PALEOPATHOLOGICAL CONDITIONS PRESENTING IN A COLLECTION OF JUVENILES FROM A MEROVINGIAN SITE IN CENTRAL GERMANY

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

ABSTRACT

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This thesis explores the pathological conditions that affected a juvenile skeletal population dating to the Merovingian ages in what is now central Germany. The goal of this research is to gain an understanding of the physical health of this sub-adult population through the use of physical anthropology and historical evidence. In 1960 the cemetery of Mannheim-Vogelstang was excavated, revealing 149 juvenile skeletons dating from the sixth to the eighth century CE. Of the 149 recovered from the site, 105 were used in this research. These individuals were thoroughly visually examined for any indication of nutritional, infectious or congenital conditions, as well as evidence of trauma. All individuals were closely examined and any abnormalities were noted. Signs of porotic hyperostosis, hypoplasia, abnormal bending/bowing, fractures, abnormal growth, caries and dental abscesses were all present in this population. Porotic hyperostosis (PH) was the most prevalent pathological condition found in this population. Signs of porotic hyperostosis were found in 21.49% of the individuals. Linear enamel hypoplasia (LEH) was the second most common condition found within this population, occurring in 11.21% of the individual. Signs of PH and LEH are both indicators of metabolic distress. SD08, 600-620CE, revealed the largest number of individuals with signs of pathological conditions.

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LIST OF ACRONYMS

ACD- Anemia of Chronic Disease

CE- Common Era

IRB- Institutional Review Board

LEH-Linear Enamel Hypoplasia

PH-Porotic Hyperostosis

SD- *Spalte Datierung* (German for Column Dating)

CHAPTER ONE. INTRODUCTION

Overview

This thesis utilizes physical anthropology in a historical context to analyze the physical health of sub-adults in a sixth to eighth century CE Merovingian population in what is now central Germany. The aim of the thesis research is to gain an understanding of the pathological conditions that affected a specific collection of juvenile skeletons. During this research I have analyzed skeletal material from a Merovingian population in Germany; the material dates from the sixth through the eighth centuries CE. Specifically, I have looked for different signs of pathology within this population.

The fifth century CE produced many changes within the borders of Europe. As the Roman armies retreated from north central Europe various "barbarian" groups filled in the void (James 2001). After the exodus of the Roman army the Merovingians established their rule in northern Gaul. Merovingian society was composed of four socioeconomic classes. According to Dr. Koch, Merovingian society was composed of four socioeconomic classes not including the king (interview, March 15, Ursula Koch). The first two classes under the king were warrior classes. The first class consisted of the landed aristocracy; these noble men were owners of land and livestock. The second social class was made up of soldiers who earned their place through participation in warfare. Under the warrior classes were the farmers, making up the third socioeconomic class, followed by peasants and freed slaves. Although agricultural technology was primitive compared to the technology of the Roman Empire a wide variety of food were produced. Although there was an array of foodstuffs produced within Merovingian society the availability of food throughout the four socioeconomic classes is unclear. Chapter Two provides deeper historical information on this society.

This research utilized material excavated from the Merovingian cemetery of Mannheim-Vogelstang. Mannheim-Vogelstang is located north east of Mannheim in central Germany. The cemetery of Mannheim-Vogelstang spanned the sixth through eighth centuries. The cemetery was excavated in 1966 by Dr. Ursula Koch, an archaeologist based at the Reiss-Englehorm Museums in Mannheim, Germany. The various socioeconomic classes, spanning several centuries allowed for a comprehensive look at Merovingian society. A total of 149 juvenile skeletons (ranging from neonatal to approximately 18 years of age) were excavated from three different layers within the cemetery, representing three separate time periods. Of the 149, I personally examined 107 skeletons (the remaining 44 were not recovered from the museum's archive). I used paleopathological evidence to evaluate conditions and disorders caused by various circumstances including nutritional distress and physical injury. Conditions related to nutritional deficiencies may be observed in skeletal remains since the condition may affect human growth and development. In addition to nutritional distress, I also looked for evidence of physical trauma, as well as chronic and infectious disorders and conditions. Each individual has been thoroughly examined visually for any signs of nutritional, infectious or congenital conditions as well as evidence of trauma. By closely analyzing each individual skeleton I have noted any abnormalities such as bone wear, erosion, calcification, ossification, fractures and breakage. The specific definition of these terms, as applied in this research, and the processes used to examine the remains is discussed in Chapter Three.

Chapter Four presents the analysis and results of the conditions which were observed include: bending/bowing of the bones, porotic lesions, breaks and fractures, dental caries, dental calculi and linear enamel hypoplasia (LEH) and abnormal growth. The two most prominent conditions found during this research were LEH and porotic hyperostosis (PH). Metabolic distress is the cause of these two conditions; however, the exact cause of the distress is debatable. Dietary distress has two main causes (Djuric et al 2008). First, the foods that one is consuming may not hold the desired amount of nutrients. Second, individuals may not have access to required food sources. Access to the required nutrition may be limited by food availability (e.g. during periods of famine, plague or siege), or by a lack of means to acquire available food.

Ethical Issues Regarding Human Remains Research

When working in the field of paleopathology, one must keep in mind ethical constraints. A number of anthropological associations have their own code of ethics and while working in the field it is important to be conscious of these codes. It is very important to treat the material with the respect that all humans deserve, whether alive or deceased (American Anthropological Association 1998). It is also important to know the local origin of the remains. Knowing the context of the material is crucial. Research conducted with material which was not obtained legally or ethically will not be received well in the academic community and it may also put the researcher in a vulnerable legal situation. It is also important to be mindful of the laws and regulations required in particular regions when working with remains. In addition, the Institutional Review Board (IRB) has various regulations to abide by. This research did not require IRB approval because the population is deceased. Also, different countries have different laws concerning repatriation and it is critical to be mindful of these regulations. There are many ethical issues to be dealt with in the field of paleopathology; the issue of ethics is a deep and growing concern. As the guidelines and regulations change so will the field of paleopathology.

Issues with Historical Populations

When examining a historical population, several different types of sources must be employed and one must be conscious of possible limitations. First, if possible, primary sources should be referenced; primary sources supply first-hand accounts. A lack of primary sources makes it difficult to gain a historically accurate view of society. When using primary sources however, researchers must be careful as they may be biased. For this research, primary sources will provide the best information concerning food acquisition. Having knowledge pertaining to the dietary habits of region will be necessary to accurately interpret possible nutritional defects. Primary sources will also provide accounts of violence and warfare which may have disrupted agricultural production. Primary sources used in this research include Einhard's (1969) biography of Charlemagne, *De Villis* in (Herlihy 1993) and Gregor of Tours accounts of the Franks.

Secondary sources are often very valuable. A secondary source is information obtained from an individual who did not participate or observe the event first-hand. Unfortunately, secondary sources do not necessarily shed light on certain regions or populations. Secondary sources are often scholarly publications. Scholarly publications are very helpful because they are often based on research stemming from the use of primary sources.

Third, archaeological records are often able to produce information about a specific population. The main challenge when working with archaeological records is that the records provide only raw data. There are two potential problems with archaeological records; as with primary documents they rely on context, and they are open to interpretation. Although archaeological records can be problematic, there are many good reasons to incorporate their use into research. In order to acquire a comprehensive view of the past, it is best to incorporate as many sources as possible.

Environmental Issues with Human Remains Research

The environment is always changing; as a result it modifies the contents within it. In the field of paleopathology, pseudopaleopathology is a major concern as it may cause misdiagnosis. Pseudopaleopathology is a characteristic which appears to be pathological evidence, when in fact the feature was not caused by antemortem or perimortem pathology or trauma. Most often, pseudopaleopathology is caused by various environmental effects (Aufderheide and Rodriguez-Martin 1998). One must be conscious of pseudopaleopathology when working with skeletal remains which have been subject to the environment for hundreds or thousands of years.

One must always be conscious of the circumstances which may lead to misdiagnosis. In the field of paleopathology, misdiagnosis is most often caused by pseudopaleopathology. Pseudopaleopathology is a physical symptom which appears to display signs of paleopathology, when in fact the symptom was not caused by disease. Pseudopaleopathology can be caused in numerous ways. The skeletal material, which I will be working with, may display signs of pseudopaleopathology caused by one or more of several options. Damage caused during the excavation process may display pseudopaleopathology. Pseudopaleopathology may also occur as a result of poor specimen handling during post excavation examination. In addition, flora and fauna are often responsible for misdiagnosis of pathology. Microbial organisms also have the ability cause damage to skeletal material resembling pathology. Climate and soil conditions may also have an effect on the preservation of skeletal material. Finally, pressures from environmental forces may cause postmortem changes resembling pathology.

Damage to skeletal material is often caused during the initial excavation. It is common for skeletal material to be discovered during a public or private construction project. Often the machinery used during construction projects breaks, bends, fractures or scrapes the bone material. Damage may also occur during archaeological excavation. Inadequately trained individuals or novices may inflict damage to skeletal material through improper use of archaeological tools during the excavation process (Aufderheide and Rodriguez-Martin 1998). Also rough or improper handling of skeletal material during transportation may cause damage.

Skeletal material is prone to damage if not handled properly after excavation. Individuals working with skeletal material should be properly trained in handling and caring for skeletal specimens. Skeletal remains can be very brittle and fragile. If remains are not handled with care the remains may be damaged. If said damage is not recorded for future researchers, the damage may be interpreted as trauma. Another situation which researchers should be aware of is the range of normal variation for a particular diagnosis (Aufderheide and Rodriguez-Martin 1998). An example of range of normal variation is "the phenomenon of bilateral parietal bone 'thinning' may include a completely penetrating defect. Such defects have been confused with pathological lesions including metastatic carcinoma, trepanation and other proposed causes" (Aufderheide and Rodriguez-Martin 1998: 15).

The effects of environmental fauna may have severe consequences concerning the preservation of skeletal material. If skeletal remains are buried too close to the surface or not buried soon enough, local scavengers may destroy the remains. If remains are exposed it is not uncommon for larger animals to carry away portions of the appendicular skeleton. If the fauna is too small to carry away bits, they may chew and gnaw on the remains. Often smaller animals such as rodents may gnaw on bits of skeletal remains which fit their dentition (Fulcheri et al. 1986). Rodents often attack the supraorbital ridges, creating what appears to be possible trauma or osteitis (Fulcheri et al. 1986). Marks caused by gnawing rodents and insects may often appear as cut marks (Fulcheri et al. 1986).

Insects may also have an effect on paleopathology diagnosis. Material secreted by certain insects has the ability to liquefy the bone matrix "so that when subsequent groundwater action solubilized the remaining bone mineral, the localized defects can simulate disease processes" (Aufderheide and Rodriguez-Martin 1998: 16).

Flora may also affect the diagnosis of skeletal remains. Large plants or plant roots have the ability to crush fragile bone material. This may leave what appears to be fractures or breaks in the bone, resulting from postmortem trauma. Aufderheide notes that "larger plant roots may invade long bone medullary cavities through biological foramina, and subsequent bone weakening may result in ultimate fracture" (Aufderheide and Rodriguez-Martin 1998: 16). Small plant roots may also affect skeletal remains. Rootlets have the ability to wrap tightly around long bone diaphysis, causing groundwater to be trapped between the rootlets and the bone cortex (Aufderheide and Rodriguez-Martin 1998). Lytic action caused by groundwater and plant secretions may create surface grooves which may appear as vascular impressions (White and Folkens 1991).

Chemical erosion caused by soil pH levels may also cause damage to bony tissue, resembling paleopathology. Soil pH levels may extract bone material leaving the bony tissue in such a state that it appears as though the individual suffered from antemortem osteoporosis (Aufderheide and Rodriguez-Martin 1998). Mineral depleted bones are prone to bowing deformation by soil pressure (Aufderheide and Rodriguez-Martin 1998). According to Aufderheide and Rodriguez-Martin, "If the osteolytic process reaches the marrow it may simulate the lytic effects of osteomyelitis" (Aufderheide and Rodriguez-Martin 1998: 16). Ground water may also leave mineral deposits, producing what appears to be a dental calculus (Flinn et al. 1987). Deposits on the cortical surfaces of long bones may display the appearance of superficial periostitis; deposits such as these may lead to an inaccurate diagnosis of cribra orbitalia or porotic hyperostosis (Aufderheide and Rodriguez-Martin 1998).

Soil pressure may also cause bones to bow, or crush giving the bones the appearance of rickets or pseudotrauma i.e. fractures, or breaks. Bones of irregular structure will yield to pressure deformation fracturing in their weakest areas, while the denser more uniformly constructed long bones will tend to resist soil pressures (Henderson 1987). Also soil pressure has the ability to compress the cranium simulating antemortem intentional cranial deformation, scaphocephaly or frank fractures (Wells 1967). Postmortem fractures are common among ribs; however, the scapula, clavicle, forearm and lower leg bong bones are often affected as well (Wells 1967). "The absence of patina at the fracture site can often exclude excavation or post-excavation effects but can not rule out a change occurring during the *perimortem* time period" (Aufderheide and Rodriguez-Martin 1998: 17).

Bacteria in the soil may cause bony tissue to dissolve in irregular patterns which may produce pseudohistological changes characteristic of osteoclasts (Ortner and Putschar 1985). "Bacteria and fungi commonly gain access to the Haversian canals, generating acids capable of dissolving the bone mineral in irregular patterns suggestive of the histological changes produced by osteoclasts" (Aufderheide and Rodriguez-Martin 1998: 16).

Often one disease is mistaken for another, causing a misdiagnosis. Nutritional diseases cause stress on the body which often leaves physical evidence. When the human body is in nutritional distress, it will draw nutrients from any possible source, quite often the bony tissue. When nutrients are extracted from bones, the bony tissue is left in several possible states. An example of one such state would produce bones that appear thin and brittle, causing a diagnosis of osteoporosis. In reality thin, brittle bones are characteristic of several nutritional diseases including osteoporosis, arthritis, and osteomalacia.

CHAPTER TWO: MEROVINGIAN BEGINNINGS

The fifth century CE changed the social and political landscape of Europe. The fall of the Roman Empire plunged the European peoples into the Dark Ages also known as the early Middle Ages. James (2001) explains that with the retreat of the Roman legions back to Italy, the "barbarians" of northern and central Europe were no longer under Roman control. It is between 400 and 900 CE. that Europe as a whole saw radical change. By the end of the early middle ages, Northern Europe was able to claim the title of political and intellectual center of Europe (James 2001). James notes that, "The coronation in 800 of the Frank, Charlemagne, as the first northern emperor, has often been seen, and rightly, as symbolic of this shift of balance from south to north which is one of the most important developments of the early Middle Ages" (2001: 60). The fall of the Roman Empire enabled the north to become autonomous; they developed their own societies, with their own cultural and political practices. With the spread of Christianity the literacy rate increased, which means that we no longer have only Roman accounts of the past, but also first hand accounts from the northerners themselves (James 2001).

The Migrations

James suggests that, "The end of the Western Roman Empire was marked by movements of peoples" (2001:60). These migrations are known as the *Völkerwanderungen*, or wandering of peoples. In 400, the Rhine was the dividing line between the Roman and barbarian societies (James 2001). Within only a few years this was not the case. Around 406-407, the Rhine frontier collapsed, allowing for various Germanic peoples to settle in various parts of Europe (James 2001). The lower Rhine was claimed by the various peoples history calls the Franks (James 2001). It is during this time that we see most of the Roman aristocracy who owned land in Gaul, fleeing to more secure homes in the south (James 2001). In its weakened state, “the Roman army was no longer able to protect the north; indeed, the Roman army in Gaul was, by the 430s or 440s, a very motley collection of Roman soldiers, German mercenaries, and Germanic federate troops” (James 2001: 65). After the Germanic peoples crossed the Rhine, Rome was never able to hold the northern lands again. With the departure of the Roman army in central Europe, the peoples of Northern Europe found themselves migrating south, to fill the void (James 2001). Large portions of the former northern Roman territories became Germanic in language and culture (James 2001). These migrations did not only move south, but also east in to Scandinavia and the Slavic regions.

Merovingian Dynasty

With the disappearance of Roman rule from the northern lands, northern Gaul came under the rule of a new regime, the Merovingians. According to James (2001), the Merovingian King Clovis accomplished many things during his reign: he united the Romans in northern Gaul, united the Franks under his rule, conquered the Thuringians , the Alamans and destroyed the Visigothic kingdom of Alarec II. In 498 Clovis converted to Christianity and was baptized by Bishop Remigius of Rheims. When Clovis converted to Christianity, the entire Frankish population under his command converted as well (Hollister 2002). The baptism of Clovis marked the beginning of a close cooperation between the Merovingians and the Christian church that would be the “cornerstone of a policy that allowed the Franks, alone among the Germanic peoples of the Migration Period, to found a lasting kingdom on Roman soil…” (Neumayer 2007: 195).

After Clovis' death in 511, his four sons jointly ruled over the kingdom (James 2001). Childeric, the son of Clovis, is often viewed as the true founder of the Franks (James 2001). According to James, "by the middle of the sixth century the Frankish kings descended from Childeric and Clovis, known as the Merovingians, had become by far the most powerful of the barbarian heirs to the Roman Empire" (James 2001:66). Merovingian kings had a long custom of passing their estates to all of their heirs equally. Unfortunately, this tradition caused civil war and constant rivalry. According to Hollister, "After a father's death, sons would often fight each other in civil war until one of them emerged as sole king or they agreed to be content with their own bits of inheritance" (Hollister 2002:72).

Although difficult, "on occasion an able Merovingian king ruled effectively over a united Frankish kingdom or a portion thereof" (Hollister 2002: 73). One such ruler was Dagobert I. Dagobert I received a portion of his father's, Clothar II, kingdom; he eventually united the Franks, and ruled until his death in 638 (Hollister 2002). Despite the family feuding, the Merovingians managed to rule for two and a half centuries, until being replaced in 751 by the Carolingians, another Frankish dynasty.

Barbarian Society

As defined Hollister (2001), all those who lived outside of Roman society and spoke non-Greek languages were considered barbarians. "Barbarian" is not a ethnic term, but rather a way to categorize life ways. Hollister suggests that, "although we tend to think of the barbarian tribes as representing different ethnic groups, within each of which we might find one religion, one language, and one culture-this was not so, at least initially" (2001:37). According to James, "barbarian society was strictly stratified, with slaves and semi-free at the bottom and some kind of aristocrats and royalty at the top" (2001: 76). Entry into the aristocracy could be obtained, usually by acquisition of land, which was often gained through prowess on the battlefield (James 2001). According to James, "A man's legal status was rigidly defined by the law codes; each man had his 'man price' or 'honour-price" (2001:77). The Germanic barbarians developed socially stratified societies with a powerful monarchy and a landed aristocracy who were use to military life (James 2001).

Graves from the fifth century CE forward show a stratified society through grave goods (James 2001). James (2001) explains how royal graves and those of the upper socioeconomic classes displayed prominent wealth. Graves of warriors have produced weapons, spears, one-sided swords, while in the case of aristocrats we see long-swards with gold-foil sword hilts and golden jeweled pommels (James 2001).

The socioeconomic class which one belonged to was determined at birth. In the European barbarian societies the kin group was very important (James 2001). The barbarians traced kinship through both maternal and paternal lines (Hollister 2002). Hollister (2002) explains that the barbarians most likely looked to their kin for physical protection and emotional support. The kin group not only held land rights, as discussed earlier, but also held legal rights. Kin had the legal duty to bring anyone who wronged their kin to justice, leading to cycles of violence caused by violence (James 2001).

Rural and Urban Life

Ament (2007) notes that life in the rural settlements changed radically when the Romans retreated towards Italy. The stone Roman villas were replaced by individual farmsteads and communal settlements which utilized timber for structure (Ament 2007).

Urban life was different from life in the rural settlements. The towns with their large Roman walls lasted from the late Roman period through the early medieval period (Ament 2007). Also the "…essential Roman infrastructure such as their street-grid, walled circuit and places of Christian worship continued to define the townscape" (Ament 2007:214).

As the Merovingian society continued to develop it also became more stratified. The Merovingian society was "deeply rooted in the nature of its economic system, which was characterized by the monopoly of landowning in the hands of a small, extraordinarily wealthy elite, with the vast majority of the population, slave and free alike, destitute and often in desperate straits" (Geary 1988; 96). This agricultural system could not support the entire population (Geary 1988).

Agricultural technology did not develop as quickly as the society did. Frankish agricultural technology was basic during the sixth century CE producing a small surplus during the good years and frequent and devastating famine in the bad years (Geary 1988). Frankish agricultural technology was only as advanced as provincial Rome (Geary 1988). Geary notes that, "Machinery such as the mechanical harvester used in Gaul in the time of Pliny had disappeared; water mills, although in use along the Rhone and Ruiver, as well as in a few other areas, were rare; and the other tools, ploughs, scythes, hoes, etc., were largely or even entirely of wood" (1988: 97).

As the Roman and Frankish cultures merged the products of agriculture changed for both Romans and Franks. The production of grains switched from light grains such as wheat, to darker grains such as barley (Geary 1988). Bakels (2005) proposes that oats, barley, rye and bread wheat were among the cereals that were produced and consumed. Darker grains are not only hardier and preserve longer, but also because they could be easily converted into strong and nourishing beer (Geary 1988). A document titled *De Villis,* thought to be issued by Charlemagne, provides readers with a list of foods expected to be found in the homes of Merovingian stewards (Herlihy 1993). According to *De Villis*, horses, oxen, cow, pigs, geese, boars and chickens were all available in Merovingian society. Fruits trees included: apple, pear, plum, medlar, chestnut, peach, laurel, fig, chestnut, almond and mulberry (Herlihy 1993). According to *De Villis* Merovingian gardens could contain a variety of vegetables: pumpkins, peas, cucumbers, chick-peas, squill, heliotrope, lettuce, rocket salad, parsley, celery, lovage, juniper, garden poppy, beets, carrots, parsnips, kohlrabi, cabbages, onions, chives, leeks, radishes, shallots, garlic, broad beans, large peas and capers (Herlihy 1993). *De Villis* also mentions the use of cheese, mustard, wax, butter, wine, beer mead and flour. While *De Villis* provides information about foods that the stewards are required to have on their land, it does not provide information as to what the farmers and peasants ate or the availability of such foods to the latter.

Wine played a vital role in the Roman way of life, therefore with the blending of these two cultures it is conceivable that wine was also important to sixth century CE Franks. Rome introduced viniculture throughout their empire, a practice which expanded in the early Merovingian period (Geary 1988). Wine was considered the drink of the elite (Geary 1988). Einhard mentions in the biography of Charlemagne that in addition to roasted meats and fruits, the emperor enjoyed a glass of wine with his meal. Geary (1988) notes that the "increasing investment in wine cultivation at the expense of traditional subsistence-type agriculture probably indicates the growing dominance of agricultural decisions by the aristocracy" (1988: 97). If so, this shift may have had a negative impact on food availability for the peasants.

Within the city "the majority of foodstuff were made available for local consumption either by the peasants who produced it or their lords" (Geary 1988: 109). The surplus was circulated usually through gift or theft depending on the relationship between the exchange partners, less often the product was sold (Geary 1988). However, individuals with a surplus of food might sell or trade the excess for profit during times when food was difficult to obtain (Geary 1988).

The fifth century CE produces many changes for the Frankish kingdom. The blending of the Roman and Frankish cultures produced a solid foundation for the emerging Merovingian kingdom. With the conversion of Clovis and the rise in prominence of the Christian church, social stratification gradually became more prominent. A trend in agricultural change was driven by the demands and pressures of a life style less luxurious than that of the Roman Empire. Finally we see the emergence of a need for the development of commerce and artisan economies in a culture which was previously self sufficient.

Burial

Although many aspects of life changed considerably burial practices changed only slightly. Each settlement had a community cemetery and:

> The burial customs practiced in them basically corresponded to (late) Roman ones, in as much as inhumation rather than cremation of the body, a west-east orientation, and the deposition of vessels as grave-goods were the norm, but also marked a distinct departure with the sometimes extravagant furnishing of female burials with jewelry and of male burials with weapons (Ament 2007: 214).

The appearance of the deceased reflected that of the individual during life, which was not unlike that of the preceding Roman period (Ament 2007). The major difference between the late Roman cemeteries and the Germanic cemeteries was to the location. Roman cemeteries were typically located within the city walls, whereas the Frankish cemeteries were outside (Ament 2007).

CHAPTER THREE. METHODOLOGIES

Explanation of Research

This research explored the physical health of a Merovingian juvenile population dating to the sixth to the eighth centuries CE. The purpose of this research is to gain an understanding of the pathological conditions that affected this specific Merovingian population through an analysis of skeletal remains from the Mannheim-Vogelstang cemetery near Mannheim, Germany. The cemetery was excavated during the 1960s, revealing approximately 149 juvenile skeletons (ranging from neonatal to approximately 18 years of age) in three different layers, representing three separate time periods. Of the 149 skeletons that were recovered during the excavation, 107 are curated by the Reiss-Englehorm-Museums in Mannheim, Germany. These skeletons were examined in the winter of 2009 during a research trip to Mannheim. Because this population spans several centuries, it provided the perfect opportunity to study physical health of juveniles during the early Merovingian dynasty.

This population was chosen for two reasons. First, the excavation revealed multiple centuries' worth of skeletal material, providing me with an opportunity to consider the possible differences between the physical health of these individuals throughout the sixth and eighth centuries. Secondly, these individuals had not been analyzed to date and data related to the health of this population does not exist.

Fieldwork

This thesis research was conducted at the Reiss-Englehorm-Museums in Mannheim, Germany. The remains used for this research was excavated the Mannheim-Vogelstang site in the 1960s by Dr. Ursula Koch. The skeletal material used for this research has been dated in phases from 530 to 700 CE (SD05-SD11). SD stands for Spalte Datierung , which translates to column dating. The phases break down as follows: SD05 dates ca. 530-555, SD06 dates ca.555-575, SD07 dates ca. 575-600, SD08 dates, ca. 600-620, SD09 dates ca. 620-650, SD10 dates, ca 650-675 and SD11 dates ca.657-700. The Mannheim-Vogelstang collection is housed in a storage location in a building near the central museum. Upon arrival I was given an Excel file that displayed a list of the juvenile skeletons recovered from the site. The list provided the grave number, excavation location, the dimensions of the grave, potential age, sex and time period for each individual. The original list provided a total of 150 graves. Figure 1 is a copy of the cemetery layout from the excavation.

Figure 1. Mannheim-Vogelstang Cemetery

Archaeological map of Mannheim-Vogelstang Cemetery

I examined the remains primarily for diseases which indicate dietary distress. Nutritional diseases are often easily observed in skeletal remains due to the fact that they readily affect the way the human body grows and develops. Juveniles are still experiencing bone growth and development, disruptions to growth patters are relatively easy to see. Dietary distress is caused in two main ways. First, the foods that one is consuming may not hold the desired amount of nutrients. Second, individuals may not have access to sufficient food sources due to limited availability (e.g. during periods of famine, plague or siege) or a lack of means to acquire available food. I also looked for signs of several chronic and contagious diseases, finding traces of rickets, anemia, dental diseases and physical injuries.

Each skeleton was examined for any signs of pathology, as well as for evidence of any trauma. The main diagnostic technique used during this research was physical observation. By closely analyzing individual skeletons I made note of any abnormalities such as bone wear/erosion, calcification, ossification, bending/bowing, fractures and breakage. In order to ensure close inspection I have used magnifying lenses. The magnification has helped to gain a closer and more thorough inspection of the bones.

Digital photography was also utilized during my research for several reasons. First, the photographs have served as a record, as evidence-based research in paleopathology requires the use of a detailed research record. Second, the photographs have provided a detailed digital record for the museum archives. Furthermore the photographs may serve as a companion to the written records. Photographs of conditions do not always appear the same on actual bony tissue. Also, photographs of the remains can be used for comparison to other known examples. In addition, the photographs will enable me to share images with colleagues in order to obtain a second opinion. The photographs will also provide me with images which will be used in the thesis write up and conference presentations. Lastly, the digital photographs have enabled me to view the remains since my return to NDSU. The photographs have served as a record for me to reference.

The juvenile collection that I worked with was stored in labeled boxes containing the site name, the grave location, date of excavation and the type of skeleton (child or adult). The size of the box was dependent upon the amount of skeleton that was recovered. There were two individuals that I located that were not on the list. The vast majority of the skeletons were in their own box; however, several juvenile skeletons were found in the boxes of adult skeletons. After searching the archives, of the 150 skeletons on the list 107 were recovered, several of which were not on the original list.

The boxes were moved by van from their storage location to a research building half a block away. This thesis research was conducted in a lab space that was shared by museum employee who worked with the museum displays. I was granted a work space that provided room for all the boxes, along with a clean table and work space. The building the research took place in was locked by code from the outside as well as the studio space I was temporally granted.

Once all of the skeletons were moved to the studio, I began the visual inspection of each individual. Before starting the research I put together an Excel file that contained columns for the grave number, the time period according to Dr. Koch's data, the age, sex, the preservation condition of the remain, condition of the appendicular, axial and cranial skeletons along with any signs of dental conditions, bending/bowing, porotic lesions, fractures/breaks and abnormal growth. In addition to the spreadsheet I also prepared anatomy sheets which could be used to display a visual representation of the bones present for each individual.

I examined each individual one at a time. Within the boxes, the cranial, axial and appendicular skeletons were bagged separately; if not enough bones were recovered, only the cranial bones were kept separate. I first started by laying out each individual in anatomical order. Once all of the bones were laid out I took a picture of the label on the box, followed by a full-shot picture of the skeletons in anatomical order. Following the initial images I then proceeded to color in the bones which were present on the anatomic worksheets. Each individual was then visually examined. Once the initial visual examination was finished I then inserted the information concerning the preservation condition, axial, cranial and appendicular skeleton conditions, into the spreadsheet. Information such as weathering, environmental marking (floral and fauna) and the percentage of bones recovered was also recorded. Certain bones have a better preservation rates then other. Also, depending on the soil conditions, it is possible that certain sections of the skeleton preserve better then others. A second visual inspection was then performed. The second inspection was to ensure that all signs of possible conditions were thoroughly examined. Each bone that presented with possible signs of pathology was then photographed from several angles against a ruler. Following the pictures any detail concerning possible pathology was recorded in the spreadsheet. The visual inspections took roughly 30-45minutes per individual; however, the time spent on each skeleton was highly dependent on the amount of bones recovered for each individual.

Theoretical Approach

Biocultural theory is a broad theoretical paradigm which recognizes the codependent relationship between biology and culture and this thesis research uses "biocultural theory" (Sofaer 2000). Biology and culture influence one another constantly thus in order to fully understand a culture one must understand the influence of biology on culture and culture on biology.

Many paradigms have helped shape the theory behind biocultural thought. Processualism (New Archaeology) and post-processualism are both incorporated in biocultural theory. Processual archaeology revolutionized the way researchers examined culture. Processualism emphasized the importance of ethnographic field work. The goal of processual thinkers is to understand cultures through material culture remains. This particular paradigm observes the living body "whose actions could be observed in conjunction with material culture in order to establish correlation that could be transposed on to the archaeological record" (Sofaer 2000: 14-15). New Archaeology utilized the scientific method to draw conclusions about the culture and through a processualists analysis of cultural remains, one can reconstruct the culture itself. The archaeological record enables researchers to catalogue, describe and create timelines based on artifact analysis (Trigger 1989). New Archaeology utilizes cultural evolutionism which studies the effects the environment imposes on a culture (Erickson and Murphy 2003). As the environment changes the population living within will be forced to adapt. The processualist frame requires a researcher to understand the environmental constraints imposed upon a people, thereby causing tangible and intangible changes to a culture (Sofaer 2000). Cultures are required to live within an environment, and insufficient adaptation to the environment will not promote survival. Processual archaeologists understand that inadequate knowledge about the environment (physical and cultural) will not explain the causes of cultural developments.

Post-processualism has also influenced the development of biocultural theory. Sofaer (2000) mentions that although the human body was vital in the development of post-processual thought, it made clear the ever growing gap between physical science and social science. Post-processualists critiqued the use of purely scientific methodology. Post-processualism posits that cultural change can not be verified experimentally. Since humans are performing the research, there will always be personal bias reflected in the research (Trigger 1989). Within post processual thought one must understand the history of a people in order to accurately interpret the culture.

Physical anthropology is a discipline in which combining biology and various social sciences are necessary. When working with remains, if the researcher does not take the time to gain knowledge about both the biology and the culture, a vast amount of information may be overlooked. Many physical anthropologists have understood that more information can be obtained from remains through the use of a biocultural approach.

My research has tried to understand the role history plays in the development of one aspect of culture, diet. Through understanding the history of this population I have tried to gain population specific information in order to draw conclusions concerning the Merovingian diet. The field of physical anthropology often works with the human body both historic and prehistoric. Understanding the relationship between biology (both physical and environmental) and culture is crucial in obtaining thorough knowledge. This research addresses both physical and social science; hence a theoretical approach which addresses both branches is required. I have therefore used biocultural theory as a basis for this thesis research. The aim of biocultural theory is to understand how biology and culture intersect.

The use of biocultural theory in this research is essential. Since this research is addressing paleopathology, it is critical that one knows the possible causes of said pathologies. Once signs of paleopathology have been observed, one must investigate the cause of the pathology. This research found many of the conditions to be related to nutrition, therefore a deeper examination of the dietary habits, food acquisition and agricultural practices is critical in understanding why these results were found. Understanding the Merovingian culture provides context for interpreting the empirical data from the skeletal remains analysis.

Visual Analysis of Possible Conditions

Visual observation was the main diagnostic technique used during this research. Visual observation is a technique which can be used on the majority of remains. Visual observation is commonly used because a large amount of information can be obtained with minimum amount of destruction. Minimal destruction can only be achieved if the specimen is examined in an environment which promotes preservation. When working with remains it is important to keep in mind that there is always a certain level of invasiveness and the chance for destruction. There are a number of conditions which can be diagnosed through the use of visual observation.

Dental Conditions

There are numerous dental diseases which present distinct physical characteristics. A calculus is the formation of calcified deposits on the teeth. According to Belcastro et al. (2007) the deposits are formed when there is an excess of plaque in the mouth, which can be caused by increased alkalinity in the mouth or poor oral hygiene. As dental plaque becomes stagnant it begins to calcify, forming a calculi (Aufderheide and Rodriguez-

Martin 1998). Dental caries are another condition which is caused by excessive plaque and consumption of sucrose found in carbohydrates (Aufderheide and Rodriguez-Martin 1998). Caries can be very painful, they may cause tooth decay and cavities and if left untreated will cause destruction of the crown and section of the root resulting in tooth loss (Ortner 2003). Cavities may cause bacteria to grow which may lead to a tooth abscess (Ortner 2003). In addition to being very painful, Ortner (2003) notes that if left untreated, abscesses and another dental diseases have the ability to spread to other bones of the face and jaw causing damage to the bony tissue.

Linear Enamel Hypoplasia

The presence of hypoplasia is another condition which can be used to detect nutritional deficiencies in an individual. Enamel hypoplasia is "a defect in the structure of tooth enamel resulting from a body-wide, metabolic insult sufficient to disrupt ameloblastic physiology" (Aufderheide and Rodriguez-Martin 1998: 405). The result of enamel hypoplasia is an interruption in enamel formation resulting in horizontal lines on ones teeth. The lines develop because the enamel formation has been disrupted resulting in increased spacing of enamel growth lines (Palubechaite 2002). Afderheide and Rodriguez-Martin (1998) suggest that most hypoplasia lines form during the first year of life. The presence of hypoplasia suggests malnutrition or a change in dietary habits brought about by a decreased intake of vitamins and minerals (Palubeckaite 2002). There are many factors that may lead to the presence of enamel hypoplasia. The causes of enamel hypoplasia include "hemolytic disease of the newborn, premature birth, major febrile infections, dietary deficiencies of vitamins A, C and D, newborn hypoxia and others. The cause most frequently cited is malnutrition" (Aufderheide and Rodriguez-Martin 1998: 407). The linear lines are directly caused by an arrest in amelogenic growth resulting in an incomplete layer of enamel (Aufderheide and Rodriguez-Martin 1998). The more prolonged the state hindering enamel growth the more prominent the linear lines will appear.

Porotic Hyperostosis

Porotic hyperostosis is a condition characterized by a sponge like texture that appears on bone. According to Ortner (2003), porotic hyperostosis is a term that describes any porous enlargement of bone tissue. Often this "sponge like texture" is clearly seen within the eye orbits of individuals. Porotic lesions within the eye orbits are known as cribra orbitalia, a condition which indicates dietary distress believed to be caused by anemia. Cribra orbitalia is characterized by sieve-like lesions or porous openings on the orbital roof (Exner 2004). Anemia is often brought about in one of three ways: "iron-deficiency anemia produced by the inadequate intake or absorption of iron, the anemia of chronic disease (ACD) caused by the body's natural iron-withholding defense against microbial invaders, and megaloblastic anemia caused by insufficient intake and/or absorption of vitamin B12 or folic acid" (Sullivan 2005:2). Whichever manifestation is responsible, the body is being deprived of essential nutrients.

It is for this reason that many researchers feel that the presences of cribra orbitalia are an indicator of dietary stress. Some researchers believe that cribra orbitalia is caused by an infection or pathogen, which is brought on by a weakened immune system due to a lack of iron in the diet (Exner 2004). According to Moseley (1965), lesions develop as a result of hypertrophy and hyperplasia of the red bone marrow, which occurs in response to a type of anemic stimulus. A great many researchers agree that "cribra orbitalia found in archaeological samples is the result of acquired iron deficiency anaemia" (Obertova and

Thurzo 2007:2). Iron deficiency anemia is caused by a reduction in normal levels of hemoglobin and hematocrit within the blood stream (Obertova and Thurzo 2007). Ortner (2007) and Mensforth et al. (1978:38) reported an association between evidence of infectious disease and the presence of porotic hyperostosis; in addition, they suggested that illness and nutritional stress were key factors in the presences of iron deficiency anemia. According Gilbert (2009), the best sources of iron can be found in seafood (cod, sardines, tuna, clams, oysters, shrimp), poultry (chicken, eggs, yolks), lean red meats (beef, lamb veal, pork, liver), nuts, soybeans, vegetables (broccoli, chard, spinach, asparagus, turnips, parsley, kale, watercress, brussel sprouts), beans and fruits (dates, prunes, figs, apricots, apples raisins, coconuts).

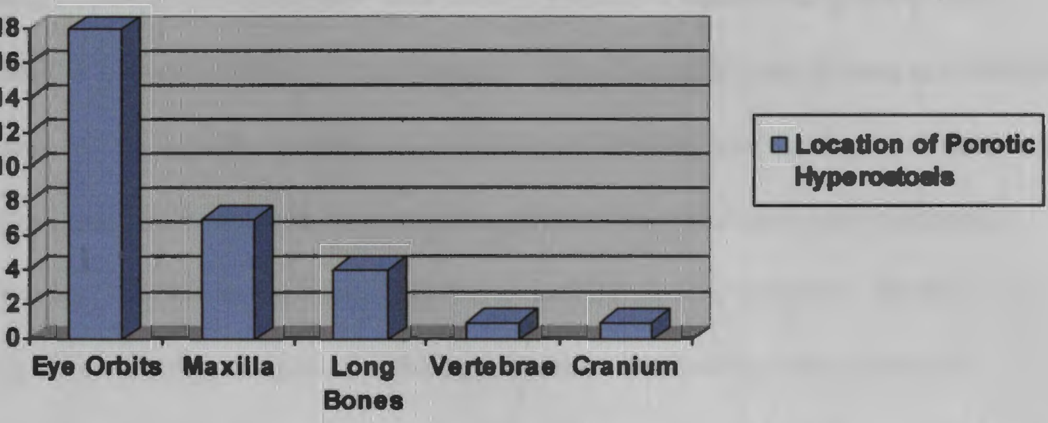
CHAPTER FOUR. DISCUSSION OF THE DATA AND CONCLUSIONS

At the Reiss-Englehorm Museums in Mannheim, Germany, a total of 107 juvenile skeletons were examined for any signs of skeletal pathology. Each individual skeleton was laid out and the bones were accounted for. A thorough and systematic visual examination was preformed with the intent of finding and recording any abnormal characteristics present on the bones. Each skeleton was examined for the following conditions, porotic lesions, bending/bowing, abnormal growth, breaks, fractures, excessively thin/brittle bones along with several dental conditions indicating hypoplasia, dental carries, calculi, abscess and tooth wear. Of the 107 individuals that were examined, 43.92% displayed signs of various pathologies. The most common condition found was porotic hyperostosis, followed by dental hypoplasia. SD08 (600-620CE) produced the largest number of individuals with pathology, with SD05 (530-555 CE) producing the second largest group of afflicted individuals.

Results

Data revealed that porotic lesions were visible in 21.49% of the skeletal remains. Of the 47 individuals that presented with pathology 48.9% displayed signs of porotic lesions. Porotic lesions are caused by porotic hyperostosis, causing the bony tissue to appear spongy. Porotic hyperostosis was found in the eye orbits, maxilla, several long bones, vertebrae and crania of 23 individuals. The dispersion of porotic hyperostosis can be seen below in Table 1. The eye orbits exhibited the most frequent signs of porotic lesions. Six of the individuals displayed porotic lesions in multiple areas.

Table 1. Dispersion of Porotic Hyperostosis



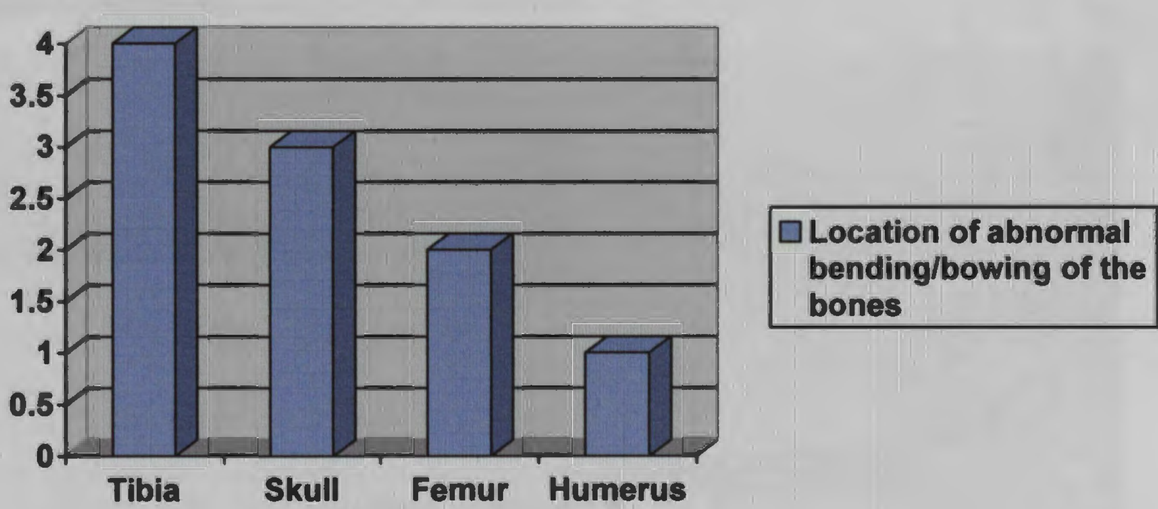
n=23 individuals with Porotic Hyperostosis

Anemia is a condition in which the body is lacking red blood cells. A drop in red blood cell count can be caused by virtually anything; however, in order for the individual to display signs of porotic hyperostosis, the condition would need to be chronic or last for a decently long time. Anemia can be caused by hundreds of conditions including: iron deficiency, infection, chronic disease (i.e. kidney disease), leukemia, bone marrow related diseases and internal bleeding.

The two most logical reasons for porotic hyperostosis in this population are malnutrition leading to an iron deficiency and chronic disease. Most diseases/conditions did not have diagnoses let alone treatment. If one of these children were suffering from kidney disease or a bone marrow disease there would have been no way to treat, or cure the individual. Conditions such as internal bleeding and infection have been ruled out because death would result relatively quickly. The presents of porotic lesions indicated that the individual was anemic long enough to distort bony tissue, which would take more than several weeks. Malnutrition and chronic disease would last long enough to cause visible porotic lesions. For most individuals in this time period, food was not easy to come by. The majority of people produced their own food (a portion of which was given to their lord). A fruitful harvest is hardly ever a guarantee: flood, drought, war, storms, and insects quite capable of causing a bad harvest. A poor harvest leads to food shortages. Nutritional distress also causes individuals to be more susceptible to bacterial and viral infections.

Bending and bowing of bones was found on 9.34% of the juveniles. Of the individuals which displayed signs of pathology, bending and bowing was reported in 21.27%. Bending and bowing of the bones was found on the tibia, skull, femur and the humerus. The tibia was the bone most often distorted, comprising 40% of the bowed/bent bones. The dispersion of bowing/bending can be seen in table two. In total 9.34% of the individuals showed signs of bending or bowing.

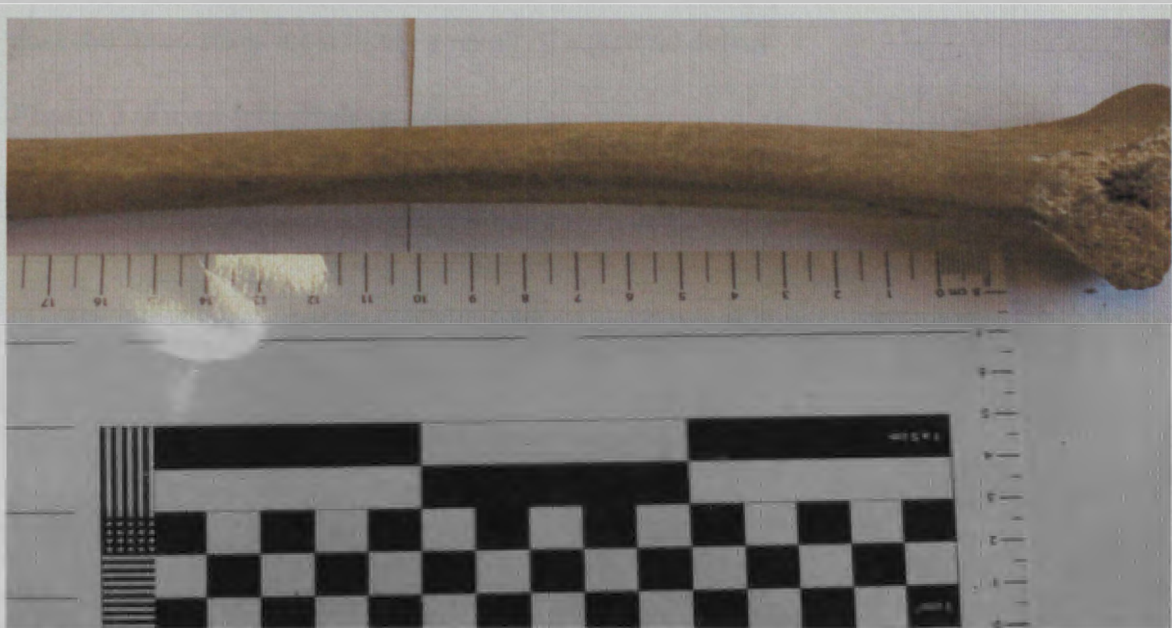
Table 2. Dispersion of Bending/Bowing



n=10 individuals with abnormal bending/bowing

The abnormal bending/bowing of bones could be caused by a number of circumstances. One example of abnormal bending/bowing can be seen on the right tibia from a 10-11 year old individual (Figure 2). The right tibia of this individual shows a lateral bending of the proximal shaft. Soil has the ability to exert pressure on the bone causing it to bend. A lack of nutrients in the bones may cause the bony tissue to weaken; weak bones often bend due to muscular and skeletal pressure. Rickets, a nutritional disorder caused by a lack of vitamin D in the diet, often produces this bowing effect. The easiest way to obtain vitamin D is through direct sunlight (Ortner 2003). Vitamin D, once absorbed, is converted into a hormone which controls calcium absorption (Ortner 2003). If the bones fail to absorb calcium, the bone matrix weakens and will eventually be destroyed (Ortner 2003). The exact cause of this particular bend is uncertain. The exact cause of this particular bend is uncertain. Since several other long bones were recovered from this individual that did not show signs of bowing, it is most likely that this particular bend is do to soil pressure.

Figure 2. Right tibia exhibiting a lateral bend



Right tibia recovered from grave 214

This research found no signs of breaks or excessively thin, brittle bones. Many broken bones were recovered during the excavation; however, based on the coloration and texture, the bones were broken post-mortem throughout the years by various environmental factors. Although no bones were found displaying signs of breaks or excessively thin or brittle, one bone was found which exhibited abnormal growth.

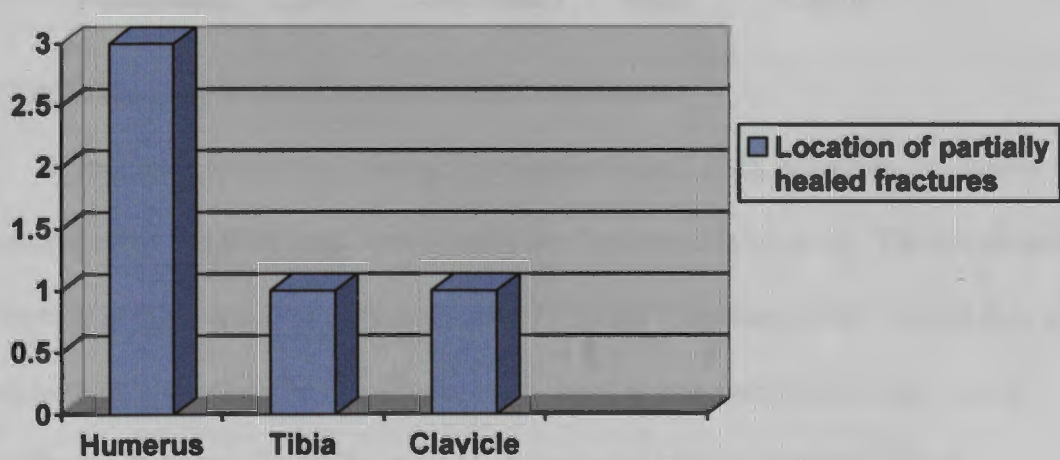
The abnormal growth was found in grave 231 (Figure 3). It appears that two left ribs were fused together. The individual in grave 231 was dated to SD08 (600-620 CE); the grave contained a juvenile that was estimated to be six to seven years of age. The skeleton was extremely demineralized and the bones were mostly fragments. The abnormal growth was only present on one individual comprising less than one percent of the pathology found during this research. Abnormal bone growth is usually attributed to a genetic defect; however it is possible that this is due to trauma. If this individual broke his/her rib it is a possibility that the ribs fused together during the healing process. In this case the fused rib is most likely a result of a genetic defect.

Figure 3. Fused left rib fragments

Fused rib recovered from grave 231

Although no broken bones were discovered, several individuals presented with possible healed fractures. Healed fractures are characterized by raised bony tissue where the fracture originally occurred. The raised tissue, called a callus is primarily coarse, fibrillar trabeculae within the fibrous callus (Schinez et al 1951-1952). According to Ortner "the periosteum will usually be broken during fracture, although this is not inevitable, particularly in young individuals. The stress that breaks the periosteum also tends to strip it from the surface of the bone for a few millimeters adjacent to the fracture site" (Ortner 2003: 126). Once the periosteum has been stripped from the bone, the osteogenic layer in the periosteum is activated and a callus is formed (Schinz et al 1951-1952). Primary callus formation occurs approximately one week after the fracture Collins (1966). Partially healed fractures appeared on the humerus, tibia and clavicle. Partially healed fractures appeared on 4.67% of the individuals and the majority of the fractures appeared on the humeri (Table 3).

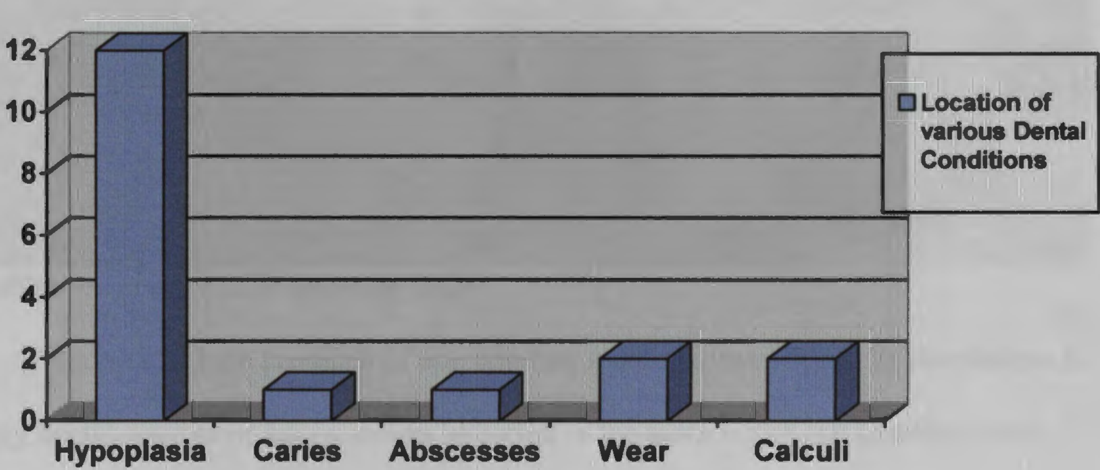
Table 3. Dispersion of Fractures



n=5 individuals presenting with partially healed fractures

Numerous dental conditions were found during visual examinations. The dental conditions which were found during the research include hypoplasia, caries, abscesses, calculi and wear (Table 4). The most prominent dental condition found was LEH, presenting in 11.21% of the individuals. Dental calculi were also noted, presenting in 1.87% of the individuals. One individual showed signs of both a single carie and a possible abscess, while two individuals displayed signs of excessive wear considering the age of the individual.

Table 4. Dispersion of Dental Conditions



n=17 individuals presented various dental conditions

Hypoplasia, known as linear enamel hypoplasia (LEH), is a dental condition characterized by the horizontal lines formed on the enamel (Figure 4). The horizontal lines are formed in the enamel on the bucal surface of teeth (Suckling 1989). Figure four shows hypoplasia on almost all the mandibular teeth, most pronounced on the right canine. According to Boldson (2007) the most likely cause of LEH is metabolic stress. Physiological distress results when the body is subjected to metabolic imbalances.

Diseases/infections and malnutrition are proponents of metabolic imbalances. The display of LEH in this population appears to be of the same origin as that of porotic hyperostosis.

Figure 4. Enamel hypoplasia found in grave 250

Mandible from grave 250 showing LEH

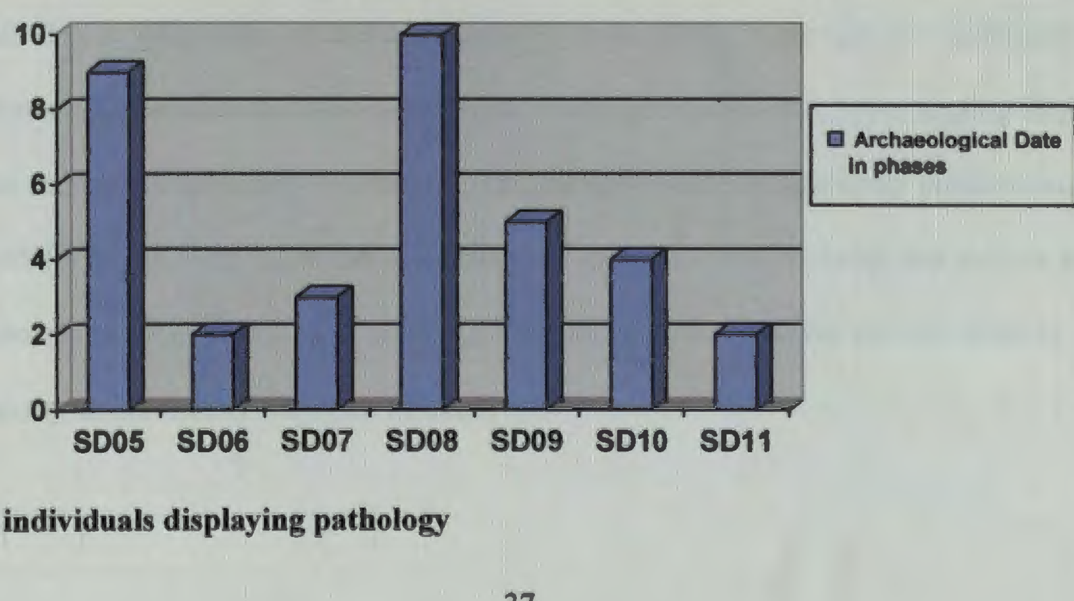
Data revealed the presence of one possible tooth abscess (Figure 5). An abscess is another dental disease which causes an infection in the tooth which left untreated can spread to the bones of the face (Aufderheide and Rodriguez-Martin 1998). Aufderheide and Rodriguez-Martin also mention that "…maxillary periapical abscesses may also perforate into the maxillary sinus" (Aufderheide and Rodriguez-Martin 1998). In figure five, the bony tissue of the maxilla has been infected. The result of this infection is a slightly raised and demineralized area of bony tissue. The right lateral area of the maxilla shows porous area caused by infection where the bone is being eaten away. Given enough time the bony tissue would disappear exposing the roots of the teeth.

Figure 5. Possible maxillary abscess found in grave 109

Maxilla from grave 109

The material used for this research spanned several centuries. After compiling the data, it was found that, SD08 (600-620) contained the largest number of individuals suffering from pathological conditions (Table 5). SD08 comprised 28.57% of all pathological conditions noted. SD05 (530-555) closely followed SD08 providing 25.71%. SD11 (657-700) provided the fewest individuals presenting with pathological conditions; displaying 5.71% of the total paleopathology noted.

Table 5. Dispersion of Pathological Condition According to Archaeological Date



n=35 individuals displaying pathology

Conclusion

The purpose of this research was to determine the pathological conditions/disorders in this Merovingian juvenile population. A total of 107 juvenile skeletons dating from 530CE to 700CE were examined. Of the 107 individuals found in the archives, 35 presented with various potential pathology. The pathological conditions found through the course of this research included: porotic hyperostosis, abnormal bending/bowing, fractures, hypoplasia, dental abscess and dental caries. The most common condition found throughout the research was porotic hyperostosis, closely followed by hypoplasia. These results of this research proved that these juveniles primarily suffered from conditions resulting from dietary distress caused by malnutrition or infection.

The most common pathological condition was porotic hyperostosis. Signs of porotic hyperostosis were found in 21.49% of the individuals. Porotic hyperostosis is a condition characterized by porous lesions on bony tissue, most commonly the eye orbits. As mentioned in chapter three, porotic hyperostosis is caused by anemia. What caused the anemia is a harder question to answer. Most researchers feel that anemia is caused by an inadequate intake of iron rich food; however, chronic disease and insufficient intake of vitamin B12 or folic acid may lead to anemia (Sullivan 2005). Although iron deficiency and chronic diseases are the most likely cause of the observed porotic hyperostosis, they are not necessarily the cause of death. It is impossible provide an absolutely positive cause of death for any of these individuals, we can only speculate. Is it probable that anemia may have been a factor or the cause of death for these individuals; however we will never be able to say with certainty the cause of death.

The second most prevalent conditions was linear enamel hypoplasia (LEH), occurring in 11.21% of the individuals. LEH can be caused by several different circumstances including genetic diseases, infections, malnutrition and dietary habits (Pindborg 1970). Enamel hypoplasia dose not result in death; however, it is an indicator that the individual most likely suffered from malnutrition or infection. Either of which may have caused or been involved with the death of the individual.

SD08, 600-620CE, presented with the largest number of individuals containing signs of pathological conditions/disorders. Agriculture may have struggled through out SD08. Agriculture may have struggled due to drought, insects or flood. Spread of disease may also have attributed to the large number of individuals within this time phase. It is probable that a virus or bacterial infection spread through the community causing individuals to suffer from infection, forcing the body to fight the infection while preventing it from producing essential nutrients. Unfortunately the exact reason for SD08 producing the largest amount of individuals with signs of pathology will take more research.

De Villis provided information concerning the types of food that are ideally required on the estates of Merovingian stewards. This document listed food that were ideally kept on the estates, more research would be necessary to conclude what foods were actually available on the estates. This document has shown that with the types of foods available anemia, caused by nutritional distress, should not have been a problem within Merovingian society. However, since such a large percentage of individuals displayed signs of anemia despite the fact that iron rich foods existed in society, one must ask why these individuals were not receiving the required nutrients. There are several possible reasons. First, it is possible that the food on the estates were not made available to everyone. People of lower socioeconomic classes may have been denied access to certain foods causing nutritional distress. Secondly, the agricultural production may have been inadequate to feed everyone. Agriculture is very susceptible to insects, disease, poor weather conditions and cultural circumstances such as war. A bad harvest for whatever reason would effect all socioeconomic classes. A thorough examination of the archaeological record and historical records would be needed in order to determine if such environment and cultural conditions were responsible for the lack of iron rich foods.

It is clear that a large portion of these juveniles suffered physiological stress at some point in their lives. The conditions explored during this research can not determine the cause of death; only provide insight into conditions with affected these individuals. This research has shown that this Merovingian population had a difficult time obtaining the nutrition required for the body, leading to the osteological conditions displayed in this collection.

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