Skeletal trauma analysis
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Case studies in context

EDITED BY

Nicholas V. Passalacqua
Joint POW/MIA Accounting Command – Central Identification Laboratory,
Joint Base Pearl Harbor – Hickam, HI, USA

Christopher W. Rainwater
New York City Office of Chief Medical Examiner and New York University, New York, NY, USA

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List of contributors

**Bradley Adams**  
New York City Office of Chief Medical Examiner, New York, NY 10016, USA

**Eric J. Bartelink**  
Department of Anthropology, California State University – Chico, Chico, CA 95929-0400, USA

**Hugh E. Berryman**  
Forensic Institute for Research and Education, MTSU, Murfreesboro, TN 37132, USA

**Ciarán Brewster**  
Department of Archaeology, University College Cork, Cork, Ireland

**Luis L. Cabo**  
Department of Applied Forensic Sciences, Mercyhurst, Erie, PA 16546, USA

**Hugo F.V. Cardoso**  
Department of Archaeology, Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada

**Angi M. Christensen**  
Federal Bureau of Investigation Laboratory, Quantico, VA 22135, USA

**Popi Th. Chrysostomou**  
Joint POW/MIA Accounting Command – Central Identification Laboratory, CONUS Annex, 106 Peacekeeper Drive, Suite 2N3, Building 301, Offutt AFB, NE 68113  
and  
School of Science & Engineering, Teesside University, Middlesbrough, Tees Valley, TS1 3BA, UK

**Luis F.N. Coelho**  
National Institute of Legal Medicine and Forensic Sciences – North Branch, 4050-167 Porto, Portugal
Eugénia Cunha
Department of Life Sciences/Forensic Sciences Centre, University of Coimbra, Coimbra, Portugal

José Miguel Carretero Díaz
Laboratorio de Evolución Humana, Burgos, Spain

Anthony E. Dwyer
Butler County Sheriff’s Office, Hamilton, OH 45011, USA

Paul Emanovsky
Joint POW/MIA Accounting Command – Central Identification Laboratory, Joint Base Pearl Harbor–Hickam, HI 96853-5530, USA

Christina L. Fojas
Department of Anthropology, University of Tennessee, Knoxville, TN 37996, USA

Marina Martínez de Pinillos González
National Research Centre on Human Evolution, 09002 Burgos, Spain

Gina Hart
New York City Office of Chief Medical Examiner, New York, NY 10016, USA

Joseph T. Hefner
Department of Anthropology, Michigan State University, East Lansing, MI 48823

Jennifer C. Love
Office of the Chief Medical Examiner, Washington, DC 20024, USA

Elizabeth A. Murray
Mount St. Joseph University, Cincinnati, OH 45233, USA

Nicholas V. Passalacqua
Joint POW/MIA Accounting Command – Central Identification Laboratory, Joint Base Pearl Harbor–Hickam, HI 96853-5530, USA

João Pinheiro
National Institute of Legal Medicine and Forensic Sciences, Coimbra, Portugal

Katerina S. Puentes
National Institute of Legal Medicine and Forensic Sciences – North Branch, 4050-167 Porto, Portugal
Christopher W. Rainwater  
New York City Office of Chief Medical Examiner and New York University, New York, NY 10016, USA  
and  
Department of Anthropology, Center for the Study of Human Origins, New York University, New York, NY, 10003

Lauren Regucci  
Federal Bureau of Investigation Laboratory, Quantico, VA 22135, USA

Tiffany B. Saul  
Forensic Institute for Research and Education, MTSU, Murfreesboro, TN 37132, USA

Victoria A. Smith  
Oak Ridge Associated Universities

Brian F. Spatola  
Anatomical Division, National Museum of Health and Medicine, Silver Spring, MD 20910, USA

Steven A. Symes  
Department of Applied Forensic Sciences, Mercyhurst, Erie, PA 16546, USA

MariaTeresa A. Tersigni-Tarrant  
Center for Anatomical Science and Education, Department of Surgery, Department of Pathology, St. Louis University School of Medicine, St. Louis, MO 63104, USA

Jason M. Wiersema  
Harris County Institute of Forensic Sciences Houston, TX 77054, USA

Nikki A. Willits  
Joint POW/MIA Accounting Command – Central Identification Laboratory, Joint Base Pearl Harbor–Hickam, HI 96853-5530, USA
The focus of this volume is human skeletal trauma in a forensic context, specifically for the forensic anthropologist or forensic pathologist.Forensically, skeletal trauma is extremely important as it may be the only direct evidence of violence indicating the decedent’s cause of death after the decomposition of soft tissues. Therefore, an accurate understanding and interpretation of skeletal trauma is key to forensic investigations.

Forensic anthropologists are increasingly being asked to consult on skeletal trauma cases and the majority of courtroom testimonies provided by forensic anthropologists concern interpretations of skeletal trauma (Murray and Anderson, 2007). The scope and necessity of forensic anthropology has evolved beyond developing a biological profile in order to determine the identity of the unknown remains (Dirkmaat and Cabo, 2012). Forensic anthropologists now routinely reconstruct the death event through detailed skeletal trauma analysis, archaeological recovery, and taphonomic analyses – none of which were envisioned in a routine forensic anthropology consultation in the 1970s (Stewart, 1979).

A better understanding of skeletal trauma has developed over the last few decades through a number of different research avenues; however, the root of modern skeletal trauma interpretation goes back to forensic anthropologists working alongside forensic pathologists at the Medical Examiner’s Office in Memphis, Tennessee (Passalacqua and Fenton, 2013). These original case study interpretations of known incidents set the precedent for how bones break and how to interpret skeletal trauma.

More recently, forensic science and peer-reviewed research has begun to trend toward experimental research with a strong statistical basis and large sample sizes. While this approach to skeletal trauma research informs the field (e.g., Baumer et al., 2010), it is often first-hand experience that is most instructive, as well as the basis for subsequent
large-scale skeletal trauma research projects. As peer-reviewed journals are no longer the best outlets for these types of publications, we felt an edited volume would be a worthy addition to the investigation of skeletal trauma analysis in the field of forensic anthropology. Additionally, many forensic anthropology programs do not receive enough case work to sufficiently train students in skeletal trauma interpretation and it is our hope that this volume will help in developing trauma analysis skills beyond an introductory level.

Skeletal trauma can be considered as any *in vivo* damage that affects bone or hard tissues (e.g., cartilage, dentition) and the importance of skeletal trauma analysis is the fact that these hard tissues offer a permanent record of a traumatic event regardless of the mechanism, and thus skeletal trauma can be broken down into several categories. *Antemortem trauma* deals with any skeletal injury that occurred prior to death and exhibits some evidence of healing or callus formation. While the proper interpretation of antemortem trauma is paramount for documenting a history of repeated injuries that may be seen in child or elder abuse cases, antemortem trauma can also be particularly useful in identification efforts. *Blunt force trauma* occurs when a bone fails (fractures) following an inability to resist extrinsic force. Perimortem blunt force trauma interpretation can reveal the direction of force as well as a minimum number, and possibly sequence, of injuries. *Sharp force trauma* involves an impact with an object with a cutting surface where the bone is incised. This involves knife cut wounds, hacking or chopping events, and dismemberment with both knives and saws. *High-speed projectile or ballistic trauma* results from a fast-moving object where anisotropic bone will respond as a brittle material. Like blunt force trauma, the direction of force and number or sequence of impacts may be interpreted. *Thermal alterations or burned bone* relate to a rapid dehydration of bone as the heat from the fire destroys the organic material of the bone. As a general postmortem process, it is important to distinguish thermal damage from perimortem trauma. As soft tissue is rapidly degraded, the forensic anthropologist is often consulted on these types of cases. These categories of trauma are not discrete and often operate on a continuum which may result in multiple forms of trauma being present simultaneously.

**Skeletal trauma analysis: case studies in context**

The goal of this volume is to present a number of real forensic anthropology case studies by practicing forensic anthropologists. The chapters
that follow deal with a number of issues ranging from how forensic anthropologists approach trauma analysis, to how perpetrators perceive forensic science and attempt to alter the evidence based on their perceptions.

Forensic anthropology is a perpetually developing field whose existence within a medicolegal context requires constant re-evaluation of methods. Spatola opens this volume in Chapter 2 with a challenge to move away from typological approaches of trauma-type classification, and towards the use of descriptive anatomical language and a more focused look at the wound production’s biomechanical continuum. He successfully illustrates how weapon-centric classification can bias or result in over-reaching interpretations of the cause of death. This is especially noticeable in ambiguous cases and can lead to problematic outcomes. His chapter is complimented by that of Pinheiro and colleagues (Chapter 3) who note that the entire process from death to discovery must be known in order to achieve accurate trauma interpretations. They emphasize two types of case knowledge: that contextual details specific to the case must be known, and that the analysts must have an understanding of biological and taphonomic processes. The authors show that a lack of knowledge in either of these areas can have a profound effect on the final case interpretation. Importantly, they demonstrate that the fullest and most accurate understanding of the cause of death is best achieved through a medicolegal death investigation that incorporates multidisciplinary discourse between forensic pathologists, forensic anthropologists, and law enforcement.

Collaboration and a thorough knowledge of biomechanical processes is also discussed in Chapter 4 by Wiersema and Love, who demonstrate that forensic anthropologists play a key role in the interpretation of repetition and the sequence of skeletal injuries – trauma that is not often apparent with only a soft tissue examination. They highlight the importance of this refined skillset to the investigation of child abuse.

The sequence of skeletal injuries is also emphasized by Bartelink’s case study in Chapter 5 involving the documentation of blunt force trauma to the skull and antemortem injuries to the knee. Anthropological findings regarding the antemortem injuries allowed investigators to make progress towards establishing the identification of the decedent. In this case, perimortem trauma analysis was useful as it contradicted the statements made by the suspects and played an important role in developing a plea-bargain for the accused.

Passalacqua and colleagues (Chapter 6) contribute an example focusing on the importance of patterns of trauma on individuals recovered
from a Spanish Civil War (1936–1939) mass grave. They provide a unique perspective of what repetitive, state-sanctioned institutionalized violence looks like and how alternative interpretations are worth investigating for individuals whose trauma pattern deviates from the norm.

Cardoso and colleagues (Chapter 7) demonstrate that the physical environment in which the remains are deposited can have significant impacts on the duration of the perimortem interval of bone. Their case study demonstrates that human remains submerged in water allowed the bone to remain in a plastic state and thereby complicated an interpretation of peri- and postmortem lesions. Cardoso and colleagues show that contextual information is key to understanding trauma related to the death event versus damage that occurred postmortem.

Context of the deceased is important in the case study provided by Hart in Chapter 8, who demonstrates the utility of forensic anthropology in distinguishing between ballistic and carnivore trauma by reconstructing skull fragments resulting from a gunshot wound. This analysis contributed to the ruling on manner of death and emphasizes the importance of having anthropologists on staff in the medical examiner’s office.

Berryman and Saul (Chapter 9) present a known case with skeletal evidence of sexual abuse. Through close examination of scavenged remains, they found details useful for the identification of the deceased, the cause of death, and evidence of severe traumatic sexual assault via osseous trauma.

Several chapters in this volume examine blunt force trauma interpretation.

Love (Chapter 10) emphasizes the importance of understanding forces associated with skull fracture patterns. She presents two cases of blunt force trauma in adult crania, and discusses adult cranial fracture pattern interpretation in terms of impact surface, impact energy, typical location of fracture initiation, and amount of fracture propagation.

Blunt force perimortem trauma discussed by Tersigni-Tarrant (Chapter 11) focuses on the axial skeleton as a result of a fall from a height. It also presents a discussion of ante-, peri-, and postmortem modification to the skeleton, all of which were important for the identification of the individual and interpretation of the death event and subsequent taphonomic processes.

Emanovsky (Chapter 12) presents another interesting look at blunt force trauma though his examples of deceleration trauma from low-velocity airplane crashes. The goal of his chapter is to provide
terminology for discussing and reporting on perimortem trauma characteristics using examples from historic aircraft crashes with long postmortem intervals and numerous taphonomic modifications.

The next few chapters are contributed by professionals who have had experience working with specific instances of unique, or destructive forms of trauma.

As noted by Christensen and Smith in Chapter 13, blast trauma is a non-typical type of trauma observed in traditional laboratories; however, increasing involvement of forensic anthropologists in areas of conflict requires a deeper understanding of this type of trauma. Christensen and Smith’s chapter provides a useful discussion of the literature, the processes behind the creation of blast trauma, and distinguishing characteristics of blast trauma compared with other trauma. They illustrate their discussion with non-human exemplars, demonstrating the nature of blast injuries in a forensic setting with a focus on blast-related rib fractures.

Another discussion of blast trauma is provided by Willits and colleagues in Chapter 14. Their analysis of two individuals killed during the Korean War shows evidence of blast trauma via skeletal trauma patterns and the presence of embedded shrapnel. Furthermore, the authors argue that based on the skeletal evidence, each of the individuals was subject to multiple blast events and each were at different distances from the blast epicenter.

Thermal modification to the body is discussed by Chrysostomou (Chapter 15), who presents a case dealing with the reconstruction of highly fragmented, thermally altered remains in order to establish identity, and examine patterns of burning and thermally induced fractures. Importantly, this was the first case in the Republic of Cyprus’ legal system where an anthropologist testified in court leading to a successful conviction. This has led to growing acknowledgement of the importance of forensic anthropological methods in analysis and the use of forensic anthropologists in cases involving skeletal material.

The importance of forensic anthropology in medicolegal investigations requires continued testing and development of methods for the analysis of human remains. Fojas and colleagues (Chapter 16) have contributed a newly developed, systematic approach using Geographic Information Systems (GIS) in the interpretation of burn patterns to bodies. Their approach provides a quantitative classification system to the overall burn pattern of bodies.

Rainwater (Chapter 17) proposes three typological methods of dismemberment using both weapon type and dismemberment pattern,
which allows for a more in-depth discussion and presentation of modes of dismemberment. He presents unique exemplars for each dismemberment mode.

The case presented by Regucci and Adams in Chapter 18 shows that even when the perpetrator goes to extreme measures to get rid of a body, forensic anthropological knowledge can still find significant evidence relating to the death event and identity of the individual. The skeletal remains of the victim in this case were reduced to a highly fragmentary and burnt state. Forensic anthropological understanding of the processes and results of cremation and fragmentation encouraged multiple scene recoveries, resulting in the successful recovery of large amounts of cremated skeletal remains.

Finally, Murray and Dwyer (Chapter 19) close the volume with an interesting look at the future criminal and how the popularization of “forensics” in pop culture has created the “CSI Effect.” They present a case with multiple forms of trauma resulting from perpetrators’ (mis)understanding of forensic science, and their attempts to alter evidence and destroy remains in order to prevent being caught.

The combination of case studies included within this volume attempts to present a variety of approaches to the analysis of skeletal trauma. The authors and contributors hope that the perspective gained from these chapters and the new directions of methodological approaches will provide professionals with an increased understanding and ability to interpret damage to the skeleton no matter what the origin. Only through increased exposure to skeletal trauma can analysts gain the experience required to properly interpret trauma to the skeleton.

References


CHAPTER 2
Atypical gunshot and blunt force injuries: wounds along the biomechanical continuum

Brian F. Spatola

Introduction

The purpose of trauma analysis in forensic anthropology is to determine the mechanism and timing of bone trauma and to address other related medicolegal problems (Scientific Working Group for Forensic Anthropology, 2011). By applying principles of biomechanics bone trauma can often be classified as arising from sharp force, blunt force, or gunshot trauma and in so doing serve an important role in guiding medicolegal death investigations (Berryman and Symes, 1998; Smith et al., 2003; Symes et al., 2012). However, over-reliance on weapon-centric classification, with its occasional misclassification or over-reaching interpretation, can introduce legal concerns affecting the pathologist’s ruling of cause and manner of death. Physical and contextual evidence of trauma is therefore examined judiciously before an opinion is rendered. Some injuries may not be easily classified due to the involvement of novel mechanisms of force. Additionally, deviation in magnitude and scale of extrinsic factors typically associated with a particular mechanism can lead to misclassification. Such cases may be better approached by emphasizing the continuous nature of biomechanical factors that influence wound production (Kroman, 2007, 2010). The use of descriptive anatomical and biomechanical terminology is often more useful for conveying the appearance, location, and characteristics of confounding or equivocal injuries. Atypical wounds such as these attest to the problematic nature of weapon centric classification.

Cranial vault injuries hold a particular interest in the forensic sciences due to their frequent role in unexplained death (Moritz, 1954;
Spitz, 1993; DiMaio and DiMaio, 2001; Saukko and Knight, 2004). Anthropologists have given considerable attention to cranial trauma (Berryman and Symes, 1998; Galloway, 1999; Fenton et al., 2003; Smith et al., 2003; Hart, 2005). This chapter presents four documented medicolegal \( n = 3 \) and historical \( n = 1 \) cases of atypical cranial vault injuries from the collections of the National Museum of Health and Medicine (NMHM) that emphasize the importance of balancing the typological approach to trauma analysis required to support medicolegal investigation with the variation in wound production associated with a biomechanical continuum as described by Kroman (2007, 2010). Autopsy reports, police reports, and historic museum records were available for the cases presented. These cases illustrate potential issues that may arise from over-reliance on weapon-centric classification in skeletal trauma analysis.

**Background**

The traditional categories of skeletal trauma used by anthropologists were first developed by forensic pathologists in order to classify wounds according to the common types of mechanical force that produce them (Courville, 1954; Spitz, 1993; DiMaio and DiMaio, 2001). Each of the three main classifications (sharp force, blunt force, and gunshot trauma) relate to classes of objects or weapons where each possess a limited range of physical and dynamic impact factors. Sharp and gunshot trauma each represent well-defined classes (sharpened beveled edges with low-velocity impact and relatively blunt projectiles with high-velocity impact, respectively), while blunt force involves a relatively broader class of objects (various shaped striking surfaces with low- to moderate-velocity impact) under a single classification, it lacks the specificity of the other two. In the absence of the signature characteristics of sharp and gunshot trauma, blunt injury characteristics can be conceived as the “default” mechanism. One example of the difficulty of using a typological system based on weapon-centric parameters is exemplified by arrow injuries. Arrows are ballistic objects with a variety of points ranging from sharpened blades to blunt rounded tips that can cause injuries with a combination of sharp and blunt trauma (Otis, 1870). Describing arrow injuries and other combinations of less common mechanism of force can lead to confusing terms such as sharp blunt force or blunt sharp force. In another example, blunt
injuries from captive bolt guns used to stun livestock can produce circular punched-out lesions similar to gunshot wounds with internal beveling (Perdekamp et al., 2010). [Captive bolt guns involve retractable conical shaped 10–12 mm bolts with up to 45 m/s velocity (100 mph), roughly 1/6 that of the slowest handgun ammunition.] The limitations of traditional classification are clearly evident by these examples. Case studies exemplifying similar situations will be detailed below.

The early use of the classification system (Gonzales, 1937) predated the bulk of the modern biomechanical research of the mid twentieth century that sought to explain the mechanical basis of fracture production and the tolerance of the human skull to impacts (Gurdjian et al., 1950a, b; Evans, 1957; for a summary of early and modern studies, see Yoganandan and Pintar, 2004). In time, anthropologists and pathologists increasingly recognized that biomechanical and engineering principles explained the signature characteristics of bone trauma across the three primary mechanisms commonly observed in forensic work (Moritz, 1954; Reilly and Burnstein, 1974; Dixon, 1982; Harkess et al., 1984; Smith et al., 1987; Spitz, 1993; Berryman and Symes, 1998; DiMaio and DiMaio, 2001; Saukko and Knight, 2004; Kimmerle and Baraybar, 2008; Symes et al., 2012). While a typological and weapon-centered approach to trauma analysis is often necessary to provide useful information to medicolegal authorities, descriptions of trauma are sufficient when a classification is not forthcoming (Berryman et al., 2013). However, knowledge of variation in wound patterns with regard to significant deviations of kinetic factors, such as velocity and surface area, from those that are typically encountered in a given classification should be understood.

Forensic anthropology texts and articles on trauma analysis often include a requisite overview of bone biomechanics discussing the importance of intrinsic and extrinsic factors, further accompanied by a presentation of typical characteristics common to each mechanism (Berryman and Symes, 1998; Galloway, 1999; Symes et al., 2012). However, introductory texts that emphasize the signature characteristics of each mechanism (Byers, 2002) greatly oversimplify trauma analysis. Additionally, many fracture characteristics are not unique to a single mechanism. Blunt fracture characteristics, for example, are a frequent finding in sharp trauma and in low-velocity gunshot exit wounds (Smith et al., 1993; Symes et al., 2012). Radiating and concentric fractures are found in both gunshot and blunt force injuries, and methods exist to differentiate between the two (Berryman and Symes, 1998; Hart, 2005). The discussion of differences of commonly occurring features within a
classification has necessarily outweighed the discussions of similarities in order to further the goal of classification. This is the situation regarding characteristics of entrance or impact sites of injuries.

Identification of impact sites is typically determined from the appearance of depressed fractures, their margins, and associated fracture patterns, or in some cases tool marks. Impact sites can be either penetrating or non-penetrating. Non-penetrating injuries typically take the form of depressed and linear fractures (Saukko and Knight, 2004). Penetrating injuries are those that cross both the skull and dura directly impacting the brain. Examples include sharp force injuries, gunshot injuries, and less frequently depressed fractures, particularly those involved in impalements or when blunt objects are delivered with a higher than usual amount of kinetic energy.

The margin characteristics of the entrances of penetrating gunshot and sharp force injuries are specific and well-established (DiMaio, 1985; Symes et al., 2012), while those belonging to penetrating and depressed fractures from blunt injuries are more varied with characteristics that can overlap with the former. Typically, the margins of blunt impacts are created by circular or curvilinear fractures with inwardly depressed fragments circumscribing the site at various distances. Blunt objects that sufficiently lacerate the scalp may come into contact with bone and obliquely impact the margin of a depressed fracture leaving crushed or “terraced” fractures (Saukko and Knight, 2004). The margins may also be sharp (not crushed or depressed) with internal beveling of bone (Perdekamp et al., 2010).

A review of gunshot and blunt force trauma will help inform the discussion on problematic aspects of impacts and penetrating wounds associated with the case studies that follow. The approach advocated here is that gunshot wounds can be conceived of as a subcategory of blunt force trauma with an emphasis on increased velocity and reduced surface area of impact.

**Gunshot trauma**

Typical gunshot injuries are high-velocity penetrating or perforating wounds caused by projectiles. They are fast-loading injuries that typically produce a brittle fracture response with little to no deformation. The entrance wound is a depressed fracture (Gurdjian and Webster, 1958), although it is not often described as such. The typical entrance wound is a round-to-oval punched-out defect with sharp edges on the outer
Atypical gunshot and blunt force injuries

Table and internal beveling (DiMaio, 1985). In some circumstances the entrance edges can also involve chipping, fracturing, and depressed margins to a substantially lesser degree than blunt force depending on several factors, including angle of impact and bone structure or shape. Bone beveling is characterized by the circumscribed radius of exposed diploe at the gunshot injury site visible only on the side opposite the direction of force and typically viewed on the internal cranium. Exits have similar characteristics as entrances, but with beveling of the outer table. Often the exit is a larger defect than the entrance, but this is not always the case. External beveling of entrances can be seen in tangential bullet strikes resulting in “keyhole” defects and more extensive “gutter” wounds. Some rare entrance wounds may show external beveling similar to exit wounds (Coe, 1982; Peterson, 1991).

Radiating and concentric fractures are also common features of gunshot wounds. Projectiles from guns may produce temporary cavitation pressures inside the skull depending on bullet design and velocity (Ragsdale, 1984). These forces may cause concentric fractures around entrance and exit sites. Triangular or irregularly shaped pieces of bone, formed by concentric fractures surrounding impact sites subsequent to the formation of radiating linear fractures, can be lifted or “heaved” away from the skull by forces associated with cavity formation (Smith et al., 1987; Berryman and Symes, 1998).

The gunshot wound is arguably a special category of localized blunt injury whereby projectiles with a small cross-sectional surface area impact at high velocity. Velocity is the lynchpin of gunshot injuries as it is the greater magnitude of velocity that makes an object with relatively little mass and surface area capable of severe wounds (Moritz, 1954; DiMaio, 1985). The surface area of the impacting projectile and resulting depressed fracture varies for reasons that include the caliber and shape of the projectile, the amount of projectile deformation on impact, angle of impact, and degree of bullet yawing. The velocity of projectiles and associated wound severity also varies with type of weapon and ammunition.

**Blunt force trauma**

Blunt force trauma is the classification for injuries involving low-velocity mechanical forces from broad and blunt surfaces. Examples include, but are not limited, to punches, kicks, blows with objects, falls, transportation accidents, shrapnel, blast pressure waves, and crushing injuries. Blunt
injuries are caused by objects with a wide variety of physical and dynamic characteristics, including fists, poles, steering wheels and concrete floors. These are slow-loading injuries that typically exhibit a ductile response in bone prior to fracturing, creating the irreversible deformation of bone material (plastic deformation).

Blunt force fractures are classified as linear or depressed (Itabashi et al., 2007). Characteristic linear fractures can be single or multilinear and can be further described variously as radiating, curvilinear, and stellate. Depressed fractures may be further described as comminuted, mosaic (spider-web), pond, and/or terraced (Saukko and Knight, 2004). Features of many types and descriptions can often be present in the same injury. Fractures and fracture patterns are also influenced by surface area of the object. Broad impacts impart linear and comminuted fractures, while narrow impacts result in depressed and potentially penetrating fractures (Galloway, 1999). Blunt injuries are less likely to result in penetrating injuries than injury caused by stabbing or gunshot (Gonzales et al. 1954).

**Biomechanical continuum**

As Kroman (2007, 2010) has pointed out, wound production occurs on a biomechanical continuum with regard to several factors including force, surface area, and acceleration/deceleration. (Deceleration in engineering is understood simply as negative acceleration.) Under the laws of physics, combinations of the primary intrinsic and extrinsic factors contribute variously to the three typological classifications of mechanical injury based primarily on weapon or object type, usual mode of delivery, and associated loading rate. For example, sharp force trauma typically involves the small surface areas of blades, saws, and similar weapons delivered at low velocity with slow rate of loading, and gunshots involve small cross-sectional surface area of high velocity, rapidly loaded projectiles from small arms. Blunt force is the most inclusive category as it involves broad, small, and angular surface areas of a variety of objects impacting within a range of low to moderate velocity.

Classification, however, may be confounded when one or more factors are significantly different than expected under the usual scheme. For example, decelerated projectiles can cause shallow depressed and comminuted fractures (Otis, 1870). Blunt and dull-edged objects like gunshot injuries can also cause penetrating injuries with sharp uncrushed entrance margins and beveling, especially when they present...
with reduced cross-sectional surface area at increasing velocity (see Case 4 below). It is important to understand that the response of bone to force is influenced by continuous and typically undetermined variables, such as force and surface area. Classification, although often scientifically justifiable and useful, is still in many ways just a convenient typological method for communicating underlying observations of complicated biomechanical processes.

Intrinsically, bone is a viscoelastic material. As a result, the magnitude and rate of loading of force make important contributions to the overall patterning of bone trauma. These factors determine how much and how rapidly stress (i.e., force per unit area) is applied to bone, and subsequently the rate at which it is fractured or deformed. Very-low-magnitude, slow-loading stress will not significantly deform bone beyond its ability to rebound without permanent damage. When the magnitude of stress exceeds the elastic limits, slow rates of loading to bone will elicit a permanent ductile failure response. Bullet impacts occur at very high rates of loading causing the cranium to rapidly fail with a brittle response and little to no deformation. These responses make up a critical component of the evidence used to classify fracture patterns (Berryman and Symes, 1998).

In some circumstances, interpreting features of penetrating and depressed injuries of the cranium can be challenging due to the gradation of characteristics across classifications especially those found in the margins of entrances and impact sites in gunshot wounds and some blunt impacts. Internal and external marginal features, like beveling and sharp, non-crushed edges are often paired features in traumatized diploic bone. These features are seen in both textbook gunshot wounds and localized penetrating blunt impacts (i.e., impalement). Recognition of the graduating and “transitional” nature of these features with regard to velocity and surface area of impact can be critical to avoid misclassification and error in analysis. The biomechanical continuum perspective helps to deemphasize the need to determine the type of weapon involved in injury. The model is a theoretical reminder to anthropologists that classifications are convenient typologies applied to the spectrum of physical and dynamic factors affecting wound production. The continuum concept is useful for understanding the case studies provided as they represent the types of wounds that occur within hypothetical “transition zones” between typical classifications, such as that between blunt and gunshot injury, or even sharp and blunt injury.
Case 1: depressed fracture of inner table from historic gunshot contusion

Background
A 20-year-old, male, Civil War soldier from the Company C, 35th Wisconsin was shot in Tupelo, Mississippi on 18 July 1864 by a musket ball. The projectile reportedly struck the skull obliquely, and inflicted a scalp wound between the sagittal suture and left parietal eminence. He died 10 days later. The following description is taken from the Medical and Surgical History of the War of the Rebellion (Otis, 1870).

At the autopsy the pericranium was found to be contused and detached at the seat of injury; but no alteration was visible in the outer table of the skull. Directly beneath the scalp wound the inner table was fractured and depressed ... the dura mater was wounded and there was a large abscess in the left cerebral hemisphere.

Description
The specimen consists of an approximately 10 × 9 cm section of left parietal bone removed at autopsy (Figures 2.1 and 2.2). Thickness of the section ranges from 5 to 8 mm. The outer table of bone shows no visible

Figure 2.1 Case 1. Historic gunshot wound from an obliquely angled shot by a musket ball. The outer table shows no signs of injury.
signs of fracturing even when aided by stereomicroscopy. The inner table shows two parallel linear fractures that measure 3.5 and 1.5 cm in maximum length. The fractures are 2 cm apart with two secondary fractures between them contributing to three triangular comminuted fragments of depressed bone.

**Case 2: depressed fracture from .32 caliber, short, Smith & Wesson projectile**

**Background**

The deceased was a 37-year-old female (5 ft 3 in., 160 lb; 1.60 m, 72.6 kg) shot in a bedroom by her boyfriend. The autopsy revealed that the decedent suffered multiple gunshot wounds ($n = 3$) with injuries to the heart, chest, neck and head. The perpetrator used a Clerke 1st model five-shot revolver that fired .32 caliber, short, Smith & Wesson ammunition. The description of the wound from the autopsy report is:

This was a bullet entrance wound situated in the right frontal region of the scalp just posterior to the hairline at a height of 5’ 2” above the right heel and at a distance of 1½” from the midline in front. It was round and measured 3/16”
Figure 2.3 Case 2. Outer table of non-penetrating close-contact gunshot injury from a .32 caliber projectile with a circular depressed fracture and a single radiating fracture. The projectile is said to have struck with the base first.

in diameter and was surrounded by a zone of powder stippling and measuring about 1 1/2" in diameter. [Standard units of measurement are retained in quoted reports.]

The bullet entered the body ... in the right frontal region of the skull, striking the bone base first. After penetrating the skin the bullet flattened out against the skull resembling a daisy head. The bullet did not penetrate the skull, but instead caused a slightly depressed fracture of the outer and inner tables. A small subdural hemorrhage was present over the right cerebral hemisphere.

Description
The specimen is a rectangular section of frontal bone taken at autopsy that measures approximately 6.5 × 6.0 cm in maximum dimensions with thickness varying from 6 to 9 mm (Figures 2.3 and 2.4). External injury is a slightly depressed, circular fracture 1.5 cm in diameter. The depression is more easily felt with a fingertip than can be appreciated visually. A single linear fracture extends from within the circular depressed fracture. The periosteum is intact on the majority of the ectocranial surface with the exception of the circular region of impact within the depressed fracture. Stereomicroscopic evaluation facilitates discrimination between the margins of torn periosteum and fractures. This is particularly important
since the specimen has trapped dirt in the periosteum, which makes it easily mistaken as a fracture as they are nearly superimposed.

On the inner table, a depressed and circumferentially comminuted and larger ($4 \times 3$ cm) fracture is seen with a central plate of bone ($2.5 \times 2.5$ cm) containing faint stellate fractures, corresponding with the impact site. Peripheral to the plateau, the series of comminuted fragments (3–10 mm) are buckled with respect to the central plate. A wide shearing fracture parallel to the endocranial surface can be seen in the cross-section. The production of faint stellate linear fractures from the center of the plate precedes the marginal fragmentation as indicated by the fracture sequence.

**Case 3: penetrating depressed fracture from detached umbrella tip**

**Background**
A 12-year-old child was struck in the head with an umbrella. The case file states that the end of the umbrella had become detached while it was being swung by another child.
Description

The specimen is a relatively thin (3–4 mm) section of diploic bone from the left anterior cranial vault measuring approximately 5.8 × 2.3 cm (Figures 2.5 and 2.6). Portions of the cross-section consist of a single table of cortical bone, such as that found in the antero-lateral vault. There is a circular penetrating injury 9 mm in diameter with sharp margins giving the appearance of a “textbook” gunshot wound. A 3 mm portion of the margin comprising approximately a quarter of the circumference of the defect is missing. Adjacent to this area are very small fragments of depressed bone. The inner table of the defect shows circumscribed beveling from 2 to 5 mm from the margin of the wound.

Figure 2.5 Case 3. Outer table with a 9-mm circular umbrella injury resembling a gunshot wound. Surface abrasions are the result of aggressive cleaning on the part of technicians.

Figure 2.6 Case 3. Inner table with internal beveling.