly concern themselves with, however, is an analysis and subsequent discussion of how variation in the outcomes of the healing process (potentially associated with access to treatment) may impact the likelihood of suffering an injury in the future, if it does at all. Fracture complications, such as deformity and non-union, would be expected to alter the biomechanical stability of traumatized elements and their affected joints, particularly in the limbs (Lovell 1997; Ortner 2003; Fulton et al. 2014). In other words, their presence on the human skeleton suggests that the healing process failed to restore stability to the affected limbs and joints. Therefore, the presence of these comorbidities may contribute to the neuromuscular deficits described above, adding to a greater risk of future injury. The question then becomes, how important is variation in the healing process, and by association access to treatment, in the risk of subsequent injury? By answering this question, anthropologists can add a layer of depth to their understanding of the patterning of single and multiple injuries in both archaeological and modern human populations.

Summary

The human skeleton is a physical record of life experiences. Anthropologists can examine human skeletal remains in the past using bioarchaeological and paleopathological theory, particularly the biocultural approach, to make sense of observed patterns of skeletal pathologies, and advance their understanding of their evolution throughout human history. Born out of ecological anthropology and processual

archaeology, the biocultural approach posits a dynamic interaction between human biology and culture. Proponents of the biocultural approach argue that culture is an adaptive mechanism used to buffer against the biological consequences of daily life, and that through studying both aspects of human life, anthropologists can examine the adaptability of culture.

By examining the characteristics of traumatic injury to the skeleton, anthropologists can reconstruct the biological and cultural circumstances that led to its occurrence in the past. They can also observe the morphological outcomes of the healing process, such as fracture deformity and non-union, to learn more about the biological and cultural forces that influenced it, including access to treatment, which involves the reduction, immobilization, and mobilization of an affected element or joint. Treatment is difficult to infer in the archaeological record, however, due to an absence of information concerning individual medical histories. If it was received in the past, it would be impossible to determine when any observed complications developed, and what biological or cultural mechanism influenced their development. However, consideration of the clinical and forensic literature, and contextualization of treatment using historical sources can aid the researcher in making stronger inferences about treatment in the past.

Repeated interactions with the physical and cultural environment increases the risk of injury following a previous traumatic episode. What may contribute to this increased risk are the outcomes of the healing process, which may be influenced by an individual's access to treatment. Regardless of whether treatment was sought out and received, neuromuscular deficiencies may accompany a healed or healing injury, and may contribute to subsequent injury and, potentially, the development of recidivist

behaviors. The question is how much does variation in the healing process, which may be associated with access to treatment, impact neuromuscular deficiencies and consequent injury? By answering this question, anthropologists can add a layer of depth to their understanding of observed patterns of single and multiple traumatic injuries and their long-term outcomes in the archaeological past.

CHAPTER III

HISTORICAL BACKGROUND

Industrial history is not primarily about machines, raw materials, processes, and producers. It is about the people who created, innovated, labored, suffered, acquired, bought and enjoyed, became rich or died young, lived comfortably on the profits, or were crushed by the harshness of it all. (Trinder 2013:38)

Introduction

This chapter provides the historical background necessary to contextualize treatment for traumatic injuries, the possible impact that socioeconomic status may have had on its distribution among Britain's industrial population, and the potential outcome of that interaction. Specifically, it is divided into four main parts. The first part provides an overview of the Industrial Revolution in Britain, what caused it, how it altered the social hierarchy, and how it affected risk of injury. The second part delves into the presence of medical plurality in Britain's Industrial period, and recounts how the medical profession changed to meet the needs of the sick and injured, yet ultimately remained constrained by the changing social hierarchy. The third part discusses some of the sociocultural circumstances in eighteenth and nineteenth century Britain that might have contributed to the development of recidivist behaviors. The last part of this chapter identifies and discusses pertinent background information about the St. Brides Lower Churchyard and Chelsea Old Church cemetery samples used in this thesis.

Britain's Industrial Revolution

The Industrial Revolution in Britain was once thought to be an immensely overbearing and rapid reorganization of the entirety of British culture around large-scale factories and mining operations (Trinder 2013). This sociocultural transition in Britain's history was historically confined to the period AD 1760-1840 (e.g., Mantoux 1961). In recent decades, however, many historians have revisited the anecdotal and hyperbolic interpretations of the historical data that influenced previous perceptions of this important period in Britain's history. With more rigorous and systematic methods for analyzing and interpreting archival and archaeological data, historians have begun to paint a new picture of Britain's industrial period. The Industrial Revolution is now viewed as the gradual integration of new technologies into the facets of everyday life that altered Britain's social, economic, and political landscape (Trinder 2013; Morgan 2004; Belchem 1990; Pawson 1979). Although its roots are considered to extend back as early as the Renaissance, between approximately AD 1485-1620, most current historians consider the Industrial Revolution to specifically encompass most of the eighteenth and nineteenth centuries (Trinder 2013).

Important to the change in the conceptualization of the Industrial Revolution and its impact on British society is how historians define the terms industrial and revolution (Trinder 2013). Industrial is a descriptor for any sort of process or cultural domain that involves the procurement, combination, and transformation of raw materials into a specific product. It does not necessarily require or equate to the use of large machines with the capacity to debilitate its workers. Revolution typically refers to a dramatic, wide sweeping movement with the goal of social, political, or economic

change. With the Industrial Revolution, however, historians consider the term revolution to refer to a mosaic pattern of slow, gradual, change associated with the integration of industrial activities into British society. This section outlines the causes of the Industrial Revolution in Britain, and identifies the ways in which it contributed to social differentiation, and created or modified differences in risk of injury between existing and emerging social classes.

The Causes of the Industrial Revolution in Britain

Prior to the industrial revolution, and partially responsible for its success, labor and energy were exchanged between the industries of agriculture, craft, and urban services (Pawson 1979). Increases in Britain's population size in the eighteenth and nineteenth centuries associated with in-migration and higher fertility rates contributed to a rise in the demand for resources produced by these industries (Trinder 2013; Morgan 2004; Pawson 1979; Mantoux 1961). To meet these demands, the agricultural and craft industries, in particular, underwent gradual, yet considerable reorganization. These events, however, were by no means planned (Trinder 2013).

One of the major movers of the industrial revolution was the influx of laborers from the agricultural industry in the rural areas to crowded urban centers in search for work in factories, mines, quarries, construction, and markets, among others (Trinder 2013; Morgan 2004; Pawson 1979; Mantoux 1961). This gradual out-migration of individuals from the rural areas was associated with Parliament's decision to enclose fields shared by the commonwealth beginning in the eighteenth century. Enclosure involved a considerable degree of consolidation of several smaller fields into large farms

where specific crops could be intensified over others. The overproduction of agricultural products at the local level had a considerable impact on stymieing hunger at the national level, as produce was distributed via enhanced transportation systems to several of the major urban centers in England, including London. It should be noted that enclosure began to occur with remarkable frequency in the seventeenth century, but was typically instigated by the selling of common fields to interested parties by the land owners. At that time, however, laborers could utilize other adjacent fields that had not yet been enclosed. With Parliamentary action, the rate of enclosure skyrocketed, leaving the common folk with little room to maintain their agricultural lifeways. Hence, they made their way towards urban centers around England where, simultaneous to the enclosure movement, the craft industry was experiencing a gradual overhaul.

Increased trade and exchange within and between communities and cultures, facilitated by improvements in transportation, created new channels for production (Trinder 2013; Morgan 2004; Pawson 1979; Mantoux 1961). To maximize production, new ways of making commercial goods emerged. These new ways of crafting using new methods and technologies fueled an increase in the division of labor. Increased occupational specialization, in turn, resulted in an increase in the number of low-wage employment opportunities, of which immigrants from the countryside and elsewhere took advantage. Cheap labor produced a surplus of goods, which were sold to local communities, and through improvements in transportation, distant communities and cultures. The drive to capitalize on consumer goods, particularly in a growing consuming culture, provided fuel for the development of innovation after innovation to the point that, by the nineteenth century, Britain had seen the development of some of its greatest

innovations (e.g., steam engine). Reliance on factories, mines, and quarries was integral to such triumphs. Factories, in particular, were hubs for intensified production. The utilization of specialized machinery made possible the concentration and mass multiplication of production at an accelerated speed. With the increasing popularity of the factory, small-scale crafting industries were headed towards extinction, and laborers were forced to seek employment in large-scale industries.

The effects of the reorganization of the agricultural and crafting industries were felt all over Britain. Nowhere was this more apparent than in London, Britain's capital. Between 1750-1825, London nearly doubled in population size (Barnett 1998). During this time, it became one of the largest industrial centers in the world. It was also one of the world's largest consumer cultures. Following the enclosure movement and subsequent in-migration of laborers to the City, the diversity and number of industries with their own labor specializations increased drastically. However, not all factories were large-scale, and not all were labor intensive (Trinder 2013; Barnett 1998). Trinder (2013) posits that large-scale and labor intensive industries were less common in London, because wage rates in the City were much higher than in other areas of the country, creating a higher cost of labor. Many manufacturing industries relocated to the Midlands to the north, which had greater prospects of cheaper labor. They also posited that many large-scale industries fled to other areas of the country, because too many members of London's population were employed in other sectors, such as finance, medicine, and public service. Taken together, the historical data suggest that London, although comparatively less factory oriented than other areas of Britain, experienced immense sociocultural change with the Industrial Revolution.

Ultimately, it is important to remember that Britain's Industrial Revolution was not some deterministic force (Trinder 2013); it did not have an all encompassing impact on every aspect of society. Factories, in particular, were not nearly as overbearing as commonly thought. They were, on average, small in scale, and far from proliferative until at least the 1840s, particularly in London (Trinder 2013; Barnett 1998; Belchem 1990). The idea that they completely obliterated small-scale crafting industries is false as well, as even by the 1870s, there were hundreds if not thousands of workers in the craft industry who had never even experienced factory life (Trinder 2013). Belchem (1990) reminds us that, when considering the impact that industrialization had on British culture, emphasis should be placed on the *process* rather than the *technology*, because technological innovation, while both the impetus for and outcome of the Industrial Revolution, was not nearly as important as the social ramifications of the processes that produced and amplified it.

Social Differentiation and Risk of Injury in Britain's Industrial Period

The Industrial Revolution brought with it the reorganization of the British social hierarchy. Specifically, it facilitated the emergence of the middle and working classes (Trinder 2013; Belchem 1990; Pawson 1979; Mantoux 1961). Along with affluent families, members of the new middle class profited off the shoulders of the poor and working classes, perpetuating and strengthening the disparity between the rich and poor members of British society. Modification of the social hierarchy altered the roles of urban and rural peoples, and exposed them to new environmental hazards both at home and in the workplace (Roberts and Cox 2003; Belchem 1990; Mantoux 1961).

The middle and working classes emerged from the reorganization of the agricultural and craft industries in the industrial period (Trinder 2013; Belchem 1990; Pawson 1979; Mantoux 1961). Individuals who invested in enclosed fields hired rural laborers for cheap to tend to the land, and stood to make a considerable amount of money by providing food that was in high demand. Factory owners, middle men, merchants, and tradesmen regulated industrial markets, and profited off the shoulders of the working class (Trinder 2013; Mantoux 1961). Factory owners were able to hire cheap labor, which produced a surplus of goods that were sold to merchants and tradesmen through middle men. These individuals, in turn, sold these goods at high prices to maximize profit. In a major consumer market like London, these middle class individuals flourished. At the same time, members of the poor and working classes who worked low-wage jobs were often unable to circumvent poverty due to a disproportionately high cost of living (Belchem 1990). In other words, the working poor could not afford the very goods and services they produced.

The immense social differentiation promoted by the Industrial Revolution was not just apparent in occupational differences between the classes; it was also apparent in the residential patterning of many of Britain's towns and cities (Belchem 1990; Pawson 1979; Mantoux 1961). Working and poor class families sought to establish their homes in urban centers, as they were close to where most of the job opportunities were, and because of the ease of access to the public services that they relied on to support their families. The influx of members of the lower social classes into Britain's urban centers created overcrowding, and subsequently contributed to the development of unsanitary conditions and an increase in the prevalence of violent encounters. In response to this

change in the urban environment, many middle and upper class families fled to the suburban and rural areas of the country.

The rigid differentiation in occupation and residency between Britain's social classes had implications for injury-related mortality in the industrial period. Affluent families thrived off the labor of the lower classes, while minimizing their exposure to the hazardous industrial environment (Trinder 2013; Belchem 1990; Pawson 1979; Mantoux 1961). In contrast, laborers in both rural and urban communities, and in both the agricultural and manufacturing industries, were at elevated risk of injury (Henderson et al. 2013; Roberts and Cox 2003). This elevation in risk of injury was associated with the development and modification of the industrial workplace, which brought with it new forms of traumatic injury, including crushing and burn injuries from machinery, and injuries from a fall. This was particularly the case in factory, farming, construction, mining, and transportation industries. Henderson et al. (2013) postulate that the industrial workplace exposed people to new types of technology with which they had little working knowledge or practical experience. As a result, many employers maintained health and safety standards that provided insufficient protection for their employees. Insufficient protection coupled with lack of knowledge and experience with the hazardous industrial workplace, in turn, equated to an elevated risk of injury for Britain's working and poor classes.

Injury-related mortality became more and more frequent with the gradual, yet hazardous, industrial changes to Britain's physical and social environment (Henderson et al. 2013; Roberts and Cox 2003). In the seventeenth century, injury-related mortality, specifically injuries involving fractures, accounted for, on average, 0.25 to 0.50 percent

of all deaths in Britain according to the London Bills of Mortality. This rate increased to 2.00 percent in the early nineteenth century. In London, the effects of the industrial work place on injury-related mortality were even higher. According to Forbes (1983), between 1819-1872, St. Bartholomew's Hospital attributed the deaths of more than 35.00 percent of its patients to traumatic injury, which included burns, fractures, and soft tissue trauma.

In sum, the Industrial Revolution was not as much about new innovative technologies as it was about the reorganization of Britain's social and economic spheres. The enclosure of agricultural lands forced many of Britain's farmworkers into rural and urban manufacturing towns in search of low-wage jobs. Those who invested in the enclosure movement and firms that would soon transform into small-scale and large-scale manufacturing industries profited off the shoulders of Britain's new working class, and subsequently comprised the bulk of its emergent middle class. These changes in Britain's social and economic spheres had implications for injury-related mortality in the industrial period, particularly for the working class. Exposure of a large portion of Britain's population to the hazardous industrial environment instigated an increase in the incidence of workplace injuries. These injuries, particularly the complex ones, would have likely required some sort of treatment to buffer against injury-related mortality.

Medical Pluralism in the Industrial Period

There is an abundance of literature on the history of medicine, particularly in the Medieval (AD 400-1485) and Post-medieval (1485-present) periods. The amount of medical historical knowledge, however, diminishes considerably when the focus moves from medicine to treatment for traumatic injuries, which, in this thesis, is most closely

aligned with the concept of surgery. Researchers often forget that medicine and surgery, while very similar in scope and practice, were treated as separate entities in the Medieval and early post-Medieval periods (Wear 1995; Lawrence 1993). Medicine was considered a sophisticated science, requiring years of university education, while surgery was viewed synonymously with butchery, as a brutal skill to be used under extreme circumstances (Agarwal 2010; Lawrence 1993). Not until the emergence of the consultant and the general practitioner in the mid-nineteenth century were medicine and surgery treated as a whole (Lawrence 1993; Waddington 1984).

Great attention in the medical historical literature has been paid to advances in medicine, as a result of an increasing knowledge of anatomy and physiology, and the development of epidemiological thought, which occurred in response to the rising demand for public health measures in overcrowded and underfunded urban centers (Porter 1995; Granshaw 1993; Wear 1995; Waddington 1984). Although it has made significant leaps in the last century and a half – most notably with the development of anesthesia and aseptic techniques for reducing pain and minimizing post-operative infection – surgical technique prior to the 1870s remained largely unchanged (Wear 1995). Indeed, prior to anesthesia and asepsis, the most notable change in surgical technique was attributed to the Greek physician Hippocrates (460-370 BC), the father of modern medicine, who was responsible for developing methods for fracture reduction, immobilization, and physical therapy (Agarwal 2010; Lawrence 1993). Thus, the absence of significant change in surgical technique in the Medieval and early part of the post-Medieval periods equates to a dearth of literature on the specific techniques used in the treatment of specific fractures in the eighteenth and early nineteenth centuries.

From Classical Greece to modern industrial societies, the teachings of and basic methods developed by Hippocrates have continued to aid medical professionals in the proper care for simple fractures and other traumata (Agarwal 2010; Roberts and Manchester 2005; Lawrence 1993). Although surgery remained an effective means to properly treat injuries, there were other avenues for care that created a state of medical plurality in Britain in the eighteenth and nineteenth centuries (Porter 1995). This section attempts to identify some of those different avenues for treatment, paying special attention to how the medical profession became the premier hub for accessing care in the Industrial period.

The Power of Surgery and the Decision to Seek Care

Individuals from modern populations have come to expect surgical procedures to cure their injuries with little to no complication (Porter 1995). This perspective on the power of surgery has only recently emerged with the surgical innovations of the last century and a half. In the Industrial period, expectations of effective surgical relief were low (Porter 1995; Lawrence 1993). Treatment was sought out in hopes of at least some improvement that would permit the individual to resume work. Indeed, seeking treatment was almost as ineffective (or as risky) as self-treating injuries. Only minor injuries were viewed with less consternation, and that was because invasive surgeries with high mortality rates were unnecessary. Instead, minor injuries, like simple fractures, could be treated by the individual, or by their family or community.

The absence of a positive perspective on the power of surgery, while not unfounded, explains why many of Britain's sick and injured looked to a variety of other

modes of treatment, some ritualistic and some community and family-based (Porter 1995; Risse 1993). Spiritual healing, while it may have had an impact on one's emotional state, did not necessarily have a positive impact on the actual healing process itself.

Community and family care, while more effective than spiritual healing in terms of biology, were ill-equipped for dealing with some of the more complex injuries experienced by many individuals in the Industrial period. That the injured would choose these avenues over others speaks to the public's concern for the effectiveness of surgeons.

The public viewed surgeons as butchers, as immoral and irreligious men who constantly exposed themselves and other members of the public to the disease and decay of Britain's incurables (Wear 1995; Porter 1995; Lawrence 1993; Waddington 1984). Despite public opinion, surgeons rarely engaged in invasive procedures. They – more than any other medical professional – knew the dangers inherent with exposing the viscera to the external environment. Without anesthesia to quell the pain, and without aseptic techniques to minimize infection, surgeons expected high mortality, and thus refused to operate on most occasions. Instead of invasive surgery, they routinely tended to external conditions; they treated burns, reduced closed fractures via manipulation, and even diagnosed health conditions unrelated to injury.

It is clear from the archival evidence that the few instances of fatal surgical intervention that plagued British surgeons and other medical professionals in the Industrial period spoke more to the public than all of their successes with non-invasive procedures. As a result, many individuals were suspicious of them (Porter 1995). If the injured did not treat themselves, they relied on their families, communities, and even the

clergy for help. Individual families, particularly in rural areas where rates of injury were high even prior to the Industrial Revolution, kept pharmacopoeias or medical recipe books that included recipes for pain relievers, fever reducers, and techniques for treating wounds and injuries. In the instance where an individual did not have access to a pharmacopoeia, they might have sought out help from individuals in the community. Differentiation in tasks ascribed to the members of a community lent itself well to the likelihood that at least one individual or family member had some recipe for treating an injury. In other instances, the injured would pay a visit to the Church or other religious institution to seek help. Historically, churches and monasteries around Britain served the injured both at home and in what could be considered proto-hospitals (Porter 1995; Granshaw 1993; Waddington 1984).

Development of Medical Professionalism

As mentioned in the previous section, the medical profession was met with consternation and genuine mistrust by the public in Britain's Industrial period. Much of this had to do with the state of the medical profession at the onset of the Industrial revolution (Waddington 1984). Throughout most of the eighteenth and nineteenth centuries, however, the medical profession underwent rapid, tumultuous change in its organization, consequent with the industrial changes in British society (Porter 1995; Wear 1995; Granshaw 1993; Lawrence 1993; Risse 1993; Waddington 1984). These changes affected not only where and with whom care was received, but also who had access to it.

By the beginning of the eighteenth century, three classes of medical practitioner had been established in Britain: physicians, surgeons, and apothecaries

(Porter 1995; Wear 1995; Lawrence 1993; Risse 1993; Waddington 1984; Stevens 1966).

Although largely unregulated until the nineteenth centuries, British law kept them separate in terms of their scope of practice. Physicians were expected to diagnose and order treatment for their patients. Treatment typically involved consultation with a surgeon or an apothecary; the former only saw to matters of surgery, while the latter was restricted to preparing and dispensing medicines. In other words, physicians, according to English law, were responsible for regulating surgeons and apothecaries. This type of environment fostered a stringent hierarchy among medical professionals in the eighteenth century, in which university educated physicians ranked above apprentice-trained surgeons and apothecaries, the former directing the labor of the latter two.

Despite the clear distinctions made by British law, many physicians attempted surgical procedures, and many surgeons and apothecaries prescribed and dispensed medicine without consent from physicians (Porter 1995; Waddington 1984). Indeed, the distinction between these medical professions wore away in the nineteenth century, and were replaced with two new classes of medical practitioner: the general practitioner, and the consultant (Waddington 1984). The erosion of the old organization of medical practitioners in Britain was largely attributed to the sociocultural ramifications of the Industrial Revolution. The class of general practitioners emerged in response to a rising demand for affordable medical care brought on by the middle class, while the class of consultants, who established themselves in voluntary hospitals, appeared out of the rising need for care for Britain's working and poor classes (Porter 1995; Granshaw 1993; Waddington 1984).

The emergent middle class, while it profited off the backs of the lower classes, was still comparatively less wealthy than Britain's affluent class (Trinder 2013). Access to treatment for traumatic injuries was difficult for middle class families, as they could not afford highly specialized private care, and they refused to seek help through infirmaries and hospitals, as these institutions had become places for the sick and destitute members of the lower social strata (Porter 1995; Waddington 1984). Instead, middle class families demanded a class of medical professionals who could provide all of the services of the physician, surgeon, and apothecary at an affordable price. Consultants who increasingly found themselves working for free in the newly established voluntary hospitals acted as physicians, surgeons, and apothecaries, and often maintained their own private practices that catered to members of the affluent class who were willing to pay more. General practitioners, in contrast, while having been educated and trained similarly to consultants, took to the streets in Britain's towns and cities, offering affordable care to middle class and upper working class families from the comfort of their own homes. Although general practitioners offered their services for a comparatively lower price than consultants, their fees were often too high for most of the working and poor classes (Waddington 1984). Instead, those individuals who decided to seek out professional treatment, but who could not afford it, often resorted to in-patient or out-patient care in voluntary hospitals, where consultants worked free of charge (Porter 1995; Granshaw 1993; Waddington 1984; Stevens 1966).

Emergence of the Voluntary Hospital. Hospitals, while a common feature of the modern landscape, were virtually absent in Britain prior to the eighteenth century (Porter 1995; Granshaw 1993; Waddington 1984). Those hospitals that did function prior

to this time were typically affiliated with the Catholic monasteries, and often restricted their services to specific groups of individuals with a limited range of medical conditions (Granshaw 1993). The only two hospitals that survived the Reformation in the sixteenth and early seventeenth centuries were St. Thomas' and St. Bartholomew's Hospitals, located in London (Porter 1995; Granshaw 1993). Following the dissolution of the English monasteries in the mid-sixteenth century, the City Corporation of London purchased them (Granshaw 1993). The Corporation believed that these hospitals could serve as a haven for medical relief for the sick and injured members of the poorer communities, and that, without them, people would suffer. Following this decision, five new hospitals were constructed in the eighteenth century in London: the Westminster (1720), Guy's (1724), St. George's (1733), the London (1740) and the Middlesex (1745) hospitals (Porter 1995).

These hospitals were voluntary; they relied on charity for funding rather than their patients (Porter 1995; Fox 1993; Granshaw 1993; Waddington 1984). Many charitable organizations emerged with the purpose of ameliorating Britain's declining social and health conditions, which were brought on by industrialization and urbanization (Andrew 1989). Members of these organizations worked tirelessly to muster up donations to send to various institutions. In doing so, they thought they could improve the lives of the poor and contribute to the prosperity of the nation by helping people get back on their feet and into the workplace. They also sought to improve their own social standing as well.

That hospitals were voluntary meant that their employees, most notably consultants who assumed the position of both physician and surgeon, worked without pay

(Waddington 1984). In return, they received honorary titles, which increased their popularity, and attracted the attention of upper middle and affluent class families searching for care (Porter 1995; Granshaw 1993; Waddington 1984). As a result, their private practices, which were external to the hospital, flourished. Being affiliated with the hospital, consultants also earned money by teaching medical students and bringing on apprentices. The voluntary hospital thus became a place where medical professionals could tend to the lower social strata without charging fees, yet still make a living for themselves.

Although voluntary hospitals catered to Britain's lower social strata, they remained highly selective of who they admitted (Granshaw 1993). The charitable individuals and organizations that donated to voluntary hospitals got to decide on who were admitted, and they typically relied on social instead of medical criteria (Granshaw 1993; Andrew 1989). The socially invalid (e.g., prostitutes, drunks, etc.) and the incurables, for example, were barred from admission. Those individuals who were unable to gain admission to a voluntary hospital ultimately resorted to seeking help from their families and communities (Porter 1995; Granshaw 1993; Waddington 1984).

In sum, although treatment for traumatic injuries was widely available in the Industrial period, the historical documentation reviewed suggests that access to it was remarkably more difficult for some individuals than others. Recognizing that historical documentation may provide a biased representation of the past, the question becomes, just how accurate is it in representing the totality of all lived experiences with treatment for traumatic injuries in Britain's Industrial period? As mentioned in the previous chapter, anthropologists can look to the human skeleton to address this question, as it

provides an unbiased record of individual lived experiences with injury and, through inference, treatment.

Injury Recidivism in Britain's Industrial Environment

As mentioned in the previous chapter, traumatic injuries do not occur due to random chance; they are the consequence of the interaction between the sociocultural and biological aspects of daily life. Individuals who experience multiple traumatic injuries throughout their lives are considered to be injury recidivists, and tend to be young adult males who come from impoverished backgrounds (Judd 2002; Dougherty 2011). Some clinical research associates violent altercations with the development of recidivist behaviors (e.g., Hedges et al. 1995; Smith et al. 1992), while others suggest that accidental injuries may also be implicated in their development (e.g., Poole et al. 1993). That inflicted and accidental injuries play a variable role in the development of these behaviors in different settings suggests that cultural context is key.

Injuries resulting from violent altercations and accidents became more prevalent in eighteenth and nineteenth century Britain, consequent with industrialization and subsequent urbanization (Trindler 2013; Henderson et al. 2013; Roberts and Cox 2003). The frequency at which violent altercations occurred in large urban areas like London increased dramatically with the in-migration of the working and poor classes and the simultaneous out-migration of the middle and affluent classes (Trindler 2013; Belchem 1990; Pawson 1979; Mantoux 1961). At the same time, Britain experienced a massive influx of people from outside the country, each individual bringing with them their own cultural ideologies and practices. Increases in the concentration of

impoverished communities in Britain's urban centers, combined with the presence of conflicting cultural ideologies and practices, explains why interpersonal violence became so widespread.

Accidental injuries proliferated in the Industrial period. In Britain's crowded towns and cities, people often found themselves falling off of uneven sidewalks, and getting thrown from or crushed by horse-drawn carriages, among other things (Henderson et al. 2013). In the workplace, people ran the risk of getting their limbs, hair, or clothing caught in machinery, possibly resulting in devastating injuries (Henderson et al. 2013; Trinder 2013; Roberts and Cox 2003). Many workers in the Industrial period reported injuries from falls as well. Many fell from cranes, ladders, and scaffolds. Some even fell down elevator shafts. This was particularly the case for individuals who were employed in factories, and worked in construction and transportation industries.

In Britain's rural areas, individuals were more prone to injuries resulting from agricultural work (Henderson et al. 2013). Given that most individuals in rural areas lived and worked on farms, it was incredibly difficult to separate their home life from the workplace (Roberts et al. 2009; Judd and Roberts 1999). Rural peoples were known to have suffered injuries through their interactions with livestock, usage of threshing machines and other dangerous devices for sowing and harvesting crops, and other miscellaneous accidents associated with maintaining farmland and transporting goods (Trinder 2013; Henderson et al. 2013; Judd and Roberts 1999). The rate of occurrence of these injuries increased with a rise in demand for food to feed Britain's growing population in the Industrial period.

Although violent altercations and accidents generally produce injury, Fulton and colleagues (2014) suggest that the injury itself, regardless of the ultimate mechanism that produced it, is what ultimately increases one's risk of future injury. They argue that neuromuscular alterations, including deficits in strength, balance, and ease of movement, compromise the biomechanical stability of the affected limbs. What they fail to state explicitly is that these post-traumatic alterations can be remedied by proper treatment. But, again, cultural context is everything.

Clinically, immobilization and subsequent physical therapy are time consuming post-reduction phases that are important components of the treatment process (Hamblen & Simpson 2007; Patton 1992). In the Industrial period, access to these phases would have likely been attainable only by those individuals from the middle and upper social strata, as they could afford the time to immobilize their injuries and money to seek out physical therapy (Trinder 2013; Porter 1995; Granshaw 1993; Waddington 1984). With a high demand for labor and a high supply of low-wage laborers, companies could easily replace their employees (Bronstein 2008). Workers were, therefore, expendable, and the injured could have easily lost their jobs if they could not work.

Individuals injured on the job had a difficult time obtaining compensation from their employers. This was because, prior to the 1880s, worker's compensation laws were nonexistent (Bronstein 2008). Injured individuals could only receive compensation through suing their employers, which was a long and arduous process likely requiring more time than the healing process. In other words, the period of treatment and recovery from injury likely outpaced the receipt of compensation. Beginning in the 1840s three defense tactics were commonly in use by employers for the purposes of avoiding

disbursing compensation, which made it increasingly difficult for injured workers to receive aid (Bronstein 2008; Guyton 1999). Under the defense of contributory negligence, employers were not required to compensate for injuries incurred by workers who were responsible for their own injury. In addition, according to the fellow-servant rule, employers were not responsible for disbursing compensation to workers whose injuries were instigated by the action or negligence of other employees. Lastly, employers argued that, under the assumption of risk defense, which stated that employees recognized the inherent dangers of their work environment, they were not responsible for the injuries incurred by their employees.

Bronstein (2008) argues that, although most employers were largely successful at circumventing workers' compensation issues in the 18th and 19th centuries, many injured individuals were able to retrieve some form of aid from others in the community, including public donations, charities, and familial support. In addition, they posit that, when the conditions proved ideal, charitable employers likely contributed aid to their injured employees. The author recognizes, though, that these public and private avenues were not systematic in their distribution of aid; it is likely that many individuals went without any form of compensation in Britain's Industrial Period. As a result, these individuals, as well as those who suffered injuries outside of the workplace, may have been more likely than others to develop a neuromuscular deficit, leading to abnormal loading of contralateral and other supportive muscle groups and adjacent bones, and subsequent secondary joint changes (Fulton et al. 2014). These post-traumatic alterations to the biomechanical stability of the affected limb or region of the body may have, in

turn, contributed to an individual's injury-related morbidity, or the likelihood that they might suffer a future injury as a result of their current health status (Dougherty 2011).

Site Background

The Parish of St. Bride, London

The Parish of St. Bride is historically located within the limits of the City of London, but outside the London Wall (Miles and Conheeny 2009; DeWitte et al. 2015). Just north of the River Thames, it is bordered to the north by the Parish of St. Andrew Holborn, to the northeast by the Parish of St. Sepulchre, to the east by the Parish of St. Martin Ludgate, to the southeast by the Parish of St. Anne Blackfriars, and to the west by the Parish of St. Dunstain. At its southern end, it is bordered to the west by the Whitefriars Precinct, and to the east by the Bridewell Precinct. The presence of artifacts dating to the Roman period indicate that the parish grounds may have been in use as early as the first century (Perrone 2013). Based off of parish documentation, the parish itself was likely founded in AD 1180.

In the Industrial period, the Parish of St. Bride was home to London's working and poor classes (Miles and Conheeny 2009; DeWitte et al. 2015). Its population was extremely dense, with most houses filled to the brim with fifteen or more individuals crammed into at most six bedrooms (Miles and Conheeny 2009). Records of baptisms from this time period, which included the occupations of fathers, suggested that individuals living in the parish were employed in a diverse array of workplaces. Individuals who were not independently wealthy or extremely poor and unemployed tended to work as artisans, merchants, or craftsmen. Interestingly, parish records show a

decline in the proportion of parishioners working high-wage jobs over time, suggesting that, with industrialization and subsequent urbanization, inhabitants of the Parish of St. Brides became increasingly impoverished.

Deceased parishioners were interred at St. Bride's Church in one of three possible locations: the Church crypt, the the burial grounds around the church, or the lower churchyard (Miles and Coheeney 2009). St. Bride's Church is located on Bride Lane, which is near the intersection of Fleet and Farringdon Streets north of Blackfriar Bridge. The lower churchyard, in contrast, is located north of St. Bride's Church. It is bordered to the north by Stonecutter Street, to the south by Harp Alley, to the east by Farringdon Street, and to the west by St. Bride Street. Where one was buried often indicated their socioeconomic status, as individuals with a higher family income were typically buried closer to the Church (Milne 1997).

St. Bride's Lower Churchyard Sample. The lower churchyard constitutes the burial grounds for some of the poorest individuals from St. Bride's Parish, including individuals from Fleet Prison and the Bridewell workhouse (DeWitte et al. 2015; Miles and Coheeney 2009; Milne 1997). Burials began at the lower churchyard in the seventeenth century as a result of overcrowding at the Church burial grounds (DeWitte et al. 2015). Based off of archaeological evidence, the site was specifically in use from AD 1770-1849 (Miles and Coheeney 2009). This site is significant, because it was the first parish churchyard dated to after the Great Fire of 1666 to have been excavated in London.

Remains from the lower churchyard were exhumed following the City's decision to develop the area into a neighborhood (Miles and Coheeney 2009).

Excavations took place in the summer and winter of 1991. A total of 606 individuals representing 50.00 percent of the cemetery population were exhumed, 198 sub-adults and 408 adults. Of those individuals exhumed, only 544 were subjected to osteological analysis. The remaining individuals were reburied for various reasons, including poor preservation. Most burials were oriented east to west, and many of the burials were stacked. All individuals were placed in plain wooden coffins in earth-cut graves with few grave goods (DeWitte et al. 2015).

A formal report on the St. Bride's Lower Churchyard cemetery sample has not been published, but pertinent information is available through the Museum of London Centre for Human Bioarchaeology Website, as well as a recent unpublished manuscript (Miles and Coheeny 2009). The current collection contains 175 sub-adults and 369 adults. Of the adults, 194 are male and 125 are female. Adults were assigned to one of the four age categories: 18-25, 26-35, 36-45, and >46 years old at death. Ten individuals were assigned to the young adult group (18-25 years), forty-four individuals were assigned to the early middle adult group (26-35 years), eighty-eight individuals were assigned to the late middle adult group (36-45 years), and one hundred and sixty-two individuals were assigned to the mature adult group (>46 years). Sixty-five adults were not assigned to an age at death category.

Several published and unpublished studies have utilized the remains associated with the St. Bride's Lower Churchyard cemetery collection. Most of these studies are concerned with osteoporosis (Brickley 2002; Day 2007; Ives 2006; Agarwal 2001; Brickley 1997), likely due to the presence of a higher proportion of older adult individuals in the collection. This collection has also been used in studies of syphilis

(Tucker 2007; Bouwman 2007), skeletal trauma (Kausmally 2006; Waldron 1996), and dental health (Rando 2007; De La Rosa 2007). Ultimately, it would seem that the St. Bride's Lower Churchyard cemetery collection, given its size and demography, may adequately represent the impoverished peoples living in the Parish of St. Bride; however, there is a higher prevalence of individuals from Fleet Prison and the Bridewell workhouse in the sample, which may potentially affect just how representative it is.

Chelsea, London

Chelsea is well outside the historical limits of the City of London (DeWitte et al. 2015). In the Industrial period, it was bordered to the north by Brompton and the Parish of Kensington, to the south by the River Thames, to the east by Five Fields (modern day Belgravia), and by Fulham to the west (Perrone 2013). Evidence in Chelsea's archaeological record suggests that the land upon which it was built was in use since before the period of Roman occupation (Russett and Pocock 2004). Artifacts found along the river bank, such as pottery and weaponry date to the Bronze and Iron Ages. There is even evidence of sacrificial burial.

In the eighteenth and nineteenth centuries, Chelsea was known for its affluence (DeWitte et al. 2015; Cowie et al. 2008; Russett and Pocock 2004). It was home to duchesses, scholars, and statesmen, as well as individuals of other affluent professions. Many villagers also worked the land. The inhabitants of Chelsea, particularly those from the affluent and middle classes, would have been buried either in the Chelsea Old Church burial grounds or one of the other seven burial grounds located in the area.

Chelsea Old Church was built in the twelfth century (Russett and Pocock 2004). It served as the parish church until St. Luke's was built in AD 1819-24 to address

the issue of Chelsea's rising population. Following a bombing raid in 1941, the old church was destroyed (Walker 1987). Subsequently, a new building was constructed using the original surviving foundation (Russett and Pocock 2004). It was reinstated as a parish church in 1951 and renamed All Saints, Chelsea Old Church.

In the Industrial period, rural Chelsea gradually transformed into a suburb of London (Cowie et al. 2008; Russett and Pocock 2004). At the start of the eighteenth century, it was a large, rural settlement of approximately 300 houses that was surrounded by orchards, nurseries, fields, and market gardens (Cowie et al. 2008). As London continued to grow and expand, it gradually began to consume the area (Cowie et al. 2008; Russett and Pocock 2004). Fields and orchards were replaced by housing and parks. By the middle of the nineteenth century, Chelsea had begun to look like an urban center.

Chelsea Old Church Sample. The Chelsea Old Church cemetery sample includes some of the most affluent members of London's rural population (Cowie et al. 2008). Although it has existed since the twelfth century, only part of the churchyard has been excavated. The part that was excavated included individuals interred in the churchyard between AD 1700-1850, as indicated by the burial context. The churchyard was excavated following the decision to demolish the church vicarage and another building in order to build a new structure.

Excavations by the Museum of London Archaeological Services took place in April of 2000 off 2-4 Old Church Street in Chelsea (Cowie et al. 2008). The site was located just north of All Saints, Chelsea Old Church, and east of Old Church Street. A total of 290 individuals were exhumed. Of those individuals, only 198 were subjected to osteological analysis. They were buried in either lead lined coffins, or brick lined shafts

and vaults (DeWitte et al. 2015). These mortuary archaeological findings strongly suggest that the individuals exhumed from the churchyard were of higher social standing than others in the community, given that wooden coffins were much cheaper to procure, and that earth-cut graves required fewer materials and laborers. Additionally, there is evidence of coffin coverings and fine copper-alloy buttons, which further suggests that these individuals were from affluent families (Cowie et al. 2008).

Information concerning the demographic structure of the cemetery collection can be found either online through the Museum of London Centre for Human Bioarchaeology webpage, or Cowie et al. 2008, a recently published manuscript. The current collection contains 33 sub-adults and 165 adults. Of the adults, 78 are male, and 74 are female. Thirteen individuals could not be sexed. Adults were assigned to four age cohorts: 18-25, 26-35, 36-45, and <46 years old at death. Fourteen individuals were assigned to the young adult group (18-25 years), seventeen individuals were assigned to the early middle adult group (26-35 years), forty-six individuals were assigned to the late middle adult group (36-45 years), and seventy-two individuals were assigned to the mature adult group (>46 years). Sixteen adults were not assigned to an age cohort.

Several unpublished studies have utilized the human skeletal remains associated with the Chelsea Old Church cemetery sample. Some are concerned with sex (Clark 2007; Scott 2006) and age (Buckberry and Bosiljic 2006) estimation, while others have used the remains to study metabolic disease (Ives 2006), dental health (Rando 2007), and cultural modification (Cross 2006). There has even been a study using stable isotope analysis of diet and mobility (Trickett 2004). Ultimately, this cemetery collection may represent some of the more affluent individuals living in Chelsea in the Industrial

period. One of the potential issues that may compromise the integrity of its representation is that there are likely some individuals interred in the churchyard, especially within the first thirty years of its occupation, that may actually come from the middle and working classes (Cowie et al. 2008). However, Cowie et al. (2008) posit that a majority of the burials likely represent members of London's affluent rural families.

Summary

The Industrial Revolution dramatically altered Britain's physical and social environment. The in-migration of poor and working class individuals into urban centers to find better job opportunities than those offered on newly enclosed lands created a surplus of labor for many of the country's burgeoning industries, both large and small in scale. Consequent out-migration of Britain's emergent middle class and its perpetually affluent families to the rural and suburban areas of the country strengthened the divide between the social classes and contributed to the social division of labor. Coupled with the development of complex technologies, this new industrial environment brought with it the potential for hazardous human-environmental interactions for some more than others.

To cope with the outcomes of interacting with the hazardous industrial environment, many injured individuals sought treatment. Due, in part, to both severe distrust of the medical profession until the Industrial period, and a growing socioeconomic divide between the upper and lower classes over the centuries, a sort of medical pluralism had emerged in Britain. Injured individuals, if they did not self-treat, may have sought out treatment from a member of the clergy, a bonesetter, a family

member, or someone in the community. Hippocrates' basic methods for reducing and immobilizing fractures had become commonplace knowledge over the centuries, making medical plurality possible. As injuries became more frequent and severe in the eighteenth and nineteenth centuries, people from all social classes regularly began to look to the growing medical profession for help. Some individuals, however, had better (or easier) access to professional care than others, and this was largely based on socioeconomic status.

The industrial environment created new opportunities for the development of recidivist behaviors. Given that some clinical studies identify previous injury as an important factor in risk of injury, the rising prevalence of accidental and inflicted injuries in the Industrial period may have fueled the development of a high-risk sub-population in Britain likely comprised of members of the lower social strata. The poor and working class individuals tended to work more labor-intensive jobs than the middle and affluent classes, and, if injured, they were less likely to be able to afford the time and money to immobilize their injuries or seek out physical therapy. They were expendable as a result of the emergence of a low cost, high profit market driven economy in the Industrial period. Additionally, they were often unsuccessful in obtaining worker's compensation for their injuries when they were work-related. The neuromuscular deficits and other complications that could have arisen from this context may have impacted risk of subsequent injury.

The historical context developed in this chapter will be evaluated anthropologically using two skeletal assemblages from Industrial-era London. Poor and working class individuals living in the Parish of St. Bride make up the St. Bride's Lower

Churchyard cemetery sample. Affluent class individuals, in contrast, living in Chelsea make up the Chelsea Old Church cemetery sample. The Parish of St. Bride was an urban community just outside the London Wall, while Chelsea was a rural community to the southwest of the City that slowly became engulfed by London throughout the Industrial Period. The rural and urban differences between the cemetery samples, in addition to their socioeconomic differences, may lend unique insight into patterns of treatment and subsequent injury in eighteenth and nineteenth century London.

CHAPTER IV

MATERIALS AND METHODS

Introduction

This chapter outlines and describes the sampling strategy and methods of data collection employed in this thesis. Included in the sampling strategy portion of this chapter is a discussion of the criteria used to construct the study sample, including time period, socioeconomic status, skeletal preservation, age at death, and trauma status. Included in the methods portion of this chapter is a discussion of the methods for both estimating sex and age, and identifying and analyzing skeletal trauma and its complications. The statistical framework described at the end of this chapter will be used in subsequent chapters to evaluate the research hypotheses under investigation.

Cemetery Samples

The cemetery samples included in this study are curated by the Museum of London Centre for Human Bioarchaeology (CHB). They consist of the Chelsea Old Church (site code OCU00) and St. Bride's Lower Churchyard (site code FAO90) cemetery samples. For the remainder of this thesis, the Chelsea Old Church cemetery sample will be referred to as the Chelsea sample, and the St. Bride's Lower Churchyard cemetery sample will be referred to as the St. Bride's sample. As mentioned in the previous chapter, the Chelsea cemetery sample represents members of the affluent

community of Chelsea (AD 1700-1850), located on Old Church Street north of the River Thames and southwest of the City of London. In contrast, the St. Bride's cemetery sample represents members of the poor parish of St. Bride (AD 1770-1849), located north of Southwark and the River Thames.

Sampling Strategy

The remains of the individuals interred in and exhumed from these cemeteries were analyzed at the CHB over the summer in 2015. Prior to arrival, the Wellcome Osteological Research Database (WORD) was consulted to prepare the study sample. The database includes information on the sex, age, and pathological conditions of every individual exhumed from the cemeteries under study. Inclusion into the study sample was contingent upon several conditions, which helped to narrow down the list of possible individuals (see Table 1 for a breakdown of each condition).

Table 1. Conditions Required for Inclusion in the Current Study

Condition	Classification	Explanation
Time Period	Industrial	AD 1700-1850
Socioeconomic Status	Upper Class Lower Class	Based on mortuary context as outlined in the Museum of London Archaeological Site Reports
Skeletal Preservation	Good	Based on skeletal inventories recorded by Museum of London anthropologists
Age At Death	18-25 Years 26-35 Years 36-45 Years >46 Years	Based on estimations of age produced by anthropologists at the Museum of London Centre for Human Bioarchaeology
Trauma Status	Trauma Present	Evidence of fracture on appendicular skeleton previously diagnosed by anthropologists at the Museum of London Centre for Human Bioarchaeology

To be included in the sample, burials needed to date to the Industrial period (A.D. 1700-1850). The Industrial period represents a period of massive sociocultural flux associated with rapid industrialization and subsequent urbanization. Changes in technology produced a greater demand for care, as more complex injuries had become commonplace both at work and at home (Bronstein 2008). Additionally, this period witnessed the development of a rigid social structure, which departed from its pre-industrial predecessor by severely limiting mobility between the different social classes (Roberts et al. 2009). These cultural and biological changes provide a good opportunity to examine the influence that socioeconomic status had on access to treatment.

Inclusion in the sample was also dependent on socioeconomic status, which can be generally divided into three categories in the Industrial period: the upper, middle, and lower classes. To maximize the differences between the classes, only individuals from the upper and lower social classes were included in this study. According to the WORD, each cemetery was made up of individuals from the same social class, a likely manifestation of the rigid nature of the English social hierarchy. Therefore, for this thesis, socioeconomic status was essentially synonymous with cemetery sample, as the Chelsea sample included individuals from the upper class, while the St. Bride's sample included members of the lower social class. It should be noted, however, that socioeconomic status was based off of the mortuary context, not documentation directly linking each individual to a specific class except for cases where a headstone or other identifier was recovered.

The next requirement for inclusion into the study sample was the level of skeletal preservation. The absence of skeletal material does not mean an absence of pathology. It means an absence of information, or that a condition is unobservable;

therefore, poorly preserved skeletal remains are analyzed with extreme caution. Fortunately, most of the industrial cemetery samples housed at the CHB included individuals of relatively good preservation. Therefore, this requirement did not necessarily narrow down the possible pool of potential study subjects. It should be noted that 89 percent of the individuals included in the entire Chelsea collection were well preserved, while 94 percent of individuals in the St. Bride's collection were well preserved.

Age at death above 18 years was another requirement for inclusion in this study. The manifestations of skeletal trauma vary due to inherent age-related differences in the biomechanics of bone fracture and repair (Lovell 1997). By excluding subadults, this variation is minimized. Issues with density-mediated attrition are also minimized by excluding individuals under 18 years of age (Buzon 2011). Further, subadults tend to be frailer than adults in terms of most pathological conditions, including trauma, which means that they tend to suffer greater trauma-related mortality regardless of the level of treatment received (DeWitte et al. 2015).

The last criterion for inclusion in the study sample was that an individual had to have suffered a minimum of one traumatic event that manifested itself on the skeleton (e.g., fracture). Only individuals with evidence of skeletal trauma on the appendicular skeleton were selected for study. This decision was based on the fact that injuries to the axial skeleton, such as fractures to the ribs or vertebrae, were (and still are) difficult to reduce without internal fixation, which is a practice that did not emerge until some time after the end of the study period (Browner et al. 1992). Intra-articular fractures, with the exception of the Bennett's fracture, were also excluded from analysis, because they are

considerably less intuitive than other fracture types in terms of what they contribute to the dialogue on treatment (Buckwalter and Brown 2004).

Following the parameters outlined above, and in consultation with the WORD, a total of 46 individuals were considered for the current study. Of those individuals, 13 (28.26%) came from the Chelsea sample, and the remaining 33 (71.74%) came from the St. Bride's sample. In addition to these individuals, a random sample of 25 individuals from the Chelsea cemetery sample, and 29 individuals from the St. Bride's cemetery sample were analyzed for the purposes of assessing observer agreement in diagnoses of skeletal trauma specific to this study. This assessment acted as a control for any potential undocumented traumatic injuries, and provided an opportunity to examine the utility of the WORD database as an open access source of osteological data. The analysis included the computation of a percent observer agreement and associated Cohen's Kappa test statistic for each cemetery sample, as different CHB researchers were responsible for identifying individuals with traumatic injuries in each sample.

While the percent agreement provides a good indicator of the amount of agreement in observations made between two or more individuals, it does not take into account the amount of observer agreement generated by random chance. The Cohen's Kappa test statistic, on the other hand, considers random chance in inter-observer agreement (McHugh 2012). Similar to a correlation coefficient, the kappa test computes a value between +1 and -1 that indicates the degree of observer agreement. If the kappa value is statistically significant ($\alpha=0.05$), then observer agreement is significantly different from zero. A percent agreement above 80 percent and a kappa test statistic above 0.60 suggest strong observer agreement. If neither the percent agreement nor kappa

test statistic reach these levels, then the data are considered to be inaccurate, and all analyses are rendered null.

Table 2 provides a summary of the statistics associated with the analysis of inter-observer agreement. Percent agreement for the Chelsea and St. Bride's samples was

Table 2. Results of the Cohen's Kappa test for Observer Agreement

Cemetery Sample	n	% Agreement	Cohen's Kappa	Standard Error	<i>p</i>	95% Confidence Interval
Chelsea	38	92.11	0.841	0.088	<0.001	0.669-1.000
St. Bride's	62	90.32	0.786	0.081	<0.001	0.627-0.945

92.11 (35/38) and 90.32 percent (56/62), respectively. The kappa values for both cemetery samples were statistically significant ($\kappa_{\text{Chelsea}}=0.841, p<0.001$; $\kappa_{\text{St. Bride's}}=0.786, p<0.001$). These results suggest that any inter-observer error present in the identification of traumatic injuries in both cemetery samples is negligible. Therefore, all 46 individuals with a total of 60 observed traumatic injuries were included in the current study. Thirteen of these individuals were from the Chelsea cemetery sample, while 33 were from the St. Bride's cemetery sample.

Methods for Estimating Sex and Age

The WORD was used to assign each individual to an estimated sex and age category. In an earlier study, Perrone (2013) found no significant difference between their estimations for sex and age, and that of the WORD. The Chelsea sample was part of that analysis. Given this, the sex and age estimates provided by the WORD were used in this study. The protocols for estimating and recording sex and age are outlined and described below.

Anthropologists from the CHB estimated sex based on fourteen non-metric traits specific to the pelvis and cranium (see Table 3). Each trait was scored using a five-point system (see Table 4). Unobservable traits were assigned a code of 9. Metric

Table 3. Summary of Methods Employed for Sex Estimation

Skeletal Element	Morphological Feature	Reference
Skull	Supraorbital Ridge	Brothwell 1981
	Inion Protuberance	
	Nuchal Crest	
	Mastoid Process	Bass 1987, 1982
	Slope of Forehead	
		Zygoma Root
Mandible	Gonion	Brothwell 1981
Pelvis	Ventral Arc	Phenice 1969
	Medial Portion of Pubis	
	Greater Sciatic Notch	
	Preauricular Sulcus	Bass 1987, 2003, 2004, 2005
	Subpubic Angle	
	Subpubic Concavity	
	Median Ischiopubic Ridge	

Source: Data table from Powers, N., ed., 2012, Human Osteology Methods Statement. Museum of London.

Table 4. Criteria for Estimating Sex

Score	Sex
1	Male
2	Probable Male
3	Intermediate
4	Probable Female
5	Female
9	Element not observable/undetermined sex

Source: Data table from Powers, N., ed., 2012, Human Osteology Methods Statement. Museum of London.

assessment was completed when necessary following the guidelines outlined by Bass (1987). The pelvis was given preference over the cranium in the overall estimation of sex. Final sex estimation was also scored using the same five-point system as the non-metric traits; however, highly ambiguous results were assigned a code of 7.

Age at death was estimated using a combination of degenerative changes to the symphyseal surface of the pubic symphysis (Brooks and Suchey 1990) and the auricular surface (Lovejoy et al. 1985), the morphology of the sternal end of the fourth rib (Iskan et al. 1984; Iskan et al. 1985), and, when necessary, dental attrition (Brothwell 1981). In the case of fragmentary remains, CHB anthropologists relied on epiphyseal union and the eruption of the third molars to distinguish between adults and subadults (Buikstra and Ubelaker 1994). After examining the remains, they then assigned each individual to one of the following age cohorts: young adult (18-25 years), early middle adult (26-35 years), late middle adult (36-45 years), or mature adult (>46 years).

Traumatic Injuries and Their Complications

All individuals in this study were assessed for the presence or absence of single and multiple traumatic injuries, and the prevalence of fracture complications, including fracture deformity and non-union. All observations were macroscopic, as radiographic records and technologies were unavailable for the cemetery samples under study. Therefore, it is entirely possible that some skeletal injuries were overlooked. In the remaining sections of this chapter, methodologies employed for the identification and statistical assessment of traumatic injuries and their complications are outlined, and a brief summary of the materials and methods included in this study is provided.

Identification of Traumatic Injuries

In this study, a traumatic injury is defined as any physical break in bone, whether complete or incomplete. This definition is most parsimonious with bone fracture (Ortner 2003). Therefore, all individuals included in this study were observed macroscopically for evidence of one or more fractures. As recommended by Lovell (1997), when a fracture was encountered, its location and position, type, mechanism, and timing were recorded. This information provides a context for what kinds of injuries were suffered by individuals from the different cemetery samples under study.

As stated previously, only fractures of the appendicular skeleton, mostly long bones, were considered for the current study. Each fracture encountered was recorded by element and side. To facilitate comparison between the cemetery samples, all observed fractures were further divided up into five groups based on fracture position: proximal epiphysis, proximal 1/3 of shaft, shaft, distal 1/3 of shaft, and distal epiphysis (Buikstra and Ubelaker 1994).

Following the identification of fracture location and position, fracture type was assessed. When possible, observed fractures were separated by fracture eponym. When an eponym was either unidentifiable or unavailable to describe a specific fracture, the fracture was described using the criteria outlined by Lovell (1997) (e.g., transverse, oblique, spiral). It should be noted that there is contention over the use of fracture eponyms in paleopathology, specifically that they imply causation (Judd 2008). However, they are useful for referencing clinical literature to identify methods of treatment for specific fractures. Fractures whose shape and contour were obscured by extensive healing were categorized as unknown.

After fracture type was assessed, the mechanism of injury, when possible, was identified. Each fracture was classified as being caused by direct or indirect forces, pathological processes, or repeated stress. Fractures classified as direct (e.g., transverse fracture) are located at the point of impact, while indirect fractures (e.g., spiral fracture) occur at a different location than the point of impact (Lovell 1997). Pathological fractures occur when bone quality, quantity, or thickness is altered by a pathological condition (e.g., vitamin D deficiency, osteoporosis) that affects the biomechanical stability of the bone (Ortner 2003). Stress fractures occur when bone is subjected to repeated stress over a period of time (e.g., hairline fracture) (Lovell 1997). Fractures whose mechanism of injury was obscured by healing processes were categorized as unknown.

Lastly, the timing of injury was assessed. Each fracture observed was classified as either antemortem or perimortem. At a minimum, fractures were classified as antemortem when evidence of bone remodeling along the fracture margins was observed, specifically rounded rather than sharp edges (Ortner 2003). Fractures were classified as perimortem when there was no evidence of bone remodeling along the fracture margins (i.e., sharp rather than rounded edges).

After observed fractures were described in terms of their location, position, type, mechanism of injury, and timing, they were then grouped by the context identification number. Context identification numbers were specific to each individual buried in their respective cemetery sample. By grouping them in this way, data concerning multiple injuries could be collected. Judd (2002) argues that it is difficult to estimate the total number of separate injury events experienced by individuals in the archaeological past. Instead, she recommends that each fracture is considered a separate

injury event. Therefore, individuals exhibiting multiple fractures were classified as exhibiting more than one injury, while individuals with only one fracture were classified as exhibiting one injury (see table 5). Unobserved fractures of the axial skeleton recorded in the WORD were included in the assessment of multiple injuries. This decision was supported by minimal observer disagreement in the assessment of fractures of the appendicular skeleton (see Table 2).

Table 5. Criteria for Scoring the Presence of Multiple Injuries

Score	Criteria
0	1 Injury
1	1+ Injuries

Identification of Fracture Complications

In this thesis, a fracture complication is defined as a secondary pathological condition or disease process that aggravates an existing traumatic injury. They include atrophy, bone necrosis, infection, traumatic osteoarthritis, and fracture deformity and non-union (Ortner 2003). Initially, atrophy, bone necrosis, infection, and traumatic osteoarthritis data were collected for inclusion in the current study, but, due to time constraints, they were excluded for analysis. This data will be analyzed at a later time.

Fracture deformity and non-union were selected for analysis, because they can be used to generate stronger inferences about treatment than other fracture complications. Fracture deformity (e.g., angulation, rotation, etc.) results from a combination of poor fracture reduction and immobilization, both of which are important for treating traumatic injuries (Roberts and Manchester 2005). Non-union occurs when an individual fails to immobilize their injury adequately, leading to repeated interruption of the healing

process, and, in cases of pseudoarthrosis, the development of a fibrocartilagenous joint (Ortner 2003). Therefore, the prevalence of these fracture complications within and between cemetery samples can tell researchers something about fracture reduction and immobilization, and, by inference, treatment in the archaeological past.

All observed fractures of the appendicular skeleton included in this study were assessed for the presence or absence of fracture deformity and non-union. Fracture deformity was divided into five separate types, including angulation, rotation, apposition, overlap, and shortening. Data collection protocols associated with each of these fracture complications are discussed in the sections below.

Fracture Complications Specific to This Study

With the exception of apposition and shortening, all fracture complications were recorded as either absent, present, or unobservable (see Table 6). Fractures with extensive healing, post-mortem damage, or absence of a contralateral element (i.e., the same bone on the opposite side of the body) were coded as unobservable and excluded from the frequencies generated for analysis. Comparison of frequencies of fracture complications between cemetery samples permitted the assessment of socioeconomic status-related differences in access to treatment for traumatic injuries.

Table 6. Criteria for Scoring the Presence of a Fracture Complication

Score	Criteria
0	Absent
1	Present
2	Unobservable

Angulation. Individuals with united antemortem fractures were assessed for angulation. All non-united fractures were coded as unobservable for angulation.

Angulation was defined as any linear deviation of the distal end of a fractured bone from its natural longitudinal axis (Grauer and Roberts 1996). A fracture was coded as present for angulation when the distal end of the fractured bone deviated, at a minimum, one-degree from the atraumatic contralateral element. This was measured using a standard ruler and protractor. When possible, the direction of angulation was recorded for context.

Rotation. Similar to angulation, only united antemortem fractures were assessed for rotation. All remaining non-united fractures were coded unobservable for rotation. Rotation was defined as any rotational deviation of the distal end of a fractured bone about its natural longitudinal axis (Grauer and Roberts 1996). All fractures assessed for rotation were compared to their contralateral counterparts. A fracture was coded present for rotation when its distal fragment exhibited macroscopic evidence of rotational deviation about the bone's natural longitudinal axis. When possible, the direction of angulation was recorded for context.

Apposition. Only antemortem fractures were assessed for apposition. All remaining fractures were coded as unobservable. Apposition was defined as the degree of linear re-articulation between or re-association of fractured ends (Grauer and Roberts 1996). The data were collected two ways. First, individual fractures were coded as exhibiting either 100 percent or less than 100 percent apposition (see Table 7). Afterwards, they were coded as exhibiting varying degrees of apposition (see Table 7) (Redfern 2006). Measurements were made using a standard ruler.

Table 7. Criteria for Scoring the Presence and Degree of Apposition

Score	Criteria
	Presence or absence of apposition
0	<100% apposition
1	100% apposition
2	Unobservable
	Degree of apposition
0	0% apposition
1	0.01-25.00% apposition
2	25.01-50.00% apposition
3	50.01-75.00% apposition
4	75.01-100.00% apposition
5	100% apposition
6	Unobservable

Overlap. Similar to angulation and rotation, only united antemortem fractures were assessed for fracture overlap. All remaining non-united fractures were coded as absent or, when necessary, unobservable. Overlap was defined as the extension of the distal end of the fractured bone into the proximal end (Grauer and Roberts 1996). All fractures assessed for overlap were compared to their contralateral counterparts. A fracture was coded present for overlap when the distal end of the fractured bone extended past the fracture margin and into the proximal end at least one millimeter. This was measured using a standard ruler and protractor.

Shortening. Similar to angulation, rotation, and apposition, only antemortem united fractures were assessed for shortening. All non-united fractures were coded unobservable for shortening. Shortening is defined as a decrease in the overall length of an element due to either fracture overlap or some other injury-related complication (e.g., necrosis, atrophy, etc.) (Ortner 2003). All fractures assessed for shortening were compared to their contralateral counterparts. Similar to apposition, shortening data were

recorded two ways. First, a fracture was coded present for shortening when it exhibited at least a one millimeter difference in overall length from the contralateral element.

Otherwise, it was recorded as absent. All specific measurements were then recorded in millimeters. Measurements were recorded using a standard osteometric board or, when necessary, standard sliding calipers.

Non-Union. Only antemortem fractures were assessed for non-union. All remaining fractures were coded as unobservable. Non-union was defined as the isolation of fractured ends, resulting from failed mineralization of the fibrocartilagenous callus, that exhibit evidence of healing (Resnick et al. 1995). A fracture was coded present for non-union when its margins exhibited evidence of healing, such as rounded edges or a hard callus, but both proximal and distal fragments remained isolated from one another. Fractures with evidence of non-union were not assessed for pseudoarthrosis.

Statistical Framework

Following data collection, descriptive and inferential statistical analyses were run using the IBM Statistical Package for the Social Sciences (version 23.0). Descriptive statistics were computed to assess the frequencies of individuals (n=46) by sex and age cohorts, and observed fractures of the appendicular skeleton (n=60) by element, position, type, mechanism, and timing of injury. Inferential statistics were then utilized to make quantitative comparisons of the prevalence of fracture complications between and within cemetery samples. Due to the nature of the data collected – typically nominal or ordinal data comprised of small samples and non-normal distributions – non-parametric statistics were employed. Statistical significance was determined using an alpha level of 0.05.

Pearson's Chi-Square and Fisher's Exact tests were most commonly implemented to analyze the data. These non-parametric statistical tests are useful for assessing relationships between nominal and ordinal variables (Field 2013). The Fisher's Exact test was only used when the expected counts of a particular cell in the computed contingency table were less than five. A statistically significant finding ($p < 0.05$) suggested that the two variables under study were related. Because these two tests have less statistical power than their parametric alternatives, the likelihood of committing a type II error is higher. Therefore, if statistical significance was encountered, a Phi coefficient or a Kramer's V coefficient was computed. These coefficients are measures of effect size, meaning they measure the strength of the association between the two variables under study. They range from +1 to -1, with 0 indicating no association.

Studies cite that demography can have a confounding effect on the prevalence data extrapolated from osteological analysis (Wood et al. 1992). Therefore, prior to conducting analyses to test the two main hypotheses of the current study, the sex and age distributions of both cemetery samples were compared quantitatively using a Fisher's Exact test. If the age and sex structures of the two samples were dissimilar, it would become difficult to make appropriate comparisons between them. Alternatively, the presence of similar demographic patterns between the two cemetery samples would strengthen any inter-sample comparisons made.

Following these preliminary analyses, and to address the first research hypothesis, frequencies of the presence or absence of fracture deformity and non-union were compared between cemetery samples. Angulation, rotation, overlap, and non-union were assessed using either a Chi-Square test, or, when necessary, a Fisher's Exact test.

Apposition, in particular, was assessed in two phases. First, the number of fractures with 100 or <100 percent fracture apposition were compared quantitatively between samples. Then, the number of fractures with 0.00, 0.01-25.00, 25.01-50.00, 50.01-75.00, 75.01-100.00, and 100.00 percent apposition were compared. For both analyses, a Fisher's Exact test was computed. Shortening was also assessed in two phases. First, the frequency of individuals with and without at least one millimeter of shortening were compared quantitatively between cemetery samples using a Pearson's Chi-Square test. Then, specific measurements of the amount of shortening present (mm) on the traumatized elements under study were compared between samples using a Mann-Whitney U test, a non-parametric alternative to the student's t-test that is useful for comparing the medians of two groups (Field 2013).

To address the second research hypothesis, patterns of fracture deformity and non-union were compared between individuals with and without evidence of multiple fractures in both cemetery samples combined ($n=46$ individuals). Afterwards, the same statistical analysis was run with each cemetery sample analyzed separately ($n_{\text{St. Bride's}}=33$ individuals, $n_{\text{Chelsea}}=13$ individuals). Prior to these analyses, however, a common odds ratio (OR_c) and associated Pearson's Chi-Square test were computed to assess the effect that cemetery sample had on the prevalence of individuals with single and multiple injuries. The OR_c is a prevalence statistic that provides a value and an associated confidence interval, both of which consider the age structure of the cemetery samples included in this study. To calculate the OR_c , an odds ratio (OR) was computed for each age cohort in each cemetery sample. The number of individuals in each age cohort exhibiting more than one injury (the numerator) were compared to the number of

individuals with only one injury (the denominator). The odd's ratios for each cemetery sample were then compared for each age cohort, with the OR for the St. Bride's sample in the numerator and the OR for the Chelsea sample in the denominator. The resulting ORs were summed, producing the OR_c . Following computation of the OR_c , statistical significance was determined by computing a Chi-Square test.

Following this analysis, a series of Fisher's Exact tests, and, when appropriate, Pearson's Chi-Square tests, were computed to explore the effect, if any, that fracture deformity and non-union had on the prevalence of individuals with multiple injuries when both cemetery samples were combined and then assessed separately. To assess the relationship between fracture apposition and the prevalence of multiple traumata, however, individuals with and without multiple injuries were divided into two groups: 100.00 and <100.00 percent apposition. For all other analyses, fracture deformity and non-union were related to the prevalence of individuals with and without multiple fractures using presence or absence data. Individuals with evidence of multiple fractures were coded present for a particular fracture complication if at least one of their fractures exhibited evidence of that specific complication.

Summary

Two cemetery samples representing two different echelons of industrial London's population were purposively sampled to examine the effect that socioeconomic status had on access to treatment for traumatic injuries, and to explore the long-term health consequences of that interaction. Following the exclusion of atraumatic individuals and intra-articular fractures, a total of 46 individuals were examined. To address the first

research hypothesis, non-parametric tests, including Pearson's Chi-Square, Fisher's Exact, and Mann-Whitney U tests, were used to statistically evaluate the effect that cemetery sample had on the prevalence of fracture deformity and non-union. Following these analyses, and to address the second research hypothesis, the same non-parametric tests were employed to assess the effect that fracture deformity and non-union had on the prevalence of individuals with multiple injuries for both cemetery samples combined and separated. The results of these tests will be presented and discussed in subsequent chapters.

CHAPTER V

RESULTS

Introduction

This chapter is divided into four main sections. The first section includes the results of an analysis of the age and sex structures of both the St. Bride's and Chelsea samples. The second section provides a breakdown of the distribution of fractures in each cemetery sample by location, type, and mechanism of injury. The third section provides the results of analyses pertinent to address the hypothesis that the quality of treatment received was unevenly distributed among London's population in the Industrial Period (A.D. 1700-1850). In this section, the prevalence of fracture complications associated with deformity and non-union are compared between the St. Bride's and Chelsea samples. The last section of this chapter provides the results of analyses necessary to address the hypothesis that the quality of treatment received influenced the likelihood of subsequent injury. The associations between fracture complications and the prevalence of individuals with multiple fractures are examined for both cemetery samples combined. These associations are then analyzed for each cemetery sample separately.

Sample Demographics

Due to time constraints, estimations of biological sex and age were taken from the Wellcome Osteological Research Database. Table 8 depicts the prevalence of

Table 8. Prevalence of Males, Females, and Individuals of Unknown Sex (n = 46)

Biological Sex	Frequency	Percent	Cumulative Percent
Male	33	71.74	71.74
Probable Male	3	6.52	78.26
Female	7	15.22	93.48
Probable Female	1	2.17	95.65
Undetermined	2	4.35	100.0

Note: Assessments provided by the Museum of London, Centre for Human Bioarchaeology.

individuals included in the study sample by sex. Males and probable males make up 71.74 percent (33/46) and 6.52 percent (3/46) of the final study sample, while females and probable females make up 15.22 percent (7/46) and 2.17 percent (1/46), respectively. Sex estimations for two individuals (4.35%) yielded ambiguous results.

The age distribution of the sample by cemetery sample is depicted in Figure 1 below. All individuals were assigned to one of the following age cohorts: young adult (18-25 years), middle early adult (26-35 years), middle late adult (36-45 years), or mature

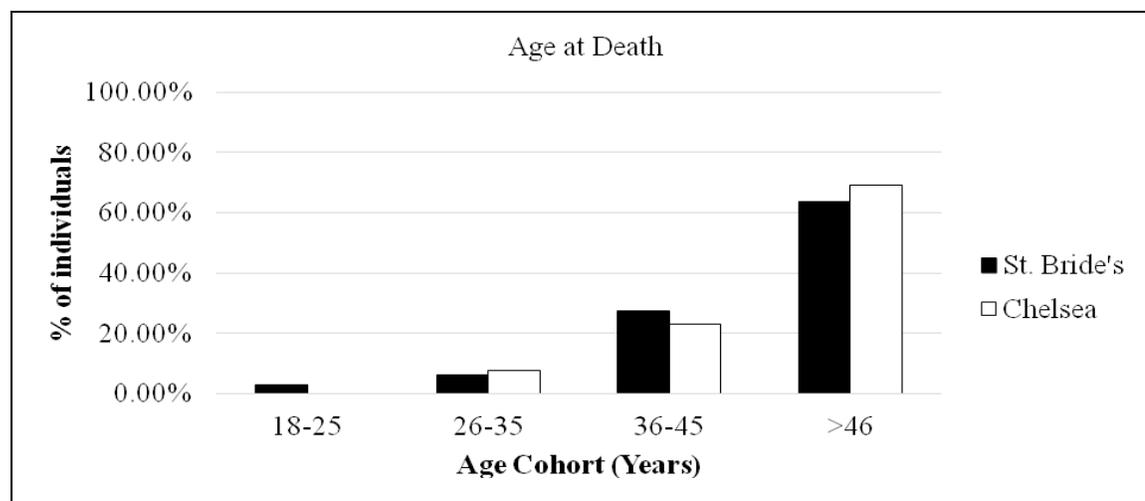


Figure 1. Distribution of age at death estimates by sample (n = 46). All estimates provided by the Museum of London, Centre for Human Bioarchaeology.

adult (> 46 years). Of all individuals included in the final study sample, 2.17 percent (1/46) were assigned to the young adult cohort, 6.52 percent (3/46) were assigned to the early middle adult cohort, 26.02 percent (12/46) were assigned to the late middle adult cohort, and 65.22 percent (30/46) were assigned to the mature adult cohort (see Table 9).

Table 9. Prevalence of Young Adults, Middle Adults, and Mature Adults (n = 46)

Age	Frequency	Percent	Cumulative Percent
18-25 Years	1	2.17	2.17
26-35 Years	3	6.52	8.69
36-45 Years	12	26.02	34.71
>46 Years	30	65.22	100.0

Note: Assessments provided by the Museum of London, Centre for Human Bioarchaeology.

Fracture Demographics

For each fracture encountered, the location, type, and mechanism of injury were recorded. The prevalence of fractures by element, position, and cemetery sample are listed in Table 10. Fractures to the distal 1/3 of the radius were the most common fracture observed in the St. Bride's sample (9/42 or 21.43%). In contrast, fractures to the proximal 1/3 of the first metacarpal were the most common fracture observed in the Chelsea sample (3/18 or 16.67%).

The prevalence of fractures by type and cemetery sample are included in Table 11. A total of 18 fractures could not be identified by type. When unidentified fractures were excluded, oblique fractures were the most common fracture type observed in the St. Bride's (12/33 or 36.36%) and Chelsea (4/9 or 44.44%) samples.

The prevalence of fractures by mechanism and cemetery sample are listed in Table 12. A total of 18 fractures could not be identified by mechanism. When

Table 10. Prevalence of Fractures by Element, Position, and Sample (n = 60)

Element	Position	Cemetery Sample			
		St. Bride's		Chelsea	
		n	%	n	%
Clavicle	Shaft	0	0.00	1	5.56
	Distal Epiphysis	0	0.00	1	5.56
Scapula	Acromion	1	2.38	0	0.00
	Body	1	2.38	0	0.00
Humerus	Proximal Epiphysis	1	2.38	1	5.56
	Shaft	2	4.76	1	5.56
Radius	Shaft	1	2.38	2	11.11
	Distal 1/3	9	21.43	1	5.56
Ulna	Proximal Epiphysis	2	4.65	0	0.00
	Shaft	0	0.00	1	5.56
	Distal 1/3	0	0.00	1	5.56
MC1	Proximal 1/3	3	7.14	3	16.67
	Distal 1/3	1	2.38	0	0.00
MC3	Shaft	1	2.38	0	0.00
MC2	Shaft	0	0.00	1	5.56
MC4	Proximal 1/3 Shaft	0	0.00	1	5.56
Innominate	Ilium	1	2.38	2	11.11
Femur	Proximal Epiphysis	3	7.14	0	0.00
	Proximal 1/3	2	4.76	0	0.00
	Shaft	2	4.76	0	0.00
	Distal 1/3	0	0.00	0	0.00
Patella	Body	2	4.76	0	0.00
Tibia	Shaft	1	2.38	0	0.00
	Distal 1/3	1	2.38	0	0.00
Fibula	Proximal 1/3	1	2.38	0	0.00
	Shaft	0	0.00	0	0.00
	Distal 1/3	4	9.52	0	0.00
MT2	Distal 1/3	0	0.00	1	5.56
MT3	Shaft	2	4.76	0	0.00
MT5	Proximal 1/3	1	2.38	1	5.56
	Total	42	100.00	18	100.00

unidentified fractures were excluded, fractures caused by an indirect force were the most common in both the St. Bride's (18/33 or 54.55%) and Chelsea (7/9 or 77.78%) samples.

Table 11. Prevalence of Fractures by Fracture Type and Sample (n = 60)

Fracture Type	Cemetery Sample			
	St. Bride's		Chelsea	
	n	%	n	%
Transverse	2	4.76	0	0.00
Colles'	7	16.67	1	5.56
Smith's	2	4.76	0	0.00
Oblique	12	28.57	4	22.23
Bennett's	3	7.14	3	16.67
Spiral	2	4.76	0	0.00
Comminuted	1	2.38	0	0.00
Surgical Neck	4	9.52	1	5.56
Unknown	9	21.42	9	49.98
Total	42	100.00	18	100.00

Table 12. Prevalence of Fractures by Mechanism and Sample (n = 60)

Fracture Mechanism	Cemetery Sample			
	St. Bride's		Chelsea	
	n	%	n	%
Direct	3	7.14	0	0.00
Indirect	18	42.86	7	38.89
Pathological	12	28.57	2	11.11
Unknown	9	21.43	9	50.00
Total	42	100.00	18	100.00

Fracture Complications

Before any comparisons of patterns of fracture healing can be made between the St. Bride's and Chelsea samples, the sex and age distributions of the individuals from these samples must first be assessed. If the demographic structures of these two cemetery samples are dissimilar, it becomes difficult to make appropriate comparisons between

them, because demography can have a confounding affect on prevalence data extrapolated from osteological analysis. To address this issue, age and sex distributions were compared between cemetery samples. To facilitate quantitative analysis, all individuals classified as “probable male” were collapsed into “male,” and individuals classified as “probable female” were collapsed into “female.” A Fisher’s Exact test indicated that there was no significant association between cemetery sample and sex ($p = 0.676$), nor between cemetery sample and age ($p = 1.000$). These results indicate that the age and sex structures of both cemetery samples are similar, and that comparisons of fracture complications can be made between the them to test the first hypothesis.

To test the first hypothesis that the quality of treatment received was unevenly distributed among the population, patterns of fracture deformity and non-union were compared between cemetery samples. Fracture deformity, in particular, included assessments of the associations between cemetery sample and the prevalence of (1) angulation, (2) rotation, (3) apposition, (4) overlap, and (5) shortening. Each assessment involved a two-step process. First, each fracture complication was assessed qualitatively. Following assessment, the associations between cemetery sample and each of the complications mentioned previously were quantitatively analyzed. Quantitative analyses were non-parametric in nature, and included Pearson’s Chi- Square, Fisher’s Exact, and Mann-Whitney U tests.

Angulation

A summary of the prevalence of angulation in both cemetery samples is presented in Figure 2. Issues of preservation precluded the analysis of four fractures (6.67%). Of the 56 fractures observed, 55.36 percent (31/56) exhibited evidence of

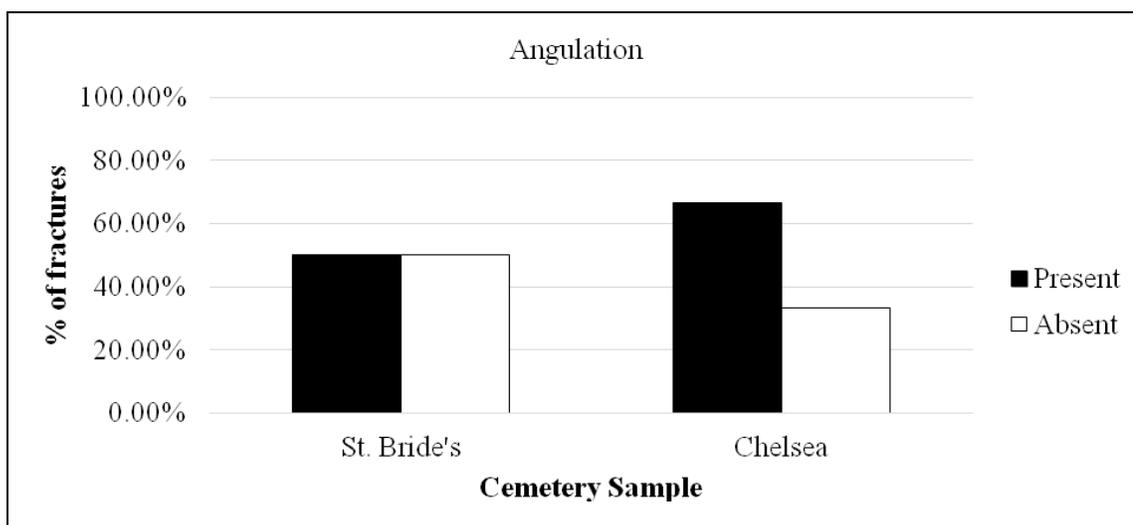


Figure 2. Prevalence of angulation by cemetery sample (n = 56).

fracture angulation. When separated by cemetery sample, the prevalence of angulation was higher in the Chelsea sample (12/31 or 66.67%) than in the St. Bride's sample (19/38 or 50.00%). However, the results of a Pearson's Chi-Square test indicated that cemetery sample had no effect on the prevalence of angulation ($X^2 = 1.373$, $df = 1$, $p = 0.241$).

Rotation

The prevalence of fractures with evidence of rotation in both cemetery samples is depicted in Figure 3. Issues with preservation and the availability of photographs necessary to measure the degree of rotation precluded the inclusion of 6.67 percent (4/60) of the fractures observed in the analysis. Of the remaining fractures, 21.43 percent (12/56) exhibited evidence of rotation. When compared by cemetery sample, 21.05 percent (8/38) of fractures observed in the St. Bride's sample exhibited evidence of rotation. The prevalence of fractures with evidence of rotation in the Chelsea sample was

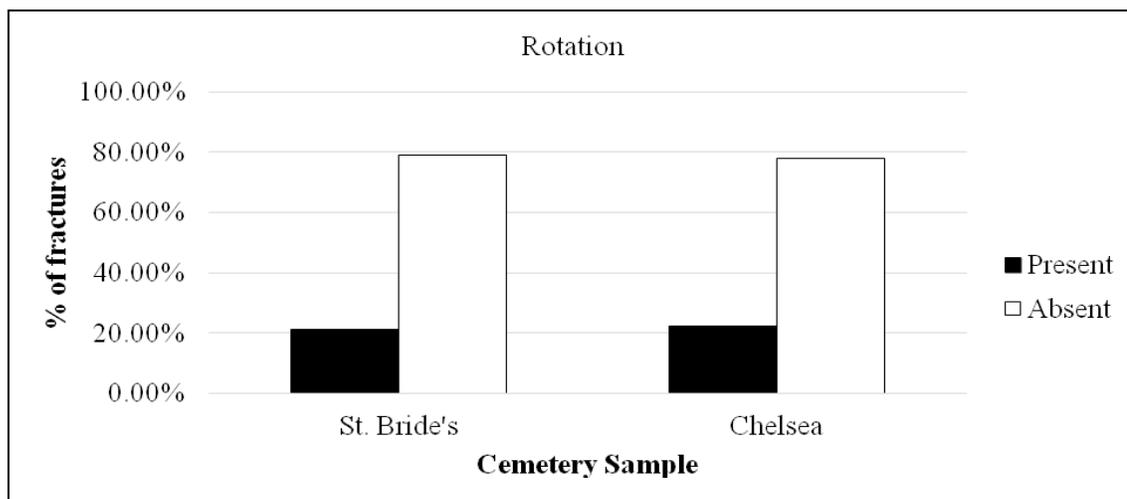


Figure 3. Prevalence of rotation by cemetery sample (n = 56).

qualitatively similar (22.22% or 4/18). The results of a Fisher's Exact test indicated that cemetery sample had no effect on the prevalence of rotation ($p = 1.000$).

Apposition

A summary of the prevalence of fractures with 100.00 percent or less than 100.00 percent apposition of fractured ends by cemetery sample is presented in Figure 4.

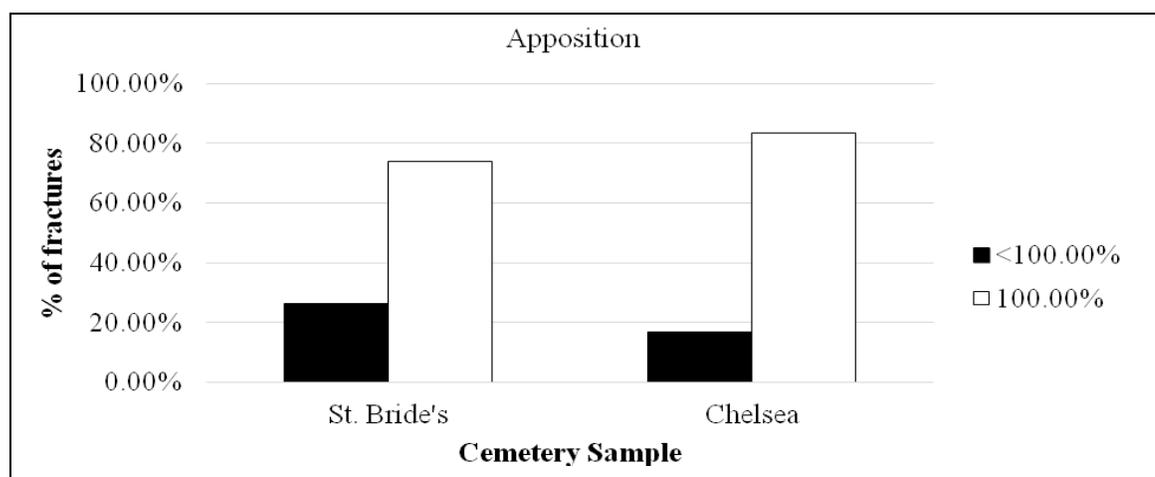


Figure 4. Prevalence of 100.00 percent and less than 100.00 percent apposition by cemetery sample (n = 60).

Overall, 23.33 percent (14/60) of fractures observed exhibited less than 100.00 percent apposition. When separated by cemetery sample, fractures with less than 100.00 percent apposition were more prevalent in the St. Bride's sample (11/42 or 26.19%) than in the Chelsea sample (3/18 or 16.67%). The results of a Fisher's Exact test indicated that cemetery sample had no effect on the prevalence of apposition ($p = 0.520$).

The prevalence of fractures with varying degrees of fracture apposition in both cemetery samples is depicted in Figure 5. Issues of preservation precluded the

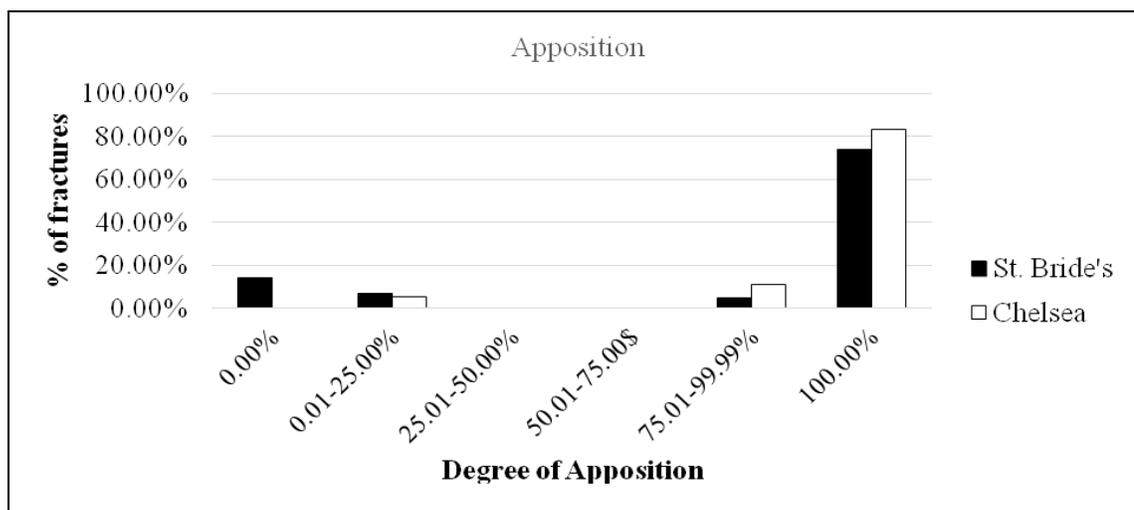


Figure 5. Prevalence of apposition by cemetery sample (n = 59).

inclusion of 1.67 percent (1/60) of observed fractures in the analysis. In general, most fractures (77.97% or 46/59) exhibited 100.00 percent apposition of the broken ends, but 5.08 percent (3/59) exhibited 75.01-99.99 percent apposition, 6.78 percent (4/59) exhibited 0.01-25.00 percent apposition, and 10.17 percent (6/59) exhibited 0.00 percent apposition. When separated by cemetery sample, 75.61 percent (3/41) and 83.33 percent (15/18) of fractures from the St. Bride's and Chelsea samples, respectively, exhibited

evidence of 100.00 percent fracture apposition; and 2.44 percent (1/41) and 11.11 percent (2/18) of fractures from the St Bride's and Chelsea samples, respectively, exhibited evidence of 75.01-99.99 percent apposition. Additionally, 7.32 percent (3/41) and 5.56 percent (1/18) of fractures from the St. Bride's and Chelsea samples, respectively, exhibited evidence of 0.01-25.00 percent apposition; and 14.63 percent (6/41) and 0.00 percent (0/18) of observed fractures exhibited evidence of 0.00 percent fracture apposition. The results of a Fisher's Exact test indicated that cemetery sample had no effect on the prevalence of apposition when fractures were separated into more than two groups ($p = 0.190$).

Overlap

A summary of the prevalence of fracture overlap in both cemetery samples is presented in Figure 6. Issues of preservation precluded the analysis of 18 fractures (30.00% of 60). Of the 42 fractures observed, 23.81 percent (10/52) exhibited evidence of overlap. When separated by cemetery sample, the prevalence of fracture overlap was

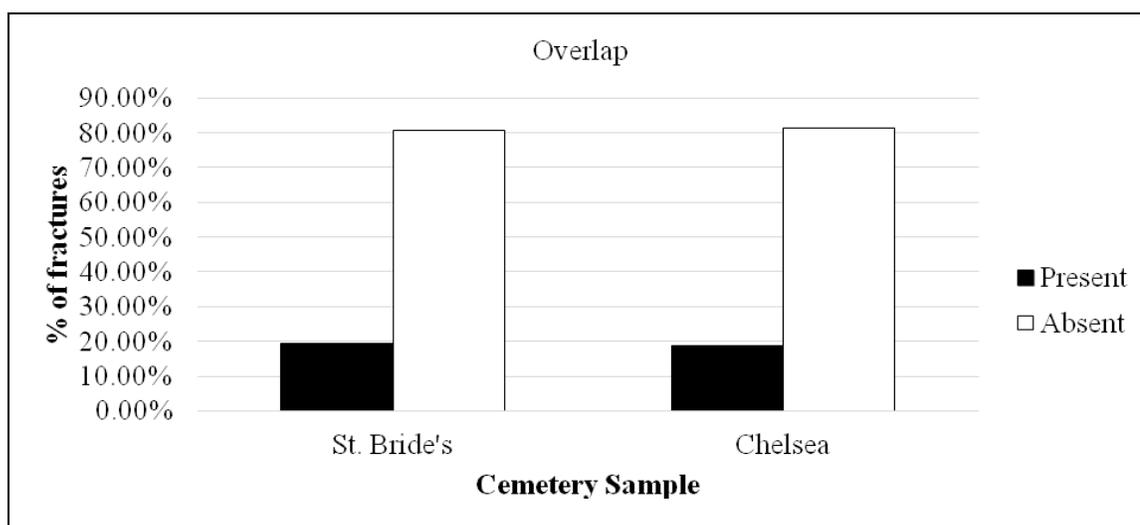


Figure 6. Prevalence of overlap by cemetery sample (n = 52).

higher in the St. Bride's sample (7/36 or 19.44%) than in the Chelsea sample (3/16 or 18.75%). However, the results of a Fisher's Exact test indicated that cemetery sample had no effect on the prevalence of overlap (Fisher's Exact, $p = 1.000$).

Shortening

The prevalence of shortening in both cemetery samples is depicted in Figure 7. Issues of preservation precluded the analysis of 18 fractures (30.00% of 60). Of the 42 fractures observed, 64.29 percent (27/42) exhibited evidence of shortening. When separated by cemetery sample, the prevalence of shortening was higher in the Chelsea sample (12/17 or 70.59%) than in the St. Bride's sample (15/25 or 60.00%). However, the results of a Pearson's Chi-Square test indicated that cemetery sample had no effect on the prevalence of shortening ($X^2 = 0.494$, $df = 1$, $p = 0.482$).

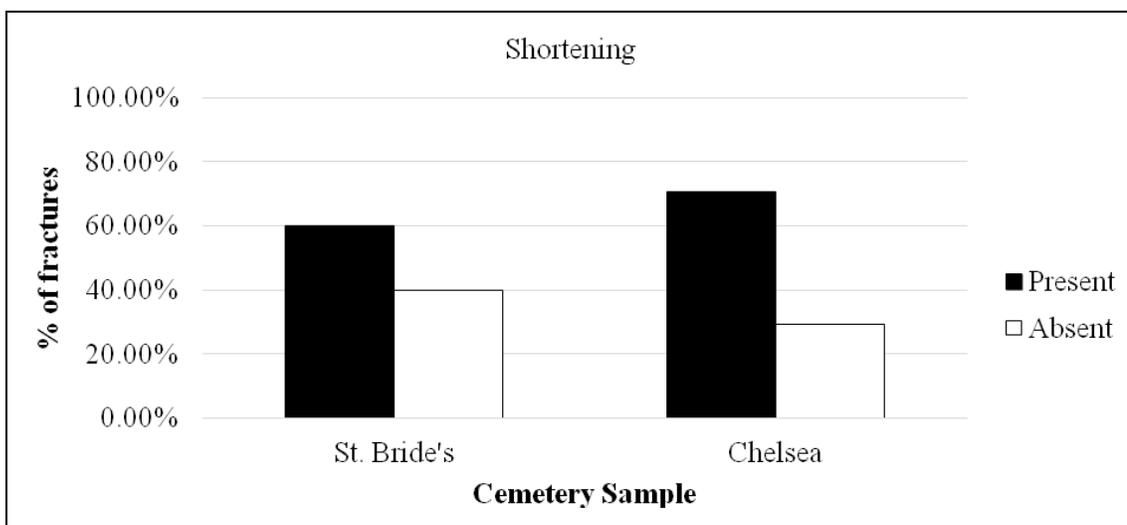


Figure 7. Prevalence of shortening by cemetery sample (n = 42).

A summary of the variation in shortening (mm) of fractured elements in both cemetery samples is presented in Table 13. Fractures included in this analysis must have

Table 13. Mann-Whitney U Test Comparing Patterns of Fracture Shortening (mm) by Cemetery Sample (n = 18)

Variable	n	Median	Mean Rank	U	<i>p</i>
St. Bride's	8	15.50	12.19	18.500	0.055
Chelsea	10	5.50	7.35		

exhibited evidence of at least one mm of shortening when compared to the antimer.

Median degree of shortening for the St. Bride's and Chelsea samples was 15.50 mm and 5.50 mm, respectively. The mean rank for the St. Bride's and Chelsea samples was 12.19 and 7.35, respectively. The results of a Mann-Whitney U test indicated that there was no statistically significant difference in the mean rank of the degree (mm) of fracture shortening between fractures from the St. Bride's and Chelsea cemetery samples ($U = 18.500, p = 0.055$).

Non-Union

The prevalence of non-union in both cemetery samples is depicted in Figure 8.

Ten percent (6/60) of all observed fractures exhibited evidence of non-union. One-

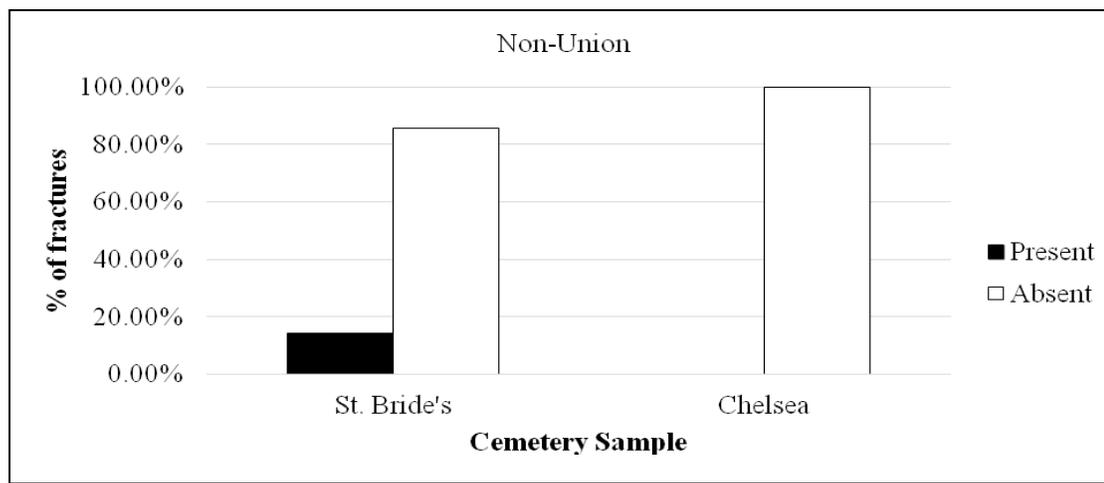


Figure 8. Prevalence of non-union by cemetery sample (n = 60).

hundred percent (6/6) of cases of non-union observed in this study were encountered in the St. Bride's sample (6/42 or 14.29%). The results of a Fisher's Exact test indicated that cemetery sample had no effect on the prevalence of non-union ($p = 0.165$).

Patterns of Multiple Traumata

As mentioned in the previous section, the age and sex structures of both the St. Bride's and Chelsea cemetery samples are similar. Therefore, comparisons can be made between them in order to test the second hypothesis that the quality of treatment received influenced the likelihood of subsequent injury. To do this, the proportion of individuals with and without multiple injuries were compared between cemetery samples using a Common Odds Ratio. Following this analysis, a series of Pearson's Chi-Square tests, and, when necessary, Fisher's Exact Tests, were computed to examine the effect that each of the fracture complications examined in the previous section had, if any, on the prevalence of individuals with multiple injuries in both cemetery samples. Analyses were run with both cemetery samples combined, and then each sample was assessed separately.

It is important to note that the level of analysis for the second hypothesis shifted from fractures ($n = 60$) to the individuals who suffered those fractures ($n = 46$). Individuals exhibiting any evidence of multiple fractures, including those that were not sampled for reasons outlined in the previous chapter, were classified as exhibiting two or more injuries (e.g., 1+ fractures). Those same individuals were further classified as present for a particular fracture complication if at least one of their fractures exhibited the characteristics of that specific complication, and absent if the condition was not met.

Multiple Traumatic Injuries

A summary of the prevalence of individuals with evidence of either one injury, or two or more injuries in both cemetery samples is presented in Figure 9.

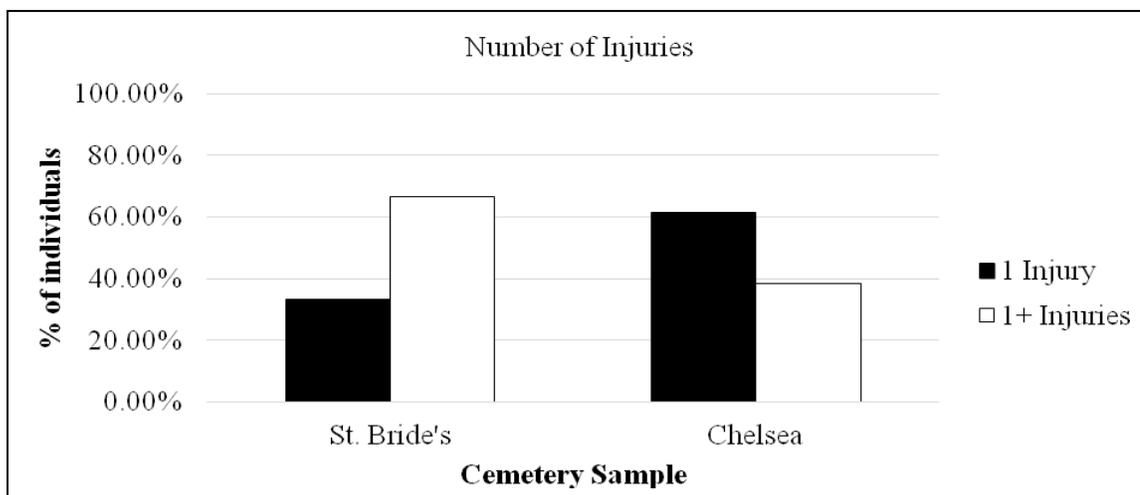


Figure 9. Prevalence of individuals with evidence of one or more injuries by cemetery sample (n = 46).

Individuals exhibiting two or more injuries made up 66.67 percent (22/33) of the St. Bride's sample, while only 38.46 percent (5/13) of the individuals in the Chelsea sample exhibited two or more injuries. In any analysis of multiple injuries, however, there may be inherent differences in the age structures of individual cemetery samples when their constituents are classified as exhibiting either "one injury" or "two or more injuries." If this is the case, then any comparisons made between cemetery samples will yield results that do not appropriately approximate their true prevalence. To remedy this potential issue in the current study, a Common Odds Ratio (OR_c) was computed.

The OR_c is a prevalence statistic that provides a value and an associated confidence interval, both of which consider the age structure of the cemetery samples

included in this study. Following computation of the OR_c , statistical significance is determined by computing a Chi-Square test and associated probability value. To calculate the OR_c , an odds ratio (OR) was computed for each age cohort in each cemetery sample. The number of individuals in each age cohort exhibiting more than one injury (the numerator) were compared to the number of individuals with only one injury (the denominator). The ORs for each cemetery sample were then compared for each age cohort, with the OR for the St. Bride's sample in the numerator and the OR for the Chelsea sample in the denominator. The resulting ORs were summed, producing the OR_c . The results of this analysis indicated that cemetery sample had no effect on the prevalence of individuals with multiple injuries ($OR_c = 2.64$, $p = 0.102$, [95% CI = 0.812 to 8.569]; see Table 14).

Table 14. Common Odds Ratio for the Prevalence of Individuals with One or More Injuries (n=46)

Variable	OR (18-25 Years)	OR (26-35 Years)	OR (36-45 Years)	OR (>46 years)	OR_c
St. Bride's/ Chelsea	2.00	2.00	0.625	5.00	2.64

Angulation

A summary of the prevalence of angulation among individuals from both the St. Bride's and Chelsea cemetery samples who exhibited one or more injuries is presented in Figure 10. Due to issues of preservation, three individuals (6.52% of 46) could not be assessed for the presence or absence of this fracture complication. Of those individuals with evidence of multiple injuries (26/43 or 60.47%), seventeen (65.38% of

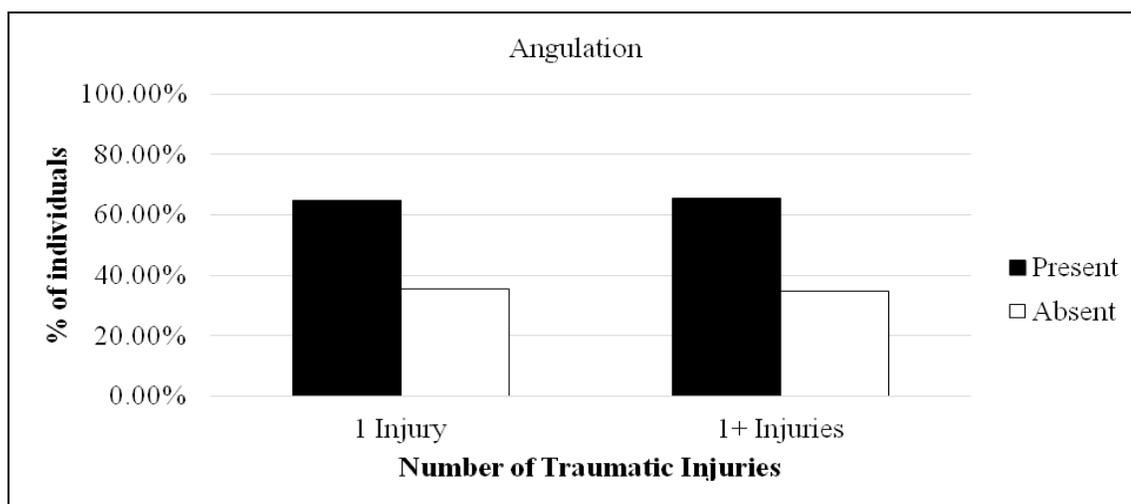


Figure 10. Prevalence of angulation among individuals with one or more injuries from the St. Bride's and Chelsea cemetery samples ($n = 43$).

26) also exhibited evidence of fracture angulation. Of those individuals who presented with one injury (17/43 or 39.53%), eleven (64.71% of 17) also exhibited evidence of fracture angulation. The results of a Pearson's Chi-Square test indicated that when both cemetery samples were combined, angulation had no effect on the prevalence of individuals with multiple injuries ($X^2 = 0.002$, $df = 1$, $p = 0.964$).

The prevalence of angulation among individuals from the St. Bride's sample who exhibited one or more injuries is depicted in Figure 11. Due to issues of preservation, three individuals (9.09% of 33) from the sample could not be assessed for the presence or absence of angulation. Seventy percent of the sample (21/30) available for this analysis exhibited evidence of multiple traumatic injuries. Of those, 66.67% (14/21) also presented with evidence of angulation. Of those with evidence of one traumatic injury (9/30 or 30.00%), only 44.44 percent (of 9) presented with angulation. The results of a Fisher's Exact test indicated that angulation had no effect on the

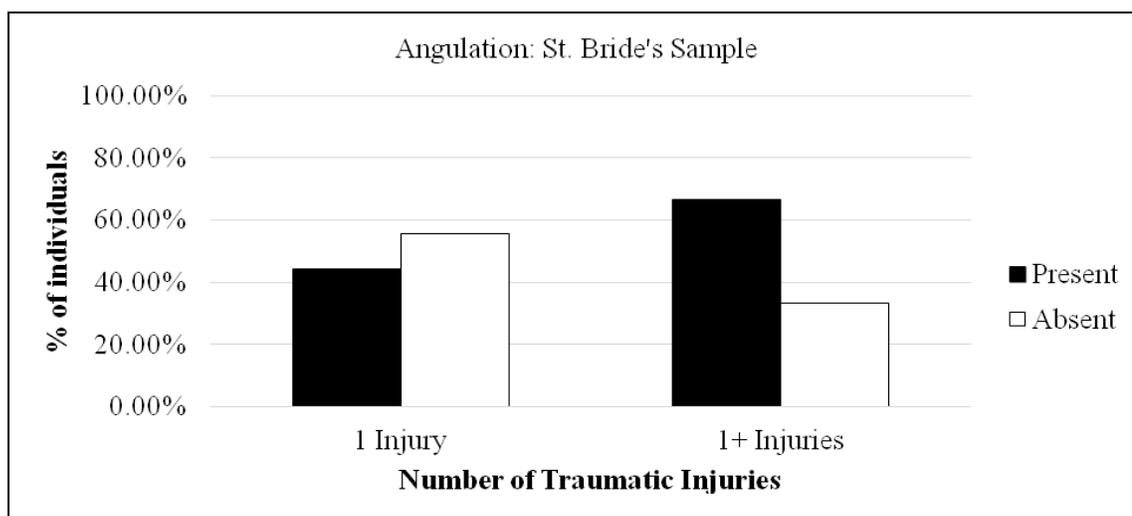


Figure 11. Prevalence of angulation among individuals with one or more injuries from the St. Bride's sample ($n = 30$).

prevalence of individuals with multiple traumatic injuries in the St. Bride's sample ($p = 0.418$).

A summary of the prevalence of angulation among individuals from the Chelsea sample who exhibited one or more injuries is presented in Figure 12. Compared

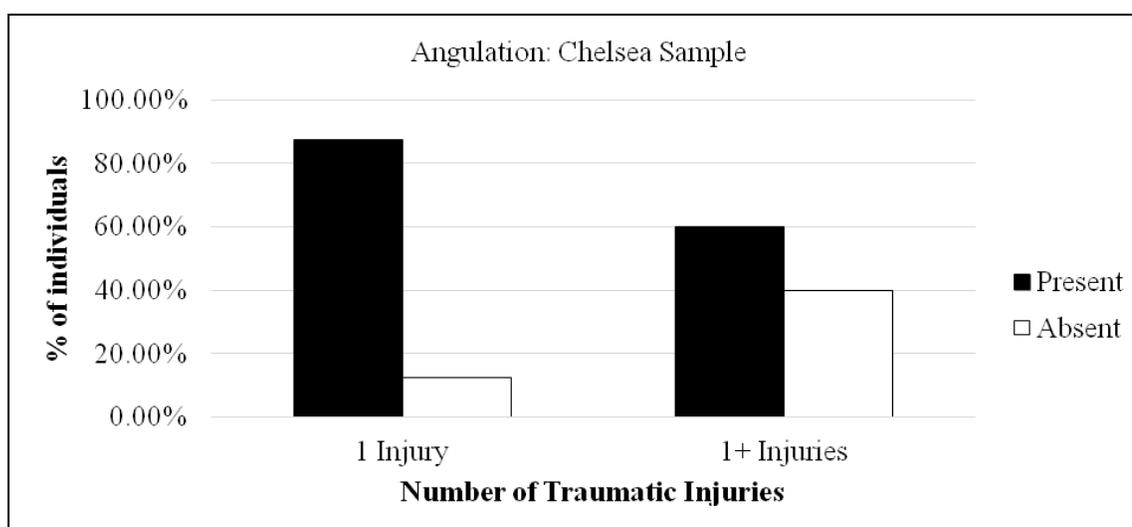


Figure 12. Prevalence of angulation among individuals from the Chelsea sample exhibiting one or more injuries ($n = 13$).

to the St. Bride's sample, only 38.46 percent (5/13) of the individuals examined exhibited evidence of multiple traumatic injuries. However, similar to the St. Bride's sample, 60.00 percent (3/5) of those individuals with two or more injuries also presented with evidence of angulation. Of those with evidence of only one traumatic injury (8/13 or 61.54%), 87.50 percent (7/8) also presented with angulation. The results of a Fisher's Exact test indicated that angulation had no effect on the prevalence of individuals with multiple traumatic injuries in the Chelsea sample (Fisher's Exact, $p = 0.510$).

Rotation

The prevalence of rotation among individuals from both the St. Bride's and Chelsea cemetery samples who exhibited one or more injuries is depicted in Figure 13.

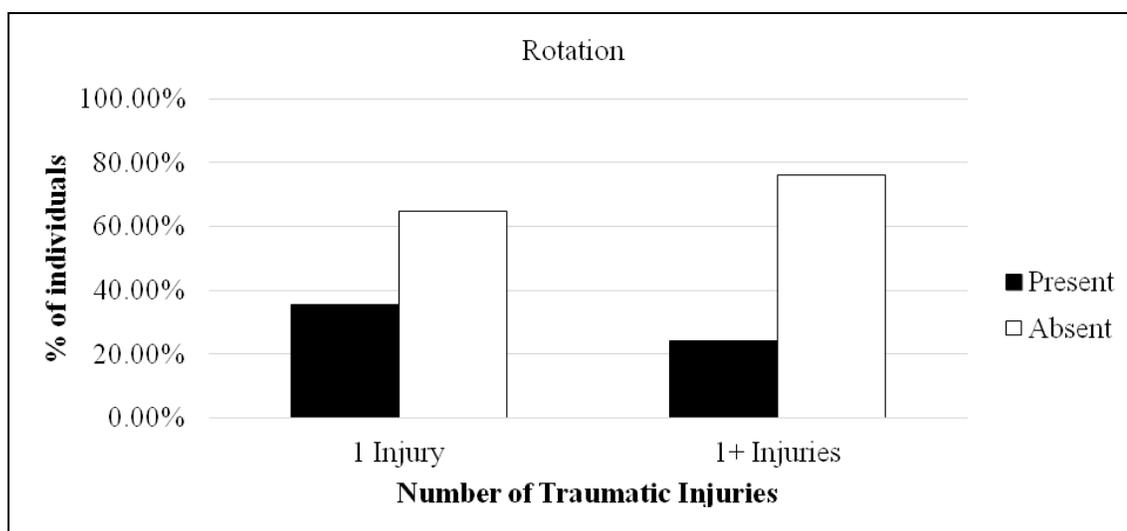


Figure 13. Prevalence of rotation among individuals from the St. Bride's and Chelsea cemetery samples exhibiting one or more injuries ($n = 42$).

Due to issues of preservation, four individuals (8.70% of 46) could not be assessed for the presence or absence of this fracture complication. Of those individuals who presented with multiple injuries (25/42 or 59.52%), six (24.00% of 25) also exhibited evidence of

rotation. Of those individuals who presented with one injury (17/42 or 40.48%), six (35.29% of 17) also exhibited evidence of rotation. The results of a Pearson's Chi-Square test suggested that, when both cemetery samples were combined, rotation had no effect on the prevalence of individuals with multiple injuries ($X^2 = 0.632$, $df = 1$, $p = 0.426$).

A summary of the prevalence of rotation among individuals from the St. Bride's sample who exhibited one or more injuries is presented in Figure 14. Due to

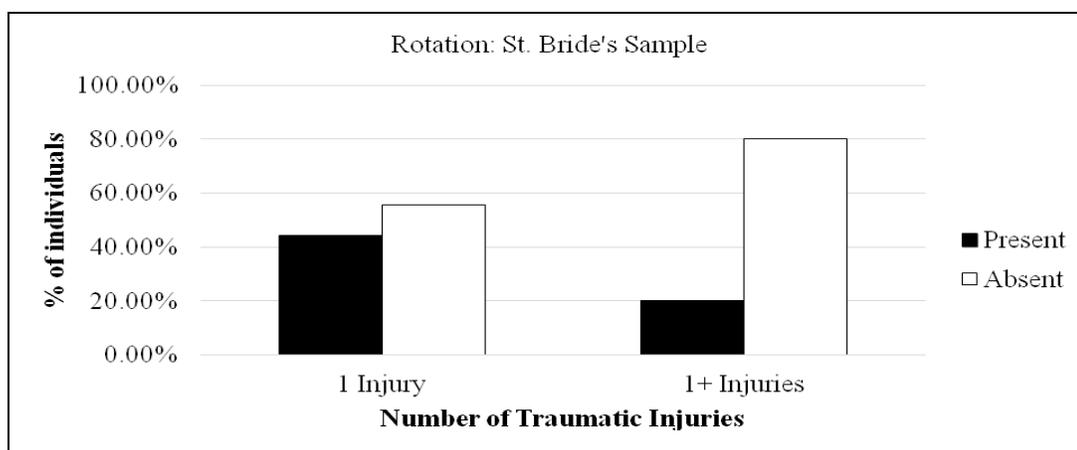


Figure 14. Prevalence of rotation among individuals from the St. Bride's sample exhibiting one or more injuries ($n = 29$).

issues of preservation, four individuals (12.12% of 33) from the sample could not be assessed for the presence or absence of rotation. A total of twenty individuals (68.97% of 29) exhibited evidence of multiple traumatic injuries. Only four of those individuals (20.00% of 20) presented with evidence of rotation. In contrast, of those with evidence of only one traumatic injury (9/29 or 31.03%), 44.44 percent (4/9) presented with rotation. The results of a Fisher's Exact test indicated that rotation had no effect on the prevalence of individuals with multiple traumatic injuries in the St. Bride's sample (Fisher's Exact, $p = 0.209$).

The prevalence of rotation among individuals from the Chelsea sample who exhibited one or more injuries is depicted in Figure 15. Compared to the St. Bride's

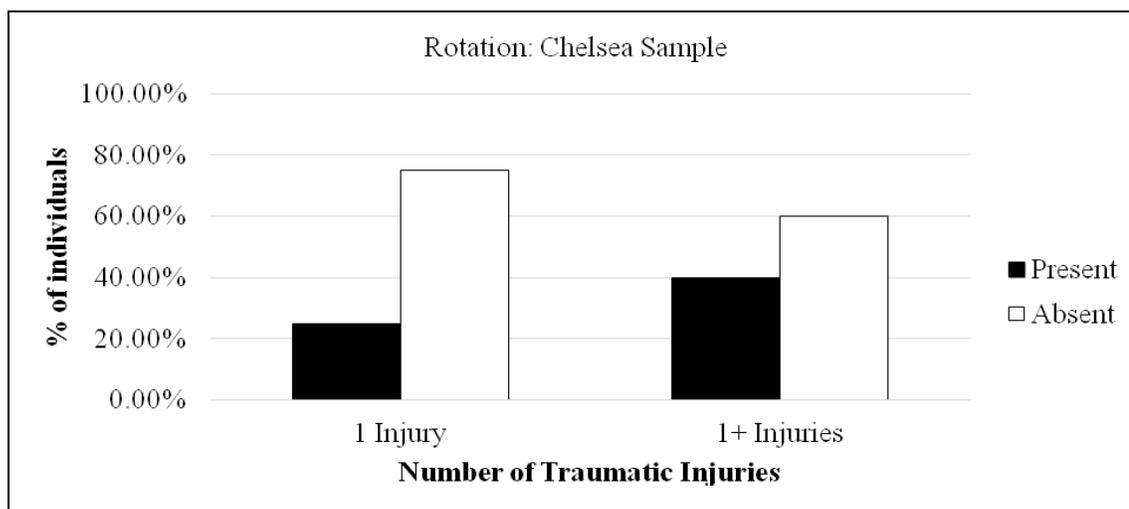


Figure 15. Prevalence of rotation among individuals from the Chelsea sample exhibiting one or more injuries (n = 13).

sample, only 38.46 percent (5/13) of individuals analyzed exhibited evidence of multiple traumatic injuries. However, unlike the St. Bride's sample, forty percent (2/5) of those individuals presented with rotation. Of those with evidence of only one traumatic injury (8/13 or 61.54%), twenty-five percent (2/8) presented with rotation. The results of a Fisher's Exact test indicated that the rotation had no effect on the prevalence of individuals with multiple traumatic injuries in the Chelsea sample (Fisher's Exact, $p = 1.00$).

Apposition

A summary of the prevalence of 100.00 and less than 100.00 percent apposition among individuals from both the St. Brides and Chelsea cemetery samples who exhibited evidence of one or more injuries is presented in Figure 16. Of those

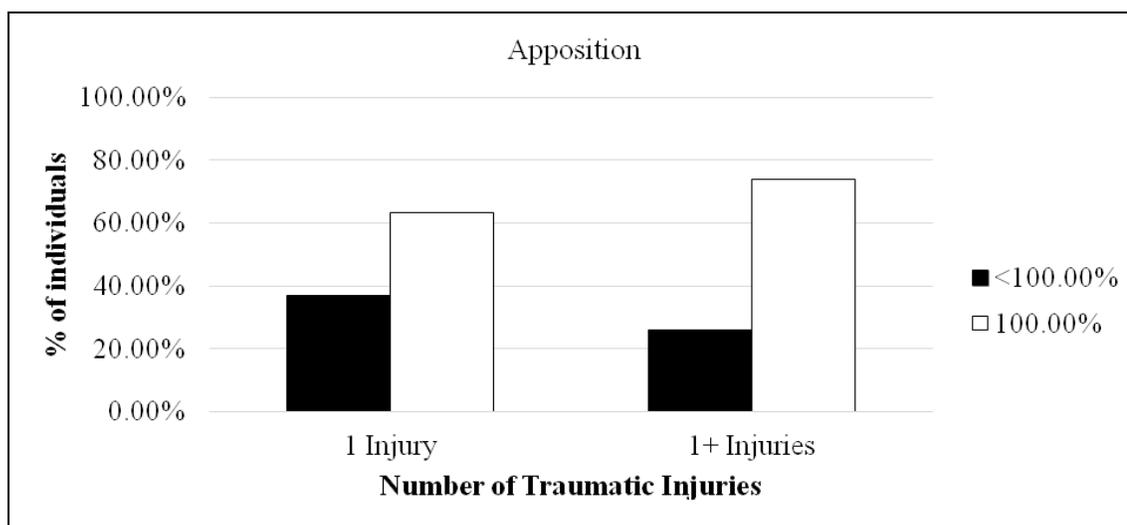


Figure 16. Prevalence of apposition among individuals from the St. Bride's and Chelsea cemetery samples ($n = 46$).

individuals who presented with multiple injuries (27/46 or 58.70%), seven (25.93% of 27) also exhibited evidence of less than 100.00 percent apposition of the fractured ends. Of those individuals who presented with only one injury (19/46 or 41.30%), seven (36.84% of 19) also exhibited evidence of less than 100.00 percent apposition of the fractured ends. The results of a Pearson's Chi-Square test indicated that, when both cemetery samples were combined, the degree of apposition had no effect on the prevalence of individuals with multiple injuries ($X^2 = 0.632$, $df = 1$, $p = 0.428$).

The prevalence of apposition among individuals from the St. Bride's sample who exhibited one or more injuries is depicted in Figure 17. A total of 22 individuals (66.67% of 33) exhibited evidence of multiple traumatic injuries. Only six of those individuals (27.27% of 22) presented with less than 100.00 percent fracture apposition. In contrast, of those with evidence of only one traumatic injury (11/33 or 33.33%), 45.45 percent (5/11) presented with less than 100.00 percent fracture apposition. The results of

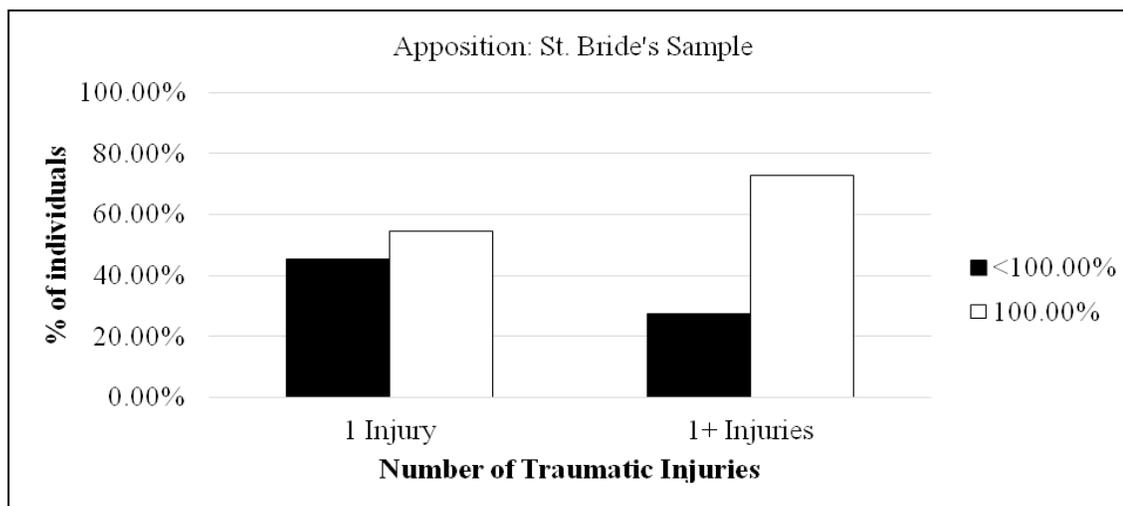


Figure 17. Prevalence of 100.00 and less than 100.00 percent apposition among individuals from the St. Bride's sample exhibiting one or more injuries (n = 33).

a Pearson's Chi-Square test indicated that the degree of fracture apposition had no effect on the prevalence of individuals with multiple traumatic injuries in the St. Bride's sample ($X^2 = 1.09$, $df = 1$, $p = 0.296$).

A summary of the prevalence of 100.00 and less than 100.00 percent apposition among individuals from the Chelsea sample who exhibited one or more injuries is presented in Figure 18. In contrast to the St. Bride's sample, 38.46 percent (5/13) of individuals observed in this analysis exhibited evidence of multiple traumatic injuries. Similar to the St. Bride's sample, twenty percent (1/5) of those individuals presented with less than 100.00 percent apposition. Similarly, of those with evidence of only one traumatic injury in the Chelsea sample (8/13 or 61.54%), twenty-five percent (2/8) presented with less than 100.00 percent apposition. As to be expected from these qualitative results, the degree of apposition had no effect on the prevalence of individuals with multiple traumatic injuries in the Chelsea sample (Fisher's Exact, $p = 1.00$).

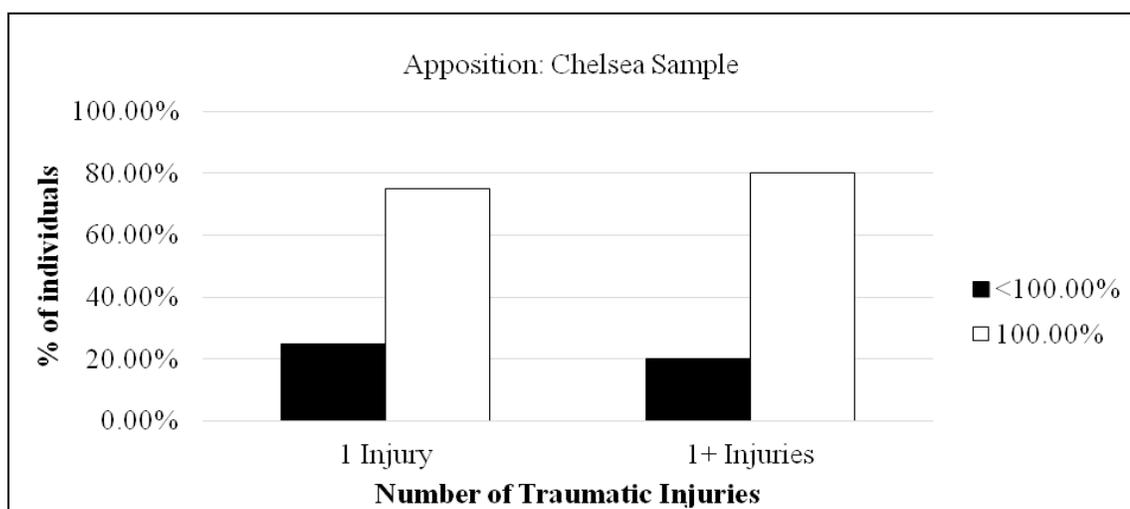


Figure 18. Prevalence of 100.00 and less than 100.00 percent apposition among individuals from the Chelsea sample exhibiting one or more injuries (n = 13).

Overlap

The prevalence of overlap among individuals from both the St. Bride's and Chelsea cemetery samples who exhibited one or more injuries is depicted in Figure 19. Due to issues of preservation, six individuals (13.04% of 46) could not be assessed for

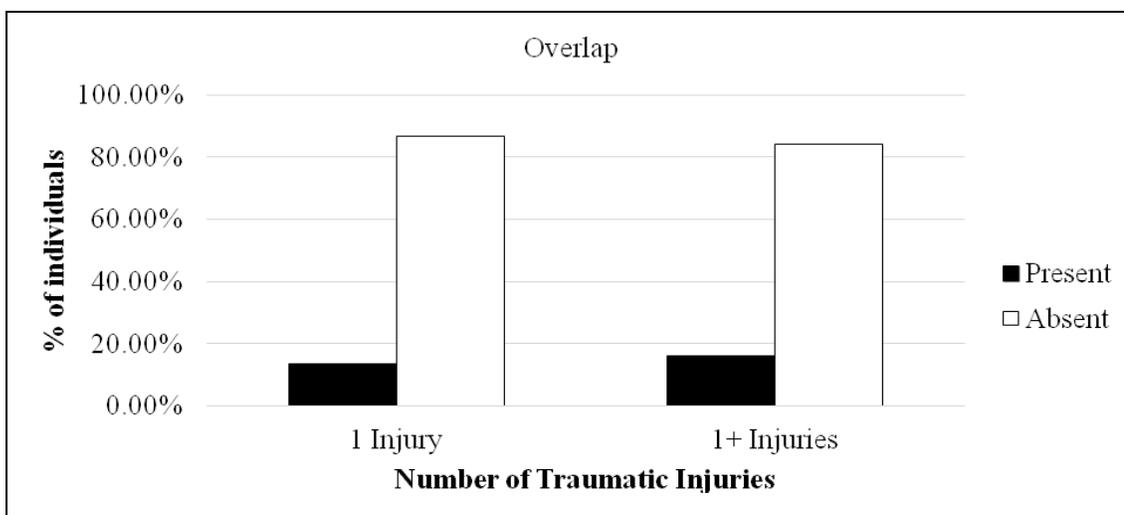


Figure 19. Prevalence of overlap among individuals from the St. Bride's and Chelsea cemetery samples exhibiting one or more injuries (n = 40).

the presence or absence of overlap. Of those individuals who presented with multiple injuries (25/40 or 62.5%), four individuals (16.00% of 25) also exhibited evidence of overlap of the fractured ends. Of those individuals who presented with only one injury (15/40 or 37.5%), two (13.33% of 15) also exhibited evidence of overlap. The results of a Fisher's Exact test suggested that overlap had no effect on the prevalence of individuals with multiple injuries ($p = 1.000$).

A summary of the prevalence of overlap among individuals from the St. Bride's who exhibited one or more injuries is presented in Figure 20. Due to issues of

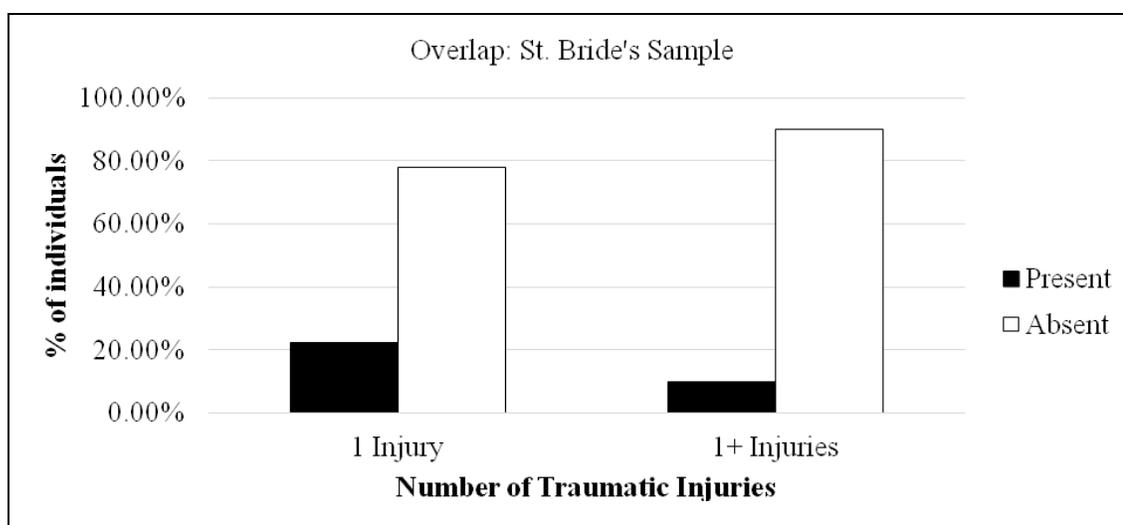


Figure 20. Prevalence of overlap among individuals from the St. Bride's sample exhibiting one or more injuries ($n = 29$).

preservation, four individuals (12.12% of 33) from the sample could not be assessed for the presence or absence of overlap. Twenty individuals (68.97% of 29) exhibited evidence of multiple traumatic injuries. Ten percent (2/20) of those individuals also presented with evidence of overlap. In contrast, of those with evidence of only one traumatic injury (9/29 or 31.03%), 22.22 percent (2/9) presented with overlap. However,

the results of a Fisher's Exact test indicated that overlap had no effect on the prevalence of individuals with multiple traumatic injuries in the St. Bride's sample (Fisher's Exact, $p = 0.568$).

The prevalence of overlap among individuals from the Chelsea sample who exhibited one or more injuries is depicted in Figure 21. Due to issues of preservation, two

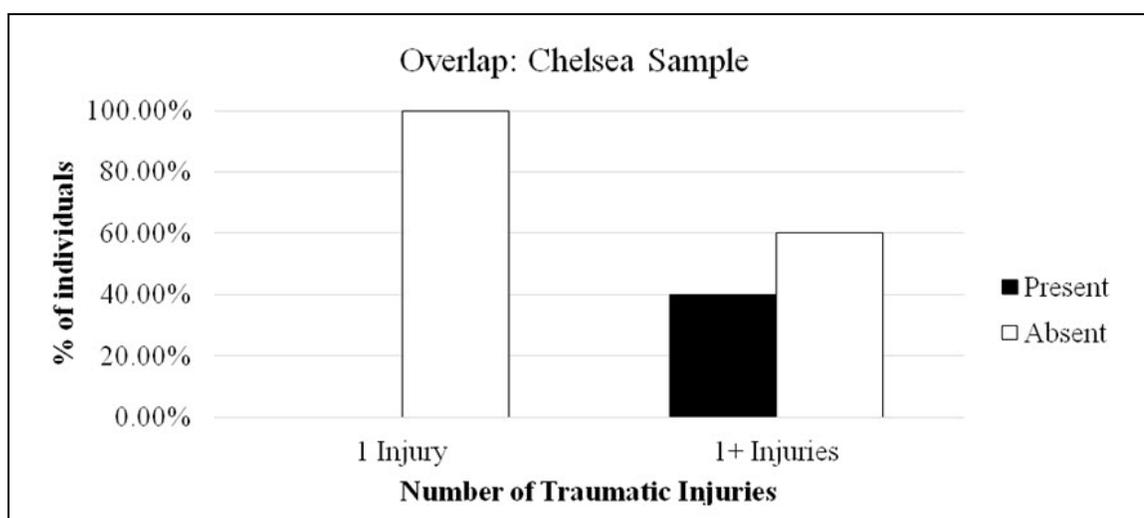


Figure 21. Prevalence of overlap among individuals from the Chelsea sample exhibiting one or more injuries ($n = 11$).

individuals (15.38% of 13) from the sample could not be assessed for the presence or absence of overlap. Compared to the St. Bride's sample, only 45.45% (5/11) of the individuals analyzed exhibited evidence of multiple traumatic injuries. However, unlike the St. Bride's sample, forty percent (2/5) of those individuals presented with overlap. In contrast, of those with evidence of only one traumatic injury in the Chelsea sample (54.55% or 6/11), no one presented with overlap. The results of a Fisher's Exact test indicated that overlap had no effect on the prevalence of individuals with multiple traumatic injuries in the Chelsea sample (Fisher's Exact, $p = 0.182$).

Shortening

A summary of the prevalence of shortening among individuals from both the St. Bride's and Chelsea cemetery samples who presented with one or more injuries is presented in Figure 22. Due to issues of preservation, fifteen individuals (32.61% of 46)

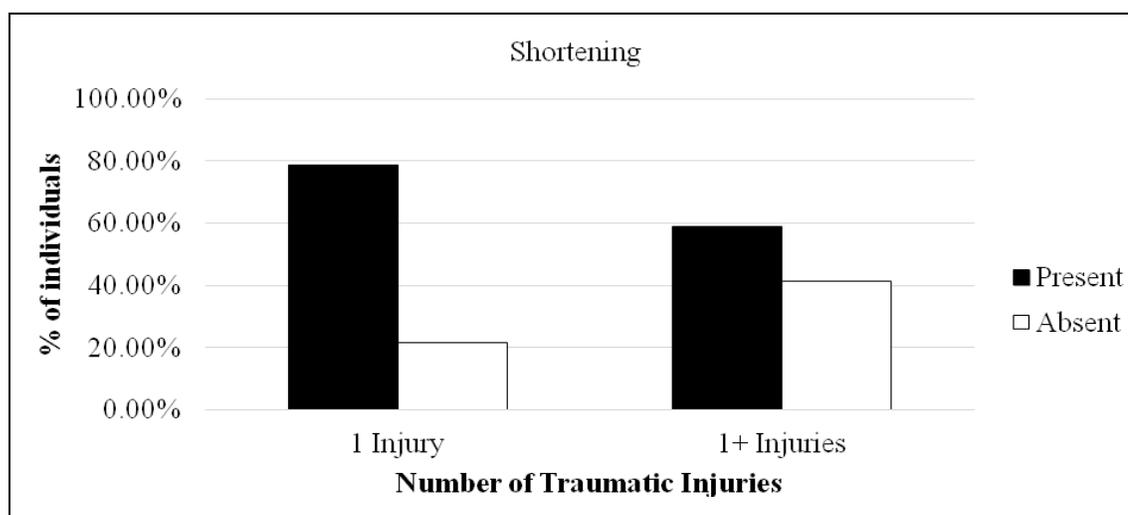


Figure 22. Prevalence of shortening among individuals with one or more injuries from the St. Bride's and Chelsea cemetery samples (n = 31).

were unable to be assessed for the presence or absence of shortening. Of those individuals who presented with multiple injuries (17/31 or 54.84%), ten (58.82% of 17) also exhibited evidence of shortening. Of those individuals who presented with one injury (14/31 or 45.16%), eleven (78.57% of 14) also exhibited evidence of shortening. The results of a Fisher's Exact test indicated that, when both cemetery samples were combined, shortening had no effect on the prevalence of individuals with multiple injuries ($p = 0.280$).

The prevalence of shortening among individuals from the St. Bride's sample who exhibited one or more injuries is depicted in Figure 23. Due to issues of

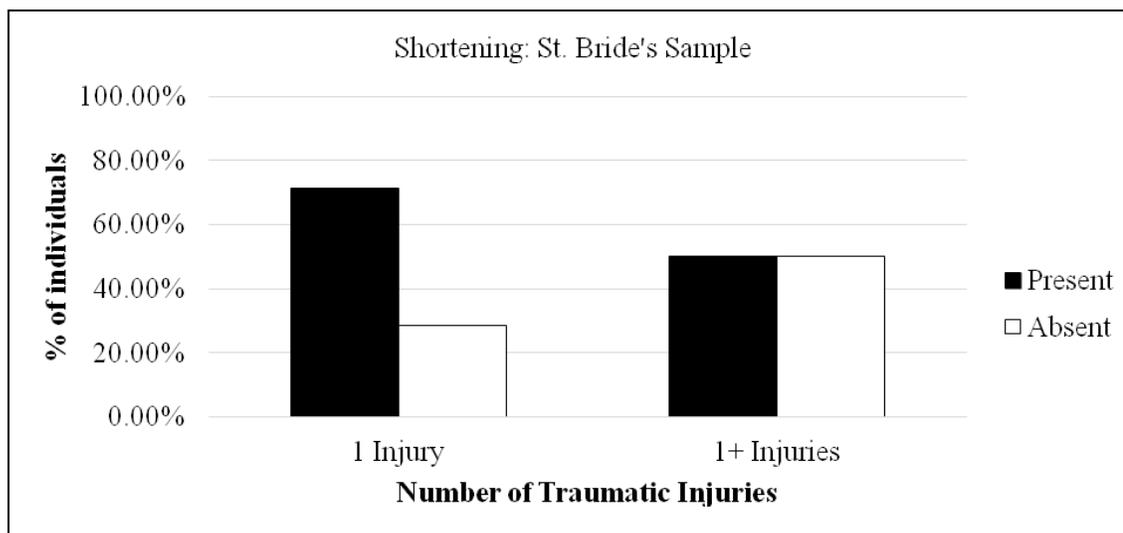


Figure 23. Prevalence of shortening among individuals from the St. Bride's sample exhibiting one or more injuries (n = 19).

preservation, 14 individuals (42.42% of 33) from the sample could not be assessed for the presence or absence of shortening. A total of 12 individuals (63.16% of 19) exhibited evidence of multiple traumatic injuries. Fifty percent (6/12) of those individuals presented with evidence of shortening. In contrast, of those with evidence of only one traumatic injury (7/19 or 36.84%), 71.43 percent (5/7) presented with shortening. The results of a Fisher's Exact test indicated that shortening had no effect on the prevalence of individuals with multiple traumatic injuries in the St. Bride's sample (Fisher's Exact, $p = 0.633$).

A summary of the prevalence of shortening among individuals from the Chelsea sample who exhibited one or more injuries is presented in Figure 24. Due to issues of preservation, one individual (7.69% of 13) from the sample could not be assessed for the presence or absence of shortening. Compared to the St. Bride's sample, only 41.67 percent (5/12) of individuals analyzed exhibited evidence of multiple

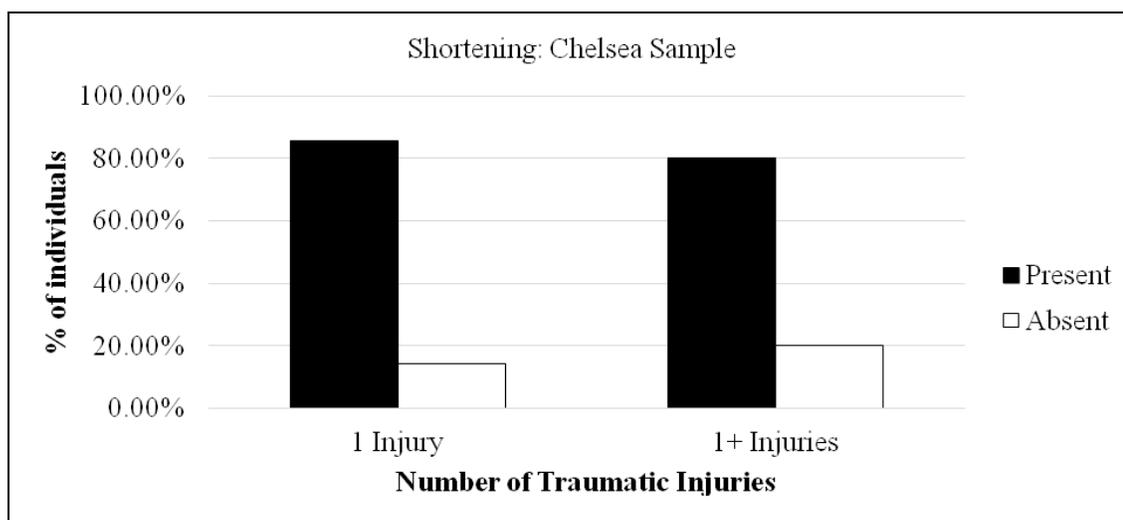


Figure 24. Prevalence of shortening among individuals from the Chelsea sample exhibiting one or more injuries ($n = 12$).

traumatic injuries. However, unlike the St. Bride's sample, 80.00 percent (4/5) of those individuals presented with shortening. Similarly, of those with evidence of only one traumatic injury (7/12 or 58.33%) in the Chelsea sample, 85.71 percent (6/7) presented with shortening. As expected from these qualitative results, the results of a Fisher's Exact test indicated that shortening had no effect on the prevalence of individuals with multiple traumatic injuries in the Chelsea sample (Fisher's Exact, $p = 1.00$).

Non-Union

The prevalence of non-union among individuals from both the St. Bride's and Chelsea cemetery samples who presented with one or more injuries is depicted in Figure 25. Of those individuals who presented with multiple injuries (27/46 or 58.70%), two (7.41% of 27) also exhibited evidence of non-union. Of those individuals who presented with only one injury (19/46 or 41.30%), four (21.05% of 19) also exhibited evidence of non-union. The results of a Fisher's Exact test indicated that, when both cemetery

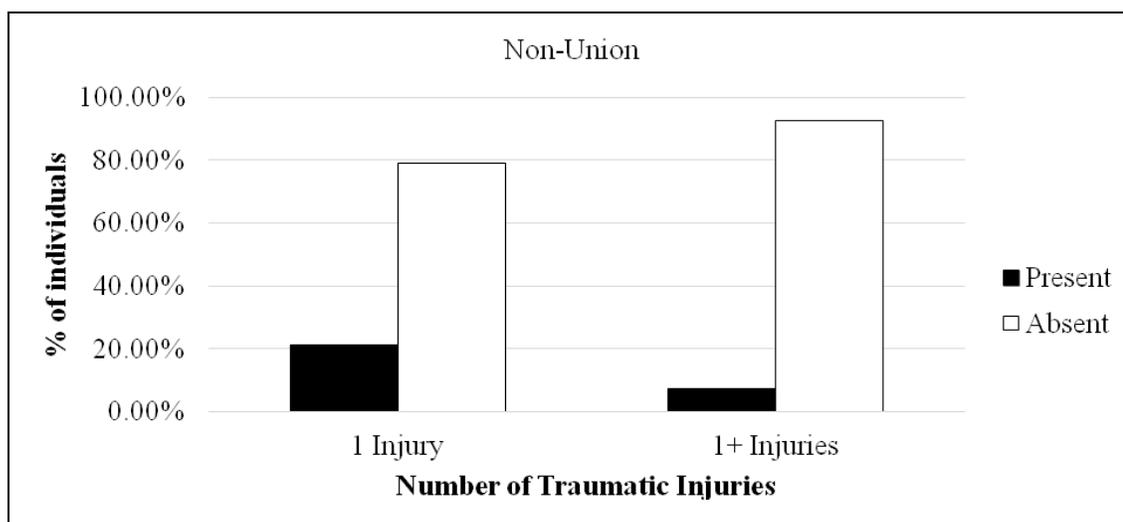


Figure 25. Prevalence of non-union among individuals with one or more injuries from the St. Bride's and Chelsea cemetery samples (n = 46).

samples were combined, non-union had no effect on the prevalence of individuals with multiple injuries ($p = 0.213$).

A summary of the prevalence of non-union among individuals from the St. Bride's sample who exhibited one or more injuries is presented in Figure 26. A total of

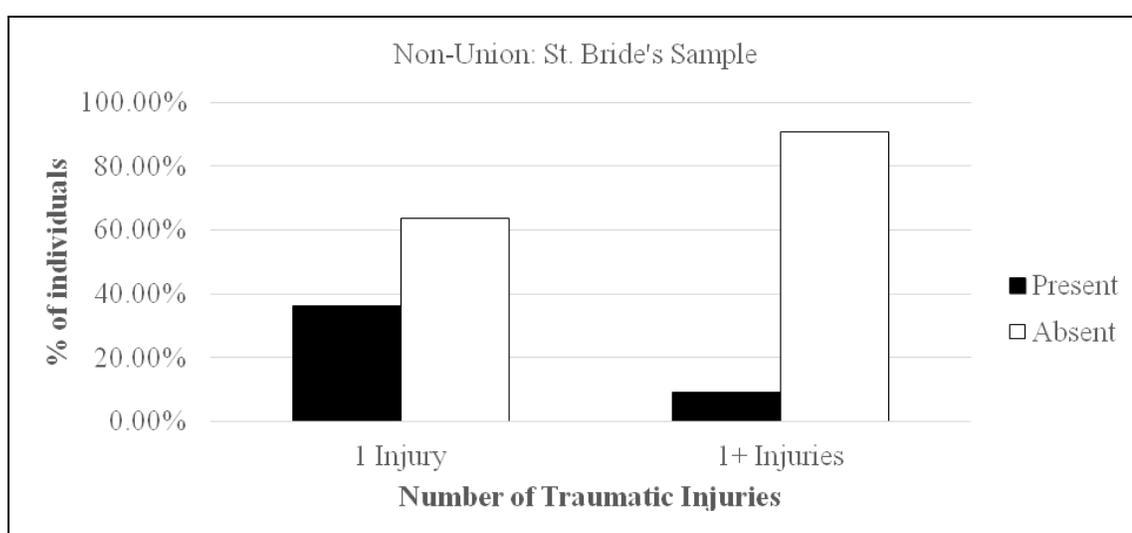


Figure 26. Prevalence of non-union among individuals from the St. Bride's sample exhibiting one or more injuries (n = 33).

22 individuals (66.67% of 33) exhibited evidence of multiple traumatic injuries. Only two of those individuals (9.09% of 22) also presented with evidence of non-union. Of those with evidence of only one traumatic injury (11/33 or 33.33%), 36.36 percent (4/11) presented with non-union. However, the results of a Fisher's Exact test indicated that non-union had no effect on the prevalence of individuals with multiple traumatic injuries in the St. Bride's sample (Fisher's Exact, $p = 0.146$). Evidence for non-union was absent in all cases examined ($n = 13$) in the Chelsea sample.

Summary

The objective of this study was to examine (1) the effect that socioeconomic status had on the distribution of treatment for traumatic injuries, and (2) the effect that status-related access to treatment potentially had on the prevalence of subsequent injury in two socioeconomically disparate cemetery communities from industrial London (A.D. 1700-1850). The first expectation was that treatment for traumatic injuries would not be evenly distributed among the cemetery samples under study. To test this hypothesis, the prevalence of fracture complications suggestive of inadequate care were compared between the St. Bride's and Chelsea cemetery samples. The second expectation was that the uneven distribution of treatment for traumatic injuries would have influenced patterns of subsequent injury in both cemetery samples. To test this hypothesis, both samples were combined and analyzed for associations between fracture complications and their distribution among individuals with one or more fractures. Afterwards, the same analyses were run for each cemetery sample separately.

Before any comparisons could be made between the cemetery samples, non-parametric analyses of their age and sex distributions were conducted. The results of those analyses indicated that the demographic structures of both samples were comparable. In other words, any age or sex-related differences between the cemetery samples had minimal influence on the prevalence data extrapolated from osteological analysis.

None of the statistical tests used to test the first hypothesis identified any associations between fracture complications and their distributions between the St. Bride's and Chelsea samples. A summary of the prevalence data for the fracture complications examined to address the first hypothesis is presented in Table 15. Interestingly, there are observable differences in the prevalence of angulation, apposition, shortening, and non-union. Despite these qualitative differences, the first hypothesis was rejected. There is no quantitative evidence to suggest that treatment for traumatic injuries was unevenly distributed among London's population.

Table 15. Summary of the Prevalence of Fracture Complications by Cemetery Sample

Fracture Complication	Prevalence (%)	
	St. Bride's	Chelsea
Angulation	50.00	66.67
Rotation	21.05	22.22
Apposition	26.19	16.67
Overlap	19.44	18.75
Shortening	60.00	70.59
Non-Union	14.29	0.00

None of the statistical tests used to test the second hypothesis identified any statistical associations between fracture complications and their distributions among

individuals with one or more fractures. Summaries of the prevalence of fracture complications between individuals with one or more traumatic injuries are presented in Tables 16 and 17. For the first table, both cemetery samples were combined. For the second, the samples were analyzed separately.

Table 16. Summary of the Prevalence of Fracture Complications Among Individuals with One or More Injuries When Both Cemetery Samples Were Combined

Fracture Complication	Prevalence (%)	
	1 Injury	1+ Injuries
Angulation	64.71	65.38
Rotation	35.29	24.00
Apposition	36.84	25.93
Overlap	37.50	16.00
Shortening	78.57	58.82
Non-Union	21.05	7.41

Table 17. Summary of the Prevalence of Fracture Complications Among Individuals with One or More Injuries When Cemetery Samples Were Analyzed Separately

Fracture Complication	Prevalence (%)			
	St. Bride's		Chelsea	
	1 Injury	1+ Injuries	1 Injury	1+ Injuries
Angulation	44.44	66.67	87.50	60.00
Rotation	44.44	20.00	25	40
Apposition	45.45	27.27	25	20
Overlap	22.22	10.00	0.00	40.00
Shortening	71.43	50.00	85.71	80.00
Non-Union	36.36	9.09	0.00	0.00

Interestingly rotation, apposition, overlap, shortening, and non-union were more common among individuals who presented with one fracture than those who presented with multiple fractures when both cemetery samples were combined. When the cemetery samples were analyzed separately, there were clear qualitative differences in the prevalence of all fracture complications assessed between individuals with one or more injuries from the St. Bride's sample. These differences were also found in three of the six analyses (50.00%) involving the Chelsea sample. Despite these qualitative differences, the second hypothesis was rejected. There is no quantitative evidence to suggest that treatment for traumatic injuries influenced the likelihood of subsequent injury.

Despite the fact that both research hypotheses were rejected, the osteological data collected for this study need further discussion. Qualitative differences in the prevalence of post-traumatic complications are apparent within and between the St. Bride's and Chelsea samples. Additional lines of evidence, including historical and clinical data, are required to uncover the nuances in treatment for traumatic injuries and its effect on the prevalence of subsequent injury in the cemetery samples under study.

CHAPTER VI

DISCUSSION

Introduction

This chapter discusses the results provided in the previous chapter. It is divided into two sections. The first section evaluates the quantitative results of this study that are associated with the first hypothesis that the quality of treatment received, if any, was unevenly distributed among the population. To assess these results, the osteological data are discussed by fracture location, position, and type, using clinical and historical data. The last section evaluates the results associated with the second hypothesis that differential treatment influenced the likelihood of subsequent injury. Both sets of results, those in which the cemetery samples were combined, and those where both samples were analyzed separately, are assessed with consideration of fracture location and type.

Evidence for Differential Treatment

According to the quantitative results presented in the previous chapter, there was no association between cemetery sample and the prevalence of individuals with or without fracture deformity and non-union. These results preliminarily suggest that socioeconomic status may have had little, if any, impact on an individuals' access to treatment for their traumatic injuries. There were, however, qualitative differences in the prevalence of fracture complications that required further evaluation. In this section,

these qualitative differences are explored using clinical, and where possible, medical historical literature.

As mentioned in previous chapters, most medical professionals in the Industrial period were hesitant to operate invasively on their patients to treat their injuries and other maladies, because risk of infection and subsequent mortality was too high (Henderson et al. 2013; Roberts and Cox 2003; Wear 1995; Porter 1995; Lawrence 1993; Waddington 1984). Therefore, successful reduction with minimal deformity or chance of non-union would have been difficult to achieve. Even with fractures requiring traction, such as fractures to the femoral shaft, where weight is loaded onto a fractured limb in the hopes of stabilizing the fracture site, techniques and associated technologies had not yet been developed (Redfern 2010; Hamblen and Simpson 2007; Roberts 1988). Thus most fractures with a high re-displacement rate – that is, those fractures with a high likelihood of failed reduction, such as oblique and spiral fractures – that exhibited minimal deformity would have only healed as they did if the injury was immobilized for an extended amount of time, or the individual was very lucky (Redfern 2010; Hamblen and Simpson 2007). This historical information is important for contextualizing interpretations of fracture complications as evidence for treatment.

Clavicle

Two individuals from the Chelsea cemetery sample presented fractures to the clavicle, one on the right and the other on the left. The right clavicular fracture was oblique, while the one on the left was of an unknown type. Clinical treatment of clavicular fractures involves placement of the arm in a simple sling for the purposes of pain relief (Hamblen and Simpson 2007; Patton 1992). Clinical practitioners will not

resort to internal fixation, unless the fracture is complicated by severe deformity or non-union. The right clavicular fracture exhibited evidence of less than 25 percent apposition, and was shortened by two millimeters. The left clavicular fracture exhibited evidence of angulation, although the amount of angulation present was unmeasurable. Despite the fact that a comparison of clavicular fracture complications could not be made between cemetery samples, the minimal degree of deformity present suggests that these individuals from the Chelsea sample likely had access to some form of treatment. Since surgery was not an option, individuals who suffered these types of fractures would have likely resorted to immobilizing the injury in a sling, if they had the time and money to do so (Hamblen and Simpson 2007).

Scapula

There were two individuals from the St. Bride's sample who presented fractures to the scapula. One of the individuals exhibited a fracture to the acromion of unknown type, while the other presented a comminuted fracture to the left body of the scapula. Treatment for an acromial fracture is similar to that of the clavicle. The clinical literature recommends that the individual wear a sling and begin exercises to restore musculoskeletal function as soon as the pain decreases (Hamblen and Simpson 2007; Patton 1992). The fracture to the acromion was complicated by non-union. Although infection is a potential cause of non-union (Hamblen and Simpson 2007), the fracture did not exhibit evidence of any type of specific or non-specific infection. Instead, it is likely that either there was interposition of soft tissue between the fractured ends, or the individual was exposed to repetitive mechanical tasks that impeded union.

Most fractures to the body of the scapula, regardless of whether or not they are simple or comminuted, do not require reduction of the fractured ends (Hamblen and Simpson 2007; Patton 1992). This is because the musculature around the scapula acts as a natural splint. Therefore, in instances with mild deformity, reduction in the form of either manipulation or fixation is unnecessary. What is necessary in the treatment of this fracture, according to the clinical literature, is the use of a sling to minimize movement until pain subsides and therapeutic exercises can begin. The fracture to the scapular body was complicated slightly by angulation, although the amount of angulation present was unmeasurable. The minimal amount of angulation observed suggests that this individual may have attempted some form of immobilization with subsequent physical therapy. The scapular fractures observed in this study provide mixed results. One fracture was complicated by non-union, while the other was complicated by slight angulation. These mixed results suggest that, while some individuals living in poverty in the St. Bride's Parish had access to treatment for scapular fractures, others did not.

Humerus

A total of two individuals from the Chelsea sample and five individuals from the St. Bride's sample presented fractures to the humerus. Two of these fractures were located at the surgical neck, while the remaining three fractures were located on the shaft. Surgical neck fractures, particularly those that are impacted, are usually stable, which means they are less likely to re-displace following an attempt at reduction (Redfern 2010; Roberts 1988). The clinical literature recommends that the arm be placed in a sling, and that physical therapy should begin as soon as pain subsides (Hamblen and Simpson 2007; Patton 1992). Fractures that are unimpacted, however, are considered to be unstable.

They may re-displace if the fractured element is mobilized too soon (Redfern 2010; Roberts 1988). Therefore, the element should be immobilized for three weeks prior to beginning therapeutic exercises (Hamblen and Simpson 2007; Patton 1992).

Of the individuals who presented surgical neck fractures to the humerus, one was associated with the St. Bride's sample and the other with the Chelsea sample. The fracture from the St. Bride's sample was complicated by shortening of 18 millimeters. The clinical literature suggests that shortening of less than 20 millimeters is acceptable, and reduction is unnecessary (Redfern 2010). The fracture from the Chelsea sample was complicated by angulation and rotation. The extent of deformity, although visually minimal, was unmeasurable. These results suggest that individuals from both the St. Bride's Parish and Chelsea had access to some form of treatment for surgical neck fractures.

Fractures of the humeral shaft are treated differently depending on the fracture type. Transverse fractures are stable, and often require manipulative reduction, followed by splinting, and mobilization following a period of several weeks (Hamblen and Simpson 2007; Patton 1992). Oblique and spiral fractures are unstable (Redfern 2010; Roberts 1988). To prevent failed reduction of a fracture of either of these types without resorting to external and internal fixation methods, the clinical literature recommends that the injury be wrapped in a spica, or a bandage that is arranged in a spiral pattern (Hamblen and Simpson 2007; Patton 1992). The limb is then splinted and immobilized for a period of several weeks.

Fractures to the shaft of the humerus, both stable and unstable, run the risk of displacement, especially if they are located below the insertion for the deltoid muscle, as

the muscle may contract violently, displacing the fractured ends (Redfern 2010; Resnick and Goergen 2002). If these fractures heal well, it suggests that reduction was attempted and successful. Humeral shaft fractures exhibiting angulation of less than 30 degrees are considered acceptable by clinical standards, and operative surgery is unnecessary (Redfern 2010; Resnick and Goergen 2002; Klenermen 1969).

Three individuals presented fractures to the shaft of the humerus. One individual was associated with the Chelsea cemetery sample, while the other two were included in the St. Bride's sample. The individual from the former exhibited an oblique fracture of the left humeral shaft. The fracture was complicated by angulation of 15 degrees, and shortening of which the extent was unmeasurable. The fractured ends were 75-100 percent apposed. Both individuals from the St. Bride's sample presented spiral fractures to the right humeri. One fracture was complicated by rotation and overlapping of the fractured ends, but the extent of deformity was unmeasurable. The other fracture was complicated by angulation of 19 degrees, shortening of seven millimeters, and an unmeasurable degree of rotational deformity. These results, as well as the results for surgical neck fractures, suggest that treatment for humeral fractures was likely available to individuals living in both St. Bride's Parish and Chelsea.

Radius and Ulna

Sixteen individuals presented a total of seventeen fractures to the radius and ulna. Specifically, there were thirteen cases of fractures to the radius, and four cases of fractures to the ulna. Reduction of these elements is vital for minimizing injury-related impairment of the rotation function of the forearm (Hamblen and Simpson 2007; Patton 1992; Roberts 1988). In clinical settings, manipulative reduction of radial and ulnar

fractures is often first attempted (Hamblen and Simpson 2007; Roberts 1988). If that reduction attempt fails, then external or internal fixation techniques are often considered (Hamblen and Simpson 2007; Patton 1992). In London's Industrial period, medical professionals and other care providers rarely attempted surgical procedures due to high mortality rates associated with infection. Therefore, the presence of a failed reduction would not necessarily have indicated poor access to treatment. It may actually better reflect the limitations of surgical and medical knowledge and practice.

There were a total of thirteen fractures to the radius encountered in this study. Three fractures were located on the shaft, while the remaining ten were located at the distal end. Ten fractures came from the St. Bride's cemetery sample, and three were encountered in the Chelsea sample. One individual from the Chelsea sample presented with an oblique fracture to the right radial shaft that was complicated by unmeasurable overlap and consequent shortening. The fractured ends were 75-100 percent apposed. Another individual from the Chelsea sample exhibited evidence of a fracture to the radial shaft of unknown type. That fracture was complicated by angulation of eight degrees, and overlap and consequent shortening of 19 millimeters.

In comparison, one individual from the St. Bride's sample presented an oblique fracture to the left radial shaft that was complicated by rotation, overlap, and consequent shortening, all of which were unmeasurable. It was also complicated by angulation of 20 millimeters. According to Hamblen and Simpson (2007), oblique fractures to the radial shaft are highly unlikely to reduce well without external or internal fixation techniques. That the radial shaft fractures observed in this study were well healed

with minimal deformity (less than 30 millimeters of shortening), suggests that they were subjected to successful reduction and consequent immobilization through splinting.

In addition to the radial shaft, there were ten fractures to the distal end of the radius, eight of which were classified as Colles' fractures, and two of which were classified as Smith's fractures. One individual from the Chelsea sample presented a Colles' fracture, while the remaining seven fractures of that type were found in individuals from the St. Bride's sample. Both Smith's fractures were observed in the St. Bride's sample.

Colles' fractures are stable, and may be treated with manipulative reduction, immobilization in a below elbow plaster, and physical therapy, to restore proper function (Redfern 2010; Hamblen and Simpson 2007; Patton 1992; Roberts 1988). Angulation is a common complication of the Colles' fracture, and is considered to be clinically acceptable – and operative surgery is determined as unnecessary – if less than 45 degrees (Redfern 2010; Resnick and Goergen 2002). Three left and three right Colles' fractures from the St. Bride's sample were complicated by an unmeasurable amount of angulation. Another individual from the St. Bride's sample presented a Colles' fracture to the left radius that was complicated by angulation of 20 degrees and shortening of 13 millimeters. The remaining Colles' fracture, which came from an individual from the Chelsea sample, was complicated by an unmeasurable amount of angulation and shortening of nine millimeters. The acceptable amount of deformity present in most of these fractures from both cemetery samples suggests that individuals from the upper and lower social strata had access to treatment for their Colles' fractures.

Smith's fractures, unlike Colles' fractures, are unstable, and are typically reduced and immobilized operatively (Roberts 1988). Given that operative surgery was rarely attempted, individuals with Smith's fractures likely received treatment through manipulative reduction and immobilization in an above elbow plaster (Patton 1992). Both Smith's fractures observed in the St. Bride's sample, one on the left and the other on the right side, were complicated by an unmeasurable amount of angulation. The latter was also complicated by an unmeasurable amount of rotation. Due to the absence of information, any interpretations made concerning the Smith's fractures are inconclusive.

In addition to the radius, four fractures to the ulna were observed, two to the proximal epiphysis from the St. Bride's sample, and an additional two to the shaft from the Chelsea sample. Proximal epiphyseal fractures to the ulna are clinically treated operatively using internal fixation techniques (Hamblen and Simpson 2007; Patton 1992). The likelihood of failed reduction is high, due to the displacement of the fractured ends by the contraction of the *triceps brachialis* muscle at its insertion on the olecranon process of the ulna. This is particularly the case for complete fractures. In the St. Bride's sample, one individual presented with a complete fracture to the left olecranon process, which resulted in non-union. The other individual presented with an incomplete fracture to the right olecranon process. No deformity was observed. These results are inconclusive, since complete fractures to the proximal epiphysis of the ulna require operative treatment to successfully reduce, and non-union of this fracture type would have, therefore, likely occurred regardless of socioeconomic status. That the other fracture reduced well likely indicates that successful reduction was the result of its

incomplete nature, random chance, or another underlying circumstance that is unknowable.

The remaining two fractures to the ulnar shaft observed in the Chelsea sample were of an unknown type. Ulnar shaft fractures are treated in a similar way to radial shaft fractures. The fracture to the right ulnar shaft was complicated by an unmeasurable amount of rotation and shortening of five millimeters. The fracture to the left ulnar shaft was complicated by angulation of seven degrees and shortening of six millimeters. The minimal amount of deformity present suggests that these individuals received treatment for their injuries.

Taken together, these results suggest that individuals living in St. Bride's Parish and Chelsea were able to treat their radial and ulnar fractures. It should be noted, however, that there were two instances where the information gleaned from analysis was inconclusive: Smith's fractures of the radius, and proximal epiphyseal fractures of the ulna. This was due to an absence of pertinent information.

Metacarpals

Ten individuals presented fractures to the metacarpals. Seven of those individuals suffered fractures to the first metacarpal (MC), while the remaining three fractures were observed on the second, third, and fourth MC. Clinically, hand fractures generally require minimal reduction effort, and immobilization of these injuries, particularly in MC1, should be of short duration to diminish the likelihood that joint stiffness develops (Patton 1992). One individual from the St. Bride's cemetery sample presented with a fracture to the distal shaft of the right MC1 of an unknown type. This fracture was complicated by an unmeasurable amount of shortening.

The remaining six fractures to MC1 were Bennett's or boxer's fractures. In clinical settings, fractures of this type are usually reducible via manipulative reduction, and are unlikely to displace (Hamblen and Simpson 2007; Patton 1992). Following reduction, the hand is splinted in a plaster that includes the forearm and wrist. The thumb should be extended at the carpometacarpal joint. Three of the observed Bennett's fractures were associated with the St. Bride's cemetery sample, while the remaining three fractures were encountered in the Chelsea sample. One of the fractures to the right MC1 from the St. Bride's sample was complicated by angulation of eleven degrees, and shortening of two millimeters. Another fracture from that same cemetery sample was complicated by an unmeasurable amount of angulation. The remaining Bennett's fracture from the St. Bride's sample was located on the left side, and was complicated by angulation of 13 degrees with an unmeasurable amount of shortening.

The Bennett's fractures from the Chelsea cemetery sample also presented complications. Two of these fractures were located on the right MC1, while the remaining fracture was located on the left. One of the fractures to the right MC1 was complicated by angulation of ten degrees and shortening of four millimeters. It also exhibited an unmeasurable amount of rotation. The other was complicated by angulation of thirteen degrees and shortening of three millimeters. The fracture to the left MC1 was complicated by angulation of 25 degrees.

The remaining three fractures of the hand were of an unknown type. One was encountered in the St. Bride's cemetery sample, while the other two were observed in the Chelsea sample. A fracture from the St. Bride's sample was observed on the shaft of the right MC3. It was complicated by angulation of 20 degrees. A fracture from the Chelsea

sample was observed on the shaft of the right MC2. It was complicated by angulation of ten degrees and shortening of seven millimeters. The other fracture observed in the Chelsea sample was located on the shaft of the right MC4. It was complicated by angulation of three degrees and shortening of seven millimeters.

The amount of deformity present in both cemetery samples is remarkable considering that fractures to the hands are reducible (Hamblen and Simpson 2007; Patton 1992). Grauer and Roberts (1996) argue that fractures to the hands, feet, and other smaller bones are less likely to compel an individual to actively seek treatment than fractures to the long bones or other larger elements. If this were the case, then it would explain why these fractures are poorly aligned. Any conclusions made about differential treatment of this fracture type would therefore be inconclusive.

Innominate

Three individuals presented with fractures to the innominate, specifically the ilium. According to the clinical literature, unless fractures occur at the pelvic ring, fractures to the innominate usually require minimal treatment (Hamblen and Simpson 2007; Patton 1992). The supine position puts pressure on the pelvis to close up, making union an almost invariable occurrence without need of manipulative reduction (Patton 1992). Short-term rest in this position is deemed necessary, and should be followed by careful mobilization of the pelvis through walking (Hamblen and Simpson 2007). One individual from the St. Bride's sample presented a fracture to the right ilium of an unknown type. It was complicated by an unmeasurable amount of angulation. An individual from the Chelsea sample also fractured their right ilium. The fracture type was unknown, but was complicated by an unmeasurable amount of overlap. Another

individual from the Chelsea sample presented an oblique fracture to the left ilium, which was complicated by an unmeasurable amount of angulation.

These results are inconclusive, since the observed fracture complications could not be measured. However, given that there were no visible observations of gross deformity, these individuals were likely able to immobilize their injuries for an appropriate amount of time (Hamblen and Simpson 2007; Patton 1992). This suggests that individuals from both social strata were able to seek treatment for their pelvic fractures.

Femur

Seven individuals presented fractures to the femur. Three were observed at the surgical neck, and the remaining four were observed on the shaft. The clinical literature indicates that surgical neck fractures require operative surgery to ensure union (Redfern 2010; Hamblen and Simpson 2007; Patton 1992; Roberts 1988). In fact, 25 to 33 percent of surgical neck fractures may result in non-union if surgery is not considered (Hamblen and Simpson 2007). Without surgical intervention, chances of non-union and other post-traumatic complications are lowered only through extending the period of immobilization for up to 12 weeks (Redfern 2010). In Industrial London, given that invasive surgeries often resulted in infection and subsequent mortality, individuals suffering surgical neck fractures would have needed the time to heal their injuries to minimize deformity and prevent non-union.

All individuals who presented fractures to the surgical neck came from the St. Brides cemetery sample. Of the three fractures observed, only one – to the left femoral surgical neck – was complicated by non-union. The remaining two fractures, both of

which were on the right side, were complicated by an unmeasurable amount of rotation. One of these fractures was also complicated by shortening of 50 millimeters, which represents severe deformity (Hamblen and Simpson 2007). However, that it united at all suggests that some form of treatment was received. While these results suggest that most individuals in the sample were able to receive treatment for their femoral surgical neck fractures, differential treatment between the social classes could not be assessed, as none of the observed fractures of this type were observed in the Chelsea sample.

Femoral shaft fractures, in contrast, do not always require operative surgery. Instead, clinical pathologists recommend that these fractures are subject to sustained weight traction (Hamblen and Simpson 2007; Patton 1992; Roberts 1988). Traction, as a technique for treating fractures, involves putting pressure on the fracture site to keep the ends in apposition with minimal deformity or chance for non-union (Hamblen and Simpson 2007). However, this technique was not employed until the early twentieth century. Therefore, rest for sixteen weeks or longer would have been the requisite for successful healing following manipulative reduction.

All observed femoral shaft fractures came from the St. Bride's cemetery sample. Two individuals presented left femoral shaft fractures that were complicated by non-union. In addition, there were two right femoral fractures with considerable deformity. One individual presented a femoral shaft fracture that was complicated by angulation of 15 degrees, poor apposition of fractured ends of less than 25 percent, and shortening of 64 millimeters. In addition, rotation and overlap were evident, but not quantifiable. The other right femoral shaft fracture observed was complicated by angulation of 29 degrees, apposition of fractured ends of less than 25 percent, and

shortening of 60 millimeters. Rotation and overlap were also evident, but, again, not quantifiable.

Femoral shaft fractures, and surgical neck fractures of the femur, in general, were difficult to reduce in the Industrial period without surgical operation or at least some form of traction, both of which were not feasible (Henderson et al. 2013; Hamblen and Simpson 2007; Peltier 1968). Therefore, evidence of well healed femoral fractures would suggest that, instead, a lengthy period of immobilization between 12 and 16 weeks would have been necessary, particularly for unstable fractures. All fractures, with the exception of one surgical neck fracture, healed with extensive deformity. That only three of them healed with non-union, suggests that some period of immobilization was achieved (Redfern 2010; Hamblen and Simpson 2007). These results, however, are inconclusive when applied to an analysis of differential treatment, as none of the individuals with femoral fractures came from the Chelsea cemetery sample.

Patella

Two individuals presented with fractures to the patella. Incomplete fractures do not require surgical intervention, while complete fractures cannot reduce without it (Hamblen and Simpson 2007). Treatment of incomplete fractures involves placing the leg from the groin to the medial and lateral malleoli in a plaster cast in almost complete extension for approximately three weeks. Following this, the *quadriceps* muscle must be exercised to restore full patellar mobility. In contrast, the proximal segments of complete patellar fractures are displaced by contraction of the *quadriceps* muscle. Therefore, for those fractures, surgical fixation is required prior to immobilization and subsequent therapy.

Both types of fractures were encountered in the St. Bride's cemetery sample. One individual presented an incomplete oblique fracture to the body of the patella that did not exhibit any visually identifiable deformation. Another individual presented a complete transverse fracture to the body of the patella that was complicated by non-union, as was would have been expected without surgery. The well-healed patellar fracture suggests that the individual was able to immobilize their injury for the recommended length of time. The non-united patellar fracture, in contrast, suggests that the individual either neglected treatment or received poor treatment. Alternatively, the poor healing pattern may be a direct manifestation of inhibited access to operative surgery. These results are inconclusive.

Tibia and Fibula

Six individuals presented fractures to the tibia and fibula. Two of those fractures were to the tibia, and the remaining five were fractures to the fibula. Hamblen and Simpson (2007) posit that fractures to the tibia require considerably more attention than fractures to the fibula. While fibular fractures usually unite without need for reduction due to its minimal role in locomotion and the influence of the surrounding musculature, tibial fractures often require manipulative reduction, and in severe cases, external and internal fixation (Hamblen and Simpson 2007; Patton 1992). Treatment via manipulative reduction is recommended, except in cases of severe injury to the tibia. Following this, the leg should be placed in a full-length plaster cast for between three and four months.

Both tibial fractures were observed in the St. Bride's cemetery sample. One individual presented an oblique fracture to the shaft of the left tibia that exhibited no

evidence of deformation. The other presented a fracture to the right tibial shaft of an unknown type. The fracture was complicated by an unmeasurable amount of angulation and shortening of seven millimeters. Both tibial fractures were well-healed, suggesting that treatment was received. This is particularly the case for the oblique fracture, as it is often unstable, and therefore at high risk of re-displacement.

All five fibular fractures were also encountered in the St. Bride's cemetery sample. Three of them were oblique and located on the left fibula. One of these fractures was complicated by less than perfect apposition of the fractured ends (75-100%). One other fracture was complicated by an unmeasurable amount of angulation. The remaining two fibular fractures were located on the right fibula. Both were oblique, and were complicated by an unmeasurable amount of shortening. One of these fractures was also complicated by imperfect apposition of fractured ends (0-25%) and an unmeasurable amount of shortening. The well-healed nature of these fractures is expected regardless of treatment, given that fractures to the fibula – particularly those where the tibia remains atraumatic (n=4) – are supported by the tibia, which acts as a natural splint (Redfern 2010). However, the tibial fractures exhibited minimal deformity, suggesting that individuals from St. Bride's Parish were able to receive treatment for their tibial fractures in the Industrial period. Unfortunately, a lack of data on tibial fractures in the Chelsea sample precluded the analysis of differential treatment for this fracture type.

Metatarsals

Five fractures to the metatarsals (MT) were observed in this study. Metatarsal fractures generally do not require manipulative reduction or surgical intervention (Hamblen and Simpson 2007; Patton 1992). Instead, in clinical settings, emphasis is

placed on immobilization for approximately three to four weeks in a walking plaster cast. One individual from the Chelsea cemetery sample presented a fracture to the distal shaft of MT2 that was complicated by shortening of four millimeters. Two individuals from the St. Bride's sample presented fractures to the shaft of the left MT3. One of the fractures was oblique and complicated by 75-100 percent apposition of fractured ends. The other fracture was of an unknown type. It was well-healed with no visible signs of deformity. The remaining two fractures were located on MT5. One was encountered in the Chelsea cemetery sample, and the other was observed in the St. Bride's sample. The fracture observed in the former was of an unknown type. It was located on the right proximal shaft, and exhibited no evidence of deformation. In contrast, the fracture observed in the latter sample was oblique. It was located on the left proximal shaft, and exhibited an unmeasurable amount of rotation.

That all fractures observed exhibited minimal deformity suggests that the individuals who suffered them received some form of treatment. Additionally, there seems to be no difference in the healing patterns of MT fractures between cemetery samples, which suggests that treatment was evenly distributed amongst individuals living in St. Bride's Parish and Chelsea in the Industrial period. It should be noted, however, that these fractures heal well without treatment, and that individuals would have been less likely to seek treatment as a result (Grauer and Roberts 1996).

In sum, the qualitative evaluation of the evidence for differential treatment in the St. Bride's and Chelsea cemetery samples is consistent with the quantitative results. There was no discernable relationship between cemetery sample and the presence or absence of fracture complications. Therefore, the first hypothesis was rejected. Treatment

was evenly distributed among the injured individuals from the two communities under study.

Evidence for Subsequent Injury

According to the quantitative results presented in the previous chapter, the presence or absence of a fracture complication had no effect on the prevalence of individuals with one or more fractures when both samples were combined. These results suggest that subsequent injury is not affected by whether or not an individual presents a fracture complication. Clinically, previous injury is a strong predictor of subsequent injury (Fulton et al. 2014; Madden et al. 1997; Brooke et al. 2006). The neuromuscular deficits that accompany traumatic injury are exacerbated by deformity and non-union (Fulton et al. 2014; Ortner 2003; Roberts 1988). Therefore, differential patterns of fracture healing, and by association, treatment, should have had an effect on the risk of subsequent injury, but they did not (Fulton et al. 2014). This may be due to uncontrolled heterogeneity in the social and physical environments of the two cemetery samples included in this study.

Clinical studies of injury recidivism in different social and physical environments developed recidivist profiles that were not always congruent (Hedges et al. 1995; Poole et al. 1993; Smith et al. 1992). This may have been due to the fact that differences in the physical environment, as well as the sociocultural circumstances that govern exposure to it, tend to have an effect on the patterning of fractures and their healing processes (Buzon 2011). The individuals in the current study, who were of different socioeconomic statuses, also came from different environments. They had

different occupations and lived in different types of residential settings (i.e., rural and urban communities) (Miles and Coheeney 2009; Cowie et al. 2008). Therefore, it was necessary to re-examine the relationship between fracture complications and subsequent injury for each cemetery sample separately, as these differences may have influenced the integrity of the combined samples approach.

For both cemetery samples, quantitative analyses indicated that the presence or absence of a fracture complication had no effect on the prevalence of individuals with single and multiple traumatic injuries. These results suggest that, in both communities, previous injury and the complications associated with it had no effect on the likelihood of suffering a future injury. Explanations for these results pertain to fracture location and type. These influencing factors are discussed below.

Fracture Location and Type

Fulton et al. (2014) found that injuries to the lower extremities were shown to exert a strong influence on the likelihood of future injury. They attributed their findings to the development of neuromuscular deficits during the healing process. Of all fractures observed in this study, most were located on the upper extremity (36/60 or 60.00%). When all observed fractures were separated by cemetery sample, the same patterns held true. Only 20 out of 42 fractures (47.62%) from the St. Bride's cemetery sample were located on the lower extremity. Similarly, only four out of eighteen fractures (22.22%) from the Chelsea sample were located on the lower extremity. The disproportionately high prevalence of upper extremity injuries in both cemetery samples may explain why no association was observed between fracture complications and subsequent injury.

Further, neuromuscular deficits and other complications are more likely to develop in instances of complex injury (Fulton et al. 2014). As mentioned previously, few fractures observed in this study were complex in type (6/60 or 10.00%). When all observed fractures were separated by cemetery sample, the same patterns held true. Only seven out of forty-two fractures (16.67%) in the St. Bride's sample, and one out of eighteen fractures (5.56%) in the Chelsea sample were complex in type. The disproportionately low prevalence of complex fractures in both cemetery samples may also explain why there was no statistically significant relationship between fracture complications and subsequent injury.

In sum, the quantitative results presented in the previous chapter indicate that, when the cemetery samples were combined, the presence or absence of fracture complications had no effect on the prevalence of individuals with one or more fractures. This was also the case when both cemetery samples were analyzed separately. Therefore, the second hypothesis was rejected. Differential treatment did not influence the likelihood of subsequent injury.

Summary

This chapter evaluated evidence for differential treatment and subsequent injury in Industrial-era London. Quantitative and qualitative analyses of the evidence for differential treatment did not support the first hypothesis. The quality of treatment was evenly distributed among injured individuals living in St. Bride's Parish and Chelsea. Quantitative analyses of the evidence for subsequent injury did not support the second hypothesis either. Differential treatment did not influence the likelihood of subsequent

injury. The conclusions and potential considerations generated from these analyses, in addition to a discussion of the limitations of this study and potential avenues for future research, will be detailed in Chapter VII.

CHAPTER VII

CONCLUSIONS

Introduction

This chapter details the conclusions of this study. It is comprised of three parts. The first and second parts of this chapter provide the conclusions and potential considerations associated with the first and second research hypotheses, respectively. The third part of this chapter identifies and discusses the general limitations of this study, and suggests potential avenues for future research. This chapter ends with a summary of the findings of this thesis and their implications for the study of treatment for traumatic injuries in contemporary and archaeological skeletal populations.

Was Differential Treatment a Function of Socioeconomic Status?

Both quantitative and qualitative analyses of the evidence for differential treatment in London's Industrial period yielded results that were in direct conflict with the first research hypothesis. They suggest that, when the same injuries were observed in both cemetery samples, treatment may have been evenly distributed among the injured living in St. Bride's Parish and Chelsea. These results are incongruent with what some of the historical literature indicates. Specifically, that it was exceedingly more difficult for individuals of the lower social classes to gain access to treatment by licensed medical professionals. This was not the case for members of London's upper social stratum who

did not have to risk being denied admission to a voluntary hospital (Porter 1995; Granshaw 1993; Waddington 1984). Instead, they could afford in-home private care provided by some of London's most famous medical practitioners. Why, then, did individuals in the St. Bride's and Chelsea cemetery samples exhibit similar patterns of healing?

The development of medical pluralism in London and the rest of Britain over the centuries may be the best response to this question. The rising distrust of the medical profession in the Medieval and early post-Medieval periods, created an environment of care through which individuals of any social status could have gained access to treatment for their injuries. However, with the introduction of dangerous industrial work environments and simultaneous spike in population growth in the Industrial period, came an increase in the prevalence of injury, and an increase in the complexity of those injuries (Henderson et al. 2013; Trinder 2013; Roberts and Cox 2003; Waddington 1984). The medical profession essentially reorganized itself around this issue, creating avenues for individuals from the newly emerging middle and lower working classes to receive affordable professional care, and developing techniques for treating some of the more complicated cases of injury (Waddington 1984). It became an important line of defense in preventing injury-related mortality, yet remained inaccessible to many individuals from the lower social classes. If the injuries suffered were as prevalent or complex as the literature suggests, yet more difficult to gain access to treatment for, why would there be an absence of perimortem trauma in the St. Bride's cemetery sample on the appendicular skeleton where some of the most debilitating and fatal injuries occur? This question is best answered by looking more closely at the context of the sample.

The St. Bride's Lower Churchyard sample, while supposedly representative of the lower and lowest social strata, was predominantly made up of individuals from Fleet Prison and the Bridewell Workhouse (DeWitte et al. 2015; Miles and Coheeney 2009; Milne 1997). Fleet Prison, in particular, was used for both low and high status individuals and their families who owed money to debtors, or who had declared bankruptcy (Thornbury 1878). Additionally, many inmates imprisoned in Fleet Prison came from other locations around England. This historical information suggests that some of the individuals interred in the St. Bride's sample could have been from the upper social strata, and that some of these individuals may have also come from outside of London. These two circumstances may have introduced variation or statistical noise into the data.

The Bridewell Workhouse, like other workhouses, catered to the impoverished, orphaned children, and the elderly (Brown 1996). It was a haven for relief, where inmates were fed, treated for their health conditions, and given a place to stay in return for labor. In the nineteenth century, expectations and regulations surrounding the workhouse increased, and became more stringent. Workhouses transformed into punitive and unpleasant places for the poor. Regardless of this change, workhouse inmates were exposed to treatment when needed.

For both the Fleet Prison and Bridewell Workhouse, consultants, aside from parish nurses, would have been the primary medical practitioner utilized for the purposes of tending to the sick and injured (Brown 1996; Thornbury 1878). As mentioned in previous chapters, consultants privately consulted with affluent families, while they treated poorer families through voluntary hospitals and workhouses (Waddington 1984). General practitioners, in contrast, were reserved mostly for the middle classes, as they

were not popular among the affluent families, and poor and working class families could not afford their services. While general practitioners may have serviced middle class families confined to Fleet Prison, consultants would have been the most likely medical practitioners to have treated the individuals observed in the St. Bride's sample.

That both the upper and lower social strata utilized consultants, suggests that patterns of treatment should actually be similar between the two social groups. Therefore, status differences in access to treatment between the affluent Chelsea sample and the somewhat socioeconomically variable St. Bride's sample would actually be expected to be minimal, which they were, both quantitatively and qualitatively. Only the ability to immobilize an injury would have differed between social classes given London's economically driven industrial environment. However, individuals in Fleet Prison and the Bridewell Workhouse were not engaged in the industrial work environment; they were often expected to contribute to housekeeping efforts more than harsh manual labor, but only when their injuries permitted, and not when their empty pockets did (Brown 1996; Thornbury 1878). Thus, although immobilization is a vital component of the treatment process, it would not have varied between individuals for socioeconomic reasons; it would have varied for reasons directly related to the location, type, and severity of fracture, and the availability of reparative knowledge and techniques.

Potential Considerations

There are several limitations specific to the first hypothesis related to the nature of the fractures observed, the socioeconomic contexts of both cemetery samples, and the urban and rural differences between the cemetery samples. Only ten percent (6/60) of fractures observed were considered to be complex, one comminuted and five

surgical neck (Lovell 1997). Simple fractures, which generally require considerably less treatment than complex fractures, are less likely to require professional reduction, meaning fewer individuals would have been less likely to seek out treatment from medical professionals (Hamblen and Simpson 2007; Grauer and Roberts 1996). Instead, they may have simply given their injuries time to heal without regard to some of the fracture complications observed (Grauer and Roberts 1996). Therefore, the socioeconomic statuses of individuals who suffered the fractures observed in this study may have played a minor role in their lived experiences with treatment.

The low prevalence of complex trauma in the Chelsea sample (1/18 or 5.56%) is expected given the socioeconomic statuses of its constituents. However, its low prevalence in the St. Bride's sample (5/42 or 11.90%) is perplexing, given the historical literature. It may be that most poor individuals living in St. Bride's Parish either did not engage in labor-intensive industrial jobs – as explained by a disproportionate contribution of decedents from the Fleet Prison and Bridewell Workhouse – or that individuals who suffered complex trauma were admitted to hospitals where they suffered injury-related mortality and went unclaimed by their families for the purposes of avoiding burial fees (Hurren 2004). If the latter were the case, then it would suggest that the St. Bride's cemetery sample is a poor representation of the injured people living in the parish of St. Bride.

The Chelsea sample may also be a poor representation of its injured denizens. The sample is said to consist of individuals from the upper social strata, but it is entirely possible that individuals from the middle class were also buried at Chelsea Old Church (Cowie et al. 2008). The presence of coffin plates associated with members of London's

affluent families does suggest that these individuals were of higher status; however, none of the individuals in this study were associated with coffin plates, which may suggest that they came from less affluent families, and may have had different lived experiences with treatment for their injuries that may be playing into observed patterns of fracturing healing.

Urban and rural differences between the cemetery samples may also be influencing observed patterns of fracture healing. While most of the individuals from the St. Bride's sample were not employed in labor-intensive occupations, many individuals from the Chelsea sample likely sought employment in agriculture (Miles and Coheeney 2009; Cowie et al. 2008). Differences in the work environment, in addition to differences inherent in rural and urban residency patterns, produced different forms of traumatic injury (Buzon 2011). Most fractures observed in the St. Bride's sample were either of the oblique type (28.57% of 42) or they were Colles' fractures (16.67% of 42). In contrast, while oblique fractures were still the most prevalent in the Chelsea sample (22.23% of 18), Bennett's fractures were the second most common fracture type (16.67% of 18). These differences in the prevalence of fracture type between samples, which reflect differences in rural and urban living, precluded the analysis of differential treatment between cemetery samples in many cases, contributing to the difficulties inherent in generating any conclusions pertaining to the first research hypothesis.

Was Subsequent Injury a Long-Term Health Outcome of Differential Treatment?

As mentioned in previous chapters, the clinical literature identifies previous injury as a predictor of future injury. Fulton et al. (2014) posit that part of the predictive

power of previous injury derives from the development of neuromuscular deficits that may accompany poorly treated injuries. Given this association, it was expected that there would be a relationship between fracture complications and subsequent injury, but there was not. This was the case for both cemetery samples combined, and when each sample was analyzed separately. Taken together, these results suggest that subsequent injury was not a long-term health outcome of differential treatment in London's Industrial Period, at least not for the individuals living in St. Bride's Parish or Chelsea.

Also mentioned previously is that the individuals associated with the St. Bride's Lower Churchyard sample, although of the working and lower classes, were predominantly associated with Fleet Prison and the Bridewell Workhouse. They were not, therefore, employed for industrial purposes. Individuals that were unaffiliated with either of these institutions were often employed as artisans or merchants; their occupations were not labor-intensive or industrial in character. Thus, in either circumstance, they would have been less likely to suffer complex trauma, and less likely to risk early mobilization of their injuries following a failed attempt at obtaining worker's compensation.

The injured individuals buried at the Chelsea Old Church cemetery grounds were members of affluent and middle class families. They were either independently wealthy, or managed to turn a profit through ownership of enclosed lands, which were used to harvest crops to meet the demands of Britain's growing urban centers. While some may have suffered severe injury, most individuals, based on their assumed socioeconomic statuses, would have been more likely to find the time to immobilize their injuries for an appropriate amount of time to avoid the risk of subsequent injury.

Potential Considerations

There are several limitations specific to the second hypothesis that should be considered. They relate to the identification of subsequent injury, the causes of it, and the sampling strategy employed to explore it in the current study. First and foremost, it is difficult to identify subsequent injury. An individual who presents with multiple fractures did not necessarily experience multiple injury events (Dougherty 2011; Redfern 2010; Judd 2002). Injury recidivist research in anthropology recognizes this major limitation, but continues to count individual fractures as separate injury events as a conservative measure. It is conservative, because researchers do not currently have the ability to identify the timing of antemortem injuries. It is also a conservative measure, because they do not know about the soft tissue injuries that are considered to contribute to lived experiences with injury. As a result, researchers severely underestimate the prevalence of subsequent injury in the archaeological record. Therefore, although the same protocol was followed for estimating the minimum number of injury events, it is likely that the prevalence of subsequent injury was underestimated in the current study.

While previous injury is a powerful predictor of future injury, other factors invariably contribute to it. In other words, the neuromuscular deficits associated with the development of fracture complications are not the only factors influencing risk of injury. As mentioned in previous chapters, there are other biosocial variables that influence risk of injury, and ultimately introduce uncontrolled variation into the data. These may include age, biological sex, gender, biological ancestry, ethnicity, general activity patterns, occupation, and residential patterns (Zuckerman et al. 2013; Zuckerman and

Armelagos 2010; Buzon 2011). Most of this information is either incomplete or entirely lost in the archaeological record.

Another set of variables that may have influenced the patterning of subsequent injury in the current study were the pathological fractures (e.g., Colles' and Smith's fractures) encountered in the St. Bride's sample. Pathological conditions, including neoplastic and metabolic disease, increase an individual's risk of injury (Redfern 2010; Hamblen and Simpson 2007; Roberts and Manchester 2005; Ortner 2003; Lovell 1997; Patton 1992). Twelve of the fractures observed were pathological in mechanism (28.57% of 42). When unknown fractures were excluded, these fractures made up 36.36 percent of the St. Bride's sample (12/33). The high prevalence of pathological fractures, while likely a function of a disproportionately high prevalence of adults over the age of 46 years (21/33 or 63.64%), is also partially explained by the impact of pollution and poor diet on the prevalence of vitamin D deficiency in those living in London's urban areas (Perrone 2013). It is possible that the inclusion of these pathological fractures into the study sample may be muting the relationship between fracture complications and subsequent injury, because they alter bone fragility and susceptibility to fracture. Further analysis is necessary.

Lastly, the sampling strategy used to test the second hypothesis posed a major limitation to this study. Specifically, to ensure that all injuries were accounted for, fractures and other traumata not observed directly by the author, that is, injuries of the axial skeleton, were included in the study sample. As a result, the author was unable to determine whether or not all traumata were observed and recorded. It should be noted, however, that the results of the Cohen's Kappa test discussed in Chapter IV suggest that

there was strong agreement between observers concerning the diagnosis of trauma. Thus, this limitation may not be as confounding as initially thought.

Limitations and Future Research

All interpretations and conclusions made in this research are restricted to the injured individuals who lived, worked, and died in St. Bride's Parish and Chelsea in the Industrial period. As such, the patterns of treatment and subsequent injury observed in this study should not be taken as true for all of Industrial London. Even though treatment was available to individuals in both communities, and even though subsequent injury was not associated with patterns of treatment in either, the same cannot be said for other contemporaneous communities in urban and rural London without further investigation. There are several limitations specific to both research hypotheses, such as that described above, that warrant discussion. In this section, limitations associated with the logistics of research and the nature of treatment in the archaeological record are discussed, and ideas for future research are presented.

Research Logistics

This study employed a highly purposive sampling strategy that was dependent, in part, upon the observations of others, although a study of observer agreement in Chapter IV indicated that the author's diagnoses of skeletal trauma were consistent with those of the researchers from the Museum of London, Center for Human Bioarchaeology. This sampling strategy also involved the exclusion of other forms of trauma, such as dislocations and avulsion injuries, which may have been able to contribute to the dialogue on treatment for traumatic injuries and its long-term health

outcomes. Due to the highly selective nature of this sampling process, the sample size for this study was very small and, consequently, very difficult to work with statistically. It raises the question of whether or not the 33 individuals from St. Bride's Parish and the 13 individuals from Chelsea adequately represented the injured members of their communities. Additionally, the disparity between samples, though partially remedied by treating counts as proportions quantitatively and qualitatively, likely affected the results of this study. For these reasons, the conclusions described in previous sections (and summarized below) should be heeded with caution.

This research is also limited by the absence of x-rays or radiographs, which can provide reliable measurements concerning the degree of angulation, rotation, and apposition, and the amount of overlap and consequent shortening (Redfern 2010; Hamblen and Simpson 2007; Patton 1992; Roberts 1991; Roberts 1988). Radiographs are also important for determining with a high degree of certainty whether or not a fracture was or was not impacted, which has implications for interpreting evidence for treatment in the archaeological record (Roberts 1988). Further, they can inform researchers about underlying pathologies, such as cysts, neoplastic defects, or osteoporotic changes to bone that might increase an individual's risk of injury. (Ortner 2003; Roberts 1988). It is the opinion of the author that this type of research should be avoided unless x-rays or radiographs can be consulted, as the absence of these images poses a serious limitation to the current study.

Lastly, the lack of archival literature directly documenting surgical practices in the Industrial period poses a considerable limitation that warrants discussion. Data collection for this study was conducted in July of 2015 at the Museum of London, Centre

for Human Bioarchaeology. To supplement the osteological data, archival data were collected from various archival institutions in London, including the Royal Colleges of Surgeons and Physicians, the London Metropolitan Archives, the Wellcome Library, and the St. Bartholomew's Hospital Museum and Archives. The information gleaned from the archival data was supposed to be used to contextualize treatment practices. However, during the writing process, all archival documentation (and photographic evidence of the osteological data) were stolen from the author through an act of car theft. Thus, to contextualize treatment for traumatic injuries, a variety of historical and medical historical publications were consulted, and the interpretations of the archival data that were consistent between researchers were emphasized over those that were not. Despite these exhaustive efforts, the capabilities of the care providers, that is, the techniques that were employed for the purposes of fracture treatment in the Industrial period, are largely unknown.

The Nature of Treatment

One of the concepts that spans both research hypotheses is treatment. It is one of the last lines of defense in preventing injury-related mortality, yet is experienced differently by different people, and, as a result, varies in its effectiveness (Leppäniemi 2004). Although easy to observe in modern clinical contexts, evidence for treatment in the archaeological record is elusive (Tilley and Oxenham 2011; Redfern 2010; Roberts and Manchester 2005; Ortner 2003; Grauer and Roberts 1996; Roberts 1988). Information concerning reduction, immobilization with splints, plasters, or casts, and subsequent physical therapy is often lost in the archaeological record. Instead, researchers most often encounter traumatized remains exhibiting patterns of healing that represent the

outcome of individual experiences with treatment, or more conservatively personal or interpersonal care.

Complications that develop throughout the healing process become currency in analyses that examine evidence for treatment in the archaeological record, because they may be aided or mitigated by the presence or absence of effective treatment (Redfern 2010; Hamblen and Simpson 2007; Ortner 2003; Patton 1992; Roberts 1988). Determining the etiology of any given complication, however, requires a differential diagnosis of the possible events that led up to its development. A complication or suite of complications may arise due to a failed attempt at reducing a fracture, or the decision to opt-out of (or inability to gain access to) fracture reduction. It may even be that the care provider thought that proper reduction was achieved. Prior to the discovery of x-rays and the development of radiographic technologies, care providers were unable to regularly consult radiographs of their patients' fractures, a practice that is recommended by orthopedic surgeons today (Hamblen and Simpson 2007).

Complications may also arise following a failed attempt to immobilize an injury for the recommended amount of time, although it is entirely possible that the fracture develops complications regardless of immobilization (Redfern 2010; Hamblen and Simpson 2007; Patton 1992; Roberts 1988). Further, it is possible that the injury was immobilized for what was thought to be an appropriate amount of time, but either union was not achieved, or it was achieved with minimal stability and subsequently re-fractured, causing deformity or non-union (Hamblen and Simpson 2007). Lastly, complications may develop due to either an underlying pathology that negatively impacts the healing process, or a random accident at any stage in the treatment process.

The existence of a plethora of potential circumstances leading to the development of fracture complications in past human populations, thus, makes it difficult to examine treatment for traumatic injuries in the archaeological record. In this study, inferences about treatment were made using the presence or absence of fracture complications, specifically fracture deformity and non-union. Complications other than deformity and non-union were excluded from analysis due to time constraints. Fracture deformity and non-union were recorded as present or absent, because the author did not have access to radiographs, which, as mentioned previously, are important for quantitatively and qualitatively measuring their characteristics (Redfern 2010; Roberts 1991; Roberts 1988). Together, these limitations provide ample justification for the cautious interpretations of the findings of this research.

Future Research

Limitations aside, research of the type conducted here deserves further exploration, both within London's Industrial period, and throughout other time periods and geographical regions. The current study could be expanded to include other Industrial communities in London, and other fracture complications, such as osteoarthritis, avascular necrosis, atrophy, and traumatic *myositis ossificans*. Alternatively, the framework developed in this thesis could be applied to more recent human populations (AD 1870 and after), particularly those in which care providers were able to operate on their patients using anesthesia to quell pain, and aseptic techniques to minimize post-operative infection and subsequent mortality.

Researchers should also consider exploring patterns of multiple traumata in the archaeological record, because they reflect hazardous human-environmental

interactions, and because they represent repeated interactions with those environments. Studies of injury recidivism, and, more conservatively, subsequent injury, in particular, offer unique ways of interpreting those patterns. Part of this research effort should be devoted to gaining a better understanding of the relationship between previous injury and future injury, with particular emphasis on lower limb injuries, their complications, and their contributions to injury-related morbidity.

Lastly, it is recognized that radiographs are difficult to acquire for studies that are either time sensitive or minimally funded. As discussed above, the inability to utilize radiographs in the current study confined data collection to presence/absence observations, which were unable to account for variation in the expression of complications, and, by inference, potential variation in treatment. It may, therefore, be worth while to explore the possibility of photogrammetry as a method for measuring fracture complications, specifically the degree of angulation, rotation, and apposition.

Summary

This study investigated evidence of treatment for traumatic injuries and its long-term health outcomes in two socioeconomically disparate communities from Industrial-era London. Quantitative analyses indicated that cemetery sample had no effect on the prevalence of fracture deformity and non-union. These findings were supported by subsequent discussion of the crude prevalence data, taking into consideration relevant clinical and historical literature. These results suggest that individuals from both the upper and lower social classes living in St. Bride's Parish and Chelsea had access to some form of treatment for their injuries that was made possible by the medically plural

industrial environment, and the emergence and dispersion of professional care that was consequent with the reorganization of the medical profession and the establishment of the voluntary hospital.

Quantitative analyses also indicated that, when cemeteries samples were analyzed together and separately, the presence or absence of fracture complications had no effect on the prevalence of individuals with single or multiple fractures. These findings suggest that the quality of treatment received by those living in St. Bride's Parish and Chelsea did not impact lived experiences with subsequent injury, or, more conservatively, multiple traumatic injuries. These results may be explained by the complexity and distribution of observed fractures, or by the historical contexts of both cemetery samples, neither of which necessarily involved repeated exposure to the hazardous industrial environment.

This study is one of the few that have attempted to open up a dialogue in paleopathology and bioarchaeology on social inequality and its impact on access to treatment. It was designed to move beyond the ultimate cause of injury towards an investigation of the the events that happened after the injury event. It demonstrates that the historical literature is not unbiased; that relevant osteological information should be considered in the interpretation of past historical events when possible. Additionally, it draws attention to the importance of considering the cultural and historical contexts of archaeological samples when making interpretations and generating conclusions.

Most importantly, this research has implications for the current global health crisis. It investigated the ways in which culture might constrain access to treatment in one of the world's first nations to industrialize. In a world where industrialization is becoming

a global phenomenon, research of this type may be able to lend unique insight into how the biological consequences of industrialization, including increases in the rate of injury-related mortality, might be mitigated.

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APPENDIX A

STATEMENT ON RESEARCH ETHICS

In the last few decades, there have been significant efforts to develop and advance a dialogue concerning human skeletal remains (HSR) research and repatriation in many post-imperial nations, including the United States and Great Britain (DeWitte 2015). Major advocates for this legislative push have come from indigenous communities, religious institutions, political bodies, and academia. While there is extensive literature regarding the repatriation of HSR in the United States (e.g., Buikstra 2006; DeWitte 2015; Ferguson 1996; Rose et al. 1996), there is a dearth of literature of a similar nature in Great Britain. However, like the United States, there is extensive legislation in Great Britain concerning research and repatriation of HSR. The purpose of this statement on research ethics is to briefly address issues of research and repatriation in the context of the current study using this legislation.

The Ethics of Osteological Analysis in the United States and Great Britain

HSR are considered by many in the United States and Great Britain to be direct evidence of past human lifeways, and therefore vital to uncovering truths about human history (Roberts 2006; DeWitte 2015). As such, they should be treated with respect and dignity, which, in this context, are ultimately defined differently by different groups of people. The American Association of Physical Anthropologists (AAPA) and the British Association for Biological Anthropology and Osteoarchaeology (BABAO), in particular, represent two major anthropological organizations with their own individual codes of ethics that are arguably constructed by their individual cultural circumstances. Both state

that HSR should be treated with respect and dignity, and promote the implementation of standardized protocols for curation, but differ in how they approach the communities directly affected by HSR research.

Following the implementation of the Native American Graves Protection and Repatriation Act in 1990, the AAPA has begun to work closely with the United States government to address claims of cultural affiliation (Rose et al. 1996). Although the AAPA exerts its influence over the process of establishing and assessing these claims, the government, for the most part, remains impartial and considers several different lines of evidence when making a decision (Watkins 2000). When affiliated groups are identified, many American anthropologists work closely with them during excavation, and defer to them for decisions about repatriation (DeWitte 2015).

The BABAQ, on the other hand, maintains a considerable amount of influence over the decision to accept or refute claims of cultural affiliation. In 2005, the Department for Culture, Media, and Sports produced a document titled, “Guidance for the Care of Human Remains in Museums,” (GCHRM) whose purpose was to outline a general protocol for managing claims for repatriation and potential reburial, among other things. The GCHRM states that all groups involved in a dispute over HSR should be treated equally and equitably; however, it also states that museums have the responsibility of deciding whether or not a claim for repatriation is legitimate, which essentially gives them control over de-accession. It should be noted, however, that when claims are legitimized, the BABAQ does collaborate with affiliated groups.

The different roles that American and British anthropologists have in addressing claims of cultural affiliation likely stem from their individual historical circumstances.

American anthropologists share a contentious historical relationship with Native Americans, having contributed to their marginalization for over two hundred years (Conn 2004). By studying the remains of individuals unaffiliated with themselves, American anthropologists became stewards of Native American history. Indeed, many still argue that they should continue to fulfill the role of steward, and that Native American history can only be constructed scientifically (Weiss 2001). In contrast, British anthropologists working in Great Britain tend to study the HSR of their ancestors (DeWitte 2015). This may account for why they are more integral to the process of accepting or refuting claims of cultural affiliation than American anthropologists. What may also explain this difference is that, according to the BABAO, the British public is more likely to accept scientific dogma and appreciate its place in the study of HSR than the American public.

Ethical Considerations for the Current Study

As demonstrated above, research ethics are culturally constructed. However, when collaborating with research institutions in other cultures, researchers must be willing to abide by the ethical paradigm of that culture. Fortunately, for the current study, the way in which the HSR were excavated, catalogued, and curated complied with the author's research ethics and the ethical codes of both the AAPA and the BABAO.

The Museum of London (MOL) – the institution that curates the skeletal remains included in this study – is one of the public museums that follows the guidelines and recommendations of the BABAO (archive.museumoflondon.org.uk). It houses HSR comprising over 17,000 individuals exhumed from cemeteries located in the City of London and the Greater London Area that were encountered through development and re-

development projects. Its purpose is to promote the scientific study of HSR by internal and external researchers, and follows recommended curatorial guidelines.

The HSR included in the current study represent citizens of London who lived in two socioeconomically disparate communities. Regardless of status at time of death, their remains were treated equally and equitably by MOL Archaeological Services. The remains were encountered during development projects, and subsequently exhumed with permission from the Ministry of Justice. Following exhumation, the remains were curated at the MOL Centre for Human Bioarchaeology following the recommendations outlined in the GCHRM. The Church of England was consulted during the exhumation and curation processes, as all individuals were buried in consecrated soil.

In conclusion, all ethical decisions made throughout the duration of the current study complied with the AAPA and BABAO codes of ethics. No extensive ethical dilemmas were encountered that would have warranted a deeper discussion of the ethical underpinnings of this study. However, this is not always the case. In many instances, researchers find themselves preoccupied with trying to utilize their own codes of ethics that conflict with those of the foreign research institutions that they affiliate themselves with when navigating ethical dilemmas abroad. Ultimately, researchers should consider including statements of research ethics in their work when the need arises. This is particularly important, because the ethical situations in which researchers find themselves need to be addressed by the broader scientific community in order to prevent their occurrence in the future.

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