Abstract

Drilling Away the Sprits: A Worldwide Study of Trepanation

by Lara Frame

May, 2010

Director: Holly Mathews

DEPARTMENT OF Anthropology

Trepanation is a worldwide phenomenon that is most often studied on a case-by-case basis, with few comparisons cross-culturally or through time and with no agreement as to why it was practiced. Earlier theories have suggested ritualistic and magico-therapeutic purposes and have proposed a higher frequency of trepanations in adult males as a result of injuries sustained in warfare and gender-specific ritual practices. A compilation of case reports and information on trepanation is, therefore, vital for a bioarchaeological study of the procedure. This research catalogues and describes 297 incidences of trepanation in the extant literature in order to present a worldwide comparison of the practice and ascertain reasons for its performance. This thesis collects and reviews all of the cases of trepanation reported in the English-language scholarly literature to look for overall patterns that might lend credence to one explanation or another and to examine temporal and geographic variation. This study is of potential significance because it establishes a baseline review of all cases that others can use to draw conclusions about the reasons for this fascinating practice worldwide or in specific localities.

Four questions are answered in the Discussion section. Are more men than women trepanned because men are more likely to be involved in warfare as the literature suggests? Yes, in fact more than twice the number of males than females were trepanned. Is there any evidence to support cultural explanations or is this a residual category used for when skeletal remains

show no evidence of pathology? It is difficult to determine if a procedure was done for cultural reasons, especially when there are no written records. Additionally, lack of skeletal pathology is linked to the osteological paradox, the fact that individuals who are the sickest die before manifesting any skeletal evidence. A third question is whether or not there is any evidence to support the theory of diffusion, which states that trepanation originated in one or two centers and then diffused to other areas. This is also difficult to prove, although there are two centers that have evidence of trepanation from the Mesolithic: Eastern and Western Europe. And lastly, is there any cultural evidence to support subadult trepanation or only biological evidence? Most of the trepanned juvenile population showed biological factors that would necessitate trepanation, except for one case.

Out of the total observed sample, sex was mentioned in 215 out of all 293 cases. Out of these 215 individuals 52.9% (155) were male, 20.45% (60) were female, and 26.62% (78) individuals' sex was indeterminate. Only 209 out of the total 293 individuals' age-at-death were reported. The majority of the sample of both sexes was under 30 years of age.

These data sources revealed that slightly more adult males were trepanned than females and children. The few trepanned children showed evidence of developmental disorders such as scurvy and hydrocephaly, but this may not necessarily have been the reason for trepanation. Since the trepanned males did not always display possible related pathologies, it is highly likely that they were trepanned for both biological and ritualistic reasons.

Drilling Away the Sprits:

A Worldwide Study of Trepanation

A Thesis

Presented To

The Faculty of the Department of Anthropology

East Carolina University

In Partial Fulfillment

of the Requirements for the Degree

Master's of Arts-Anthropology

by

Lara Frame

May, 2010

Drilling Away the Spirits:

A Worldwide Study of Trepanation

By Lara Frame

APPROVED BY:

DIRECTOR OF THESIS:_____
Holly Mathews, PhD

COMMITTEE MEMBER:_____
Linda Wolfe, PhD

COMMITTEE MEMBER:_____
Megan Perry, PhD

CHAIR OF THE DEPARTMENT OF ANTHROPOLOGY:

_____
Linda Wolfe, PhD

DEAN OF THE GRADUATE SCHOOL:

_____
Paul J. Gemperline, PhD

Acknowledgments

First and foremost I would like to thank my committee members, especially Dr. Holly Mathews, for guiding me through the process and for being eternally patient with me. I would also like to thank Kristina Killgrove who was a very important person in this process as well as Dr. Charles Ewen for helping with the last bits of editing.

Secondly, I'd like to thank my family who have always supported me even when I wasn't supporting myself.

And lastly I would like to thank my Uncle Philip, who passed away last summer, and who would always tell me stories of his time in the sheriff's department. He always thought that what I did was "cool." This is for you.

DRILLING AWAY THE SPIRITS:

A WORLDWIDE STUDY OF TREPANATION

TABLE OF CONTENTS

LIST OF TABLES……... ix

CHAPTER 1: STATEMENT OF THE PROBLEM …….. 1

CHAPTER 2: LITERATURE REVIEW/RATIONALE……. 3

What is Trepanation?.....……. 3

Skull Fractures from Warfare and Accidents.....…….. 5

Warfare…….....…….. 6

Accidents…….....……. 8

Disease and Headaches….....……. 9

Headaches…….. 9

Disease…… 10

Epilepsy…….. 15

Cultural Purposes……. 16

Spirit Possession……. 17

Other Possible Cultural Examples…….. 17

Post-mortem Ritual Modification…… 18

Diffusion…….. 20

Summary…….. 20

Contemporary Cases…… 21

Time and Geography…… 23

Summary…. 24

CHAPTER 3: METHODOLOGY..... 26

Data Collection…….. 26

Data Analysis……. 29

CHAPTER 4: RESULTS 30

Tables……..... 30

General Population Results……..... 31

Results by Geographic Region…….....…. 36

Europe…… 36

Eastern Europe……... 36

Western Europe……. 37

Scandinavia…… 38

North Sea Area…….. 39

Canada……..……. 40

United States (Native North America)…….. 40

Eastern US……. 40

Central and Western US…… 41

Mesoamerica……. 42

South America…….. 43

Africa…… 44

Middle East……... 45

Australia…… 47

Asia and the Pacific Islands…….. 47

Summary……. 48

CHAPTER 5: DISCUSSION 50

BIBLIOGRAPHY..... 56

APPENDIX A: Checklist for Case Reports……..... 60

APPENDIX B: Geographic Area Tables……..…….. 62

APPENDIX C: Sources Consulted……..…….…..... 79

LIST OF TABLES

Table 1 Comparative Table Examining Age vs. Sex

Table 2 Sex vs. Shape

Table 3 Location vs. Age

Table 4 Eastern Europe-Russia, Latvia, Siberia, Ukraine, Hungary, Czech Republic

Table 5 Western Europe-Spain, France, Portugal, Italy, Austria, and Germany

Table 6 Scandinavia-Denmark and Sweden

Table 7 North Sea Area-Ireland and England

Table 8 Canada-Ontario and British Columbia

Table 9 United States-Eastern, Central, and Western

Table 10 Mesoamerica-Mexico and Belize

Table 11 South America-Peru and Bolivia

Table 12 Africa-Egypt, South Africa, Guinea

Table 13 Middle East-Iran, Jordan, Jericho

Table 14 Australia

Table 15 Asia and the Pacific Islands (Oceania)

Table 16 Trepanation by Geographic Area (Overall Table)

Chapter 1-Statement of the Problem

Trepanation (or 'trephination') refers to the practice of drilling or scraping a hole into the human skull. The instruments and techniques used and the reasons for this practice have varied over time and place. The earliest evidence for trepanation comes from Neolithic times and it persists into the present in parts of Africa and South America. Trepanation was practiced, at different times, in nearly every European country, Africa, the Canary Islands, Egypt, Oceania, the Polynesian islands, North America, South America, Asia (including China, India, Japan, and southern Siberia), and the Middle East (Aufderheide 1998:32). Despite the widespread documentation of this practice, there is little agreement in the literature about why it was performed. Biological and medical scientists have suggested that it was performed to cure problems like convulsions, headaches, epilepsy, and infections (Ackerknecht 1947:34). Others have reported that the practice is associated with fractures and hypothesized that it was done to treat war injuries (Ackerknecht 1947:33). Several archaeologists emphasize the role of religion suggesting that trepanation might have been performed to allow for the exit or entrance of spirits believed to cause illness (Oakley et al. 1959:94) Other scholars have suggested that the reason for trepanation was the collection of skull disks, called roundels, for charms or amulets (Crump 1901:170). In this thesis it is highly probable that some of the cases labeled as cultural cases might in fact be individuals who were trepanned for an unknown biological reason. While there is much speculation in the literature about why individuals were trepanned, there is a lack of a comprehensive review of existing case studies to tease out the factors that might help in understanding the motives of people performing such surgeries.

This project involves a comprehensive review of the existing literature on trepanation, including both case reports and theoretical interpretations, in order to investigate any associations between key demographic, biological and sociocultural variables of trepanned individuals. Individual data records were compiled for each case discussed in the literature. Every attempt was made to document basic demographic data for these cases including the age and sex of the skeleton, the precise location of the trepanation, the form of the trepanation and instruments used, and the presence of any associated pathologies, injuries, diseases, or developmental deformities on the skeleton. Analysis of the literature consisted of attempting to look for relationships between these variables to determine if any of the current theories are plausible. Throughout this thesis the literature of pertinent cases will be discussed and analyzed geographically so that patterns of purpose can be discerned.

Chapter 2-Literature Review/Rationale

The main objective of this project was to undertake a comprehensive review of the existing literature on trepanation by locating as many primary case reports of the practice as possible. A second objective was to examine and code these case studies for basic demographic and biological data about the individuals who underwent the procedure. The final objective was to analyze these data sets for correlations between the practice of trepanation and any of the above variables in order to see which of the existing explanations for the practice are best supported by the comprehensive data. Trepanned males may show evidence of cranial injuries which supports warfare theories, whereas very ill individuals who were trepanned would not show any skeletal manifestations of the disease. It is expected that such correlations may only occur within particular time periods or geographic/cultural regions due to the spread of ideas and/or information.

What is trepanation?

Trepanation, broadly defined, is the surgical removal of a piece of the cranium. Although Samuel Morton, in 1839, was the first to depict a trepanned skull the significance of trepanation was not realized until Ephram George Squier brought a trepanned skull from Peru back to the U.S. (Clower and Finger 2001:1418). The skull had a rectangular opening near the top and had come from an ancient Inca cemetery in the Valley of Yucay. Squier, as quoted in Clower and Finger (2001:1418), wrote that it was "a clear case of trepanning before death…the opening having been made with a burin, or tool like that used by engravers on wood and metal." American academics and scientists investigated the find and sent the skull to Paul Broca, a famous surgeon in France. Broca determined that the trepanation was evidence of advanced

surgery from the pre-Conquest New World. As early as the 19th century, theories circulated about why this was done to the individual, and yet to this day there is no clear answer. Additional discoveries of trepanned skulls have been made all over the world since Squier's find in Peru, and reports date from the Mesolithic to the ethnographic present (Clower and Finger 2001:1418).

According to Aufderheide's and Rodriguez-Martin's *Encyclopedia of Human Paleopathology* (1998:33), there are four distinguishable methods of trepanation that include grooving, scraping, drilling, and cutting (see Figure 1). In grooving, a pointed instrument etches a round or oval groove. This action is repeated until the instrument digs through to the diplöe. The diplöe is the spongy bone in between the inner and outer layers of cortical bone in the flat bones of the cranium (White and Folkens 2005:96) Scraping is performed using a sharp, oval object, often a stone that is repeatedly scraped over the intended area. Drilling is performed using a thin, sharp tool that is repeatedly turned in a circle to cut through the skull. And finally, cutting is when a sharp, oval stone is used perpendicular to the skull, rather than at an angle as in scraping, to create four linear grooves in the form of a rectangle.

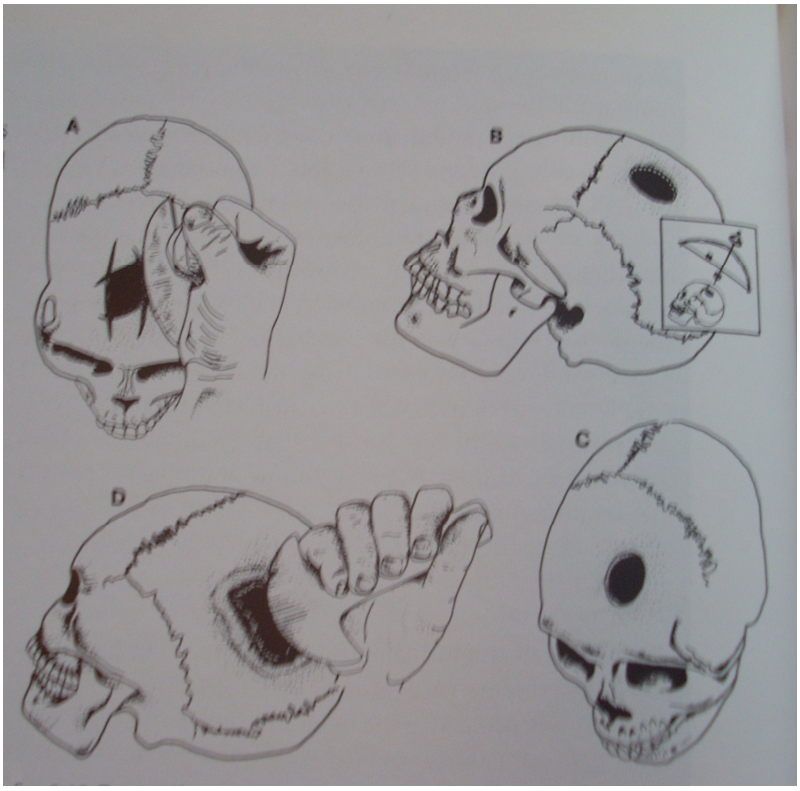

Figure 1 The four trepanation methods. A-Cutting, B-Drilling, C-Scraping, D-Grooving

Trepanation represents the first evidence of a surgical technique in humans done without modern equipment and yet there is evidence, from healing patterns on the skull, that many individuals survived this surgery. Around 80% of Neolithic and Mesolithic patients survived the operation (Aufderheide 1985:121). The finding of healed or healing trepanation is widespread in both place and time, from the Mesolithic (Aufderheide and Rodriguez-Martin 1998: 31 and England 1962:302) to the ethnographic present (Crump 1901).

The geographic and temporal distribution of trepanation is widespread. In Europe and North Africa trepanation was performed most often in the Mesolithic and Neolithic (Aufderheide and Rodriguez-Martin 1998:31). In Europe, it was also practiced during the Bronze and Iron Ages through the Middle Ages. However, after the expansion of Islam, the practice of trepanation declined and disappeared altogether shortly after the Medieval period (Aufderheide and Rodriguez-Martin 1998: 32). Trepanation was practiced, at different times, in nearly every

European country, Africa, the Canary Islands, Egypt, Oceania, the Polynesian islands, North America, South America, Asia (including China, India, Japan, and southern Siberia), and the Middle East (Aufderheide and Rodriguez-Martin 1998:32).

Many different theories have been proposed to account for why trepanation was practiced prehistorically and different types of evidence have been provided in support of each. The factors proposed to account for the practice of trepanation and of the key studies used in support of these hypotheses demonstrate that there is no consensus among investigators in part because there is no overall survey of trepanation cases worldwide. Most theories that have been advanced about the purpose of trepanation can be grouped into two categories: therapeutic and cultural. The therapeutic theories suggest that individuals were trepanned to alleviate intracranial pressure due to trauma or disease. Cultural theories suggest that the practice was tied to religion and ritual or to other ethnomedical practices within the society. Therapeutic theories will be discussed first.

Skull Fractures from Warfare and Accidents

Many investigators, such as Crump (1901), Bennike (1985), Jorgensen (1988), and Ruisinger (2003) have proposed that trepanation was done in response to a skull fracture. These fractures might have been caused by blunt-force trauma due to war injuries, traffic accidents, or felled trees. Often after cranial trauma there is internal bleeding which causes the brain to swell. Since there is limited room in the cranial vault for this expansion of the brain, the patient will often complain of headaches or intense pressure within the head. These investigators assume that trepanation was an attempt to relieve this pressure; today we would call this practice craniotomy (Moskalenko et al. 2008:299).

Warfare

Bennike (1985:93) observed 18 trepanned skulls from prehistoric Denmark. The majority of these surgeries had been performed by the scraping technique with a few showing evidence of cutting by a sharper object. Similarly, eight of the skulls found in this area were from the Middle/Late Neolithic (around 3200 BCE). She hypothesized that many of the injuries looked like battle wounds; some even showed other evidence of trauma. Since eleven of the trepanations were on the left side of the skulls she hypothesized that a right-handed opponent standing opposite the victim caused the skull injuries which necessitated the trepanations (Bennike 1985:98). Critics of this theory, however, contend that the left side may have been more convenient and easier for the surgeon (Bennike 1985:97).

Of the 18 skulls Bennike analyzed, 14 were male, 1 was female, and 3 were ambiguous/unknown. This skewed sex ratio lends credence to the idea that warfare was involved since more males than females would be involved in warfare activities (Bennike 1985:98).

However, Bennike (1985:98) does not indicate if weapons or items associated with warfare were found in the graves or around the site. If items such as this were found in proximity, the theory that these trepanations were performed to alleviate battle wounds would be strengthened. It is clear, however, that people in this time period understood when to attempt cranial surgery. Broken arms and dislocated knees were not the purpose of trepanation; these individuals were trepanned in order to relieve pain and pressure on the skull due to skull fractures. It appears that ancient societies may have had advanced medical knowledge.

Parker and colleagues (1986) analyzed a Romano-British cemetery and found the cranium of a male, aged 45-55, with a trepanation. Associated with the trepanation was a long,

linear wound that was hypothesized to be a sword cut. The trepanation was quite large and elliptical and showed signs of healing. Additionally, he is one of the few decapitations found in this cemetery (Parker et al. 1986:145).

Derums (1979) analyzed a male skull from Latvia dating to the middle Neolithic period (ca 2500 BCE) that had several trepanations. There was some bone regeneration occurring on the skull so it is highly likely that this man survived the surgery and lived for some time afterward. The author hypothesized that this individual had sustained severe combat wounds that splintered his skull in several places (1979:461-462). It is thought that his proximal cause of death was from disease rather than trauma, although without bony indications of said diseases, we cannot know for sure (1979:462).

Peru is arguably one of the world's main centers of trepanation. Jorgensen (1988) studied four skulls dating to the pre-Inca time period (between 900-1000 CE). He proposed that these four skulls show evidence of depressed fractures that were related to injury from a five-pointed club, a typical Peruvian weapon (1988:4). Three out of the four individuals died either during or immediately after surgery as there were no signs of the beginning stages of healing. It was inferred that the wounds were sustained during combat as all four individuals were male and all the wounds were on the left side of the skull or straddling the sagittal suture. In this case, the author states that trepanation was an attempt to treat depressed fractures on the skull as the trepanations were in and around the depressed fractures (1988:5). Archaeological evidence of a five-pointed club, the weapon Jorgensen hypothesizes caused the depressed fractures, lends support to his theory. One individual does show healing, indicating survival following the surgery of at least several years. The ancient Peruvians therefore had some knowledge of cranial anatomy, which might have been acquired by the actual study of the anatomy of the dead.

Daland (1935:555) describes an assemblage of skulls from Nazca, Peru, with evidence of trepanation as well as evidence of trauma. He states that it is possible these individuals, all male, were treated for depression fractures, found near the trepanations, the splinters of bone having been removed by the surgeon. Those individuals with multiple trepanations probably had multiple injuries. Many in this group show no evidence of healing, indicating that they died during surgery or immediately afterward. It is possible though, that instead of the trepanation procedure killing them, complications from the initial injury constituted the proximal cause of death (1935:555).

The geographic region known as Oceania (the islands between southern Asia and Australia/New Zealand) has produced a small sample of skulls with evidence of trepanation. Crump (1901:168) reported on one skull from the South Seas (New Britain) that showed evidence of injury in connection with the trepanation. Although the individual was completely skeletonized, the event was in the recent past of the community. Information regarding his life was well known and the assailant was still alive. Respondents reported that the victim was struck by a sling-stone from an interpersonal conflict and that he died two hours after the operation was completed (Crump 1901:168).

Accidents

Trepanation can also be used to alleviate intracranial pressure caused by accidents. Ruisinger (2003) reported on an interesting case from 1753 in Germany. A young male was involved in a traffic accident, and his head was knocked forcibly against the ceiling of the carriage. In the days following the event, he suffered from headaches, dizziness, and vertigo. Eight weeks after the accident, the individual was trepanned and the brain hemorrhage was evacuated. After a few days the doctors decided to perform another trepanation this time

evacuating thick, yellow pus. The patient began having severe epileptic seizures and the doctors, thinking this would be the best course of action, cut into the gray matter of the brain. In the end, the patient died as a result of this surgery, likely because of the several severe epileptic seizures that followed it (Ruisinger 2003:278). Another case reported by Margetts (1967) described a man from the Kisii tribe in Africa who was trepanned in the 1950s on account of the headaches he suffered after a tree fell on his head. After trepanning the man, the doctors sprinkled medicine over the wound and placed boiled fat over the incision. The individual survived.

Even though these are more recent examples of trepanation, knowledge of medicine and antiseptic procedures were known in the ancient world, it begs the question: What did the ancient peoples know that these recent historical surgeons did not? Trepanation as a method to relieve intracranial pressure in the case of injuries due to warfare and accidents is logical. If a patient showed symptoms of cranial pressure, the only method available to people in the past to relieve that pressure and drain the excess blood would have been trepanation or the opening of the skull.

Diseases and Headaches

There are several examples of skulls that have both evidence of disease and were trepanned. It is possible, therefore, that the trepanation was performed to somehow treat or relieve the symptoms of disease. These diseases include, but are not limited to, scurvy, mastoiditis, ear infection, meningiomas, hydrocephaly, brain tumors, headaches, and seizures.

Headaches

There is evidence of both physical trauma and biological disease were reasons for trepanation in the South Seas. Specifically on New Ireland, trepanation was performed as a cure for epileptic seizures and headaches in addition to skull fractures. Crump (1901) noted that an

individual who suffered from severe headaches had his or her skull trepanned at least five times. Trepanation was also done for beating and plucking sensations in the head. While Crump did not include information on epilepsy, it is clear that people in this region employed trepanation to treat both trauma and disease.

Similarly, Margetts (1967:686) described the trepanning of three members of the Kisii tribe in Guinea, Africa (one case has already been mentioned in "Accidents"). All three survived the operations. The first injured man suffered a blow to his forehead that did not result in a fracture; however, after this accident he suffered from persistent headaches for several years. Eventually, trepanation was performed by a native doctor and the headaches stopped (1967:686). The second case is that of a middle-aged man who hit his head on a door lintel and then suffered from persistent headaches after this injury. Over the next several years the patient had, at a minimum, five trepanations (1967:686-694). Margetts describes in detail the method the native doctors used, scraping, as well as the curative methods that were performed after surgery took place, such as how the wound was wrapped and various substances that were placed over the wounds (1967:686-694). In these examples the headaches are caused by actual physical trauma instead of plaguing the individuals for unknown reasons. This connection between headaches and trepanation suggests that the procedure was often used to treat symptoms resulting from trauma.

Diseases

Smrcka and colleagues (2003:327) reported a case of trepanation from the Czech Republic and argued that the unusual imprints of the meningeal arteries on the parietal bones could indicate a medical problem that necessitated trepanation. Grooves for the meningeal arteries are supposed to be smooth with few depressions. In this case, though, the right

meningeal artery groove had an irregular oval depression about 3mm deep and was deeper and wider than the left meningeal artery groove (2003:327). There was also evidence of Pacchionian bodies, which are a pronounced form of arachnoid granulations. Arachnoid granulations are responsible for regulating cerebrospinal fluid. If they become too large and turn into Pacchionian bodies they restrict the outward flow of cerebrospinal fluid and cause excessive pressure in the brain. However, in this case, the authors argued that the evidence pointed to a meningioma, a benign tumor on the meninges, that caused the depression in the meningeal artery groove (2003:328). This, too, can cause a significant increase in cranial pressure necessitating trepanation. These researchers used x-rays to show that the meningioma was the likely reason for the trepanation, as there was no external injury or trauma. No other pathological changes were found on the skull that would indicate a disease or infection. Had this skull not been x-rayed the meningioma probably would not have been detected.

Nemeskeri (1965) reports a case of osteomyelitis rarificans on the skull of male from 10th century AD Hungary. Osteomyelitis is a general infection of the bone caused by bacteria (White 1991:344), and osteomyelitis rarificans is a chronic inflammation of the frontal sinus. This individual's frontal sinus became porous due to the inflammation and most likely caused this individual a lot of pain (1965:349). Osteomyelitis is the possible causal factor in this trepanation.

A skull from an elderly female dated to the early Anglo-Saxon time period was found in England. McKinley (1992:333) analyzed the burial and found that this individual, in addition to a trepanation on the left parietal bone, had periodontal disease, dental calculus, osteophytes in the atlas and thoracic vertebrae, osteoarthritis in the cervical vertebrae, Schmorl's nodes in a thoracic vertebra, and calcified rib cartilage. Since this female was of advanced age when she

died, these diseases are most likely degenerative rather than pathological. Advanced periodontal disease can become quite painful if it severe enough and might have caused the patient enough pain to require cranial surgery. Since there is no detailed description of how advanced the individual's periodontal disease was it can be inferred that it was either the periodontal disease or some other biological factor that did not manifest on the skeleton.

Another example of periodontal disease is described by Zias (1982:55), who analyzed the skull of a female living in Roman-occupied Jericho. The only pathological evidence on her skeleton was periodontal disease. As previously stated, severe periodontal disease is quite painful and might have been the reason the young woman was trepanned (1982:55).

Oakley and colleagues (1959:95) reported an ancient trepanned skull from Jericho that showed signs of mastoiditis. They argued that an infection of the mastoid process of the temporal bone could be the reason for the trepanation (1959: 95). The authors also note a perforation of the external auditory meatus (external ear canal) of the same skull from Jericho. This is the only clue as to why this trepanation was performed; there is no other sign of disease on the skull. There is no explanation of the severity of the mastoiditis and whether this would have produced pain severe enough to have required surgery.

A condition that causes ear pain and infection, cholesteatoma, could be another possible reason why trepanation was performed (Mann 1991:166). Cholesteatoma is a condition in which the middle ear air spaces become filled with keratinizing epithelium. Mann (1991) analyzed a skull, recovered from ancient Cuzco, Peru, that showed pathological inner ear ossicles, which would have caused partial deafness on the side that was infected. Mann stated that there would be no pain or headache but possible facial numbness and/or paralysis (1991:166). It is likely that trepanation was performed in an attempt to relieve the paralysis. While this individual showed

biological evidence of a disease, it is also possible that cultural factors contributed to the disease. In coastal ancient Peru, fishing was the main sustenance method. The Pacific Ocean is very cold off the coast and Mann suggested that constant exposure to very cold water could have led to the buildup of keratinized tissue in the inner ear (Mann 1991:165).

Other conditions connected to trepanation include the presence of gliomas and possible cysts or tumors. Kidd (1930), for example, proposed that gliomas, nonmalignant tumors, might have been the cause of trepanation in a male aged 19-20 years from prehistoric Canada. Gliomas are slow-growing and would have caused increasing intracranial pressure. It is possible that this glioma forced open a suture causing distortion of the cranium (1930:86). Powell (1970) described a skull from prehistoric Connecticut that showed evidence of trepanation. The individual was male and between 20-25 years old. There were no other pathological conditions. However, Stewart (cited in Powell), who also analyzed this skull, hypothesized that the trepanation might have been related to a cyst or tumor (Powell 1970:733), although there is no pathological evidence to support this conclusion.

Another case of a possible lesion leading to trepanation was reported by Mariani-Costantini and colleagues (2000). These researchers analyzed the skull of a 5 to 6 year-old child from Imperial Rome, Italy, that showed evidence of hydrocephaly. Hydrocephaly, or "water-on-the-brain," is the abnormal buildup of cerebrospinal fluid in the ventricles of the brain, which causes the cranium to grow abnormally and can lead to brain damage (Aufderheide and Rodriguez-Martin 1998: 57). Hydrocephaly results in an elongated skull, which causes increased pressure on the child's brain. The authors, however, argue against hydrocephaly as the need for trepanation, arguing instead that it was performed to relieve pressure due to a space-occupying brain lesion in the posterior cranial fossa (Mariani-Costantini et al. 2000:306). Lesions of this

type are slow-growing and trepanation would have been an attempt to remove the lesion before it added more pressure to the brain. The authors claim that this is the most direct ancient evidence of a surgical treatment trying to specifically cure one of these lesions (*ibid*). Trepanation in this case was used to alleviate symptoms of a disease that probably would have been hard to identify in antiquity. The ancient Romans did not have the luxury of x-rays and most likely did not know of the nature of the brain. It is likely that they were, indeed, using hydrocephaly as the perceived need for trepanation, though this might not have been causing the cranial pressure. However, if trepanation was being used to cure only brain lesions then this shows that the ancient Romans had a very sophisticated knowledge of cranial anatomy and were excellent diagnosticians.

Another case has been connected to the presence of the dietary deficiency disease of scurvy. Mogle and Zias (1995) analyzed a juvenile (8 to 9 years old) skull, dating to 2200 BCE from the Middle East. The trepanation is incomplete suggesting that the child died during surgery. Signs of scurvy on the child include defects and lesions on the frontal bone and an edentulous mandible with severe alveolar resorption (Mogle and Zias 1995:77). The edentulous dentition suggests inflammation, which is a problem caused by dietary deficiencies, specifically scurvy (Mogle and Zias 1995:79). The fact that the scurvy had advanced suggests that these people may have tried other curative treatments, but none worked and trepanation was their last option. Perhaps the child died not from the trepanation, but from complications in the surgery due to scurvy. The authors state that there is some evidence that cribra orbitalia might have caused the bony changes on the skull (Mogle and Zias 1995:77), but they find the evidence for scurvy to be more compelling. In cribra orbitalia the bony changes in the eye orbits are proliferative, or increasing; however, in this skull, the bony changes are destructive, favoring scurvy (Mogle and Zias 1995:77).

Conversely, the individuals that show no evidence of skeletal pathologies could in fact be the sickest and died before their disease left a mark on the bone. The individuals with evidence of disease were the healthiest as they survived, avoided death and the disease was able to leave its mark on the bone. This is the osteological paradox, that often the sickest people show no skeletal lesion of disease as they died too quickly (Wood et al. 1992:345); these people could be mislabeled as individuals who were trepanned for cultural reasons instead of biological pathologies. Wood, for example, speculates a situation in which three subpopulations face risks that could increase the probability of death. The first subpopulation does not experience stress and, therefore, does not develop any bony lesions. The second subpopulation experience a mild form of the stress that lasts long enough to cause bony lesions, but few deaths, and these individuals who have these bony lesions survive. The third subpopulation undergoes a severe form of the stress that kills individuals quickly, before bony lesions appear. If these populations were examined archaeologically it would appear that instead of three groups, there are only two groups: those who are healthy and without bony lesions and those who are very stressed and have many bony lesions (Wood et al. 1992:345). The osteological paradox is a common problem in many bioarchaeological studies that study paleodemography.

Epilepsy

Epilepsy is a severe seizure disorder that many scholars think was likely to have been associated with trepanation. However, it is impossible to determine the presence of the disease from skeletal remains alone. In 1879, West was able to describe the case of a 14-year-old girl who suffered from traumatic seizures, possibly epilepsy. After a severe epileptic episode the girl was hospitalized and was unresponsive. The author, West, trepanned the patient and within two days, she was talking and within a week she was walking. Trepanation, in this case, was a

successful method to treat epilepsy (West 1879:28) and so we might hypothesize that severe seizures in the past were possibly treated with trepanation as well. An intriguing study by Stone and Miles (1990) describes several examples of trepanation from prehistoric Canada and the United States, which do not seem to be connected with evidence of any sort of pathological condition or injury. They argue that is possible that these trepanations could have been attempted to relieve headaches, epilepsy, or insanity (1990:1018).

When physical trauma is absent, disease appears to be a likely factor behind the practice of trepanation. The proposed diseases as causes for trepanation include tumors and lesions, bone marrow infections (osteomyelitis), periodontal disease, mastoiditis, cholesteatoma, scurvy and epilepsy. Tumors and other cranial lesions leave small indentations in the interior of the skull whereas osteomyelitis and periodontal disease eat away at the bone. Mastoiditis and cholesteatomas would cause pain near the ear and possibly intracranial pressure. Nutritional disorders such as scurvy would have caused intense facial pain whereas individuals diagnosed with epilepsy would have suffered from convulsions that ancient peoples may have attributed to demons or spirits. Many of these cases are of individuals who survived the procedure and possibly had very painful conditions that they had to deal with before and during the operation.

Trepanation for Cultural Purposes

Scholars are generally divided in how they think about the reasons for trepanation. Those who do not see it as biologically based tend to emphasize the cultural and religious reasons that might have been behind the practice. Unfortunately, it is much more difficult to support these types of explanations when the supporting data are lacking. Some of the cultural reasons suggested include trepanation to alleviate the presence of spirits inside an individual’s head or, when trepanation was performed postmortem, the use of powdered cranial bones as a curative

measure, and the use of cranial roundels as jewelry. Many cultural explanations are proposed for skull remains that show no evidence of disease, injury, or any other sort of paleopathological changes. Historians and archaeologists have suggested that perhaps these individuals were trepanned for magico-ritual, religious, and ritualistic reasons. Each of these will be discussed below.

Spirit Possession

It has been suggested that possession, by a demon or otherwise, was a reason for trepanation. Parry (1914) describes a man, from the late 19th century (location not documented) suffering hysterics and severe pain in the head, which led the patient to believe that there was a demon inside of him. During the operation the patient felt no pain, another supposed sign that he was indeed possessed by a demon. It is not stated whether the patient survived or not. Also, it is not stated whether or not the man suffered hysterics and pain after the surgery or if he was cured. Nonetheless, this example from the recent past does lend some credence to the idea that people who believe themselves possessed by spirits may have been treated with trepanation, though these individuals may also have exhibited biological symptoms that necessitated trepanation..

Other Possible Cultural Examples

Mallin and Rathburn (1976) discuss the case from the Iranian Iron Age II period (1100-800 BCE) of an 11 to 12 year-old boy, whose skull shows no evidence of depressed fractures, injury or disease (76). Since there is no biological evidence of the reason to trepan this individual, and given the fact that this individual is quite young, it is possibly part of a ritual or religious ceremony. As the authors also ask, however, why are there no other examples of trepanation found in the same population? Mallin and Rathburn (1976) say that if trepanation

was performed for therapeutic reasons, then which malady was the cause: subdural hematoma, headache, epilepsy or something else? There are three other possibilities: enlarged parietal foramina, fenestrae parietales symmetricae, and bilateral osteoporosis of the parietals. However, with further investigation of the skull the authors argue against these three possibilities and determine that this individual underwent a trepanation (1976:784). Mallin and Rathburn (1976) dismiss the diagnosis of parietal foramina because of the evidence of osseous regrowth around the parietal holes; this would not occur if these were enlarged parietal foramina (1976:785). The second diagnosis, fenestrae parietales symmetricae is not the correct diagnosis due to the presence of cut marks around the holes, ruling out this genetic anomaly. Finally, it is not bilateral osteoporosis because there is no increase in porosity or decrease in bone thickness (as seen from x-rays), which are two symptoms of osteoporosis on the cranial vault. In the end, it was concluded that this was an example of trepanation, though the reason for trepanation is unknown.

Post-mortem Ritualistic Modification

The following two descriptions support post-mortem trepanation, which suggest skulls were modified for ritualistic reasons. Ruffer (1918:91) and Oakley and colleagues (1959:93-96), for example, describe cranial bones being used as powerful religious objects that have curative powers in Medieval Europe. Ruffer briefly states that people thought powdered cranial bones had curative powers and that this belief continued up through the Middle Ages. In Gallic times (260-273 CE) bone roundels (or roundels) were worn as ornaments or amulets (Ruffer 1918:91). There is even some evidence of roundels being perforated so that they could be worn on a string or chain around the neck (Oakley et al. 1959:93-96). Cases where powdered cranial bones were

actually used were not discussed by Ruffer and there is no physical evidence, art or otherwise, presented that verifies people were wearing roundels of bones on their bodies (Ruffer 1918:91).

Parker and colleagues (1986) describe a skull from Medieval England with three unhealed holes, probably made postmortem, that were likely used to suspend the skull. They argue that this was probably a ritual act (1986:155). Another skull described by Parker and colleageues (1986) was buried with flints and charcoal. The covering of the head with flints and the burning and burial of charcoal is highly suggestive of ritual, but whether the trepanation in the skull was tied to ritual cannot be known (1986:155). The last skull they discuss is one in which the authors hypothesize that people were trying to extract the brain. The eating of the brain would certainly be a ritual act, if that was in fact what these people were doing; there is evidence of mutilation on the skull that might support this hypothesis (1986:155).

Hinsdale and Greenman (1936:12) hypothesize that many cases of trepanned skulls found in prehistoric Michigan were postmortem trepanations, and that the holes were used to suspend the skulls in a ritual or decorative manner. Fletcher (1882) also supports the cranial amulet theory. He states that often cranial bones were found showing evidence of holes, as if they were at one time worn suspended on a person (1882:6). M. Prunieres, a 19th century scholar of trepanation, believes that some of these pieces were used to make a drinking cup. He says that Norsemen used to drink out of the skulls of their enemies after victorious battles (cited in Fletcher 1992:6). Fletcher (1992:6) also reports that the ancient Roman historian Livy reported that the Gauls had this custom, as well (1992:6). While there is discussion from both ancient and modern historians of the use of skulls and skull roundels for ritual and ornamentation, no one provides first-hand accounts of people actually wearing roundels of bone on their person, or hanging these pieces of bones in their homes.

Diffusion

Diffusion is another idea that suggests that the practice of trepanation may have originated in one locale and diffused to another. Littleton and Frifelt (2006:149), for example, report on evidence of such diffusion from Oman to India. The authors argue that trepanation is a part of shared cultural heritage that moved from one place to another but was an independent invention in two main centers and then spread out from these centers. The authors argue that the practice began in the Oman peninsula and spread to India. The evidence for this is the distribution of trepanation throughout the world. In some areas, such as South America and England, there is a high incidence of trepanation, whereas in Australia and Asia it is not widely practiced (149). Brothwell (1994) argues that trepanation began in several loci and spread geographically from one or two areas. It is Brothwell's (1994:136) opinion that trepanation is too unusual a practice to have begun independently in several areas and therefore it is important to look at ways in which knowledge of trepanation may have spread (136). One theory is that Paleo-Indian peoples brought the surgical knowledge to the New World as they migrated. Another possibility is that the knowledge crossed into the New World much later, perhaps during pre-Columbian contacts with trans-oceanic voyagers, such as the Vikings (137). This idea is very difficult to establish, however, given the fragmentary nature of the evidence in most geographic regions.

Summary

There is strong evidence to suggest that in some places and time periods (Mesolithic, Neolithic, and Inca periods), trepanation was used to alleviate the cranial swelling resulting from war injuries. Numerous other cases document the association of trepanation with accidents. In

addition, there are many cases of diseases including osteomyelitis, scurvy, and mastoiditis that are associated with trepanation and it seems likely the procedure was used to alleviate the symptoms.

The non-biological theories are more difficult to evaluate. While some cases from the recent past document that individuals who believed themselves possessed by spirits were treated through trepanation, the absence of injury or disease is most often the only evidence cited as a reason to suggest that religion was the motivation for surgery. Evidence that post-mortem alteration of the skulls was done for ritual or adornment is also lacking. Nonetheless, this possibility cannot be ruled out. Given all of these many diverse explanations, often tied to individual cases from different places and time periods, it would seem important to first examine all existing case reports comparatively to look for patterns and associations before assessing the merits of competing explanations for trepanation.

Contemporary Cases

Bart Hughes is the founder of the modern-day trepanation movement. He advocates trepanation as a way to increase blood flow to the brain and coined the term "brain-blood-volume." According to Hughes, one's level of consciousness is directly related to the amount of blood in the brain (Bowen 1999). As babies, humans have a higher level of consciousness due to the fontanelle in the baby's skull that allows more blood to enter the brain. Hughes argues that once this fontanelle closes the amount of blood flowing to the brain significantly decreases. Additionally, walking upright pulls blood away from the brain resulting in a perpetual drain of blood (Bowen 1999).

Eventually, Hughes convinced several other people of the beneficial effects of trepanation, including Peter Halvorsen, the founder of the International Trepanation Advocacy

Group (ITAG). According to Halvorsen, trepanation cured his depression and gave him a permanent drug-free high (ITAG's website www.trepan.com). Including relief from depression, Halvorsen also argues that trepanation relieves anxiety and mood disorders as well as instilling feelings of freedom and serenity in the patient. Trepanation also gives one a richer emotional life, higher energy levels, and decrease in frequency and severity of chronic headaches though side effects could include injury or death from infection, stroke, brain damage, encephalitis, epilepsy, or brain abscesses (Frey 2005).

Should one want a trepanation, there are doctors who are members of ITAG will perform trepanation on any consenting adult over the age of 18. According to the medical proponents of ITAG, "Trepanation…restores the pulse pressure to the brain. The arteries and capillaries can expand again, filling with an increased amount of blood and displacing the same volume of water. A significant amount of energy, lost with adulthood, returns." (ITAG website, www.trepan.com). Between 40 to 60 Americans have been trepanned (Bjerg 2006).

However, the majority of neurosurgeons do not agree that there are benefits to trepanation. Although they all agree that a hole in the head is the first step in all neurological procedures, according to Dr. Robert Daroff, "it's just to gain access." (Bowen 1999). They also argue that this procedure is dangerous during the execution and after the procedure is finished. Once the procedure is over and the piece of bone is removed there is only a thin flap of skin between the brain and the environment (Bowen 1999).

The contemporary trepanation movement is not very popular. Most medical professionals do not condone it; however there are doctors who are part of the ITAG and who are willing to perform the procedure. Their patients argue that it is the most therapeutic method of achieving a permanent high, sharpening their senses. However, there are some individuals who

have been trepanned that say that it is an ineffectual, costly method. Trepanation, whether in the past or in the present, is performed for a number of reasons, though the purpose of contemporary trepanation seems to be the attainment of a permanent high.

Time and Geography

As discussed above, there is evidence of trepanation from all continents, excluding Antarctica, and the earliest evidence of trepanation dates to the Mesolithic. In most geographic regions trepanations date from various time periods.

Some overlap in time is observed inter-regionally. For example, trepanation in Denmark ranges from the Middle/Late Neolithic to the Early Roman Iron Age and in the Ukraine from the Mesolithic. In France the practice dates to the Early Neolithic and in Sweden dates range from the Early to the Middle Neolithic. Austria's La Tene period (450 BCE-1st century BCE) provides much of the trepanation evidence and Germany has just one case from 1753. Ireland's evidence is confined to range from the 5th/6th century CE to the 13th/14th century CE. Evidence from Hungary is strictly from the 10th and 11th centuries. Russia has evidence from the Mesolithic and the Medieval periods and Portugal's evidence ranges from the Neolithic to the Early Bronze Age. The Czech Republic only has evidence from 1298-1550 CE and Italy mostly in the Roman Imperial period. In England the practice spans the longest time from Neolithic to Early Saxon periods.

Evidence of trepanation from North America (Canada and the United States) was found on skulls dating from the Woodland Period to the Protohistoric period. The two skulls from Australia date to the same time period: 200-300 years ago, which is fairly recent as compared to most of the other evidence. Trepanations from the Middle East span the 4th millennium BCE to

the 1st century CE while evidence from Peru dates mostly from 2000 BCE to 1000 CE; Mexico's evidence is from an even narrower time period of Late Preclassic to 900-1000 CE. Canada's evidence ranges from Pre-Columbian to between 430-100 years ago. Evidence from Asia/Oceania comes from the Late Bronze Age up to the ethnographic present and Africa's from the Neolithic to the ethnographic present, as well.

Given that trepanation is widespread geographically and that it spans a long period of time, we might expect to find some common factors involved in its practice. On the other hand, the fact that the specific time periods of its use vary by geographic region, it could be that the reasons for the procedure also vary by region and time period as well. The first step in beginning to determine the influence of geography and time period on the practice is a comprehensive assessment and review of all known cases so that comparisons can be made and conclusions drawn.

Summary

Theories about reasons for trepanation vary greatly as do the types of supporting evidence provided. Some literature (Aufderheide and Rodriguez-Martin 1998:32) suggests magical reasons such as the release of a demon or spirit as well as medical reasons such as a therapeutic cure for a cranial malady. Magico-therapeutic theories view trepanation as a way to release a spirit that causes maladies associated with the head such as headaches, vertigo, coma, delirium, convulsions, etc (Aufderheide and Rodriguez-Martin 1998:33). Magico-ritual theories are often proposed for skulls that show no evidence of disease, injury, or other pathologies. These might also include skulls that were trepanned post-mortem (Aufderheide and Rodriguez-Martin 1998:32).

The most common hypothesis surrounding trepanation is that it was performed as a surgical treatment (therapeutic) in cases of skull fractures. Jorgensen (1988) and Bennike (1985) are proponents of this theory. Another hypothesis is trepanation was performed in cases of severe disease including scurvy (Mogle and Zias 1995), bone tumors and meningiomas (Smrcka et al. 2003; Mariani-Costantini et al. 2000), headaches and seizures (West 1879 and Margetts 1967) and chronic ear infections (Mann 1991). Most of these authors are able to provide some actual physical evidence to support their contentions about trepanation, thought this does not necessarily mean pathological and cultural reasons are mutually exclusive.

This thesis collects and reviews all of the cases of trepanation reported in the English-language scholarly literature to look for overall patterns that might lend credence to one explanation or another and to examine temporal and geographic variation to see if certain explanations make more sense in particular contexts. This study is of potential significance because it establishes a baseline review of all cases that others can use to draw conclusions about the reasons for this fascinating practice worldwide or in specific localities. There are four questions that are answered in the following sections: Are more men than women trepanned because men are more likely to be involved in warfare as the literature suggests? Is there any evidence to support cultural explanations or is this a residual category used for when skeletal remains show no evidence of pathology? A third question is whether or not there is any evidence to support the theory of diffusion, namely that trepanation originated in one or two centers and then diffused to other areas. And lastly, is there any cultural evidence to support subadult trepanation or only biological evidence?

Material and Methods describes how this project was organized and how the research was carried out. Results of the project will be discussed as a total population as well as in

separate geographic/culture areas. Finally, the Discussion section will tie everything together and draw out patterns in the data.

Chapter 3-Materials and Methods

The main objective of this project was to undertake a comprehensive review of the existing literature on trepanation by locating as many primary case reports of the practice as possible. A second objective was to examine these case studies and code them for basic demographic and biological data. A third objective was to determine the geographic location and cultural group associated with the individuals in each case report. The final objective was to analyze these data sets for correlations between the practice of trepanation and any of the above variables. It was expected that such correlations may only occur within particular time periods or geographic/cultural regions.

Data Collection

In order to meet these objectives a two-step process was designed. The first step was to obtain as much of the available primary published literature on trepanation as possible. Online search engines, ECU libraries, as well as Interlibrary Loans (ILL) were used to obtain literature. Key phrases such as 'trepanation', 'trephining', 'ancient cranial surgery', and 'ancient trepanation' were used to search through these online library search engines. When the articles were received, the bibliographies were searched to obtain additional reports. Articles that were in Spanish were also included as I am proficient in reading Spanish. The search attempted to include all time periods, all geographic locations, and all populations. However, articles in languages other than English and Spanish were excluded from this study. Since only English and Spanish language articles were used a lot of data from around the world is missing. Articles in other languages may have data that influence the sex and age distribution as well as factors

that affect the purpose of trepanation. Also missing are unpublished studies, cases of trepanation in museums or museum storage, and also the unknown amount of cases of trepanation that have yet to be discovered. It is unknown whether or not these cases would affect the results of this study. Then the same search was carried out for books and the bibliographies of these books were searched to see if there were any more relevant sources available. A total of 70 articles and one book were used. A complete bibliography is located in Appendix C.

The second step in data collection involved organizing and recording information in all cases of trepanation reported in the literature. There were 293 cases of trepanation recorded from this literature. Once all the articles with relevant case information were found these were divided into geographic regions and then further subdivided into countries. This was done to group cases that were in close proximity so that geographic patterns could easily be discovered. In Europe, these data were organized by country: Ireland (8), United Kingdom (44), Denmark (18), Portugal (18), Spain (8), France (1), Italy (5), Austria (6), Hungary (21), the Czech Republic (1), Germany (1), and Sweden (1). The European cases were grouped into the following areas: Scandinavia, Eastern Europe, Western Europe, and the North Sea area.

In North America, these data were organized into Canada and the United States. Canada was then divided into British Columbia (15) and Ontario (3), and the United States was divided into the Eastern US (13 cases from Wisconsin, Illinois, Michigan, Georgia, Maryland, and Connecticut), which is defined as east of the Mississippi river, Central US (two from Arkansas and South Dakota), which is defined as west of the Mississippi and east of NM, CO, WY and MT and Western US (11 from New Mexico, Washington, California, and Alaska), which is defined as NM, CO, WY, and MT to the west. Central America includes cases from Mexico (38) and Belize (1), and South America was separated into Bolivia (1) and Peru (25). Africa was

separated into South Africa (6), Egypt (2), and Guinea (1) (these were the only areas where cases were found). Cases for the Middle East were reported from Iran (1), the Palestine (3), Jordan (2), the Sinai Peninsula (1) and Jericho (7); and there were various Eastern European case reports from Russia (5), Latvia (1), Siberia (5) and the Ukraine (7). Finally, Australia (2) was a separate group and Asia (10) and Oceania were grouped together due to proximity; the islands of Oceania with case reports included Melanesia (3), New Britain (2), and New Ireland (1).

Cases were also subdivided by time periods, when remains were dated. These findings are reported in the results section. It is important to note that 287 cases come from past time periods, while 6 reports are classified as from the "ethnographic present," meaning researchers, traders or missionaries actually observed the practice at some point in the late 19th century through the 20th century. The majority of the case reports from the ethnographic present come from Africa and Asia.

The next step was to code each case for the primary demographic and biological variables reported. A standardized checklist was used for each case (see Appendix A). The demographic variables that were coded include biological factors, sociocultural factors, and archaeological context factors. Biological factors include location, size and shape of the opening; age and sex of the patient; presence/absence of pathology and disease; presence of injury; and presence/absence of dental disease, developmental disorders, and nutritional disorders. Sociocultural factors such as the culture of the people in the area, the approximate time period from which the remains came, subsistence patterns, stratification and political systems, presence of warfare, body modification practices, ethnomedical or religious practices, and kinship systems were included. The archaeological context, such as location of the site, associated artifacts, dating methods, tools used during the surgery, and time period of the burial were also recorded.

Not all cases had all the information; spaces were left blank if there was no information for a particular factor.

Data Analysis

Once all the data were separated by geographic region, they were analyzed primarily to investigate relationships between age, sex, and region of the skull in which surgery was performed. The first analysis performed was to determine the counts and frequencies, according to the trepanation cases, of sex, age, location of the wound, shape and presence of healing within geographic areas. Tables were created showing the relationships between age, sex, and location of the surgery on the skull by geographic region as well as the relationship between age, sex, and time period within geographic regions (see Results Chapter). Finally, the total population (see Results Chapter) was analyzed and the age, sex, location, shape and presence of healing percentages were determined. Relationships between these variables are presented in the Results Chapter. The significance of the information presented in the Results Chapter will be discussed in the Discussion Chapter.

Chapter 4-Results

To fulfill the previously stated objectives a total of 70 articles and one book was examined to yield 293 pertinent cases that were included in this report. The variables that were recorded from these cases included age at death, sex, location of trepanation on the skull, shape of the trepanation, method used to create the trepanation, and the presence of absence of healing. Thirty-seven individuals had more than one trepanation on their skulls.

General Population Results

When estimating the sex of an adult two areas of the skeleton are predominately used: the skull and the pelvis. Generally, male skulls are more robust, have more prominent supraorbital ridges and glabellar regions, as well as robust temporal and nuchal lines. Male skulls have larger mastoid processes, larger sinuses, and larger occipital condyles than females. Males have squarer chins than females (White and Folkens 2005). However, in many of these reports the method used for sexing the individuals is not described. For individuals that have both the skull and pelvis intact several methods are used to sex the individual. To sex the pelvis an investigator can look at the sciatic notch, presence or absence of a ventral arc, and subpubic concavity. Investigators may have relied on some or all of these methods. In this sample the sex of 215 out of 293 individuals were reported by the researchers. Of the 215 individuals, 52.9% (155) were male, 20.45% (60) were female, and 26.62% (78) of the individuals' sex was indeterminate.

It is more difficult to estimate the age at death of skeletal remains. There are numerous ways to determine age-at-death from using the teeth (mostly for subadults) to the fusion of the cranial sutures, which can be a bit unreliable. Ubelaker (1978) created a dental development chart, using a Native American sample, which is used to determine reliable ages to about 21

years. Adult age can also be estimated from cranial suture closure though this method should be combined with other age-determining techniques. However, in a study done by Krogman and Iscan (1986) it was found that the sphenooccipital suture is quite reliable in its closure, as at least 95% of individuals have fusion here between 20 and 25 years of age. Estimation of adult age can also be determined from epiphyseal closure. The fusion of epiphyses to diaphyses happens in a specific order, but the ages for these fusions can vary individually as well as by sex and population. For example, the medial epiphysis of the clavicle fuses between 21 and 25 years of age, whereas the ischium fuses around 17 years of age (Krogman and Iscan 1986:146). However, the most widely used method of aging an adult is from the pubic symphysis surface. There are two methods that are widely used: the Todd method (Todd 1920: 467-470) and the Suchey-Brooks method (Brooks and Suchey 1990: 227-238). Both methods use the topography of the surface, the margins of the surface, as well as any porosity or bony growth on the surface. The auricular surface of the ilium can also be used to age an individual (White and Folkens 2005). Investigators most likely used any or all of these in their analysis. Only 209 out of 293 individuals' age-at-death were determined. The bulk of the sample was 30 years or younger or simply categorized as "adult." For a chart comparing sex and age for the total sample see Table 1.

The shape of the trepanation is probably related to how the trepanation was created on the skull. If a grooving method was used it is mostly likely that the shape of the trepanation would be a square or rectangle as those are mostly easily produced by this method. Scraping across the surface of the skull would produce a circle or oval, as would drilling in the skull. However, only 79 cases included a report of the method used so it is difficult to relate the method to the shape. When possible, I examined the photographs of the skull to determine shape; however, if there

were no photographs of the trepanation then I relied on the author's description of the shape of the trepanation. The most common shapes present on the skulls included ovals and circles (37% and 41.4% respectively). Rectangles, irregular shapes, triangles, linear cuts, and incomplete openings are 8.13%, 2.44%, 1.63%, 3.66%, and 1.22% respectively. The following shapes were each less than 1% of the total sample: semicircle, v-shapes, polygon, cup-shaped, heart-shaped, trapezoid, urn, saucer, and hexagon-shaped. The most common method used was scraping (54.4%) and drilling (21.5%). Cutting, sawing, grooving and boring were each 10.1%, 3.79%, 7.59%, and 2.53% respectively. For a comparison between sex and shape see Table 2.

There is not a lot of variation between the number of trepanation openings on the left or right side of the skull. The left side, 118 cases, (36.6%) was more popular than the right side, 94 cases, (29.2%) but the percentage of unsided openings, 110 cases (34.2%) was higher than the percentage of the right side. The right parietal, 73 cases, (22.7%) was trepanned more often than the right frontal, 21 cases, (6.52%) or the right temporal, 1 case, (0.31%), similarly with the left side: the parietal, 79 cases, was trepanned more frequently (24.5%) then either the frontal, 31 cases, (9.63%) or the temporal, 7 cases (2.17%). The occipital, 20 cases, was the trepanned bone in 6.21% of the reported cases. Craniometric points lambda, 11 cases, (3.42%), bregma, 14 cases, (4.35%), and obelion, 2 cases, (0.62%) were trepanned at a low frequency. The sagittal suture, 28 cases, (8.70%) and the coronal suture, 9 cases, (2.8%) had higher frequencies of trepanation than the craniometric points. There is also evidence of unsided frontals, 13 cases, (4.04%), unsided parietals, 12 cases, (3.73%), and unsided temporals, 1 case, (0.31%) being trepanned.

There is a relationship between shape and method; it appears that drilling and boring create circular openings whereas scraping would create oval or oblong openings. Rectangular

shapes are efficiently created by the grooving and cutting methods. Additionally, the location on the younger individuals who were trepanned and the older individuals who were trepanned is not as widely varied as the middle-aged individuals.

Healing is an important factor as it tells us whether or not the individual survived the surgery. If there is substantial healing then we can assume that the individual lived for years afterward. According to White and Folkens (1991:23-25) if there is some bone remodeling then we can assume the individual lived for a few months after the surgery. If there is no bone remodeling then the patient either died in surgery, shortly after, or a few days after surgery. Bone begins healing itself immediately after injury has occurred. When the bone is fractured broken blood vessels in the bone leak blood into the fracture which forms a hematoma which coagulates as the blood vessels are sealed off. As the blood coagulates and forms a hematoma, a bump or callus begins to form on the outer layer of the bone, called the periosteum. This callus holds the two pieces of the bone together. Osteoblasts, bone cells that create bone, turn the callus, which consists mostly of fibrous tissue, into woven bone. This process takes about six weeks. The woven bone is then transformed into lamellar bone. Depending on how well the two pieces of bone fit together during the healing process evidence of fracture may not be observable to the naked eye (White and Folkens 2005).

There were 113 (79%) instances of trepanation that showed evidence of healing. In Eastern Europe there are eight documented cases of healing; all the cases from Hungary and the Czech Republic show evidence of healing. In Western Europe, eighteen cases show evidence of healing; most cases from Italy and Portugal and all of the cases from Austria, Spain, and France. There is no documented evidence of healing from Sweden but twelve out of the eighteen cases from Denmark show evidence of healing. The North Sea area only presents evidence of healing

of ten out of fifty-two cases from this region. Fifteen out of eighteen cases in Canada show evidence of healing, and eleven out of twenty-six cases from the United States show evidence of healing. About one-third (12) of the thirty-eight cases from Mesoamerica show evidence of healing compared to half (13) of the twenty-six cases from South America showing evidence of healing. In Africa four (out of nine) cases show healing evidence. One-third (5) of fourteen cases from the Middle East present evidence of healing, both cases from Australia show healing evidence, and only three (out of ten) cases from Asia show healing evidence. Most cases that report the presence or absence of healing describe bone remodeling indicative of healing processes and survival.

There are patterns in these factors that are more easily observable if the individuals are separated into culture areas. The objective is to examine the separate geographic patterns in terms of types and techniques by culture area and time period. Culture area was determined by geography; sites that were in the same country or in the same continent (i.e. Peru, Europe, Africa) were grouped together as outlined in the previous chapter.

Results by Geographic Region

Europe

Eastern Europe (see Table 4)

The Eastern Europe geographical area includes the countries of Ukraine, Latvia, Russia, Siberia, the Czech Republic, and Hungary. There are a total of 39 cases from this region. Out of the 10 cases that reported the presence of absence of healing, 8 showed evidence of healing. Twenty-seven out of the thirty-nine (69%) were males, eight (20.5%) were females, and four

(10.2%) were unsexed individuals. The ages ranged from 11 to 65+ with most of the individuals (27/69.2%) aged at 50 years or younger.

The most interesting, anomalous individuals come from a sample (21 cases) from Hungary; all the cases are from the 10th and 11th centuries, and 15 (71.4%) of the individuals are male. Of the trepanations, 18 or 76.9% are on the parietals and two individuals have multiple trepanations. The scholars who conducted the research suggest that trepanation was performed to treat injuries sustained in warfare (Derums 1979:462), possible tumors (Smrcka et al. 2003:327-8) and/or to treat possible infections (Nemeskeri et al. 1965:349), from these warfare injuries. The high percentage of males in this sample adds credence to the hypothesis that these individuals were trepanned due to warfare injuries since only males would have engaged in these acts. Out of the eight females in this sample only two have evidence of pathological conditions on their remains. One female shows evidence of hypervascularization and periostitis on the long bones as well as dental caries on seven out of her remaining 20 teeth. The other female has evidence only of dental abscesses, which would have been quite painful and quite possibly necessitated trepanation. Additionally, the ages are spread out instead of being confined to a particular age group; this is true for both females and males. For the whole sample the time period ranges from the Mesolithic to the 16th century AD, with a concentration in the 10th and 11th centuries AD as well as in the Early Bronze Age (see Table 4). Warfare and infection are not confined to one specific time period, therefore any and all of these hypothesis could correlate with the time periods reported in this area.

In Eastern Europe there is evidence of skeletal pathologies and/or injuries on fifteen individuals. Injuries found on the individuals include cranial fractures, wounds, cut marks, depression fractures on the frontal bone, and glabellar trauma. Skeletal pathologies on these

individuals include arthritis, frontal sinus inflammation, dental caries, periostitis, Schmorl's nodes, degenerative arthrosis, antemortem tooth loss, and ossification of the xiphoid process and sternum as well as the ossification of T11 and T12. One individual, a male from Latvia, had multiple trepanations.

Western Europe

The sample from Western Europe includes the countries of Portugal, Austria, Italy, Spain, France and Germany. This culture area has a total of 39 cases of trepanation. The cases are mostly spread out between Portugal, Austria, Italy and Spain; France and Germany only have one case each. Out of the 39 cases 27 (69%) are male, two (5%) are female, and ten (26%) are unsexed. The only documented females are from Spain. The ages ranged from 5-6 to 65+ with a large majority (24/61.5%) of the individuals 45 years or younger. Out of the 38 trepanations in this area, fifteen are on the right parietal (39.5%). The remainder were found on the left parietal (10/26.3%), left frontal (3/7.89%), sagittal suture (3/7.89%), and unsided frontal (2/5.36%); the left temporal, right frontal, unsided parietal, occipital and lambda each had one case (2.63%). This either suggests warfare injuries (since most people are right-handed, injuries would be found on the left side), or that possibly this was the easiest for the surgeon.. The time periods of these cases range from Neolithic to Early Bronze Age in Portugal, France and Austria, and during the Roman Empire in Italy. Germany's single case is from 1753 (see Table 2). Investigators from Italy suggest trepanation was performed to treat possible cranial fractures (Capasso and Capelli 1992:104) and cranial tumors (Mariani-Costantini et al. 2000:306).

Only six individuals in Western Europe showed evidence of either injury or skeletal pathologies. Injuries include frontal depressions and fractures whereas skeletal pathologies include osteitis, inflammation, and hyperostosis. Four out of the geographic sample had multiple

trepanations; one male from Neolithic France, an older adult male from Portugal, a young adult male from Bronze Age Portugal, and a 50+ individual of unknown sex from Bronze Age Portugal.

Scandinavia

The majority, (18, 94.7%) of Scandinavia's cases come from Denmark; Sweden only has one case. Out of the 19 cases 15 (79%) are males, one (5%) is female, and three (16%) are unsexed individuals. The age distribution ranges from 18 to 55 with concentrations in the 26-30 age group and 41-45 age group. The sample is mostly from the Middle/Late Neolithic and Bronze Age (see Table 3). The majority (9/47.3%) of the trepanations are on the left parietal and 85.7% (12 cases) show evidence of healing. Possible explanations include axe wounds (Bennike 1985, 70) or other sharp force trauma causing fractures of the skull cap and splanchnocranium (Bennike 1985, 97), or facial skeleton (White and Folkens 1991, 45).

Five individuals in Scandinavia showed evidence of cranial injuries, but no skeletal pathologies. These injuries include blunt force trauma, slash marks, and sword cuts. Two individuals had multiple trepanations.

North Sea Area

The North Sea area includes the countries of England and Ireland. Between the two countries there are 52 cases, the majority (44/84.6 %) being from England. Twenty-eight (54%) are males, five (9.6%) are female, and nineteen (36.4%) are unsexed individuals. The ages range from subadult to 65+ with concentrations in the 18-35 and 46-50 age groups. The majority of the trepanations are on the right (17.4%) and left (37%) parietals. The sample from Ireland is

concentrated mostly in the Medieval period (5th century to 14th century) whereas the sample from England is spread out from the Neolithic to Early Saxon periods (see Table 4). Out of the 13 cases that reported absence/presence of healing 10 (77%) showed evidence of healing. Speculation as to why trepanation was performed on these individuals include intracranial pressure and religious/ritualistic practices, such as suspension of skull for decoration (Parker et al 1986, 155), possible warfare injuries (Parker et al 1986, 145) and periodontal disease (McKinley 1992,339). Several of these individuals were unsexed, though there were two males (17-25 and 60+ years) and one elderly female. One particular individual, male, age indeterminate, from the Neolithic period was burnt. Whether this burning was part of a ritual or accidental is unclear.

In the North Sea Area fourteen individuals had evidence of skeletal injuries and/or skeletal pathologies. Wounds to the frontal bone, decapitation, depression fractures, and linear incisions are examples of skeletal injuries. Pathologies and diseases include ankylosing spondylitis, septic periostitis, and inflammation of the bone, dental abscesses, Schmorl's nodes, osteoarthritis, dental caries, periodontal disease, porotic hyperostosis, antemortem tooth loss, and osteitis. Five individuals had multiple trepanations.

Canada

The sample from Canada includes the territories of Ontario and British Columbia. Out of the 18 cases from this area, 9 (50%) are male, 6 (33.3%) are female, and 3 (16.7%) are unsexed individuals. The ages are spread out from subadult to 65+ with concentrations in the subadult age group, 18-25 age group, and 41-45 age group. The trepanations were mostly found on the occipital bone in this area, with a few instances on the left frontal and parietal bones. Fifteen (83.3%) out of the 18 cases show evidence of healing. All of these trepanations date to Pre-Columbian time periods except for the three in Ontario which date to the 1600s-1800s (see Table

8). Only two individuals from Canada show evidence of cranial injuries; the only injuries documented in this area are two instances of arrow wounds. Only one individual had multiple trepanations.

Investigators propose different reasons as to why trepanation was performed. Kidd (1930:86) analyzed a case from Ottawa and concluded that trepanation may have been to treat gliomas, small malignant tumors that are slow-growing, while Stone and Miles (1990:1018) indicate that rituals performed by shaman to cure headaches, insanity, and epilepsy may have been important in religious ceremonies or medical treatment.

United States (Native North America)

Eastern US

There are 13 cases from the Eastern US: 53.8% (7 cases) are male, 7.69% (1 case) was female, and 38.5% (5 cases) were unsexed individuals. The ages were concentrated in the 25 and younger age group and the 65+ age group. The majority of the trepanations were on the unsided parietal (3/23%) and unsided frontal (3/23%). All 6 cases that reported presence/absence of healing showed evidence of healing. All cases from this region are prehistoric. Powell (1970:733) analyzed a case from Connecticut and stated that it was possible that trepanation was performed to cure a cyst or tumor while Hinsdale and Greenman (1936:12) suggest that the practice was performed for ritualistic reasons on remains from Michigan. No individuals from this geographic area show evidence of injury or disease on the skeleton.

Central and Western US

There were only 2 cases reported from the central US. One individual was male, the other unsexed. The male was between 30 and 34 years of age, with a trepanation on the left frontal, which showed evidence of healing. All cases from this region are prehistoric. One individual had evidence of antemortem loss tooth.

The Western US yielded eleven cases, three (27.3%) were male, two (18.2%) were female, and six (54.5%) were unsexed individuals. Only four of the eleven had recorded ages which ranged from 31-35 to 65+. The majority of the trepanations, six (75%), were on the right side (frontal and parietal), and out of the seven cases that reported the presence/absence of healing, 57.1% (4 cases) showed evidence of healing. According to two research reports, it is possible that trepanation was performed to relieve intercranial pressure (Science News Letter 1935, 377) or to relieve some sort of pathological condition (Shapiro 1927:267). The time period for all sites in the United States was pre-Columbian, with most dating to the Woodland Period (see Table 9). Three individuals from the Western United States presented with sinus pericranii (a vascular anomaly), occipital flattening, and lesions on the cranial vault.

Mesoamerica

There are 39 cases reported from this geographical area; thirty-eight from Mexico and one from Belize. Of these, 31% (12 cases) are male, 54% (21 cases) are female, and 15% (6 cases) are of unsexed individuals (see Table 10) This is an unusual case, where the percentage of trepanned females is appreciably greater than the percentage of trepanned males. Additionally, the majority (18/46.1%) of the cases are subadults and individuals in the 26-30 age group, although the age-at-deaths of the whole sample ranges all the way up to 65+. The right, 18 (34%), and left, 12 (22.6%), parietals have the majority of the trepanations located on them.

Twelve (85.7%) out of the fourteen cases that reported presence/absence of healing showed evidence of healing. The time period for these cases ranges from Preclassic (about 400 BCE) to 900-1000 CE (see Table 10). The sample from Mesoamerica is largely female. None of these females show evidence of injury, only evidence of infection, arthritis and osteitis. This is quite different from the other geographical samples as they are mostly male. The significance of this large female sample from Mesoamerica will be discussed in the Discussion chapter.

Wilkinson (1975:838) suggests that treatment for injury was likely for remains found in the southern Mexican highlands. Alternatively, Velasco-Suarez and colleagues (1992:313-319) suggests that a possible brain tumor as well as relief from cranial pressure causing headaches may have been the reason to perform trepanation (1992:313-319). Ten individuals had multiple trepanations. One individual was unsexed and unaged. Three were male: one from 500-750 CE, aged 20-25; the second from around 650 CE, aged 30 years; and the third from 500-750 CE, aged 40 years. The remaining six were female. One young adult from 500-750 CE; the second young adult female from the Late Classic period; the third adult female from 100-200 CE; the fourth female, aged 21-35 from 900-1000 CE; the fifth female, aged 21-35, from 500-750 CE; and the final sixth female, aged 25-30, from the Classic Period. Fourteen individuals from Mesoamerica display evidence of injuries and disease. Injuries in this group include depression fractures and frontal depressions. Skeletal pathology in Mesoamerica includes necrosis of the sternum, osteitis, acute osteoporosis, infection, periostomata, and dental abscesses.

South America

The two areas where there are reported trepanations are Peru and Bolivia. Bolivia only has one reported case. Out of the 26 total cases, nine (35%) are male, three (11.5%) are female,

and fourteen (53.5%) are unsexed individuals. The few cases that reported ages were mostly recorded as "adult" or 65+ years. Peru's cases were spread out between the right frontal, 3 (9.68%), the right parietal, 3 (9.68%), the left frontal, 5 (16.1%), the left parietal, 3 (9.68%), the left temporal, 2 (6.45%), the occipital, 3 (9.68), the craniometric points of lambda, 1 (3.22%), and bregma, 3 (9.68%), the sagittal, 4 (12.9%), and coronal sutures, 1 (3.22%), and unsided frontal, 2 (6.45%), and temporal, 1 (3.22%) bones. A large variety of location on the skull is quite rare. This could have something to do with the larger sample in South America as opposed to the other areas, but it also might relate to the ancient Inka medical knowledge and well-known incidences of warfare. Out of the eighteen cases that documented the presence/absence of healing, thirteen (72.2%) showed evidence of healing. The age and sex of several individuals who showed evidence of healing were undocumented. There is one documented case of a female of advanced age and undocumented time period. She has two trepanations and her wounds are completely healed. The rest are male. One male is from 900-1000 CE (undocumented age) with smooth margins on the opening. The second male is middle-aged from an undocumented time period; he sustained seven trepanations and all showed evidence of healing. The final male was of advanced age from an undocumented time period that also exhibited a deep fracture.

Three individuals had multiple trepanations: two of the individuals with multiple trepanations have been described above; the third individual is a prehistoric middle-aged male who showed evidence of mild dental attrition and porosity surrounding the trepanation openings. One individual had seven trepanations ranging in size from 43mm to 26mm in diameter all over the skull: frontal, parietal, temporal, and near bregma. These cases ranged in time from 2000-1200 BC to 900-1000 CE (see Table 11). Only five individuals from South America showed evidence of skeletal pathologies or injuries. These include frontal sinus inflammation, osteitis,

spinal degeneration, bipartite patellae, internal porosity, dental caries, dental attrition, and one case with a depression fracture.

Africa

Africa has evidence of modern and prehistoric trepanation. In an article by Margetts (1967) three modern cases are described, all male, all involved in traumatic head accidents. All three survived (cases described in Literature Review) (Margetts 1967:684-691).

The prehistoric cases come from Egypt, Guinea, and South Africa. Out of the nine cases reported here, six (66.6%) are female and three (33.4%) are male. Only three of the ages are reported (18-35), and the majority of the trepanations are located on the right (33.3%) and left (25%) parietals. Four (80%) out of the five cases that reported presence/absence of healing showed evidence of healing. The time period for these cases range from Neolithic to 1st century Roman (see Table 7). Speculation as to why trepanation was performed here includes treatment for epilepsy (Drennan 1937:189) and treatment for depression fractures and head injury (Margetts 1967, 678).

Seven individuals from Africa display skeletal injury and skeletal pathology including depression fractures, gashes in the skull, and cut marks. Pathologies include linear enamel hypoplasias and pitting on the cranial vault. In one individual the nasal septum was right-skewed which could be congenital or due to an injury; there was also evidence of skull flattening. One individual, from the prehistoric group, had multiple trepanations.

Middle East

The Middle East yielded cases from Iran, Jordan, and the city of Jericho. There were 14 cases total; six (42.8%) were male, two (14.3%) were female, and six (42.8%) were unsexed

individuals. The ages ranged from 11 years to 65+ years. Most of the individuals were 50 years or younger. Eleven (55%) cases of the trepanations were located on the right and left parietals. Six cases reported the presence/absence of healing and five (83.3%) out of these six cases showed evidence of healing. Four of the five were male. The first male, aged 35-45, is from the Bronze Age and showed evidence of healing indicating survival of several years. The second male, same age, is dated to the 4th millennium BCE. The third male, aged 40-50, dates to the 1st century CE and shows some regeneration at the trepanation opening. The fourth and final male, same age, dates to the same time period. The fifth individual, a subadult aged 11-12, is from the Iron Age II period (1100-800 BCE). This individual shows evidence of osteitis. The time period for these cases ranges from the 4th millennium BC to the 1st century AD (see Table 10).

There are three individuals from the Middle East that are worth mentioning. The first individual, a 35-40 year old male, was from the 4th millennium BCE. He had two trepanations, both on the right side near bregma. There are no injuries or skeletal pathologies present on the skeleton, though the facial region is twisted to the right, perhaps a congenital condition. The second individual is dated to the Middle Bronze Age and is an 8 to 9 year old juvenile. This juvenile shows exacerbated conditions of scurvy, the mandible completely edentulous as well as alveolar absorption. The last individual is another juvenile, dating to the Iron Age II period, aged 11 or 12 who presents with osteitis near and around the trepanation site. There is evidence of bone regeneration showing that the juvenile survived the operation.

Four individuals had multiple trepanations, two males, two females. The first male is aged 20-30 years and dates to the Bronze Age; he has trepanations on the frontal and right parietal. He also shows evidence of dental caries and periodontal disease. The second male is aged 35-40 and is dated to the 4th millennium BCE; he has evidence of trepanation on the parietal

near bregma and on the right parietal near the coronal suture. The first female is 25-35 years and dates to the Roman period (1st century AD). She shows evidence of periodontal disease and has two trepanations to the left of the sagittal suture on the left parietal. The second female is aged 35-45 and dates to the Bronze Age. She has three trepanations, one on the left parietal and two on the occipital. Nine individuals presented evidence of pathology, but there were no skeletal injuries. Dental caries, periodontal disease, inflammation, tibia osteitis, antemortem tooth loss, alveolar resorption, cribra orbitalia, and scurvy are the pathologies from this geographic area.

Mallin and Rathburn (1976:782) analyzed cases from Iran and proposed that trepanation was performed to treat fractures. Zias (1982:55), on the other hand, discusses a case from Jericho where periodontal disease was also present and may have been a factor for the trepanation. Finally, Mogle and Zias (1995,:77) analyzed subadult remains from Israel and based on bone resorption concluded that scurvy was present and may have led to treatment by trepanation. One researcher (Littleton 2006) discussed a possible case of diffusion as reason for trepanation. These cases are from Oman and date to the Hafit period (3200-2600 BCE). Littleton (2006:149) argues that since the idea and practice of trepanation is part of a shared cultural heritage then it is possible the idea began in one or two areas and then spread out from these areas.

Australia

Webb (1988) describes two cases from Australia. Both were female, possible Aborigines, as they are dated to around 200-300 years ago (see Table 12). These skulls were discovered by Webb in different collections that were created during a paleopathological survey of Australian Aboriginal skeletal remains that was carried out in 1983. There is no record of when they were found or who found them. Both trepanations show evidence of healing; one trepanation is on the right parietal and the other on the sagittal suture. The shape of the

trepanations is not consistent with any weapons associated with fighting so there is a lack of evidence that these skulls were related to combat injuries. The two individuals from Australia only show evidence of grooving, which could be connected to the trepanation procedure. The author does not believe that there is ethnographic evidence for the practice of trepanation among the Aborigines since there are only two skulls that exhibit such a practice.

Asia and the Pacific Islands

Out of ten skulls, 80% were male, 10% were female, and 10% were unsexed. The only recorded ages were "adult" and the trepanations were located all over the skull. There are 13 individual trepanations (some individuals have more than one trepanation): right (2/15.3%) parietal, left frontal (4/30.7%) and temporal (1/7.69%), occipital (3/23%), the coronal suture (1/7.69%), and the craniometric point of lambda (2/15.3%). Three (out of five reported) showed evidence of healing and two individuals had multiple trepanations. Four individuals show evidence of skeletal pathology or injury including inflammation of the cranial vault, disease in the right frontal, and skull fractures in the cranial vault.

Asia and Oceania are areas where there are both modern and prehistoric cases of trepanation. The individuals from Asia who were trepanned in modern times were most likely trepanned due to injuries from sling-stones, which can cause a cranial hemorrhage (Crump 1901:167). The three semi-contemporary cases from the South Seas include three males, reported by Crump on his visit there in the early 20th century. The first male of undocumented age was struck by a sling-stone; after trepanation he never regained consciousness and subsequently died. The second survived for seven years after the trepanation; and the third had the operation to cure headache. Crump (1901: 167), who previously authored an article on

native surgery on this area, was in the South Seas area doing research when he spoke with inhabitants who witnessed the three trepanations and he subsequently recorded them.

An adult male from 5th to 3rd century Mongolia had seven trepanations ranging in size from 5mm long to 23mm long. These seven trepanations were spread over the skull but were most concentrated on the left frontal and the lambdoid suture. The four prehistoric cases are from the 5th-3rd century BCE Mongolia (see Table 9). All of these individuals are male and all categorized as adult. Two of these individuals have multiple trepanations; one male showed evidence of seven trepanations. Two of the prehistoric individuals had multiple trepanations.

Summary

Most of the individuals trepanned were males, as previously observed. The two most common age ranges of trepanned individuals is "adult," between 18-30, and older than 55 years. The left parietal is the most commonly trepanned bone and the craniometric points and sutures are the points on the cranium that are least commonly trepanned. There is a wide variety of trepanation opening shapes ranging from common ovals to trapezoids and heart-shapes. The most common shape in this total sample is the circle (41.4%), the oval (37%) follows close behind. Over three-quarters of the sample show some sort of evidence of healing and thirty-seven individuals have more than one trepanation opening. Only 79 cases mention the method used to trepan the individual and out of these the most common method is scraping, which may or may not be related to the most common shape of the trepanation. Scraping is most likely the easiest method to open the skull without killing the patient. Other methods include cutting, drilling, sawing, grooving, and boring. There are patterns in the individual geographic samples that will be summarized in the following chapter. See Table 16 for a comparison of trepanation by time period throughout the world.

Chapter 5-Discussion/Conclusions

In the Results Chapter, I reported a statistically significant difference in male/female ratio of the trepanned individuals. This indicated that males are more likely to be trepanned than females. This supports one hypothesis that trepanation is related to warfare, typically a male pursuit. On the other hand, it could simply mean that fewer females were found in general, as compared to the males discovered. That is, the authors of these reports do not mention the entire sample examined (including non-trepanned individuals). Therefore, if there are proportionally fewer females than males then this significant difference may no longer hold. Another possible theory involves decreased bone density and soil acidity. The bone density of females generally decreases over time, more than it does in males. This decreased bone density combined with the acidity of the soil in which these individuals are being buried in could hide the evidence of trepanation through taphonomic processes. The female population generally might just be smaller than the male population, perhaps females are not living as long as males are. Another possible reason is that women are dying due to other factors, not ones connected to reasons for trepanation, perhaps childbirth or injuries not associated with the cranium. The social status of women might even be lower than the status of men and therefore it does not seem worthwhile to spend the talents of healers or shaman on the needs of women. Though probably the most likely reason for the statistical difference between males and females is the osteological underrepresentation of females; if there are less females examined, then there would naturally be less trepanned females examined.

Eastern Europe shows a fairly regular decrease in ages-at-death for trepanned individuals. The earliest trepanned individuals (dating to the Mesolithic) are older than the more recent trepanned individuals (45 years to ~30 years) plummeting to 21.5 years during the 3rd/2nd century BCE. This could be related to life expectancy of the general population or perhaps the older Mesolithic individuals are outliers in this group. The male majority remains the same throughout time as does the percentage of individuals who show evidence of healing. In Hungary, part of Eastern Europe, there is a high percentage (71.4%) of males from the 10th and 11th centuries that show evidence of trepanation. All of these males are between the ages of 25 and 55, the ages of men that would have been involved in warfare and violent activities. There is also physical evidence of violence on the bones: glabellar trauma, widespread injuries and fractures, and infection on the bone possibly from these injuries. In the 10th and 11th centuries in Hungary there were raids on the Carpathian Basin that ended in 1091. Hungary did not endure foreign warfare until the Mongol invasions of the 13th century (Engel et al. 2001: 37). These raids and wars were most likely the causes of the injuries on these individuals that necessitated trepanation.

The ages-at-death of trepanned individuals in Western Europe all fall within a small age range: 35-46, a range of eleven years. Since all the trepanned individuals are about the same age at their death then it is possible this is the typical range of ages in which individuals become sick and require medical intervention or perhaps a ritual is performed sometime during this age-span. However, the majority of these individuals show signs of healing indicating that they survived the surgery and perhaps whatever caused the need for trepanation.

Scandinavia has a much wider range of ages-at-death, from 28 years to 50 years, a 22 year range. The time period with the youngest average age-at-death is the Roman Iron Age a period characterized by Roman exploration of the European continent. The distribution of sex in

this region is heavily male, there is only one female out of the whole sample so it is probable that these males were trepanned due to injuries and related infections.

The North Sea Area ages-at-death averages range from 21.4 years to 55 years old, a 33-year range. The North Sea Area is also the largest sample in this data collection, which is why the averages are so spread out. Since the sample is large it makes sense that the reasons for trepanation would be more varied; individuals in this group have been trepanned for both biological/pathological reasons as well as for injuries and post-mortem rituals and skull modification purposes. In England, a skull dating to the Neolithic period was found with a healing trepanation opening; the skull was blackened and charred. There is no mention that other individuals had been burned, nor was there mention of evidence of burnt flora that might have indicated an environmental disaster. Since there is no other evidence of burning or charring of other materials or skulls in the vicinity this could be a cultural burning. Cannibalism is not very likely since the trepanation sites shows signs of healing which indicates the individual survived the operation and that the purpose of trepanation was not to get at the brain.

The only biological clues to the purpose of trepanation in Canada come from Ontario. Arrow wounds to the cranium are possible causes for trepanation, especially in one such case where an arrow wound was found in one of the males in Ontario. The default hypothesis for groups of crania that show no evidence of pathology or injury is that these were done for cultural or ritual reasons. However, individuals with no evidence of pathology could have succumbed quickly to a disease that left no evidence on the bone. The United States is similar in that the only pathology in this area is antemortem tooth loss, no evidence of abscesses or vault lesions. These vault lesions could indicate a disease, however, there is no other information concerning these lesions and therefore impossible to know if the lesions and the trepanation are related.

The prevalence of female cases of trepanation in Mesoamerica is also an important aspect of this study. The sample from Mesoamerica is 54% female and none of these females show any evidence of injury or fracture, only arthritis, infection, and osteitis. The females' ages-at-death are separated into younger ages ranging from 18 to 35, which coincides with child-bearing years, and older ages, 50 years and above. However, only five of the 21 female cases shows evidence of healing. The low survival rate and lack of pathology in this large group of women could signify that these women were the sickest and that trepanation was a last attempt to save their life. More often than not the sickest individuals do not show any skeletal evidence of their ill-health because they die too quickly for disease to travel to the bone. This is one possible explanation for this situation in Mesoamerica. Another possible situation is that these women were important figures in religion or politics, perhaps priestesses or relatives of leaders. Many of these women were buried without offerings, however, suggesting that perhaps they were not royalty or wealthy members of society.

The sample in Peru is significant because it is the most varied, with regards to location of the trepanation. Trepanations in this sample are spread out from the right and left frontal, the right and left parietal, the left temporal, the occipital, lambda, bregma, the sagittal suture and the coronal suture as well as unsided frontal and temporal bones. It is rare to have trepanations on the temporal bone, most likely because they are the most difficult to reach through the scalp due to the location of the ear as well as several muscles that attach on the temporal bones. These trepanations on the temporal bone could be due to the relatively large sample from Peru, though the North Sea Area has double the cases and less location variability. Some of these cases come from the time of Inca society and we can connect the trepanation to the presumed thorough

medical knowledge the Inca had. However, the sample from Peru also includes a list of pathological skeletal features that could have necessitated trepanation.

In Africa there is evidence of individuals from the Roman period, who have linear enamel hypoplasias indicating survival of some stressor. This stressor could be related to trepanation as the individuals who underwent trepanation were around 21 years of age when they died. In the Neolithic period individuals had deep gashes and other cranial injuries near and around the trepanation which might have caused intracranial bleeding and pressure, necessitating trepanation on these individuals. The reason for trepanation on the modern-day individuals from Africa is well known as the individuals survived the surgery and could report the incident that required the trepanation. There is evidence of both disease and injury in the trepanned skulls of Asia showing a strong relationship between biological causes and trepanation in this area.

The sample from the Middle East is unique in that there are two trepanned juveniles, one 8-9 years, the other 11-12, both showing evidence of disease, scurvy and osteitis respectively. Why do other geographic areas not have more evidence of juvenile trepanation? Is it that these children get too sick too quickly or something else? In the case of the 8-9 year old the scurvy was quite advanced, the mandible having become completely edentulous indicating that perhaps trepanation was a final resort for this child.

Australia has the smallest sample size: two cases total. There are several explanations for this: these two females were trepanned elsewhere and then traveled to Australia after their surgery, or trepanation was not a phenomenon in Australia as it was everywhere else, or simply the rest of Australia's sample has yet to be published, discovered, or is hidden away in the basement of a museum, university, or hospital.

To reiterate, the research questions this thesis addressed were:

Are more men than women are trepanned because men are more likely to be involved in warfare as the literature suggests? In general, yes, more males than females are trepanned, 70% vs. 30% respectively, except in Mesoamerica where the majority of the sample is female. In areas where the frequency of males trepanned is higher than that of females trepanned there is also a higher frequency of injury among the males and a lower frequency of injury among females, suggesting that males are also being trepanned for injuries due to possible warfare and violence in addition to disease.

Is there any evidence to support cultural explanations or is this a residual category used for when skeletal remains show no evidence of pathology?: Lack of skeletal evidence is connected to the osteological paradox: the fact that the sickest individuals show no skeletal evidence of their sickness so perhaps these cases that have been labeled "cultural" are actual biological cases in which the individual died before the disease could manifest on the skeleton. Therefore, it is entirely possible that the cultural category has become a residual grouping for individuals who show no pathological evidence of disease on their skeleton.

Is there any evidence to support the theory of diffusion, that trepanation originated in one or two centers and then diffused to other areas? There might be some credence to this theory, albeit it is difficult to prove, as there are two geographic areas that have the earliest evidence of trepanation from the Mesolithic: Eastern and Western Europe. Since Europe has the earliest evidence of trepanation from the Mesolithic era it is possible that groups of people retained this knowledge, after all trepanation is practiced in the Neolithic as well as the Roman era in this region, and exchanged this knowledge among other groups of people. Additionally, in areas such as Africa and Asia there is evidence of trepanation in the Neolithic whereas in Australia and

the New World the earliest evidence is around 2000 years ago indicating that trepanation as an idea could have spread as trading and exploration involved places farther away from the initial center.

And lastly, is there any cultural evidence to support subadult trepanation or only biological evidence? The few juvenile cases of trepanation are, according to the authors (Mogle and Zias 1995, Mallin and Rathburn 1976, and Mariani-Costantini et al. 2000), related to biological factors such as scurvy, tumors, and bony infection, except for one case that shows no biological factors that would necessitate trepanation (Mallin and Rathburn 1976). However, this is once again connected to the osteological paradox, as well. Children often become sick quickly and die quickly and so juveniles who are found with trepanations and no other biological evidence of disease on their skeleton might be classified as instances of trepanation for cultural reasons as there is no skeletal evidence of disease or trauma.

So what indeed is the purpose of trepanation? There is little documentation stating that cultural reasons for trepanation. None offer cultural reasons for trepanation and even people without skeletal pathologies possibly were trepanned for a disease, but could have been fatally ill and died before the illness could manifest on the bone. Through data collection the only good explanations for trepanation are mostly biological, though of course, trepanation itself is a cultural practice.

Similar to most investigative reports there is information lacking, particularly the results of forthcoming reports, archaeological sites that have yet to be excavated, and the biological and demographic information attached to these sites. Future research on this topic should include a study of trepanned skulls vs. the total amount of skulls studied by each researcher at each site, as well as skeletal analyses of trepanned skulls that are in museums, universities and libraries, and

finally translations of reports in foreign languages that were unavailable to the author would prove imperative to further study.

Bibliography

Ackerknecht, Erwin H. 1947. *Primitive Surgery* American Anthropologist 49(1):25-45.

Andrushko, Valerie A and John W Verano. 2008. *Prehistoric Trepanation in the Cuzco Region of Peru: A View into an Ancient Andean Practice.* American Journal of Physical Anthropology 137(1): 4-13.

Aufderheide, Arthur C. 1998. "Trephination" *Cambridge Encyclopedia of Human Paleopathology*:31-34.

Bennike, PA. 1985. *Paleopathology of Danish Skeletons: A Comparative Study of Demography, Disease and Injury*. Akademisk forlag:65-98.

Brooks, S. and Suchey, J.M. 1990. *Skeletal Age Determination Based on the Os Pubis: A Comparison of the Acsadi-Nemeskeri and Suchey-Brooks Methods.* Human Evolution 5:227-238.

Brothwell, D.R. 1994. *Ancient Trephining: Multi-focal evolution or Trans-world Diffusion?* Journal of Paleopathology 6(3):129-138.

Clower, William T and Stanley Finger. 2001. *Discovering Trepanation: The Contribution of Paul Broca*. Neurosurgery 49(6): 1417-1426.

Crump, JA. 1901. *Trephining in the South Seas*. Journal of the Anthropological Institute of Great Britain and Ireland 31:167-172.

Daland, J. 1935. *Depressed Fracture and Trephining of the Skull by the Incas of Peru.* Annals of Medical History 7: 550-558.

Derums, V.J. 1979. *Extensive Trepanation of the Skull in Ancient Latvia*. Bulletin of the History of Medicine. 53(3): 459-464.

Engel, Pal, Andrew Ayton and Tamas Palosfalvi. 2005. *The realm of St. Stephen: a history of Medieval Hungary, 895-1526*. I.B. Tauris & Co Ltd. New York, N.Y.

Fletcher, R. 1882. *On Prehistoric Trephining and Cranial Amulets.* Contributions to North American Ethnology 5:1-32.

Hinsdale, WB and Emerson F Greenman. 1936. *Perforated Indian Crania in Michigan*.

Occasional Contributions from the Museum of Anthropology of the University of Michigan No. 5.

Jorgenson, JB. 1988. *Trepanation as a Therapeutic Measure in Ancient (pre-Inka) Peru.* Acta Neurochir (Wien). 93:3-5.

Kidd, G.E. 1930. *A Case of Primitive Trephining.* Museum and Art Notes 5: 85-87.

Littleton, Judith and Karen Frifelt. 2006. *Trepanations from Oman: A Case of Diffusion?* Arabian Archaeology and Epigraphy 17: 139-151.

McKinley, J.I. 1992. *A Probable Trepanation from an Early Anglo-Saxon Cemetery at Oxborough, Norfolk.* International Journal of Osteoarchaeology 2:333-335.

Mallin, Robert and Ted A Rathburn. 1976. *A Trephined Skull from Iran.* Bulletin NY Acad Med 52(7): 782-787.

Mann, George. 1991. *Chronic Ear Disease as a Possible Reason for Trephination*. International Journal of Osteoarchaeology 1:165-168.

Mariani-Costantini, Renato et al. 2000. *New Light on Cranial Surgery in Ancient Rome.* Lancet 355:305-307.

Margetts, Edward L. 1967 "Trepanation of the Skull by the Medicine-men of Primitive Cultures, with Particular Reference to Present-day Native East Africa Practice" in *Diseases in Antiquity: A Survey of the Diseases, Injuries and Surgery of Early Populations* eds D. Brothwell and A.T. Sandison. Charles C. Thomas Publisher. Springfield, IL; 673-694.

Mogle, Paul and Joe Zias. 1995. *Trephination as a Possible Treatment for Scurvy in a Middle Bronze Age (ca 2200 BC) Skeleton*. International Journal of Osteoarchaeology 5:77-81.

Moskalenko, Yu. E. et al. 2008. *The Effect of Craniotomy on the Intracranial Hemodynamics and Cerebrospinal Fluid Dynamics in Humans.* Fizlogiya Cheloveka 34(3): 41-48.

Nemeskeri, J et al. 1965. *Trephined skulls from the Tenth Century*. Acta Archaeologica Academiae Scientiarum Hungaricae 17: 343-367.

Oakley, K.P., Winifred M.A. Brooke, A. Roger Akester, and D.R. Brothwell. 1959. *Contributions on Trepanning or Trephination in Ancient and Modern Times*. Man 59:93-96.

Parker, S et al. 1986. *A Review of British Trephinations with Reports on Two New Cases.*

Ossa 12: 141-157.

Parry, T. Wilson. 1914. *Prehistoric Man and his Early Efforts to Combat Disease* The Lancet:1699.

Powell, Bernard W. 1970. *Aboriginal Trephination: Case from Southern New England?* Science 170(3959):732-734.

Ruffer, M.A. 1918. *Studies in Paleopathology: Some Recent Researches on Preshistoric Trephining.* Journal of Pathology and Bacteriology 22: 90-104.

Ruisinger, Marion Maria 2003. *Lorenz Heister (1683-1758) and the "Bachman Case": Social Setting and Medical Practice of Trepanation in Eighteenth-Century Germany* in *Trepanation: History-Discovery-Theory* eds Robert Arnott, Stanley Finger, and C.U.M Smith. Swets and Zeitlinger Publishers. Lisse, The Netherlands; 2003.

Smrcka, V et al. 2003. *Meningioma Probable Reason for Trephination*. International Journal of Osteoarchaeology 13: 325-330.

Stone, JL and ML Miles. 1990. *Skull Trepanation Among the Early Indians of Canada and the United States* 26(6): 1015-1020.

Todd, T.W. 1920. *Age Changes in the Pubic Bone: I. The white male pubis.* American Journal of Physical Anthropology 3:467-470

Webb, Stephen G. 1988. *Two Possible Cases of Trephination from Australia*. American Journal of Physical Anthropology 75:541-548.

West, James F. 1879. *Trephining for Traumatic Epilepsy* pg 23-35.

Zias, Joseph. 1982. *Three Trephinated Skulls from Jericho* Bulletin of the American Schools of Oriental Research 246:55-58.

Appendix A-Case Study Checklists

Checklist of Biological Variation

Source/Investigator _____

Geographic Location of Remains _____

Culture associated _____

Date of remains/archaeological context _____

Age _____

Sex _____

Location of trepanation 1,_____ 2._____
3._____
_____

Size 1,_____ 2._____ 3._____
_____

Shape 1._____ 2._____ 3._____
_____

Pathologies noted _____

Type of disease noted _____

Type of injury noted _____

Possible fractures associated with warfare _____

Evidence of dental disease _____

Evidence of developmental disorders _____

Evidence of nutritional disorders _____

Evidence of healing/bone regeneration at the trepanation site _____

Other _____

Checklist for Archaeological Context

Location of Excavation _____

Dating method and accuracy of date _____

Site disturbed or undisturbed _____

Associated Artifacts _____

Technology used during surgery _____

Appendix B-List of Tables

	Sex	
Age	**Male**	**Female**
<18	12	12
18-25	13	5
26-30	14	14
31-35	22	3
36-40	25	7
41-45	21	6
46-50	16	2
51-55	5	1
56-60	4	2
61-65	3	
65+	8	8
Total	143	60

Table 1 - Comparative Table Examining Age vs. Sex Counts (Overall Table)

Shape	Male	Female
Oval	50	14
Circle	40	18
Rectangle	11	1
Irregular	1	
Triangular	3	0
Linear	1	2
Semicircle		1
V-shaped	1	
Cup		1
Heart	1	
Trapezoid	1	
Hexagon	1	
Saucer		2
Urn		1

Table 2 - Sex vs. Shape

Location/Age	**<18**	**18-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	**50+**	**Total**

RP[1]	1	2	4	3	4	5	1	3	23
LP[2]		10	4		6	2	1	6	29
LF[3]		1	3					4	8
RF[4]		1		1		1	1	2	6
LT[5]		1		1	1				3
RT[6]									
Occipital		4			3				7
Bregma	1	4			1				6
Lambda				1	1				2
SS[7]		1	1	2	3	1		2	10
Coronal	1	1			1				3
Parietal		1	2	2	4			2	11
Frontal	1	1	4	1	1	1	1	1	11
Obelion	1			1					2
Metopic		1							1

Table 3 - Location vs. Age

Table 4a - Eastern Europe-Russia, Latvia, Siberia, Ukraine, Hungary, Czech Republic

[1] RP-Right Parietal
[2] LP-Left Parietal
[3] LF-Left Frontal
[4] RF-Right Frontal
[5] LT-Left Temporal
[6] RT-Right Temporal
[7] SS-Sagittal Suture

Eastern Europe

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Mesolithic	45	5/6 83%	0/6 0%	1/6 16%	N/R	1/6 16%
Neolithic	35	2/2 100%	0/2 0%	0/2 0%	1/2 50%	1/2 50%
Bronze Age	29	2/5 40%	2/5 40%	1/5 20%	N/R	0/5 0%
Iron Age 3rd/2nd century BC	21.5	0/2 0%	1/2 50%	1/2 50%	1/2 50%	2/2 100%
Medieval (general)	30.75	2/2 100%	0/2 0%	0/2 0%	1/2 50%	1/2 50%
10th/11th century AD	44.6	15/21 71%	5/21 23%	1/21 4%	2/21 9%	10/21 47%
1298-1550 AD	55	1/1 100%	0/1 0%	0/1 0%	1/1 100%	0/1 0%

Table 4b – Eastern Europe-Russia, Latvia, Siberia, Ukraine, Hungary, Czech Republic

Eastern Europe

		SHAPE			LOCATION	
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Mesolithic	0/4 0%	4/4 100%	0/4 0%	5/6 83%	1/6 16%	0/6 0%
Neolithic	0/1 0%	1/1 100%	0/1 0%	0/2 0%	0/2 0%	2/2 100%
Bronze Age	1/3 33%	2/3 66%	0/3 0%	0/5 0%	0/5 0%	5/5 100%
Iron Age 3rd/2nd century BC	1/2 50%	1/2 50%	0/2 0%	0/1 0%	0/1 0%	1/1 100%
Medieval (general)	N/R	N/R	N/R	1/2 50%	0/2 0%	1/2 50%
10th/11th century AD	12/20 60%	4/20 20%	4/20 20%	8/21 38%	6/21 28%	7/21 33%
1298-1550 AD	1/1 100%	0/1 0%	0/1 0%	0/1 0%	1/1 100%	0/1 0%

Western Europe

SEX

Time Period		Avg Age	Male	Female	Indeterminate	Healing?	Pathologies?
Mesolithic		35	1/1 100%	0/1 0%	0/1 0%	1/1 100%	0/1 0%
Neolithic		46.25	7/11 63%	0/11 0%	4/11 36%	6/11 54%	0/11 0%
Chalcolithic		40	2/2 100%	0/2 0%	0/2 0%	2/2 100%	0/2 0%
Bronze Age		32.5	1/1 100%	0/1 0%	0/1 0%	0/1 0%	0/1 0%
6th-4th century BC		35	2/2 100%	0/2 0%	0/2 0%	2/2 100%	0/2 0%
La Tene Period (450 BC-1st century AD)		31.25	4/6 66%	0/6 0%	2/6 33%	1/6 16%	0/6 0%
1st/2nd century AD		30	2/3 33%	0/3 0%	1/3 33%	2/3 66%	2/3 66%
	1753	36	1/1 100%	0/1 0%	0/1 0%	0/1 0%	1/1 100%
No time period (Spain)		42.2	3/8 37%	2/8 25%	3/8 37%	3/8 37%	3/8 37%

Table 5a - Western Europe-Spain, France, Portugal, Italy, Austria, and Germany

Western Europe

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Mesolithic	0/1 0%	1/1 100%	0/1 0%	0/1 0%	1/1 100%	0/1 0%
Neolithic	5/10 50%	4/10 40%	1/10 10%	5/13 38%	4/13 30%	4/13 30%
Chalcolithic	0/2 0%	0/2 0%	2/2 100%	0/2 0%	2/2 100%	0/2 0%
Bronze Age	1/1 100%	0/1 0%	0/1 0%	0/1 0%	1/1 100%	0/1 0%
6th-4th century BC	1/2 50%	0/2 0%	1/2 50%	0/2 0%	2/2 100%	0/2 0%
La Tene Period (450 BC-1st century AD)	N/R	N/R	N/R	0/2 0%	0/2 0%	2/2 100%
1st/2nd century AD	0/2 0%	1/2 50%	1/2 50%	1/2 50%	0/2 0%	1/2 50%
1753	N/R	N/R	N/R	1/1 100%	0/1 0%	0/1 0%
No time period (Spain)	5/8 62%	2/8 25%	1/8 12%	6/12 50%	4/12 33%	2/12 16%

Table 5b - Western Europe-Spain, France, Portugal, Italy, Austria, and Germany

Scandinavia

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Neolithic	43.4	10/12 83%	1/12 8%	1/12 8%	8/12 66%	4/12 33%
Bronze Age	45	2/3 66%	0/3 0%	1/3 33%	2/3 66%	0/3 0%
405 BC	42.5	1/1 100%	0/1 0%	0/1 0%	1/1 100%	0/1 0%
Roman Iron Age	28	1/2 50%	0/2 0%	1/2 50%	0/2 0%	1/2 50%

Table 6a - Scandinavia-Denmark and Sweden

Scandinavia

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Neolithic	4/10 40%	5/10 50%	1/10 10%	7/12 58%	1/12 8%	4/12 33%
Bronze Age	3/3 100%	0/3 0%	0/3 0%	2/4 50%	0/4 0%	2/4 50%
405 BC	N/R	N/R	N/R	1/1 100%	0/1 0%	0/1 0%
Roman Iron Age	1/2 50%	0/2 0%	1/2 50%	2/2 100%	0/2 0%	0/2 0%

Table 6b - Scandinavia-Denmark and Sweden

North Sea Area

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Neolithic (E/M/L)	42.5	6/7 85%	0/7 0%	1/7 14%	1/7 14%	2/7 28%
Bronze Age	21.4	5/9 55%	2/9 22%	2/9 22%	0/9 0%	2/9 22%
Iron Age	50	1/3 33%	0/3 0%	2/3 66%	N/R	0/3 0%
Romano-British	38.3	3/3 100%	0/3 0%	0/3 0%	N/R	3/3 100%
5th-7th century CE (Anglo-Saxon)	42.6	12/16 75%	2/16 12%	2/16 12%	2/16 12%	3/16 18%
Pre 1066	55	0/1 0%	1/1 100%	0/1 0%	N/R	1/1 100%
Medieval	25	0/4 0%	0/4 0%	4/4 100%	1/4 25%	3/4 75%
9th century AD	22	1/1 100%	0/1 0%	0/1 0%	1/1 100%	0/1 0%
13th/14th century AD	N/A	N/R	N/R	N/R	1/1 100%	0/1 0%
17th century AD	N/A	N/R	N/R	N/R	N/R	0/1 0%

Table 7a - North Sea Area-Ireland and England

North Sea Area

		SHAPE			LOCATION	
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Neolithic (E/M/L)	1/5 20%	3/5 60%	1/5 20%	2/5 40%	2/5 40%	1/5 20%
Bronze Age	1/5 20%	1/5 20%	3/5 40%	4/9 44%	1/9 11%	4/9 44%
Iron Age	0/1 0%	1/1 100%	0/1 0%	0/4 0%	0/4 0%	4/4 100%
Romano-British	2/3 66%	0/3 0%	1/3 33%	1/3 33%	1/3 33%	1/3 33%
5th-7th century CE (Anglo-Saxon)	11/14 78%	3/14 21%	0/14 0%	6/15 40%	4/15 26%	5/15 33%
Pre 1066	0/2 0%	2/2 100%	0/2 0%	2/2 100%	0/2 0%	0/2 0%
Medieval	3/4 75%	1/4 25%	0/4 0%	4/6 66%	2/6 33%	0/6 0%
9th century AD	0/1 0%	1/1 100%	0/1 0%	1/1 100%	0/1 0%	0/1 0%
13th/14th century AD	N/R	N/R	N/R	N/R	N/R	N/R
17th century AD	0/1 0%	1/1 100%	0/1 0%	0/1 0%	0/1 0%	1/1 100%

Table 7b - North Sea Area-Ireland and England

Canada
British Columbia

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Pre-Columbian	38.8	5/9 55%	3/9 33%	1/9 11%	8/9 88%	0/9 0%
Post-Columbian	35	1/1 100%	0/1 0%	0/1 0%	1/1 100%	0/1 0%

Ontario

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Post-Columbian (~1600 AD)	33.3	3/3 100%	0/3 0%	0/3 0%	3/4 75%	2/3 66%

Table 8a - Canada-Ontario and British Columbia

Canada
British Columbia

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Pre-Columbian	2/6 33%	4/6 66%	0/6 0%	3/13 23%	2/13 15%	8/13 61%
Post-Columbian	N/R	N/R	N/R	1/1 100%	0/1 0%	0/1 0%

Ontario

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Post-Columbian (~1600 AD)	2/3 66%	1/3 33%	0/3 0%	0/4 0%	2/4 50%	2/4 50%

Table 8b - Canada-Ontario and British Columbia

United States
Eastern United States

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Woodland Period	22.5	1/1 100%	0/1 0%	0/1 0%	N/R	0/1 0%
Pre-Columbian	27.5	2/4 50%	2/4 50%	0/4 0%	4/4 100%	0/4 0%

Central US

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Pre-Columbian	35	1/1 100%	0/1 0%	0/1 0%	1/1 100%	1/1 100%

Western US

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Pre-Columbian	36.6	3/11 27%	2/11 18%	6/11 54%	5/11 45%	3/11 27%

Table 9a - United States-Eastern, Central, and Western

United States
Eastern United States

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Woodland Period	1/1 100%	0/1 0%	0/1 0%	N/R	N/R	N/R
Pre-Columbian	1/6 16%	4/6 66%	1/6 16%	2/11 18%	9/11 82%	0/11 0%

Central US

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Pre-Columbian	0/1 0%	1/1 100%	0/1 0%	2/2 100%	0/2 0%	0/2 0%

Western US

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Pre-Columbian	2/7 28%	3/7 42%	2/7 28%	6/8 75%	0/8 0%	2/8 25%

Table 9b - United States-Eastern, Central, and Western

Mesoamerica

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Pre-Classic (400 BC-200 AD)	27	0/4 0%	4/4 100%	0/4 0%	N/R	0/4 0%
Early Classic (200-500 AD)	30	1/3 33%	2/3 66%	0/3 0%	N/R	3/4 75%
Mid Classic (500-750 AD)	28.7	5/11 45%	6/11 54%	0/11 0%	3/11 27%	6/11 54%
Late Classic (750-900 AD)	28.4	2/6 33%	4/6 66%	0/6 0%	0/6 0%	3/6 50%
Early Post-Classic (900-1000 AD)	32.3	1/4 25%	3/4 75%	0/4 0%	1/4 25%	2/4 50%
Pre-Columbian	55	0/2 0%	2/2 100%	0/2 0%	2/2 100%	0/2 0%

Table 10a - Mesoamerica-Mexico and Belize

Mesoamerica

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Pre-Classic (400 BC-200 AD)	4/6 66%	2/6 33%	0/6 0%	4/5 80%	1/5 20%	0/5 0%
Early Classic (200-500 AD)	0/1 0%	1/1 100%	0/1 0%	2/4 50%	0/4 0%	2/4 50%
Mid Classic (500-750 AD)	3/6 50%	3/6 50%	0/6 0%	4/15 26%	6/15 40%	5/15 33%
Late Classic (750-900 AD)	1/7 14%	5/7 71%	1/7 14%	1/7 14%	3/7 42%	3/7 42%
Early Post-Classic (900-1000 AD)	2/3 66%	1/3 33%	0/3 0%	3/6 50%	2/6 33%	1/6 16%
Pre-Columbian	1/2 50%	1/2 50%	0/2 0%	0/2 0%	2/2 100%	0/2 0%

Table 10b - Mesoamerica-Mexico and Belize

South America

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
2000-1200 BCE	N/R	0/3 0%	0/3 0%	3/3 100%	2/3 66%	1/3 33%
140 +/- 60 BCE	30	1/1 100%	0/1 0%	0/1 0%	N/R	0/1 0%
900-1000 CE	45	3/4 75%	0/4 0%	1/4 25%	1/4 25%	3/4 75%
19th/20th century CE	N/R	0/1 0%	1/1 100%	0/1 0%	N/R	1/1 100%

Table 11a - South America-Peru and Bolivia

South America

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
2000-1200 BCE	0/2 0%	0/2 0%	2/2 100%	2/3 66%	1/3 33%	0/3 0%
140 +/- 60 BCE	0/1 0%	1/1 100%	0/1 0%	0/1 0%	0/1 0%	1/1 100%
900-1000 CE	0/4 0%	4/4 100%	0/4 0%	2/4 50%	0/4 0%	2/4 50%
19th/20th century CE	1/1 100%	0/1 0%	0/1 0%	0/1 0%	0/1 0%	1/1 100%

Table 11b – South America-Peru and Bolivia

Africa

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Neolithic	N/R	2/6 33%	4/6 66%	0/6 0%	3/6 50%	5/6 83%
Roman/1st century CE	21	0/2 0%	2/2 100%	0/2 0%	N/R	2/2 100%

Table 12a - Africa-Egypt, South Africa, Guinea

Africa

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Neolithic	0/6 0%	4/6 66%	2/6 33%	1/6 16%	3/6 50%	2/6 33%
Roman/1st century CE	0/2 0%	2/2 100%	0/2 0%	0/2 0%	2/2 100%	0/2 0%

Table 12b – Africa-Egypt, South Africa, Guinea

Middle East

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
4th millennium BCE (Bronze Age)	40	1/1 100%	0/1 0%	0/1 0%	1/1 100%	1/1 100%
Bronze Age	28.25	2/6 33%	1/6 16%	3/6 50%	1/6 16%	6/6 100%
Iron Age II 1100-800 BCE	11.5	0/1 0%	0/1 0%	1/1 100%	1/1 100%	1/1 100%
1st century CE	40	2/3 66%	1/3 33%	0/3 0%	2/3 66%	1/3 33%

Table 13a - Middle East-Iran, Jordan, Jericho

Middle East

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
4th millennium BCE (Bronze Age)	1/1 100%	0/1 0%	0/1 0%	0/1 0%	1/1 100%	0/1 0%
Bronze Age	1/6 16%	5/6 83%	0/6 0%	1/6 16%	3/6 50%	2/6 33%
Iron Age II 1100-800 BCE	1/1 100%	0/1 0%	0/1 0%	0/1 0%	1/1 100%	0/1 0%
1st century CE	2/3 66%	0/3 0%	1/3 33%	3/3 100%	0/3 0%	0/3 0%

Table 13b - Middle East-Iran, Jordan, Jericho

Australia

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
200-300 YA	N/R	0/2 0%	2/2 100%	0/2 0%	2/2 100%	2/2 100%

Table 14a – Australia

Australia

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
200-300 YA	1/2 50%	0/2 0%	1/2 50%	0/2 0%	1/2 50%	1/2 50%

Table 14b – Australia

Asia

		SEX				
Time Period	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Late Bronze/Early Iron 5th-3rd century BC	35	4/4 100%	0/4 0%	0/4 0%	1/4 25%	1/4 25%
Historic	35	5/7 71%	1/7 14%	1/7 14%	2/7 28%	3/7 42%

Table 15a - Asia and the Pacific Islands (Oceania)

Asia

	SHAPE			LOCATION		
Time Period	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Late Bronze/Early Iron 5th-3rd century BC	1/10 10%	5/10 50%	4/10 40%	5/10 50%	1/10 10%	4/10 40%
Historic	0/7 0%	3/7 42.8%	4/7 57%	1/3 33%	1/3 33%	1/3 33%

Table 15b – Asia and the Pacific Islands (Oceania)

Overall Table

		SEX				
Geographic Area	**Avg Age**	**Male**	**Female**	**Indeterminate**	**Healing?**	**Pathologies?**
Australia	N/R	0/2 0%	2/2 100%	0/2 0%	2/2 100%	2/2 100%
Middle East	29.9	5/11 45%	2/11 18%	4/11 36%	5/11 45%	9/11 81%
Africa	21	2/8 25%	6/8 75&	0/8 0%	3/6 50%	7/8 87%
Asia	35	9/11 81%	1/11 9%	1/11 81%	3/11 27%	4/11 36%
Scandinavia	39.7	14/18 77%	1/18 5%	3/18 16%	11/18 61%	5/18 27%
British Columbia	36.9	6/10 60%	3/10 30%	1/10 10%	9/10 90%	0/10 0%
Ontario	33.3	3/3 100%	0/3 0%	0/3 0%	3/4 75%	2/3 66%
North Sea Area	37.1	28/44 63%	5/44 11%	11/44 25%	6/38 15%	7/23 30.4%
Eastern Europe	37.2	27/39 69%	8/39 20%	4/39 10%	6/28 21%	15/39 38%
Mesoamerica	33.5	9/30 30%	21/30 70%	0/30 0%	6/23 26%	14/31 45%
Eastern United States	25	3/5 60%	2/5 40%	0/5 0%	4/4 100%	0/5 0%
Central United States	35	1/1 100%	0/1 0%	0/1 0%	1/1 100%	1/1 100%
Western United States	36.6	3/11 27%	2/11 18%	6/11 54%	5/11 45%	3/11 27%
South America	37.5	4/9 44%	1/9 11%	4/9 44%	3/7 43%	5/9 55%
Western Europe	36.4	23/35 66%	2/35 6%	10/35 29%	17/35 49%	6/35 17%

Table 16a - Trepanation by Geographic Area

Overall Table

	SHAPE			LOCATION		
Geographic Area	**Oval?**	**Circle?**	**Other?**	**Left?**	**Right?**	**Other?**
Australia	1/2 50%	0/2 0%	1/2 50%	0/2 0%	1/2 50%	1/2 50%
Middle East	5/11 45%	5/11 45%	1/11 9%	4/11 36%	5/11 45%	2/11 18%
Africa	0/8 0%	6/8 75%	2/8 25%	1/8 12.5%	5/8 62.5%	2/8 25%
Asia	1/17 5.8%	8/17 47%	8/17 47%	6/13 46%	2/13 15%	5/13 38%
Scandinavia	8/15 53%	5/15 33%	2/15 13%	12/19 63%	1/19 5%	6/19 31.5%
British Columbia	2/6 33%	4/6 66%	0/6 0%	4/14 28.5%	2/14 14%	8/14 57%
Ontario	2/3 66%	1/3 33%	0/3 0%	0/4 0%	2/4 50%	2/4 50%
North Sea Area	18/36 50%	13/36 36%	5/36 13%	20/46 43%	10/46 21%	16/36 34%
Eastern Europe	15/31 48%	12/31 38%	4/31 13%	14/38 36%	8/38 21%	16/38 42%
Mesoamerica	11/25 44%	13/25 52%	1/25 4%	14/39 36%	14/39 36%	11/39 28%
Eastern United States	2/7 29%	4/7 57%	1/7 14%	2/11 18%	9/11 82%	0/11 0%
Central United States	0/1 0%	1/1 100%	0/1 0%	2/2 100%	0/2 0%	0/2 0%
Western United States	2/7 28%	3/7 42%	2/7 28%	6/8 75%	0/8 0%	2/8 25%
South America	1/8 12.5%	5/8 63%	2/8 25%	4/9 44%	1/9 11%	4/9 44%
Western Europe	12/26 46%	8/26 31%	6/26 23%	13/36 36%	14/36 38%	9/36 25%

Table 16b - Trepanation by Geographic Area

Appendix C-Sources Consulted

Eastern Europe

Bereczki, Zsolt. 2003. *New Cases of Trephination from a 10-11th Century Hungarian Site.* Papers on Anthropology 12:21-31.

Derums, V.J. 1979. *Extensive Trepanation of the Skull in Ancient Latvia*. Bulletin of the History of Medicine. 53(3): 459-464

Grynaeus, Tamas. 1999. *Skull Trephination in the Carpathian Basin (8th-13th Century AD)* Mankind Quarterly 40(2):131-143

Jordanov, J. 1990. *Symbolic Trephinations in Medieval Bulgaria* Homo 41(3):266-273

Jordanov, J. 1988. *Symbolic Trepanations of Skulls from the Middle Ages (Ixth-Xth century) in Bulgaria.* Acta Neurochirurgica 92:15-18.

Lillie, Malcolm L. 1998. *Cranial Surgery Dates Back to Mesolithic*. Nature 391:854

Tallgren, A.M. 1936. *The South Siberian Cemetery of Oglakty from the Han Period*. Eurasia Septentrianalis Antiqua 11:69-90

Western Europe

Alt, Kurt W. 1997. *Evidence for Stone Age Cranial Surgery.* Nature (387): 360.

Beattie, John. 1930. *A Note on Two Skulls from Tenerife*. American Journal of Physical Anthropology 14(3):447-449

Capasso, Luigi and Armaldo Capelli. 1995. *A Trephined Skull from Central Italy, Dated to Roman time (1st-2nd century AD).* Paleopathology Association European Members Meeting (9th, 1992, Barcelona, Spain) p. 103-106

Glass, Nigel. 1998. *Brain Surgery was Done in the Stone Age* The Lancet 351(9119):1865

Hooten, E.A. 1970. *Trepanation* in *The Ancient Inhabitants of the Canary Islands* in Harvard African Studies (journal): 154-155

McKinley, J.I. 1992. *A Skull Wound and Possible Trepanation from a Roman Cemetery at Baldock, Herfordshire*. International Journal of Osteoarchaeology 2: 337-340.

Mariani-Costantini, Renato. 2000. *New Light on Cranial Surgery in Ancient Rome* Lancet 355:305-307

Rubini, M. 2008. *A Case of Cranial Trepanation in a Roman Necropolis (Cassino, Italy, 3rd Century BC).* International Journal of Osteoarchaeology 18:95-99

Scattarella, V., S. Sublimi Saponetti, et al. 1996. *A Skull Trephination from Late Imperial Rome.* Journal of Paleopathology 8: 85-88

Silva, Ana Maria. 1999. *Human Remains from the Artificial Cave of Sao Pedro de Estoril II (Cascais, Portugal).* Human Evolution 14(3): 199-206.

Tejerina, J.M.R. 1969. *La Trepanacion Prehistorica en Mallorca*. Asclepio: Archivo iberoamericano de historia de la medicina y antropologica medica. 20: 191-219.

Scandinavia

Persson, O. 1977. *A Trepanned Skull from the Gillhog Passage-grave at Barseback in West Scania (Southern Sweden).* Ossa 3/4: 53-61.

North Sea

Brothwell, DR, R. Powers and B Denston. 1978. *The Human Skeletal Remains from Amesbury Barrow 51 with Special Reference to the Case of Trephination and its Position in the History of Trephining in*. Wiltshire Archaeological Magazine: 43-60

Buckley Laureen and Barra O Donnabhain. 1992. *Trephination: Early Cranial Surgery in Ireland.* Archaeology Ireland 6(4): 10-12

Parry, T. Wilson 1923b. *The Collective Evidence of Trephination of the Human Skull in Great Britain during Prehistoric Times.* Proceedings of the third international congress of the history of medicine. London, July 17th to 22nd, pg. 135-141.

Parry, T Wilson. 1927. *The Prehistoric Trephined Skulls of Great Britain, Together with a Detailed Description of the Operation Probably Performed in Each Case*. Section of the History of Medicine in Royal Society of Medicine 14:27-42

Parry, T. Wilson. 1935. *The Ovingdean Prehistoric Skull Exhibiting Double Primitive Surgical Holing*. Royal Anthropological Institute of Great Britain and Ireland 35: 56-57

Piggot, Stuart. 1940. *A Trepanned Skull of the Beaker Period from Dorset and the Practice of Trepanning in Prehistoric Europe*. Proceedings of the Prehistoric Society 5:112-132

Walmsley, T. 1923. *A Trephined Irish Skull*. Man 23: 180

Wells, C. 1974. *Probable Trephination of Five Early Saxon Skulls*. Antiquity 48(192): 298-302

West, James F. *Trephining for Traumatic Epilepsy*. 1879. Queen's Hospital. Birmingham, England.

Canada

Cybulski, JS. 1980. *Skeletal Remains from Lillooet, British Columbia, with observations for a possible diagnosis of skull trephination*. Syesis 13: 53-59

Griffin, J.D.M. 1976. *Trephination Among Early Canadian Indians.* Canadian Psychiatric Association Journal. 21: 123-125.

Kidd, G.E. 1946. *Trepanation Among the Early Indians of British Columbia.* Canada M.A.J 55: 513-516

Leechman, D. 1944. *Trephined Skulls from British Columbia.* Proceedings and transactions of the Royal Society of Canada 38(2):99-102

Smith, Harlan I. 1924. *Trephined Aboriginal Skulls from British Columbia and Washington*. American Journal of Physical Anthropology 7(4):447-454

United States

Cosgrove, CB. 1929. *A Note on a Trephined Indian Skull from Georgia*. American Journal of Physical Anthropology 13(2):353-357

Gillman, Henry. 1885. *Further Confirmation of Post-Mortem Characteristics of Cranial Perforations from Michigan Mounds*. American Naturalist 19:1127-1128

Gregg, John B. and William M. Bass. 1984. *'Bullet-hole' in an Ancient South Dakota Skull, or a Trephination?* Plains Anthropologist 29: 321-326.

Hinsdale, WB and Emerson F Greenman. 1936. *Perforated Indian Crania in Michigan*. Occasional Contributions from the Museum of Anthropology of the University of Michigan No. 5

Hrdlicka, A. 1939. T*repanation Among Prehistoric People, Especially in America.* Cibia Symposia 1(6): 170-177

McGregor, J.C. and W.L. Wadlow. 1951. *A Trephined Indian Skull from Illinois.* American Anthropologist 53(1):148-152.

Moodie, Roy L. 1930. *Studies in Paleopathology XXIV: Prehistoric Surgery in New Mexico*. American Journal of Surgery 8:905-908

Powell, Bernard W. 1970. *Aboriginal Trephination: Case from Southern New England?* Science 170(3959):732-734

Richards, Gary D. 1995. *Brief Communication: Earliest Cranial Surgery in North America*. American Journal of Physical Anthropology 98:203-209

Romero, J. 1970. *Dental Mutilation, Trephination, and Cranial Deformation* in Handbook of Middle American Indians vol. 9 ed. T.D. Stewart. University of Texas Press, Austin Texas. 50-67

Shapiro, H.L. 1927. *Primitive Surgery: First Evidence of Trephining in the Southwest*. Natural History 27: 266-269

Stewart, TD. 1940. *Demonstration of an Indian Skull from Maryland with a Perforation Suggesting Trepanation*. American Journal of Physical Anthropology 27(2): 15-16

Wakefield, EG and SC Dellinger. 1936. *Probable Adaptation of Utilitarian Implements for Surgical Procedures by the Mound-Builders of Eastern Arkansas*. Journal of Bone-Joint Surgery 18:434-438

Science News Letter. 1935. *Alaska Indians Had Brain Surgeons 2000 Years Ago*

Mesoamerica

Blos, Vera Tiesler. 2003. *Cranial Surgery in Ancient Mesoamerica*. www.mesoweb.com/features/tiesler/cranial.pdf

Lumholtz, Carl and Ales Hrdlicka. 1897. *Trephining in Mexico* American Anthropologist 10(12): 389-396

Marquez Morfin, Lourdes and Ernesto Gonzalez Licon. 1992. *La Trepanacion Craneana Entre los Antiguos Zapotecos de Monte Alban*. Cuadernos del Sur 1(1):25-50.

Romero, J. 1974. *La Trepanacion Prehispanica*. Anthropologica fisica, epoca prehispanica: 179-194.

Velasco-Suarez, Manuel, Josefina Bautista Martinez, Rafael Garcia Oliveros, and Philip R. Weinstein. 1992. *Archaeological Origins of Cranial Surgery: Trephination in Mexico*. Neurosurgery 31(2): 313-319

Wilkinson, Richard G. 1975. *Trephination by Drilling in Ancient Mexico*. Bull NY Acad Med 51(7): 838-850

Winter, M.C. 1984. *La Trepanacion in Oaxaca*. Historia general de la medicina en Mexico: 59-64.

Zaid, Lagunas R. 1973. *La Trepanacion Suprainiana en Craneos de Cholula, Puebla* Comunicaciones, Proyecto Pueblo-Tlaxcala, 8: 47-50

South America

Andrushko, Valerie A and John W Verano. 2008. *Prehistoric Trepanation in the Cuzco Region of Peru: A View into an Ancient Andean Practice.* American Journal of Physical Anthropology 137(1): 4-13

Bandelier, Adolph F. 1904. *Trephining in Bolivia*. American Anthropologist 6(4): 440-446

Burton, Frank Albert. 1920. *Prehistoric Trephining of the Frontal Sinus* California State Journal of Medicine. 321-324

Jorgenson, JB. 1988. *Trepanation as a Therapeutic Measure in Ancient (pre-Inka) Peru.* Acta Neurochir (Wien). 93:3-5

Moodie, Roy L. 1929. *Studies in Paleopathology, XXIII: Surgery in Pre-Columbian Peru*. Annals of Medical History New Series 1(6):698-728

MacCurdy, George Grant. 1923. *Human Skeletal Remains from the Highlands of Peru*. American Journal of Physical Anthropology 6(3): 217-330

Oakley, K.P., Winifred M.A. Brooke, A. Roger Akester, and D.R. Brothwell. 1959. *Contributions on Trepanning or Trephination in Ancient and Modern Times*. Man 59:93-96.

Rifkinson-Mann, Stephanie. 1988. *Cranial Surgery in Ancient Peru*. Neurosurgery 23(4): 411-416

Rogers, S. 1938. *The Healing of Trephine Wounds in Skulls from Pre-Columbian Peru*. American Journal of Physical Anthropology 13(3): 321-340

Rytel, M.M. 1962. *Trephinations in Ancient Peru*. Polish Medical Science and History Bulletin 5(42):42-45.

Stewart, TD. 1943. *Skeletal Remains from Paracas, Peru*. American Journal of Physical Anthropology 1(1): 47-63

Stone, JL and ML Miles. 1990. *Skull Trepanation Among the Early Indians of Canada and the United States* Neurosurgery 26(6): 1015-1020

Stewart, TD. 1956. *Significance of Osteitis in Ancient Peruvian Trephining*. Bulletin of the History of Medicine 30(4): 293-320

Tello, J. 1913. *Prehistoric Trephining Among the Yauyos of Peru*. International Congress of Americanists; Proceedings of the XVIII session, London 1912. pp 75-83

Zimmerman, M.R., E Trinkhaus, M Lemay, AC Aufderheide et al. 1981. *Trauma and Trephination in a Peruvian Mummy*. American Journal of Physical Anthropology 55: 497-501.

Africa

Derry, DE. 1914. *Parietal Perforation Accompanied with Flattening of the Skull in an Ancient Egyptian*. Journal of Anatomy 48:417-429

Drennan, MR. 1937. *Some Evidence for a Trepanation Cult in the Bushman Race*. South African Medical Journal 11(6): 183-191

Hilton-Simpson, MW. 1913. *Some Arab and Shawia Remedies and Notes on Trephining in Algeria*. Journal of the Royal Anthropological Institute of Great Britain and Ireland 43:706-721

Rawlings, Charles E and Eugene Rossitch, Jr. 1994. *History of Trephination in Africa with a Discussion of its Current Status and Continuing Practice*. Surgical Neurology 41(6):507-513

Roney, James G. 1954. *The Occurrence of Trephining Among the Bakhtiari*. Bulletin of the History of Medicine. 28: 489-491

Middle East

Arensburg, B. and I. Hershkovitz. 1988. *Cranial Deformation and Trephination in the Middle East* Bull. Et Mem. De la Soc. D'Anthrop. De Paris 14(3): 139-150

Bourke, S. and Karen Hendrix. 2001. *Twenty Years of Australian Physical Anthropology in Jordan: Restrospects and Prospects* in *Australians Uncovering Ancient Jordan: Fifty Years of Middle Eastern Archaeology*. Ed by Alan Walmsley. The Research Institute for Humanities and Social Sciences, The University of Sydney. Sydney, Australia. 77-88.

Brothwell, DR. 1965. *The Paleopathology of the E.B.-M.B. and Middle Bronze Remains from Jericho* Excavations at Jericho 2:685-693

Goldstein, Marcus S. 1976. *Pathology of Bedouin Skeletal Remains from Two Sites in Israel*. American Journal of Physical Anthropology. 45(3): 621-640

Hershkovitz, I. 1987. *Trephination: The Earliest Case in the Middle East.* J. Isr. Prehist. Soc 20: 128-135.

Mogle, Paul and Joe Zias. 1995. *Trephination as a Possible Treatment for Scurvy in a Middle Bronze Age (ca 2200 BC) Skeleton*. International Journal of Osteoarchaeology 5:77-81

Mallin, Robert. 1976. *A Trephined Skull from Iran.* Bulletin NY Acad Med 52(7): 782-787

Parry, T Wilson. 1936. *Three Skulls from Palestine Showing Two Types of Primitive Surgical Holing: Being the First Skulls Exhibiting This Phenomenon That Have Been Discovered on the Mainland of Asia*. Man 36:170-171

Starkey, JL. 1936. *Discovery of Skulls with Surgical Holing at Tell duWeir, Palestine.* Royal Anthropological Institute of Great Britain and Ireland. Man 36:169-170

Australia

Webb, Stephen G. 1988. *Two Possible Cases of Trephination from Australia*. American Journal of Physical Anthropology 75:541-548

Asia and the Pacific Islands

Ford, E. 1937. *Trephining in Melanesia*. The Medical Journal of Australia 2:471-477

Houghton, P. 1977. *Trephination in Oceania*. The Journal of the Polynesian Society. 86(2):265-269.

Parry, T. Wilson. 1914. *Prehistoric Man and his Early Efforts to Combat Disease* The Lancet pp.1699

General Knowledge

Ackerknecht, Erwin H. 1947. *Primitive Surgery* American Anthropologist 49(1):25-45

Aufderheide, Arthur C. 1985. *The Enigma of Ancient Cranial Trepanation*. Minnesota Medicine 68: 119-122

Aufderheide, Arthur C. 1998. "*Trephination*" in Cambridge Encyclopedia of Human Paleopathology pp 31-34

Clower, William T and Stanley Finger. 2001. *Discovering Trepanation: The Contribution of Paul Broca*. Neurosurgery 49(6): 1417-1426.

Clowes, H.A. 1926. *Trepanning and Trephining*. The British Medical Journal, pp 168.

England, W. 1962. *Trephining Through the Ages.* Radiography 28: 301-314.

Loughborough, John Lovell. 1946. *Notes on the Trepanation of Prehistoric Crania.* American Anthropologist. 48(3):416-422

Lisowski, FP. 1967. *Prehistoric and Early Historic Trepanation* in Disease in Antiquity Brothwell, DR (ed). 651-672

Moodie, Roy L. 1923. *Primitive Surgery* in The Antiquity of Disease. University of Chicago Press, Chicago, IL

Parry, T. Wilson. 1923a. *Trephination of the Living Human Skull in Prehistoric Times.* The British medical Journal pp 457

Parry, L.A. 1925. *Prehistoric Trephining.* The British Medical Journal pp 977-978.

Parry, T. 1925. Wilson. *Prehistoric Trephining* The British Medical Journal pp 1089-1090

Parry, T. 1927. *Diagnosis of Holes in Prehistoric Skulls: A Differential Diagnosis of the Various Kinds of Holes Discovered in the Skulls of Prehistoric Man.* Postgrad Med J 2:122-125

Parry, T Wilson. 1928. *Holes in the Skulls of Prehistoric Man and their Significance*. The Archaeology Journal 85:1-12

Parry, LA. 1940. *Prehistoric Trephining*. The British Medical Journal: 589

Roberts, Charlotte and Keith Manchester. 2007. *The Archaeology of Disease*. Cornell Paperbacks and Cornell University Press. Ithaca, NY

Rogers, L. 1930. *History of Craniotomy: An account of the Methods*…Annals of Med Hist 2:495-514

Stewart, TD. 1957. *Stone Age Skull Surgery: General Review with Emphasis on the New World*. Smithsonian Report for 1957. 1957:461-491

Wakefield, EG. 1939. *Possible Reasons for Trephining the Skull in the Past*. Cibia Symposia 1(6):166-169

Wells, Calvin. 1964. "*Trephination*" in *Bones, Bodies, and Disease: Evidence of Disease and Abnormality in Early Man.* Frederick A Praeger, Inc. NY, NY.

Contemporary Trepanation Literature

Bjerg, Greg. 2006. *The Hole Story on Trepanation.*

Bowen, J. 1999. *The Hole Story: Drilling your skull: Is it the way to bliss or just extremely dangerous?* www.salon.com/health/feature/1999/04/29/trepanation.

Frey, R. 2005. "*Trephining"* in *Gale Encyclopedia of Alternative Medicine*. The Gale Group, Inc. Gale, Detroit. http://www.healthline.com/galecontent/trepanation.

Wadley, J.P., G.T. Smith, and C. Shieff. 1997. *Self-trephination of the Skull with an Electric Power Drill.* British Journal of Neurosurgery 11(2): 156-158.

International Trepanation Advocacy Group. www.trepan.com