A PALEOPATHOLOGICAL ANALYSIS OF SKELETAL REMAINS FROM THE SALINAR AND GALLINAZO PHASES IN THE MOCHE VALLEY (PERU)

by

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B.P. in Anthropology, University of Pittsburgh, 2018

Submitted to the Undergraduate Faculty of

University Honors College in partial fulfillment

of the requirements for the degree of

Bachelor of Philosophy

University of Pittsburgh

2018

UNIVERSITY OF PITTSBURGH

University Honors College

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Although the Moche phase of the Early Intermediate Period of the north coast of Peru has been well studied, less is known about the Salinar and Gallinazo phases that preceded it. The few pre-Moche sites that have been subject to significant investigation have primarily been inland, urban settlements. To better understand the full range of lived experiences during the Salinar and Gallinazo phases, skeletal remains of 26 individuals recovered from the two small, coastal communities of Pampa la Cruz and La Iglesia were examined. Because of the major political, social, and economic changes that were occurring during this time, these remains were examined for signs of malnutrition and chronic infectious disease to see if rates of these pathological conditions corresponded to those changes. While the small sample size precludes statistical significance in most areas of comparison, trends in the resulting data suggest that Gallinazo people led healthier lives than their Salinar ancestors.

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PREFACE

I would like to acknowledge everyone who helped me to work on this thesis and complete it. First, I want to thank my amazing advisor, Dr. Arkush for helping me every step of the way. Her passion for her work has always inspired me to learn and do more in this field. Additionally, I would like to thank Dr. Celeste Marie Gagnon with Wagner College and Dr. Gabriel Prieto with the Universidad Nacional de Trujillo for helping me acquire the data for this thesis; Dr. Marc Bermann, Dr. Celeste Marie Gagnon, and Dr. Michael Siegel for sitting on my committee and providing much appreciated feedback; the Honors College and the Center for Comparative Archaeology at the University of Pittsburgh for their financial contributions that made this research possible. Finally, I would like to thank friends and family who continued to encourage me throughout this process.

1.0 INTRODUCTION

Understanding the human past is a difficult feat. Some locations and time periods have historical records that can help illuminate how humans lived, but historical records can be fraught with errors. To further aid our understanding of the past, archaeology can illustrate how past humans altered their landscape to fit their needs and shed light on day to day lives. Unfortunately, what cannot be seen with archaeology alone is individual people – how they looked, how they hurt, how they lived, how they died. While bioarchaeology may not be able to definitively answer all of those questions, it gives us an opportunity to ask those questions and glean some semblance of an answer to them. When bioarchaeology is combined with mortuary studies and archaeology, even parts of the human experience as intangible as identity and social behavior can be hypothesized (Artelious and Svanberg 2005; Beck 1995; Knudson and Stojanowski 2009; Parker Peasron 2000; Torres-Rouff and Knudson 2017). As Clark Spencer Larsen said,

> *"A central aim of bioarchaeology is to establish a comprehensive record of skeletal and dental conditions in relation to prevalence and pattern to develop an understanding of behavior and the costs and consequences of particular lifestyle circumstances and conditions" (Larsen 2015: 6).*

These goals of bioarchaeology established the kind of extensive knowledge that is sought out when analyzing skeletal remains. While not all of these things can be definitively ascertained, bioarchaeology gives us a window into understanding how people lived in the past in many aspects of their life.

Bioarchaeology has made particularly significant contributions to our understanding of the Andean past. Over the last 20 years or so, bioarchaeologists have published innovative studies on large samples of well-preserved human remains from Andean contexts (e.g., Blom 2005; Gagnon 2006; Klaus and Tam 2009; Klaus and Toyne 2016; Knudson 2008; Kurin 2016; Torres-Rouff and Knudson 2017; Tung 2012; Verano 2016). These studies have particularly clarified patterns of ancient health, mobility, diet, and violence in the ancient Andes, while also shedding light on particular practices such as trepanation and cranial modification. This study considers the bioarchaeology of the pre-Moche societies of the Moche valley, societies that led to what most archaeologists consider the first state in the New World – the Southern Moche State (Chapdelaine 2011). Information pertaining to how they lived and the issues they faced help to illuminate the processes underway as this state came to be in existence.

In this study, skeletal remains from 26 individuals from the Salinar and Gallinazo phases in the Moche Valley were examined for signs of malnutrition or chronic infectious disease. Among the pathological conditions searched for were porotic hyperostosis, cribra orbitalia, systemic periosteal new bone growth, linear enamel hypoplasia, carious lesions, dental calculus, and abscesses. These data were collected to attempt to answer some of the following question: how did rates of pathological conditions change over time between the Salinar and Gallinazo phases and how do these changes relate to the major social, economic, and political changes that occurred during these time periods? The rates of these pathological conditions can help in identifying the overall health of the population and potentially determine what stressors were most significant to these societies.

2.0 BACKGROUND

Most archaeologists consider the Southern Moche State to be the first state in South America (Chapdelaine 2011). Yet relatively little is known of their predecessors, the Salinar and Gallinazo. The Salinar and Gallinazo phases encompass some of the first complex societies seen in this area and could be the key to understanding how the first state in South America came to be.

2.1 GEOGRAPHY

The Salinar and Gallinazo peoples existed in the Moche Valley from as far west as modern day Huanchaco Bay to as far east as the end of the trunk of the Moche River. The Moche Valley was the location of many settlement changes during the Salinar and Gallinazo phases. The Moche Valley surrounds the Moche River which is approximately 100 km long and feeds into the Pacific Ocean (Billman 1996).

Agricultural production in the Moche Valley has the ability to grow many kinds of crops with proper irrigation, but is difficult to cultivate without complex irrigation technologies (D’Altroy 2015). In the lower and middle valleys, varied topography limits the amount of arable land. Additionally, surface water irrigation from the Moche River can be difficult due to the extreme fluctuations in seasonal volume of the Moche River (Billman 2002). The highlands get enough rainfall to take advantage of rainfall agriculture and do not require utilizing the Moche River or irrigation. This means that highland agriculture requires significantly less investment in infrastructure and can be done at the household level (Billman 1996). Another important component of subsistence for people living along the Andean coast is marine recourses such as fishing and shellfish collecting.

2.2 TIMELINE

This study focuses on the Salinar and Gallinazo phases, however to better understand the trends in health in the Moche Valley over time, it is important to look at the cultural changes that occur over time.

2.2.1 Initial/Early Horizon Phase

The Initial/Early Horizon phase (approximately 1500 – 400 BCE) is defined by the introduction of pottery, a change in textile production from twined to woven textiles, and the emergence of complex settlements with irrigation agriculture. The Initial phase sites of Gramalote and Caballo Muerto exemplify what life what like during this time in the Moche Valley (see Figure 1). Gramalote is a domestic site that is located on the coast in modern day Huanchaco Bay, Peru. The majority of their animal protein came from marine wildlife (Pozorski 1979; Prieto 2018). Caballo Muerto is further inland and is made up of larger non-domestic structures and was likely a ceremonial center. The animal protein intake of inhabitants of Caballo Muerto was split between marine wildlife and inland sources and the site had a heavier reliance on irrigation agriculture (Pozorski 1979). The Initial phase indicates the emergence of the very first complex settlements in the Moche Valley.

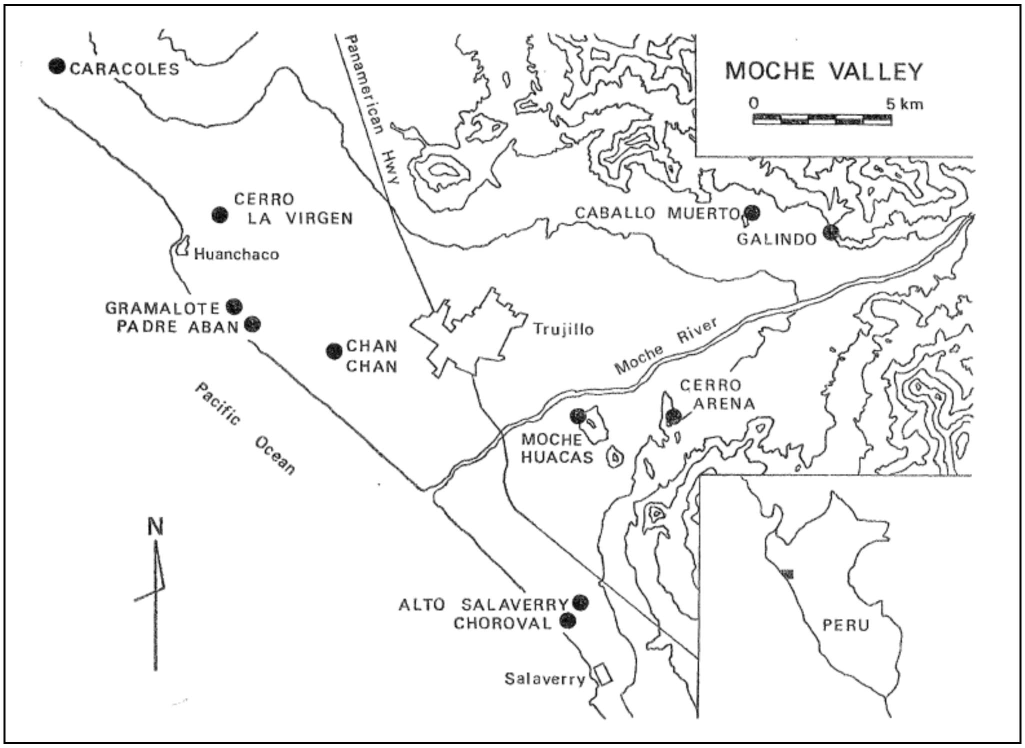


Figure 1: Map of Moche Valley (from: Pozorski 1979: 164)

2.2.2 Salinar Phase

The Salinar phase (approximately 400 – 100 BCE) was the first time when defensive structures can be seen on the north coast of Peru, which is likely due to the onset of endemic regional warfare (Brennan 1980). Additionally, ceremonial centers transition from public to more restricted access spaces suggesting that the social hierarchy started to become more stratified and defined during this time. The only site to be thoroughly excavated from the Salinar Phase in the Moche Valley is Cerro Arena (Brennan 1980). Cerro Arena is the first site where there was clear residential nucleation and hierarchy of settlement. In addition, this site gives us the first evidence of labor specialization in the Moche Valley (Brennan 1980). While there was no major monumental architecture at this time, massive labor investments were made to expand irrigation canals (Brennan 1980). This expansion allowed people living at Cerro Arena to increase their agricultural production. The combination of these things suggests a complex, centralized political and economic system and the first trends towards statehood in the Moche Valley.

2.2.3 Gallinazo Phase

Recent data indicates that Gallinazo phase pottery – both Castillo plane wares and Virú fine wares – overlap temporally with Moche phase pottery (Castillo et al. 2005). Even though this would indicate that the Gallinazo phase would span from approximately 100 BCE – 500 CE, this section will focus on the time period traditionally considered Gallinazo and distinguished by exclusively Gallinazo wares, which spans from 0 – 200 CE (Billman 1996). During this time, there was a reorganization of settlements in the Moche Valley including the abandonment of many sites. Settlements in the Moche Valley developed a unified valley-wide political system that seems to have become increasingly concentrated in the lower-middle Moche Valley. Social hierarchies changed with the incorporation of the valley-wide political system and became more defined and more widely practiced throughout the valley. Ceremonial architecture became a priority for Gallinazo peoples with an over 400% increase in construction (Billman 1996). Warfare declined which can be seen through settlement patterns, but defensive architecture is still present through the Gallinazo phase (Arkush and Tung 2013; Lambert 2011). In the later parts of the Gallinazo phase, all settlements still in these defensive structures were abandoned (Billman 1996). The site of Cerro Oreja replaced Cerro Arena as the largest site in the Moche

Valley. At the same time, there was an intensification of agricultural production at Cerro Oreja through the Gallinazo phase. This can be seen through stable isotope studies of individuals located here where it is estimated that 35-50% of their diet consisted of maize (Lambert et al. 2012). However, Cerro Oreja would be abandoned before the end of the early Moche Phase (Gagnon 2013).

2.2.4 Moche Phase

The Moche phase (approximately 200 – 750 CE) marks the start of the Moche State proper. Recent studies have shown that what used to be considered a single large, multi-valley Moche State is likely a series of smaller, independent states with common religious beliefs (Koons and Alex 2014; Quilter and Castillo 2010). Since this paper is focused on the Moche Valley, the author will be speaking exclusively on the Southern Moche State, the most important and powerful of the Moche polities, which was centered in the Moche V alley. The center of power moves during this phase from Cerro Oreja to the site of Huacas de Moche (Billman 2002). At the same time, much more monumental architecture emerged as well as an increase in large public works projects such as roads, canals, and huacas (Billman 2002). Iconography changed to what is now considered classically Moche, which came to adorn wall murals, finewares and other portable material culture used by elites. As the Moche State became more organized, social stratification increased, leading to a more complex settlement pattern and a wide range of poor and rich burials (Chapdelaine 2011). There is also clear evidence of Moche expansion into nearby valleys to the south (Virú and Santa), parts of which may have been under the direct control of the southern Moche state. Craft and labor specialization became much more widely utilized at this time (Chapdelaine 2011; Bernier 2010). Additionally, subsistence changed with the intensification of agriculture and llama became the main source of animal protein (Gagnon 2006).

The social changes that occurred during these phases changed the ways in which people ate, resided, and spent their time in general. The consequences of this can potentially be seen in how health changed over time. In particular, warfare, the rise of the state, and the full adoption of maize agriculture include many factors that could have negatively impacted the health of the population.

2.3 WARFARE

Across cultures, there are several indicators of threat of attack that can be seen archaeologically including settlement relocation, nucleation, and development of fortified architectural structures (Keeley et al. 2007; LeBlanc 1999; Vencl 1984). These social changes can be seen in the Salinar phase. Archaeological evidence for warfare in the Salinar phase includes nucleation of settlements in discrete areas, development of unoccupied buffer zones between population clusters, and significant labor investment for defensive architecture, and settlement habitation within formal fortifications (Billman 1996). In association with these changes, often these communities have less access to resources as well. The changes that are most interesting to this study are nucleation of settlements, restricted access to resources, and violence because each of these changes can contribute to negative health implications.

Nucleation of settlements often occurs during times of systemic warfare because larger settlements are safer by nature than smaller, rural areas. Furthermore, there are many specific defensive architectural elements that are easier to implement with a population that is in closer proximity to each other (Arkush 2018). In Billman's survey, the percentage of hillslope, hilltop, or ridgetop habitation sites increased from 22% of total habitation sites in this area in the Initial/Early Horizon phase to 63% in the Salinar phase (Billman 1996). This nucleation creates a new set of issues for the populations involved. People who are living closer together are in contact with more people on a daily basis which allows for infectious diseases to spread much more quickly than in less dense populations (Cohen 1977). Additionally, with more people in one area, sanitation issues become much more prominent and can also contribute to the spread of diseases (Cohen 1977). The rates of diseases visible in the bioarchaeological record clearly increase following urbanization in a number of different locations. In Pechenkina et al.'s study (2007) comparing Preceramic sites of Paloma and Chilca 1 with Initial/Early Horizon phase site Cardal, increased population density in combination with increasing reliance on plant cultivation between the Preceramic phase and Initial/Early Horizon phase led to increased rates of tuberculosis and general signs of physiological stress, or in other words, signs of disease and/or severe malnutrition without a pathognomic lesion to point to a specific disease (Pechenkina et al. 2007).

Systemic warfare often leads to restricted access to resources such as agricultural lands, hunting areas, and trade routes because populations tend to stay to a single area to ensure their safety (VanDerwarker and Wilson 2015). Less access to subsistence resources can lead to less variety in the diet as well as simply less access to food. This can negatively impact a population's health by making individuals more susceptible to vitamin deficiencies and malnutrition. Individuals with malnutrition also have suppressed immune systems which make them more susceptible to infectious diseases (Keusch 2003).

Lastly, warfare has obvious negative health consequences through direct trauma to the body. Violent trauma is visible on Andean skeletal populations in the form of healed and perimortem cranial depressions, rib fractures, forearm fractures, etc. (Arkush and Tung 2013).

2.4 THE RISE OF THE MOCHE STATE

Factors related to the formation of the Southern Moche State could have had heavy repercussions on the health of Gallinazo populations. Some scholars even argue for primary state formation occurring in the Gallinazo phase in the Virú Valley just south of the Moche Valley, further evidence that these factors affected individuals in the Gallinazo phase (Milliare 2010). The exact definition of what makes a state is difficult to quantify. However, there are a number of transitions that occurred in the formation of the Moche state which could have affected health: nucleation of settlements and urbanization, increased dependence on maize agriculture, increasingly strict social hierarchies, and craft/labor specialization (Billman 2002). Some of these transitions, especially nucleation, overlap with changes that likely occurred during Salinar phase warfare. However, increased dependence on maize agriculture, increasingly strict social hierarchies, and craft/labor specialization all have strong impacts on the health of the population and these transitions can potentially be seen in the Moche Valley mostly, if not entirely, during the Gallinazo phase.

Nucleation of settlements and urbanization are closely associated with the formation of states, perhaps because it is much easier to have control over people if they are located in close proximity (Wright 1986). The nucleation of settlements that occured in the Salinar phase intensified in the Gallinazo phase (Billman 1996). Throughout the Gallinazo phase people in the

Moche Valley implemented a valley-wide political system which caused populations to become increasingly concentrated in the lower-middle Moche Valley (Gagnon 2013). This could have led to increased rates of physiological stress in the population.

Another event that occurs during the development of states is the formation of an increasingly strict social hierarchy. This impacts health because with hierarchy comes restricted or preferential access to resources including food. As a hypothetical example, if the masters of the household had first choice of the food at each meal and always chose meat, then the servants would likely exhibit more signs of malnutrition, illness and anemia because they are not eating meat as often. Chapdelaine (2010) discusses Moche social inequality by comparing elite and non-elite burials from different Moche sites along the northern coast of Peru and came up with a hierarchical representation for Moche societies from what they found in the archaeological record in the shape of a pyramid. The data from the Huacas de Moche appears to fall into the lower parts of the pyramid with the most elite individuals belonging to the Lower Elite/Upper Class. However, it is important to note that the Huacas de Moche, the largest site in the Moche Valley where ruling elite burials would most likely be, has been heavily looted and archaeologists are likely “missing” the very top of the social pyramid in the Moche Valley (Chapdelaine 2010). Even so, there is a clear distinction between classes in burials in the Moche Valley and it is likely that those distinctions were even more clearly seen in life by people in the lower classes having less access to food or nutritious food and would be more likely to show signs of malnutrition (Gagnon 2008). Consequently, those people would also be more susceptible to infectious disease.

In order for a society to grow in population and complexity, labor specialization needs to occur. Labor specialization, ideally, allows for the people in power to focus on dealing with issues in the community and not have to worry about also trying to run a farm for their family to eat. In reality, it often leads to the exploitation of lower class people. However, it also allows for more specialized occupations to become available to people in craft production. During the height of the Moche, very complex material goods were being produced in massive quantities (Bernier 2010). This suggests that the Moche had adequate people producing food and other necessary services and that they had many people who were able to focus solely on craft production. This labor specialization did not only occur in the Moche phase. The Gallinazo phase site of Mocollope had large ceramic workshops that likely produced fineware ceramics towards the end of the Gallinazo phase (Attarian 2005). This also means that those who were in food production likely had to pay tribute to the ruler(s). These tariffs likely impacted the health of the individuals who were in food production because agriculture and fishing subsistence are physically demanding jobs to begin with and then their food supply would have been diminished. As the Gallinazo phase came closer to the Moche phase and social stratification became more and more prominent in the society, the people at higher class areas of Gallinazo phase sites likely got first choice of the food produced and thus the people giving the tribute likely had less access to nutritious food, leaving these people more susceptible to malnutrition and illness. This differential access to nutritious food can also be seen with different rates of pathological conditions between sexes. Gagnon and Wiesen (2013) showed that there are statistically significant differences between dental pathological conditions between males and females of Cerro Oreja in the later parts of the Gallinazo phase.

The rise of agriculture has been known to have negative health consequences on a population. As previously mentioned, there is full adoption of maize agriculture during the

Gallinazo phase (Lambert et al. 2012). The next section outlines how this can negatively impact on the health of a population.

2.5 THE RISE OF AGRICULTURE

The rise of agriculture in the Moche Valley was important to creating a sustainable economy for large-scale societies to grow. However, it also came with a number of health repercussions that can be seen bioarchaeologically. The pre-agricultural diet on the coast mostly consisted of marine resources since it is one of the richest areas for marine wildlife in the world. Moseley argues (1975) that utilization of marine life as a primary source of subsistence allowed large scale societies to form along the coast of South America. While this is a heavily contested theory, it is undeniable that marine life was an important resource to societies in the Moche Valley and was capable of fully supporting sedentary populations on the coast.

Agriculture originally started in the Moche Valley with limited use of cotton, gourd, and squash in the Preceramic phase (Pozorski 1979). The cotton and gourds were not cultivated for consumption, but rather for making weighted fishing nets that could be used to catch marine wildlife. Squash and other plants that were to a lesser extent seasonally cultivated made up a very small amount of the diet in Preceramic societies (Pozorski 1979). During the Initial/Early Horizon phase, there was a heavier reliance on maize and peanuts following the likely invention of more sophisticated irrigation techniques. As societies continued to grow in population through the Salinar phase, irrigation techniques became more complex allowing for more agricultural production. The major cultivated plants at this time were cotton, gourd, squash, maize, peanuts, and common beans. Salinar phase populations also started accumulating surplus agricultural products because of the systematic increase of agricultural production (Pozorski 1979). During the Gallinazo phase, irrigation systems continued to be expanded dramatically which allowed for a heavier reliance on agriculture and a de-emphasis on marine products. Because agriculture at this time consisted primarily of the starchy product maize, we see this population trade a protein-rich diet for a starch-based diet with full adoption of maize agriculture occurring in the Gallinazo phase. Existing irrigation canals were made wider to allow more people to be able to use a single canal and more canals were made, likely to compensate for increasing populations (Billman 2002). Agricultural intensification often occurs concurrently with societies becoming more populous and that is exactly what can be seen in the Moche Valley (Lambert et al. 2012; Gagnon and Wiesen 2013). Large-scale irrigation agriculture, once the technology had been put into place, has the ability to support much higher population densities. However, the transition from a mostly protein-based diet to a diet that consists mostly of starch based agricultural products may have negatively impacted the overall health of the community.

Diets which consist mostly of animal protein, whether it be shellfish or llama, allow the body to receive many nutrients that are otherwise hard to acquire, especially iron (Walter et al. 1997). The human body uses iron to make red blood cells which bring oxygen from the lungs to the rest of the body. When iron levels in the human body decrease, it is more difficult for the body to fight diseases and, in extreme cases, people will get anemia. Anemia is a condition where an individual has lower than the normal threshold of iron in their body and can cause general exhaustion and weakness as well as increase susceptibility to illnesses. Commonly, this can be seen bioarchaeologically by higher instances of porotic hyperostosis, linear enamel hypoplasias, cribra orbitalia, and other general indicators of nutritional stress such as high infant mortality rates.

South of the Moche Valley, a study was done by Pechenkina et al. (2007) comparing Preceramic sites of Paloma and Chilca 1 with Initial/Early Horizon phase site Cardal to see the health implications of increased reliance of agriculture in combination with nucleation of settlements. They found that the Preceramic site of Paloma had the lowest rates of all indicators of physiological stress. Cardal had significantly higher instances of caries and other physiological stress indicators likely due to the increased reliance on agriculture and the simultaneous de-emphasis of marine products. They continued their study to include later time periods, past the scope of this paper, and found that this trend of increased signs of physiological stress and anemia continues over time through to almost Inca occupation (Pechenkina et al. 2007). It is possible similar trends occurred in the Moche Valley.

2.6 GENERAL HEALTH INDICATORS

This section highlights each pathological condition that was examined, explains what they are and why they could be significant for this study.

2.6.1 Porotic Hyperostosis

Porotic hyperostosis is defined as areas of porosity on the external table of the cranial vault. These porosities are caused by hypertrophy of blood cell-forming tissue located within the cranial vault (Ortner and Putschar 1981). The etiology of porotic hyperostosis has been contested by physical anthropologists. It was originally thought to be caused by anemia (Buikstra and Ubelaker 1994). Anemia can be acquired or genetic, but there is no evidence that genetic anemia was present in the pre-European contact New World and therefore, the rest of this study will solely be referring to acquired anemia (Ortner and Putschar 1981). More recently, Walker et al. (2009) argues that porotic hyperostosis is caused by a vitamin B_{12} and B_9 deficiencies. In addition, anemia can also be caused by parasitic infection (Walter et al. 1997). Fortunately, all of these etiologies have the same root cause, vitamin deficiency. Iron deficiencies as well as vitamin B_{12} and B_9 deficiencies can be caused by malnutrition or diarrheal loss of nutrients due to infectious disease or parasitic infection.

There are several stages of porotic hyperostosis from least severe to most: barely discernable porosity, porosity only, porosity with coalescence of foramina (no thickening), and, finally, coalescing foramina with increased thickness (see Appendix A; Buikstra and Ubelaker 1994). In addition to the severity, healing as evidenced by sclerotic changes to the sharp edges and woven bone of active lesions can indicate how long the instance of malnutrition or infectious disease was (Buikstra and Ubelaker 1994). Most often, porotic hyperostosis forms during childhood due to children being more susceptible to nutritional loss because they are growing at a faster rate than adults. Adult lesions of porotic hyperostosis often represent childhood anemia (Stuart-Macadam 1985).

2.6.2 Cribra Orbitalia

Cribra orbitalia is characterized by abnormal porosity on the most superior part of the orbital cavity on the frontal bone. It has long been categorized as a type of porotic hyperostosis and has the same stages of development (see section 2.6.1 Porotic Hyperostosis). However, more recently, there has been some histological and clinical evidence that cribra orbitalia has a wider range of etiologies than porotic hyperostosis of the cranial vault (Walker et al. 2009). Wapler et al. (2004) did a histological study on 85 Nubian crania with cribra orbitalia and found that only 43.5% could be absolutely determined to be anemia-related. The next most common cause was subperiosteal inflammation at 25.8%. Subperiosteal inflammation is associated with any number of diseases including scurvy, rickets, hemangiomas, and traumatic injuries; most of which are also associated with the root causes of malnutrition and chronic infectious diseases. Unfortunately, radiographic analysis was outside the scope of this study and so the presence of cribra orbitalia will be assumed to indicate malnutrition and chronic infectious diseases as that is the most common cause of this condition.

2.6.3 Systemic Periosteal New Bone Growth

Periosteal new bone growth is defined by macroscopic osseous plaque that has formed from the periosteum of long bones with irregular elevations of the bony surface as an inflammatory response (Weston 2012). This pathological condition is caused by inflammation of the periosteum which, if it does not resolve itself, will signal osteoblasts and preosteoblasts to create new bone (Weston 2012). The inflammation can be both localized and systemic. Localized periosteal new bone growth can be caused by a trauma or local infection, but systemic periosteal new bone growth can indicate chronic infectious disease (Pfeiffer and Fairgrieve 1994; Pietrusewsky and Douglas 1994; Larsen 2015; Larsen et al. 2007).

2.6.4 Linear Enamel Hypoplasia

Linear enamel hypoplasia is characterized by transverse lines in the enamel of tooth crowns. It most commonly affects the incisor and canine teeth, but can also affect others as well (White et al. 2012). These lines are caused by a disruption in the normal amelogenesis (enamel forming) process. Nutritional deficiencies or nutrient loss from chronic infectious disease or parasitic infection during enamel formation can disrupt ameloblastic activity and, consequently, create a defect in the resultant enamel. Because enamel only forms during amelogenesis and does not repair itself, linear enamel hypoplasias will stay with the individual for the entirety of their life, even after the nutritional stress has resolved itself (White et al. 2012). For individuals who have this nutritional stress for the entirety of their ameloblastic activity, LEH does not form. Instead, their enamel is simply extremely thin (Ortner and Putschar 1981).

2.6.5 Dental Caries

Carious lesions can vary widely in appearance from the least severe discoloration of the enamel to more severe cases with large pieces of the crown missing. They are caused by progressive decalcification of the enamel and, eventually, dentine from bacteria in dental plaque. Plaque must form prior to the formation of carious lesions. These lesions most commonly occur on the molars, but can also occur on other teeth (White et al. 2012). There are several studies that have shown there is an increase in dental caries in populations that have moved to full dependence on agriculture for subsistence (Larsen 1983; Walker and Erlandson 1986; Tayles et al. 2000; Gagnon and Wiesen 2011).

2.6.6 Abscesses

Abscesses are characterized by a localized collection of pus in a cavity in alveolar bone formed by the introduction of bacteria into the bone (White et al. 2012). These indicate the most severe form of dental pathological condition. They can be caused by severe wear or severe carious lesions (White et al. 2012). Because abscesses are a type of infection, they stress the immune function and increase risks of several things including heart attack (Liljestrand et al. 2016).

2.6.7 Dental Calculus

Dental calculus is characterized by build-up of mineralized plaque near the cervicoenamel line (White et al. 2012). Calculus is formed when bacteria colonizes the saliva of the pellicle and then mineralizes (Lieverse 1999). Mineralization can occur within a few days.

2.7 CONCLUSION

The major transitions that occurred during the Salinar and Gallinazo phases in the Moche Valley likely had great implications for the general health of the population. The changes in urban life, social organization, subsistence, and political structure all likely affected north coast populations in largely negative ways. Meanwhile, decreasing warfare over time may have had positive impacts on health. This study aims to see if there is a difference in the instances of signs of physiological stress between the Salinar and Gallinazo phases to see if stresses associated with warfare or the rise of the state along with the full adoption of maize agriculture more heavily impacted the population.

Because of the stressors associated with the rise of the Moche State along with the full adoption of maize agriculture are occurring during the Gallinazo phase, it would be expected that rates of pathological conditions associated with malnutrition or chronic infectious disease would be greater during the Gallinazo phase. However, it is possible that the stressors associated with warfare may have had the opposite effect.

3.0 METHODS AND MATERIALS

3.1 THE SAMPLE

The skeletal remains examined in this study are from the sites of Pampa la Cruz and La Iglesia, located in modern-day Huanchaco, Peru (see Figure 2). Both sites were fishing villages located close to the ocean. All of the Salinar skeletal remains came from La Iglesia while the Gallinazo skeletal remains mostly came from Pampa la Cruz with only a couple recovered from La Iglesia (see Appendix A). Both sites, however, were occupied for much longer periods of time with La Iglesia indicating signs of numerous periods of occupation from 300 B.C.E. through to today and Pampa la Cruz indicating signs of numerous periods of occupation from the late Salinar phase through to today (Billman 1996; Donnan and Mackey 1978). All of the skeletal remains considered in this study are from individual contexts. The skeletal remains were determined to be from either the Salinar phase or Gallinazo phase based on the grave goods by the lead archaeologist on the project, Gabriel Prieto.

The skeletal remains of 26 individuals were examined for this study. The collection is owned by the Ministry of Culture and housed at the Universidad Nacional de Trujillo. All skeletal remains from the two sites that were available at the time of this study were examined. Of the 13 skeletal remains from the Salinar period, five were adults and eight were subadults. Of the 13 skeletal remains from the Gallinazo period, nine were adults and four were subadults (see

Table 1). Individuals who were estimated to be less than six months of age were excluded from this study because these individuals were simply too young to have developed the type of pathological conditions that were investigated.

Figure 2: Map of La Iglesia and Pampa La Cruz in Huanchaco, Peru (basemap from Google Maps)

Table 1: Outline of Skeletal Sample

Salinar				Gallinazo			
Adult		Subadult		Adult		Sudadult	
Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
5	38%	8	62%	9	69%	4	31%

3.2 THE DATA

The demographic data that were collected included estimations of age-at-death and sex following Buiksta and Ubelaker (1994): age was estimated using dental eruption and epiphyseal fusion for subadults and pubic symphysis for adults. Sex for adults was estimated using the pelvic girdle or complete skull. Sex was not estimated for subadults because there is not currently a reliable method to do so. These demographic data were taken to better understand the population that was examined.

Table 2: Abbreviations for Pathological Conditions

Abbreviation	Pathological Condition
PH	Porotic Hyperostosis
CO	Cribra Orbitalia
PNB	Systemic Periosteal New Bone Growth
LEH	Linear Enamel Hypoplasia
Car.	Caries
Calc.	Calculus
Absc.	Abscesses

The pathological conditions examined in this study include: porotic hyperostosis, cribra orbitalia, systemic periosteal new bone growth, linear enamel hypoplasia, caries, calculus, and abscesses. In addition, other pathological conditions were noted as they were observed. Table 2 outlines all of the abbreviations used in this paper for the pathological conditions examined. These conditions were chosen to be investigated because they are all common general indicators of health. Porotic hyperostosis, cribra orbitalia, systemic periosteal new bone growth, and linear enamel hypoplasia are all general indicators of chronic infectious disease or malnutrition. Carious lesions, calculus, and abscesses can indicate the types of food being consumed which can affect health. All of the data collected followed methods outlined in Buikstra and Ubelaker (1994). The following sections outline how the pathological conditions were diagnosed in this study.

3.2.1 Porotic Hyperostosis

An individual was considered observable for porotic hyperostosis if there was 25% or more of their cranial vault present. Porotic hyperostosis was diagnosed when abnormal porosity was noted on the cranial vault. In addition to presence or absence, the severity of the condition and whether there was any healing present was also noted.

3.2.2 Cribra Orbitalia

An individual was considered observable for cribra orbitalia if there was 75% or more of at least one orbit present. Cribra orbitalia was diagnosed when abnormal porosity was noted on the most superior part of the orbital cavity in at least one orbit. In addition to presence or absence, the severity of the condition and whether there was any healing present was also noted.

3.2.3 Systemic Periosteal New Bone Growth

An individual was considered observable for periosteal new bone growth if they had at least two complete long bones present. Systemic periosteal new bone growth was diagnosed in this study when abnormal woven bone was noted on the surface of more than one long bone or was otherwise clearly identifiable as non-localized (in other words, the entire bone or nearly the entire bone was affected). The presence or absence of this condition was noted.

3.2.4 Linear Enamel Hypoplasia

An individual was considered observable for linear enamel hypoplasia if they had at least one complete anterior tooth present – deciduous or adult. Linear enamel hypoplasia was diagnosed in this study by the presence of macroscopic transverse lines on the teeth. In addition to presence or absence, the number of teeth affected was also noted.

3.2.5 Caries

An individual was considered observable for carious lesions if they had at least one complete posterior tooth present. Carious lesions were diagnosed in this study by noting either a discoloration or cavity in the enamel of teeth. In addition to presence or absence, the severity (i.e. the amount of discoloration or size of the cavity) and number of teeth affected were also noted. The size of the cavity was noted based on the percentage of tooth affected.

3.2.6 Abscesses

An individual was considered observable for abscesses if they had 25% or more of their maxillary or mandibular alveolar bone present. Abscesses were diagnosed in this study by the presence of a cavity with distinct walls in the alveolar bone. In addition to presence or absence, the number of teeth affected was also noted.

3.2.7 Calculus

An individual was considered observable for dental calculus if they had at least one complete tooth present. Dental calculus was diagnosed in this study by the presence of plaque along the cervicoenamel line. In addition to presence or absence, the severity (i.e. what percentage of the tooth was covered in plaque) and number of teeth affected were also noted.

Each one of these pathological conditions are common indicators of generalized health (Ortner and Putschar 1981; Buikstra and Ubelaker 1994). Unfortunately, there is no reliable way to differentiate between if any particular condition was caused by malnutrition, chronic infectious disease or a synergetic interaction of both stressors. For the purposes of this study, malnutrition and chronic infectious disease are lumped together under the general concept of poor health.

3.3 THE OSTEOLOGICAL PARADOX

Although the bioarchaeological record can give clues as to how people in the past lived, it does not explain the whole story. Wood, Milner, Harpending, and Weiss (1992) identified several possible problems the types of interpretations bioarchaeologists often make based on pathological lesions identified in human skeletal materials. In particular, they mention three main issues that must be considered: 1) demographic nonstationarity, 2) selective mortality, and 3) hidden heterogeneity of risk.

Demographic nonstationarity means that unless a population is completely of constant size, the age distribution of skeletal samples reveals more about fertility levels of the population than it does mortality trends. Selective mortality means that the levels of paleopathological lesions seen in any given skeletal sample will never be directly representative of illnesses at any one time in the population, because many individuals with an illness will die before developing skeletal lesions. Individuals who died at a young age may not have any indicators of what killed them, but the fact that they are dead suggest that they suffered from some form of extreme stress. In addition, even adult individuals with a disease may not show any symptoms. It takes a long time for pathological indicators to show on bone and thus it is impossible to tell if an individual died of an illness shortly after contracting it, not showing any bony indicators of the illness, or if they were completely healthy at the time of their death. Individuals with a stronger immune system will live long enough to develop the osteological lesions associated with an illness, while individuals who may have weakened or compromised immune systems might not survive the insult long enough to develop such lesions. Finally, hidden heterogeneity of risk refers to the fact that every individual has a unique reaction to illnesses. Some people are more susceptible to illnesses and may take on the bony markers of illness earlier in the development of the illness than others who may take longer.

Because of this critique bioarchaeologists have taken several steps towards trying to lessen the impact that these issues have on bioarchaeological data (Wright and Yoder 2003; DeWitte and Stojanwski 2015). While some of these issues will never fully be rectified, advancements in our morphological understanding of pathological conditions as well as using age-at-death cohorts to examine rates of pathological conditions have allowed bioarchaeological research, to a certain degree, to surpass these issues. This study will discuss specifics on how each pathological condition was identified and will discuss age-at-death cohorts of rates of pathological conditions in order to attempt to rectify some of these issues.

4.0 RESULTS AND DISCUSSION

As discussed more fully in the Background Section, Salinar and Gallinazo phase populations experienced distinct stresses that may have affected their health, including warfare, the rise of the Moche state, and increasing dependence on maize. During the Salinar phase it is agreed that there was systemic warfare as evidenced by the amount of defensive architecture built and utilized (Brennan 1980; Billman 1996). Systemic warfare can negatively impact health due to nucleation of settlements, less resources available to allocate towards subsistence, and less available resources resulting in dietary stress. The Gallinazo phase marked processes related to the beginning of the rise of the Moche State in this area (Billman 1996). The rise of states can negatively impact health due to nucleation of settlements, development of a social hierarchy with associated redistributed access to resources, and labor specialization which can also lead to dietary stress. In addition, Gallinazo phase settlements increasingly relied on maize agriculture as their main form of subsistence (Billman 2002; Gagnon and Weisman 2013; Lambert et al. 2012). This chapter will detail how each pathological condition examined in this study lends to an understanding of how health changed with the societal changes that occurred between the Salinar and Gallinazo phases.

A summary of the data collected can be found in Table 3 (see Appendix A for more detailed information). In an attempt to determine how health changed during the Salinar and Gallinazo phases, this chapter will break down the data shown in Table 3 into the following sections: the Indicators of Systemic Stress data, Oral Pathological Conditions data, Subadult versus Adult Health, Endocranial Lesions, and Evidence for Scurvy.

Table 3. Summary Table of Data. P indicates that the condition is present and A indicates that the condition is absent. A dash indicates that the presence or absence for that condition could not be determined. G indicates that the individual is from the Gallinazo phase sample and S indicates that the individual was from the Salinar phase sample.

Skeletal Number	Time Period	Age (yrs)	± (yrs)	Sex	PH	CO	PNB	LEH	Cari	Calc	Absc	Other Path
P17-805	G	50	10	F	-	-	A	-	-	-	-	P
P17-806	G	4	1	-	P	P	A	A	A	A	A	P
P17-807	G	2	0.75	-	P	A	A	-	A	A	A	A
P17-809	G	32	2	M?	A	-	A	-	A	P	A	A
P17-810	G	0.75	0.25	-	A	-	A	A	A	A	A	P
P17-811	G	25	5	F	A	A	P	-	P	P	A	P
P17-812	G	12	3	-	P	P	A	A	A	P	A	P
P17-813	G	25	5	M	P	P	A	A	A	A	A	P
P17-814	G	50	5	F?	-	A	A	A	P	P	A	P
P17-819	G	25	5	M	A	A	A	A	P	P	P	P
P17-820	G	22	2	F	P	P	A	A	A	P	A	A
P17-821	G	40+	-	F?	-	-	A	P	P	P	A	P
P17-822	G	30	5	M	-	-	A	A	P	P	A	P
P17-816	S	4	1	-	P	P	A	A	A	A	A	A
P17-817	S	1	0.5	-	P	-	P	A	A	A	-	P
P17-818	S	1	0.25	-	A	P	P	A	A	A	A	P
P17-823	S	50+	-	F?	P	-	A	-	P	A	P	P
P17-824	S	35	5	M	P	A	A	-	P	P	P	P
P17-825	S	1	0.5	-	-	-	A	-	-	-	-	A
P17-826	S	3	1	-	P	A	A	A	A	A	A	P
P17-827	S	20+	-	I	-	-	A	-	-	-	-	A
P17-828	S	4	1	-	P	P	A	P	A	A	A	P
P17-830	S	60+	-	F	P	A	A	A	A	P	P	P
P17-831	S	5	1.5	-	A	P	A	A	A	A	A	P
P17-832	S	42	5	F	P	A	A	A	P	P	P	P
P17-833	S	12	3	-	P	A	A	A	A	A	A	A

4.1 INDICATORS OF SYSTEMIC STRESS

Table 4: Indicators of Systemic Stress Data. #P stands for the number of individuals in each category that are observed with that pathological condition. N is the number of individuals where the condition was observable (for example, if an individual did not have an associated skull, PH, CO, and all oral pathological conditions could not be recorded and thus are not included in the total n).

	Salinar			Gallinazo			Chi^2	
	#P	N	%	#P	N	%	Statistic	P-Value
PH	9	11	81.8%	5	9	55.6%	1.6258	0.2023
CO	4	9	44.4%	4	8	50%	0.0525	0.8188
PNB	2	13	15.4%	1	13	7.6%	0.3768	0.5393
LEH	1	9	11.1%	1	9	11.1%	0	1

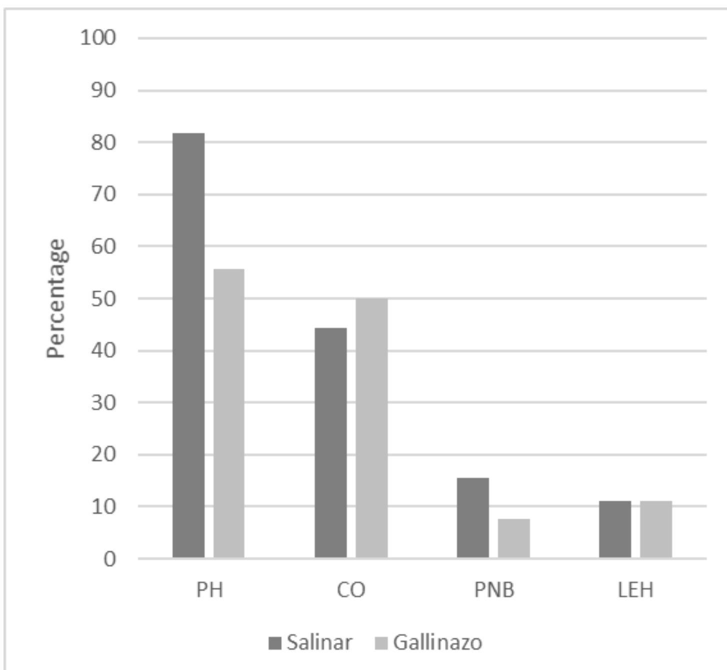


Figure 3: Indicators of Systemic Stress Data (in percentages)

Initial observations from Table 4 and Figure 3 indicate that Salinar rates of skeletal pathological conditions are much higher than the Gallinazo rates, with the exception of cribra orbitalia. Of the individuals examined in this study who were dated to the Salinar phase, porotic hyperostosis was not only more prevalent, but also had more severe cases of the condition. Four of the nine individuals with porotic hyperostosis from this time period had only porosity, but three of the nine had porosity with coalescence of foramina with all nine individuals having at least some level of porotic hyperostosis active at the time of their death. In comparison, the five Gallinazo individuals with porotic hyperostosis only had porosity without coalescence. The severity of cribra orbitalia was similar between the two populations with only one case of extreme cribra orbitalia in the entire sample dating to the Gallinazo phase. The severity of systemic periosteal new bone growth was also similar between the two populations.

The instances of linear enamel hypoplasia are consistent between the two time periods. Additionally, the number of individuals with linear enamel hypoplasia is much smaller than the number of individuals with other indicators of severe chronic malnutrition or infectious diseases. Because the other pathological conditions that indicate malnutrition or chronic infectious diseases were noted on individuals of such young ages, it is very interesting that there is not a higher frequency of linear enamel hypoplasia indicated by the data. Linear enamel hypoplasia can only be formed during amelogenesis, a process that only takes place early in life. A potential explanation for lack of linear enamel hypoplasia in these populations is that it may have been common for Salinar and Gallinazo peoples to have a prolonged weaning period. An alternative explanation could be that young children had better access to food than older children and adults. The later explanation is more problematic due to these individuals showing other indicators of malnutrition or chronic infectious diseases.

Even though none of the p-values listed in Table 4 are significant, which is not unexpected given the small number of individuals available for analysis, the results for porotic hyperostosis provide the strongest pattern that is consistent with the pattern of decreased severity in the cases where the condition was observed. The combination of higher levels and higher severity of porotic hyperostosis during the Salinar phase could indicate that malnutrition and chronic infectious diseases were more prevalent than in Gallinazo phase populations.

4.2 INDICATORS OF ORAL HEALTH AND DIET

Table 5: Indicators of Oral Health and Diet Data. #P stands for the number of individuals in each category that are observed with that pathological condition. N is the number of individuals where the condition was observable (for example, if an individual did not have an associated skull, PH, CO, and all oral pathological conditions could not be recorded and thus are not included in the total n).

	Salinar			Gallinazo			Chi^2	
	#P	n	%	#P	n	%	Statistic	P-Value
Cari	3	11	27.3%	5	12	41.6%	0.5242	0.4691
Calc	3	11	27.3%	8	12	66.6%	3.5693	0.0589
Absc	4	10	40.0%	1	12	8.3%	3.1145	0.0776

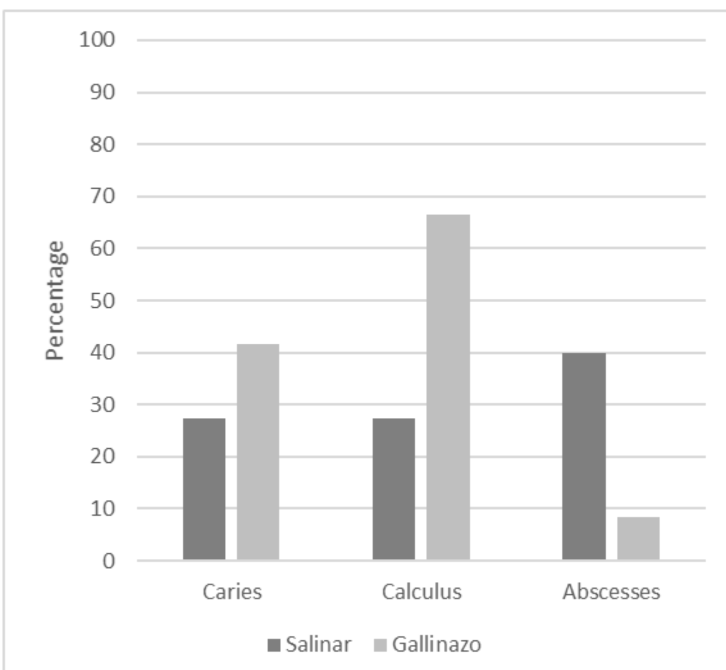


Figure 4: Indicators of Oral Health and Diet Data (in percentages)

Table 5 and Figure 4 indicate that the incidences of both carious lesions and calculus are much greater in the Gallinazo phase sample than that Salinar sample, but there is a strong trend of higher instances of abscesses in the Salinar phase (However, p-values indicate none of these differences are statistically significant at the 95% confidence interval). The increased reliance on maize agriculture could explain the increased instances of carious lesions and calculus during the Gallinazo phase (Bardolf 2017; Lambert et al. 2012; Gagnon and Wiesen 2013). Agriculture subsistence, particularly maize agriculture, brings with it a diet that lacks in protein and other important vitamins and is high in carbohydrates (Pechenkina et al. 2007). The increased reliance on maize meant that Gallinazo phase populations were more likely to get a diet that is high in carbohydrates, low in protein and much less varied than their previous non-maize agriculture subsistence. Therefore, Gallinazo phase populations were less likely to get the nutrients and protein that they need and have much more instances of oral pathological conditions. Because Salinar phase individuals relied less heavily on maize, it would be expected that the frequencies of oral pathological conditions, with the exception of abscesses, would be lower than in the Gallinazo phase which is exactly what can be seen here.

Salinar phase individuals have higher rates of abscesses than Gallinazo phase individuals. The trend of greater abscesses in the Salinar phase is very strong and is significant at the 90% confidence interval suggesting that this is a real difference in the data. This is interesting because abscesses are most often caused by severe carious lesions or wear on the teeth. During the full adoption of maize agriculture in the Gallinazo phase, it would be expected that rates of abscesses would dramatically increase due to the processing of maize commonly leaving grit in the food and causing extreme wear on the teeth. However, it appears that the exact opposite is happening. Looking at the individual people may give a better idea of why this may be happening.

All five individuals with abscesses are adults. One of these individuals is from the Gallinazo phase while four of them are from the Salinar phase. All Salinar phase individuals have other indicators of malnutrition or chronic infectious disease including porotic hyperostosis. Two of the four individuals (P17-823 and P17-824) have more severe cases of the condition. The Gallinazo phase individual, P17-819, did not exhibit porotic hyperostosis, cribra orbitalia, or periosteal new bone growth. However, this individual had vascularization on the ribs indicative of inflammation which could have been caused by any number of pulmonary illnesses. Interestingly, P17-830 (Salinar) also exhibited these vascularization impressions. It is possible that these rates of abscesses are not necessarily associated with a change in diet, but rather a change in the rates of infectious diseases. If an individual had an infectious disease in addition to wear or carious lesions, it is possible that abscesses could have formed earlier than in healthy individuals because of the suppressed immune system. This is further evidence that Salinar phase populations encountered more stress than Gallinazo phase populations.

4.3 SUBADULT VERSUS ADULT HEALTH

In the previous two sections, overall health of each population was examined. However, in light of the osteological paradox, it is also important to discuss health in terms of age-at-death cohorts to gain a better idea of how health changes over time. Due to the small sample size, this section will only separate these individuals by subadults and adults. For the purposes of this study, any individual estimated to be younger than 18 years old was included in the subadult sample while anyone estimated to be older than 18 years old at their time of death was included in the adult sample.

Table 6: Subadult General Health Indicators Data

	Salinar			Gallinazo			Chi^2	
	#P	N	%	#P	N	%	Statistic	P-Value
Cari	0	7	0%	0	4	0%	0	1
Absc	0	6	0%	0	4	0%	0	1
Calc	0	7	0%	1	4	25%	1.750	0.1859
PH	5	7	71%	3	4	75%	0.019	0.8917
CO	4	6	66.6%	2	3	66.6%	0	1
PNB	2	8	25%	0	5	0%	1.364	0.2429
LEH	1	7	14%	0	3	0%	0.419	0.5174

Table 7: Adult General Health Indicators Data

	Salinar			Gallinazo			Chi^2	
	#P	n	%	#P	n	%	Statistic	P-Value
Cari	3	4	75%	5	8	62.5%	0.172	0.6785
Absc	4	4	100%	1	8	12.5%	7.700	0.0055
Calc	3	4	75%	7	8	87.5%	0.275	0.6000
PH	4	4	100%	2	5	40%	3.200	0.0736
CO	0	3	0%	2	5	40%	1.400	0.2367
PNB	0	5	0%	1	9	11.1%	0.555	0.4563
LEH	0	2	0%	1	6	16.6%	0.332	0.5646

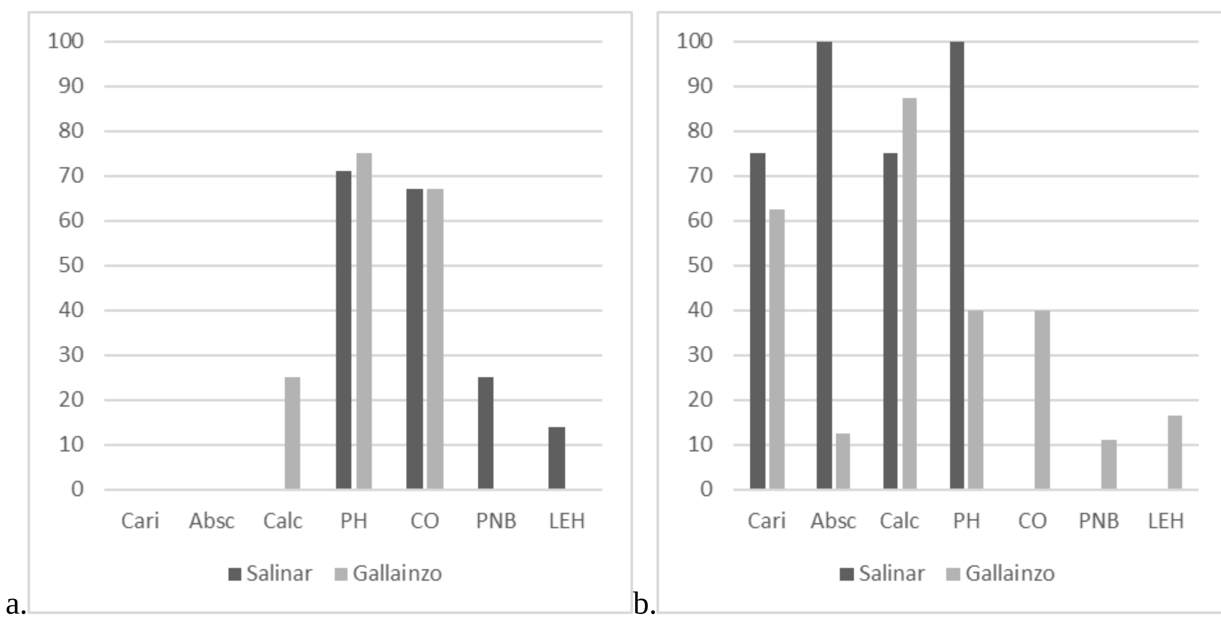


Figure 5a & 5b: Subadult (a) and Adult (b) Data (in percentages)

While the sample size is extremely small for each of these groups, some information can be extracted. In Figure 5a and Table 6, there are very similar rates of porotic hyperostosis and cribra orbitalia between the Salinar and Gallinazo phases of subadults. However, it is only in the Salinar phase sample that periosteal new bone growth and linear enamel hypoplasia occur at all. This could indicate higher instances of overall malnutrition and chronic infectious disease in the Salinar phase.

The adult data in Figure 5b and Table 7 further shows that the rates of abscesses are much greater in the Salinar phase than the Gallinazo phase. In fact, the comparison of adult Salinar and Gallinazo rates of abscesses is the only comparison that has shown statistical significance at the 95% confidence interval (p-value = 0.0055). However, this data also indicates that there are slightly higher instances of carious lesions in the Salinar phase which is interesting because of the full adoption of maize agriculture that is seen in the Gallinazo phase. Additionally, there are more indicators of systemic stress seen in the adult Gallinazo sample. These discrepancies are likely due to unbalanced and small sample sizes. The Salinar subadult sample has almost twice the number of individuals than the Gallinazo subadult sample and vice versa with the Gallinazo samples. Because of this, it is difficult to get any information from these data. However, it can reconfirm some trends noted in the overall population data. For example, the higher rates of abscesses in the Salinar phase is also reflected in this data set. In addition, the strong trend of higher rates of porotic hyperostosis in the adult Salinar sample is also reflective of earlier data trends and likely indicates that these are real results that can be seen in the data.

4.4 ENDOCRANIAL LESIONS

Four individuals in this study had endocranial lesions. Endocranial lesions generally signify swelling in the brain, but can indicate several different kinds of pathological conditions (Lewis 2004).

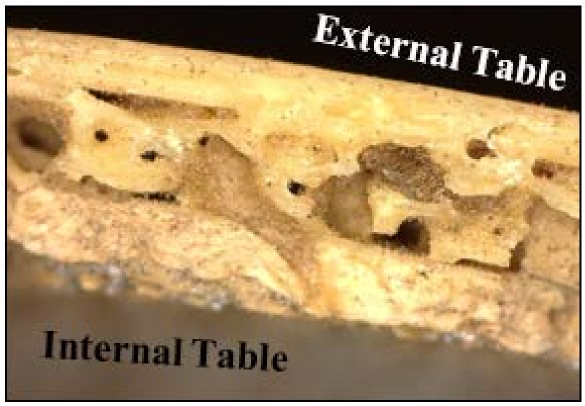
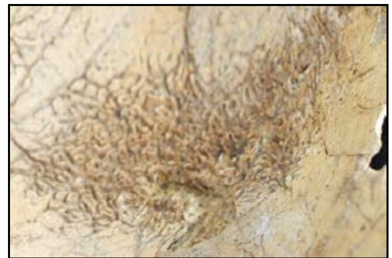
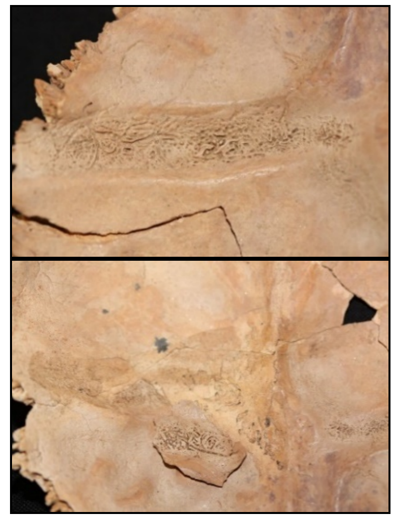


Figure 6: Lateral View of Endocranial Lesions on the Occipital Bone of P17-806

It can be determined that these lesions are mostly lytic in nature, meaning they are eating into the bone, from a lateral view of a broken piece of occipital bone. Normal diploë looks like the inside of a sponge and the external and internal tables being continuous solid pieces. In Figure 6, it can be observed that the lesion is clearly protruding through the internal table and into the diploë of the occipital bone in an unorganized manner. Table 8 outlines each of the individuals with endocranial lesions and documents each lesion with pictures.

Table 8: Endocranial Lesions by Individual

Skeleton Number	Description	Picture
P17-806	Gallinazo. Age: 4yrs: ± 1yr. The endocranial lesions on this individual extend from their frontal bone to the occipital bone with the most severe lesions occurring on the parietals (pictured). The top picture shows lesions that occur into the internal table as well as new bone growth to create those protruding coral-like lesions. The bottom picture shows only lytic lesions in the endosteum of the endocranial surface of the parietal.	
P17-817	Salinar. Age: 1yr ± 6mo. The endocranial lesions on this individual are isolated to the cruciate eminence on the endocranial surface of the occipital. It can be observed that the lesion is only unorganized lytic lesions into the internal table of the occipital bone.	
P17-826	Salinar. Age: 3yrs ± 1yr. The endocranial lesions on this individual were isolated to the occipital bone. Again, it can be observed that this individual has only lytic	

	lesions without the unorganized protruding bone growth.	
P17-828	Salinar. Age: 4yrs ± 1yr. The endocranial lesions on this individual consist of lytic lesions on the cruciate eminence (pictured in the top image) as well as porosity on the parietals. In addition to the lesions, this individual's skull has several flakes (pictured in the bottom image) with the same lesions on them. The porosity on the parietals shows some evidence of healing.	

One of the affected individuals dated to the Gallinazo phase while three were from the Salinar phase. All of the individuals with this pathological condition were subadults with the oldest estimated to be four years old (± one year) and the youngest estimated to be one year old (± six months). All of these individuals have endocranial lesions that are lytic in nature. However, individual P17-806 has both these lytic lesions as well as proliferative lesions that are protruding into the endocranial space. Additionally, the flakes seen in individual P17-828 are also suggestive of osteoblastic interaction. Additionally, all of the lesions include occipital bone activity with some having activity at other parts of the endocranial surface.

It is interesting that all of these individuals are so young because pathological conditions that produce lesions like these generally take a long time to develop before they are observable on the bone. In addition, all of these individuals had other indicators of malnutrition or chronic infectious disease, including active porotic hyperostosis, P17-806 and P17-828 also had cribra orbitalia, P17-828 had linear enamel hypoplasia on four teeth, and P17-817 had systemic periosteal new bone growth.

Many different conditions can cause endocranial lesions (Lewis 2004). Table 7 outlines some of the common pathological conditions that can cause endocranial lesions.

Table 9: Types of Endocranial Lesions and their Causes. Paraphrased summary chart with information taken from Lewis 2004

Pathological Condition	**Description of Endocranial Lesions**
Non-Specific Meningitis	Meningitis is an acute inflammation of the meninges (the outermost layers of the brain that consists of the dura mater, arachnoid mater, and pia mater). It can be caused from any number of viruses or fungal infections. The endocranial lesions for non-specific meningitis include a "rough" skull surface appearance with new bone growth that is "scale-like" ossification of soft tissue.
Tuberculosis	Tuberculosis is an infection that primarily affects the respiratory system. Individuals who have had this infection for a long time may have granular lesions on the endocranial surface as well as "corn-size" depressions thought to be caused by calcified tubercles.
Congenital Syphilis	Endocranial lesions as a symptom for congenital syphilis, is pretty rare. However, when it does occur, it primarily impacts the base of the skull around the foramen magnum. This causes abnormal

	vascular impressions and potential come other defects.
Bone Tumors	Bone tumors arise from the diploë into the inner cranium and produce lytic foci with sclerotic margins.
Subdural Hematomas	Subdural hematomas normally occur from a trauma to the skull. On the endocranial surface of the skull, this would cause localized abnormal vascular impressions. Occasionally, the hematomas may ossify.
Vitamin Deficiencies	Vitamin deficiencies most commonly cause an osteoblastic reaction to the endocranial surface. This can lead to any number of endocranial lesions including new bone formation, skull thickening, and bony projections along the areas of sinus drainage.

None of the conditions outlined in Table 9 describe the lesions that were noted in Table 8. According to Lewis (2004), non-specific meningitis, bone tumors, and vitamin deficiencies only generate osteoblastic activity. Tuberculosis is characterized by granular lesions and punched out depressions. Finally, congenital syphilis only affects bone around the base of the skull. The lesions found on the individuals listed in Table 8 are generally characterized by unorganized lytic reactions that invade through the dipolë with occasional new bone growth, which do not fit any of the descriptions above. Clearly these lesions are caused by some form of inflammation or hemorrhage of the brain. It appears as though all affected individuals have these lesions in the cruciate eminence. This could indicate that the swelling started in the transverse sinus and then continued elsewhere if the individual survived long enough.

At this time, not much can be said about the exact meaning of these lesions. However, what can be stated is that these individuals were clearly suffering from some form of long-term pathological condition that severely affected their health.

4.5 EVIDENCE FOR SCURVY

Three individuals in this study showed potential signs of scurvy. Scurvy is a condition that occurs from vitamin C deficiency. Vitamin C deficiency can occur from malnutrition or can simply result from lack of access to citrus fruits. Osteological evidence for scurvy includes porosity of the sphenoid, cranial vault, orbital plate, temporal, zygomatic, and maxilla as well as porosity on the endocranial surface (Klaus 2014; Stark 2014). There may also be some additional postcranial activity with periosteal new bone growth on the diaphyses of the long bones and fractures to the ribs (Klaus 2014).

Table 10 describes the potential scorbutic lesions on each individual. Two of these individuals, P17-818 and P17-831, have multiple lesions that could indicate that these individuals had scurvy. Even though P17-810 only has one lesion that could indicate scurvy, it is possible that since this child was so young, it simply did not survive the condition long enough to develop the additional lesions.

Table 10: Description of Potential Scorbutic Lesions

Skeleton Number	Description of Potential Scorbutic Lesions
P17-810	Gallinazo. Age: 8 mo ± 3 mo. Porosity on the endocranial surface of the petrous portion of the temporal bone.
P17-818	Salinar. Age: 1 yr ± 3 mo. Cribra orbitalia, porosity on the sphenoid, and systemic periosteal new bone growth on long bones.
P17-831	Salinar. Age: 5 yrs ± 18 mo. Cribra orbitalia, porosity on the temporal line, and generalized endocranial porosity.

The endocranial lesions observed in these individuals are not the same endocranial lesions mentioned in Section 4.4 (see Figures 7a and 7b). These lesions are distinctly different because they lack any of the coral-like structure of the other lesions.

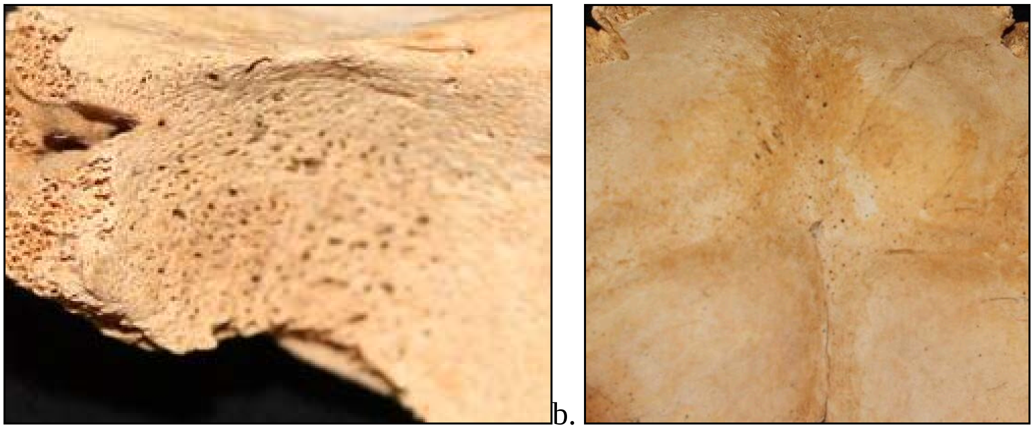
a.

b.

Figure 7a & 7b: Endocranial lesions on petrous portion of the temporal bone on P17-810 (a) and on the occipital bone on P17-831 (b).

While P17-810 (Gallinazo) only shows one potential scorbutic lesion, the other two individuals who showed multiple potential scorbutic lesions were from the Salinar phase. This may suggest that Salinar phase individuals may have had less access to a variety of nutritional sources, such as citrus fruits, than Gallinazo phase populations. Because of the warfare that was evident during the Salinar phase, obstructed and/or obliterated trade routes, less access to previous farmlands, and other outside sources of food resources would be unsurprising. Of course, with a sample of only three, no definitive statements can be made.

5.0 CONCLUSION

This study sought to discover how the health of populations and individuals who lived in the Moche Valley in the Salinar and Gallinazo phases may have been impacted by the major changes that characterized those periods, such as warfare, increasing dependence on maize, and the rise of the Moche state. Skeletal remains of 26 individuals from the sites of Pampa la Cruz and La Iglesia were examined for signs of malnutrition or chronic infectious disease. The work previously done at Cerro Oreja indicates that the intensification of agriculture that occurred during the Gallinazo phase had great implications on the rates of oral pathological conditions (Gagnon and Wiesen 2013). This study built upon her work with the added dimension of skeletal pathological conditions to see if more patterns could be seen in association with the other changes that were occurring during the time.

The Salinar rates of porotic hyperostosis observed are 26.2% higher and systemic periosteal new bone growth rates were over twice the observed rates found in the Gallinazo phase. In addition, there are more severe cases of skeletal pathological conditions in the Salinar sample than in the Gallinazo sample. Carious lesions and dental calculus are both more common in the Gallinazo sample which correlates to the full adoption of maize agriculture that occurred during this time. While these trends are less noteworthy when only adults are examined, Gagnon's (in press) data expresses the same trends in larger sample sizes. Abscesses are far more common in the Salinar phase – with 40% of observable cases when compared to the 8.3% of observable cases in the Gallinazo phase. In adults, abscesses are statistically more significant in the Salinar phase than the Gallinazo phase (p-value = 0.0055). This could indicate more severe cases of carious lesions, less care being taken towards oral health, and/or individuals with poor oral health may have had other health problems that led to severe cases of oral health problems that led to the formation of abscesses.

In addition to the pathological conditions that were investigated, an interesting pathological condition was also noted in the endocranial surface of some subadults. Of the four cases of endocranial lesions, three of them represent the Salinar phase. Finally, there were three individuals who had shown signs of potential scorbutic lesions. These indicators of multiple different types of pathological conditions suggest that infectious diseases and malnutrition may have not been the only health problems people during this period commonly encountered.

While all but one of the results presented in this thesis did not have statistical significance at the 95% confidence interval, the strong trends found indicate that pathological conditions related to malnutrition and chronic infectious diseases were more prevalent in the Salinar phase when compared to the Gallinazo phase. In addition, the trends seen in these data are similar to trends seen in Gagnon's (in press) data with a much larger sample size at Cerro Oreja during these time periods. While supporting Gagnon's (2013) earlier finding that certain dental conditions worsened over time in this area as the consumption of carbohydrate-rich staple crops increased, this study indicates that other generalized stress indicators may show improved health over time, and that overall, Gallinazo people may have lived healthier lives than their Salinar ancestors. Since there are data to suggest that oral pathological conditions worsened over time, it is likely that the worsened health that is seen in the Salinar phase is related to higher rates of chronic infectious disease rather than malnutrition. The data from this study potentially suggest that the social, economic, and political stressors associated with regional warfare in the Salinar phase may have had a greater negative effect on the health of individuals in the Moche Valley than the stressors associated with the intensification of maize agriculture and the rise of the Moche state. Despite the negative health impacts seen in these individuals, their successors went on to create the first state in the New World.

APPENDIX A

APPENDIX A: DATA TABLES

Site	Skeleton Number	Time Period	Crania Present	Dentition Present (0,1)	Long Bones Present	Age	±	Sex
PLC	P17-805	G	0	0	>75%	50	10	F
PLC	P17-806	G	>75%	1	>90%	4	1	N/A
PLC	P17-807	G	>75%	1	50%	2	0.75	N/A
PLC	P17-809	G	<50%	1	<25%	32	2	M?
PLC	P17-810	G	<50%	1	>75%	0.75	0.25	N/A
PLC	P17-811	G	>90%	1	>75%	25	5	F
PLC	P17-812	G	>90%	1	>90%	12	3	N/A
PLC	P17-813	G	>90%	1	>90%	25	5	M
IG	P17-814	G	50%	1	>90%	50	5	F?
IG	P17-819	G	>90%	1	>90%	25	5	M
PLC	P17-820	G	>90%	1	>75%	22	2	F
PLC	P17-821	G	>90%	1	>75%	40	+	F?
PLC	P17-822	G	0%	1	>90%	30	5	M
IG	P17-816	S	>90%	1	>90%	4	1	N/A
IG	P17-817	S	<50%	1	>75%	1	0.5	N/A
IG	P17-818	S	>90%	1	>90%	1	0.25	N/A
IG	P17-823	S	<50%	1	>75%	50	+	F?
IG	P17-824	S	<50%	1	>75%	35	5	M
IG	P17-825	S	0%	0	<25%	1	0.5	N/A
IG	P17-826	S	>90%	1	>75%	3	1	N/A
IG	P17-827	S	0%	0	50%	20	+	?
IG	P17-828	S	>90%	1	>75%	4	1	N/A
IG	P17-830	S	>90%	1	<50%	60	+	F
IG	P17-831	S	>90%	1	>90%	5	1.5	N/A
IG	P17-832	S	>90%	1	>90%	42	5	F
IG	P17-833	S	>90%	1	>90%	12	3	N/A

Porotic Hyperostosis and Cribra Orbitalia Severity Rating
(from Buikstra and Ubelaker 1994)

Rating	Explanation
1	Barely discernible
2	Porosity only
3	Porosity with coalescence of foramina, no thickening
4	Porosity with coalescence of foramina and increased thickness

Site	Skeleton Number	Time Period	PH (0,1,9)	PH Severity	CO (0,1,9)	CO Severity	PNB (0,1,9)	Other Pathological Conditions
PLC	P17-805	G	9	-	9	-	0	
PLC	P17-806	G	1	2	1	4	0	Endocranial lesions
PLC	P17-807	G	1	1	0	-	0	
PLC	P17-809	G	0	-	9	-	0	
PLC	P17-810	G	0	-	9	-	0	Endocranial lesions
PLC	P17-811	G	0	-	0	-	1	
PLC	P17-812	G	1	2	1	2	0	
PLC	P17-813	G	1	2	1	2	0	Bilateral auditory exostoses; bilateral porosity on acromion
IG	P17-814	G	9	-	0	-	0	Trauma to left patella, dist. portion of femur, and prox. Portion of tibia
IG	P17-819	G	0	-	0	-	0	Vascular impressions on the ribs
PLC	P17-820	G	1	2	1	2	0	
PLC	P17-821	G	9	-	9	-	0	
PLC	P17-822	G	9	-	9	-	0	
IG	P17-816	S	1	3	1	2	0	
IG	P17-817	S	1	2	9	-	1	Endocranial lesions
IG	P17-818	S	0	-	1	2	1	Porosity on sphenoid
IG	P17-823	S	1	3	9	-	0	
IG	P17-824	S	1	2	0	-	0	Trauma on left anterior Tibia with periosteal reaction; Healed trauma on left parietal; Osteoporosis
IG	P17-825	S	9	-	9	-	0	
IG	P17-826	S	1	2	0	-	0	Endocranial lesions
IG	P17-827	S	9	-	9	-	0	
IG	P17-828	S	1	3	1	2	0	Endocranial lesions
IG	P17-830	S	1	1	0	-	0	Vascular impressions on the ribs
IG	P17-831	S	0	-	1	2	0	Bilateral porosity on temporal bones
IG	P17-832	S	1	1	0	-	0	
IG	P17-833	S	1	2	0	-	0	

Site	Skeleton Number	Time Period	# Teeth	Cari (0,1,9)	Number Affected	Calc (0,1,9)	Number Affected	LEH (0,1,9)	Number Affected	Absc (0,1,9)	Abcs Number	Other Pathological Conditions
PLC	P17-805	G	-	9	-	9	-	9	-	9	-	
PLC	P17-806	G	?	0	-	0	-	0	-	0	-	
PLC	P17-807	G	?	0	-	0	-	9	-	0	-	
PLC	P17-809	G	6	0	-	1	4	9	-	0	-	ATML of 6 teeth
PLC	P17-810	G	?	0	-	0	-	0	-	0	-	
PLC	P17-811	G	9	1	2	1	2	9	-	0	-	
PLC	P17-812	G	14	0	-	1	4	0	-	0	-	
PLC	P17-813	G	?	0	-	0	-	0	-	0	-	Slight periodontal disease
IG	P17-814	G	16	1	6	1	7	0	-	0	-	AMTL of 6 teeth; periodontal disease
IG	P17-819	G	27	1	4	1	27	0	-	1	2	Periodontal disease
PLC	P17-820	G	?	0	-	1	6	0	-	0	-	
PLC	P17-821	G	17	1	3	1	17	1	1	0	-	AMTL of 6 teeth
PLC	P17-822	G	13	1	2	1	6	0	-	0	-	AMTL of 1 tooth
IG	P17-816	S	?	0	-	0	-	0	-	0	-	
IG	P17-817	S	?	0	-	0	-	0	-	9	-	
IG	P17-818	S	?	0	-	0	-	0	-	0	-	
IG	P17-823	S	15	1	3	0	-	9	-	1	1	AMTL of 2 teeth
IG	P17-824	S	14	1	4	1	2	9	-	1	1	AMTL of 2 teeth
IG	P17-825	S	-	9	-	9	-	9	-	9	-	
IG	P17-826	S	?	0	-	0	-	0	-	0	-	AMTL of 2 teeth
IG	P17-827	S	-	9	-	9	-	9	-	9	-	
IG	P17-828	S	?	0	-	0	-	1	4	0	-	
IG	P17-830	S	?	0	-	1	36	0	-	1	1	
IG	P17-831	S	?	0	-	0	-	0	-	0	-	
IG	P17-832	S	?	1	2	1	36	0	-	1	2	AMTL of 1 tooth
IG	P17-833	S	?	0	-	0	-	0	-	0	-	

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