PATTERNS IN DENTAL HEALTH AND DISEASE AT THE ARCHAEOLOGICAL SITE OF KUELAP IN CHACHAPOYAS, PERU

by

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ABSTRACT

Social organization influences individual well-being and overall community health, which may lead to health disparities that manifest in teeth. The research in this thesis explores social variability by analyzing patterns in dental disease at the archaeological site of Kuelap in Chachapoyas, Peru. The ancient Chachapoya (AD 900-1535) were a complex society but the nature of that complexity is not well understood based on traditional archaeological correlates. Since burials at Kuelap lack grave goods that are often used to discriminate variation in social status or identity, bioarchaeological dental proxies were tested. The dental remains of 106 individuals (7 subadults, 54 adult males, and 46 adult females) from five different types of mortuary contexts were analyzed using a two stage methodological approach. Three pathological indicators (caries, antemortem tooth loss, and calculus) were examined to explore cultural influences of diet and the external environment on human biology. While no significant differences exist in any of the conditions among individuals from five diverse mortuary contexts, there were statistically significant differences between males and females. These results indicate that there was a lack of explicit health disparities and hierarchical ranking (social inequality) at Kuelap. Instead, bioarchaeological analysis suggests that there is social variability with gendered differences in oral health. This thesis presents the first analysis of dental pathology from Kuelap and furthers knowledge of ancient dental health patterns and social variability in both the Chachapoya and larger Andean region. Overall, this research broadens anthropological understanding of the interconnectedness among health, social variability and complexity in ancient societies.

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To the place high in the clouds.

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CHAPTER ONE: INTRODUCTION

Social organization occurs at all societal levels, starting from the small household unit to the larger community. The ways in which groups of people organize themselves varies in each place because all societies are culturally unique and each has its own distinct history (Crumley, 2007). Societies are also dynamic and constantly adapting to their ever-changing internal constituents and external surroundings (Service, 1979). However, adaptations to these changes can cause positive, negative, or a combination of both outcomes on members of that society. A common consequence is the institutionalization of rigid, hierarchical social structures to respond to increasing complex group dynamics and environmental pressures, which can ultimately influence individual health (Marmot, 2001; Sapolsky, 2004). In particular, social inequality occurs when members of a group or community receive uneven access to resources based on their ranking (Smith, 2012). Systemic health differences may develop over time where members of lower statuses of that community have higher prevalence of nutrient deficiencies and disease loads (Rathbun and Steckel, 2003).

In a complex society, the development and institutionalization of social inequality appears to be intrinsic (Kushner, 1969; Service, 1979). Previous bioarchaeological studies (Powell, 1991; Knusel et al., 1997; Robb et al., 2001; Cucina and Tiesler, 2003; Gagnon, 2006; Pechenkina et al., 2007) have demonstrated based on differences in health and disease experiences identified in skeletal remains that social inequality existed in many past complex civilizations. The archaeological site of Kuelap (AD 800-1535) in the Chachapoyas region of Peru presents a unique case for this type of comprehensive analysis because the site contains elaborate residential structures, spatial organization, and mortuary variability to suggest that the Chachapoya were a complex society with social variability (Church and von Hagen, 2008).

Kuelap also has a large, well-preserved human skeletal sample that can be analyzed to address questions about health differences among subgroups.

Purpose of Research

The purpose of this study is to explore social variation and complexity at Kuelap through bioarchaeological observations of dental pathological conditions. The main objectives of this research include: 1) to investigate patterns in oral disease of the Chachapoya at Kuelap by combining three specific dental health indicators (caries, antemortem tooth loss, and calculus), 2) to analyze health differences between males and females and among individuals buried in different types of mortuary contexts, and 3) to explore evidence of gender diversity and social variability at Kuelap as possibly hierarchical or heterarchical.

This research furthers anthropological knowledge and contributes to growing research connecting paleopathological analysis with social structure and complexity in ancient Peru (Verano, 1992; 1997; Gagnon, 2006; Pechenkina and Delgado, 2006; Pechenkina et al., 2007; Klaus and Tam, 2010; Gagnon and Wiesen, 2013). More specifically, only a handful of archaeological articles have been published about the Chachapoyas region with topics ranging from bioarchaeological analyses of violence (Toyne and Narváez Vargas, 2014), mortuary variability (Crandall, 2012), and residential architecture (Guengerich, 2014). This area of the world is an emerging field of research and interest, and this investigation is the first to explore the relationship between dental health and social variability both at Kuelap and of the ancient Chachapoya civilization.

Additionally, the findings from this study will contribute to the holistic understanding of health and social diversity in the past. While there are many ways in which a group of people

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living in an established space can be organized, social inequality specifically influences one's overall well-being depending on the individual's ranking (Fried, 1976; Peebles and Kus, 1977; Cohen, 2007). Higher ranking people may acquire a larger share of valuable resources while lower ranked individuals obtain a substantially smaller allotment or lesser quality of resources (Peebles and Kus, 1977). Over time, disparities in resource allocations may lead to significant differences in disease susceptibility and frequency (Braveman, 2014). Throughout history and in many complex civilizations, this is a recurring trend as individuals are treated differently due to their social status in society (Peebles and Kus, 1977).

Theoretical Approach

Social Variability and Gender Inequality

Society can be organized through various means, from an egalitarian to a highly stratified society, depending on the distribution of resources, power, and decision making (Crumley, 1995). Additionally, archaeology has been predominantly focused on social ranking rather than gender inequality as male biases have dominated archaeological theory and investigations (Conkey and Spencer, 1984). In the past few decades, studies on social variability have incorporated multiple facets of organization, including the differences between heterarchy and hierarchy and gender inequality in society. This thesis follows a bioarchaeological approach to explore the connection between dental health and social complexity.

Mortuary Analysis

Bioarchaeological analysis of mortuary contexts allow for the study of material remains to infer cultural practices and the study of human remains and to interpret health and life histories. Within the past century, mortuary studies have transformed from assuming a

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disconnect between burials of the dead and the living society to better understanding how the mortuary practices are deeply interrelated to social interactions and beyond (Hertz, 1960; Goldstein, 2006). Mortuary analysis archetypally examines and compares grave goods to infer social status, but when grave goods are not present in the tombs, other proxies can include corpse treatment, tomb location, architectural design, energy expenditure, and resources exploited for burial construction (Peebles and Kus, 1977). This study incorporates mortuary contextual information with bioarchaeological analysis of dental remains to explore this relationship between social ranking and funerary practices.

Methodology

Bioarchaeological Analysis of Dental Health

Dental analysis is an important tool in bioarchaeology because teeth can offer significant contributions to investigations of ancient health despite their small size and sheer complexity. Studies of dental remains can either be conducted using teeth or individuals as the units of analysis (Gagnon and Wiesen, 2013). Both units help answer specific and broadly complex theoretical questions about cultural practices and their influence on health, disease susceptibility, and social ranking. Thus, a two stage analysis by tooth and by individual will be employed.

From Kuelap, a sample of 106 individuals was selected, and the teeth from these individuals were observed. The presence, location on tooth surface or dental arcade, size, manifestation, and frequency of caries, AMTL, and calculus were recorded per tooth and individual. Multiple indices for each dental pathological indicator was used to assess different aspects of disease accumulation and expression. These indices are arbitrary calculations for statistical comparisons among individuals and groups based on age, sex, and mortuary context.

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Research Goals, Questions, and Hypotheses

This section details the research expectations and questions to be addressed in this study. I plan to address the following research questions about health and social variability of people buried in multiple interments at Kuelap.

1. Is the combined methodology of pathological indicators an effective analytical tool to develop an informative health profile of the Kuelap sample to assess dental health of ancient human skeletal remains?

2. If significant discrepancies in disease frequencies can be found between males and females, how might this information inform us about sex differences in health and possible gender inequality? Are there also significant differences in disease frequencies among individuals from various mortuary contexts?

3. Based on these dental analyses, are the data consistent with expected health patterns at Kuelap, and can inferences be made about social complexity?

The research tests the null hypothesis that there are no dental health differences among individuals from Kuelap. The data collected from the pathological indicators will be useful in identifying differences and patterns in dental health, especially when used in conjunction with mortuary information, to explore social variability at this archaeological site. To test this hypothesis, I have created a series of expectations based on the data from the Kuelap sample.

1. I expect to find evidence of caries, antemortem tooth loss (AMTL), and calculus in the Kuelap sample, which will include both males and females of all age categories from different mortuary contexts.

2. I expect to identify varying degrees of AMTL, and record specific locations on tooth surfaces and standardized sizes of carious lesions and calculus deposits.

3. I expect that by pooling together all teeth in the sample and calculating separate pathological and dental wear frequencies for tooth, I can identify specific patterns in etiology.

4. I expect there to be some indication of coca leaf chewing among individuals from the Kuelap sample as this cultural practice is common within the Andean region.

5. I expect that there will be differences in the frequency of oral health indicators in individuals belonging to the different demographic categories defined in this study.

6. I expect to be able to identify and assess both intrinsic and extrinsic factors that cause disparities in the observed oral health indicators.

Chapter Summary and Outline of Subsequent Chapters

This study explores the influences of social ranking and gender inequality on oral health by considering disease expression coupled with archaeological information on mortuary contexts at the Chachapoya site of Kuelap. This chapter defined the research objectives, questions, and hypotheses. I also provided a brief overview of the methods used in this study. In Chapter Two, I will explore the theoretical framework of social complexity and variability, hierarchy versus heterarchy, gender diversity, contributions of bioarchaeology to understanding social inequality, and how Kuelap provides the ideal site to study social inequality and health in the past. In Chapter Three, I will also explain methods of data analysis and those employed in the present study. Chapter Four will detail my data analysis as well as present the results and in Chapter Five, I will discuss my interpretations. In the conclusions chapter, I will summarize the implications of this research for broadening anthropological knowledge and consider future investigations.

CHAPTER TWO: THEORETICAL AND BIOARCHAEOLOGICAL BACKGROUND RESEARCH

This chapter introduces the theoretical background of social complexity and inequality that provide a foundation for exploring the relationship between social variability and health in the past. Two different social structures, heterarchy and hierarchy, will be compared and explained as to how both structures can co-exist within a complex society along with the importance of gender diversity in anthropological research. In addition, I will operationalize the term "health" by briefly examining how it has been defined in both the general and anthropological literature. This is important for specifying how health will be interpreted in this study and for distinguishing between health differences and disparities. Particularly for bioarchaeological studies of social inequality, analyses of health must take the "osteological paradox" into consideration (Wood et al., 1992). Subsequently, I will explore mortuary analysis of social variability and statuses by explaining the significance of burial context, energy expenditure, and social ranking. I will provide an overview of the Chachapoya civilization, including a review of the current understanding of geography, social organization, and mortuary practices. Lastly, I will introduce the archaeological site of Kuelap by describing site architecture and layout as well as its various mortuary contexts.

Theorizing Social Complexity and Gender

What is social complexity? This term encompasses many broad interpretations that have been loosely applied to a large population of people cohabiting in roughly the same area who interact with each other regularly (Wynne-Jones and Kohring, 2007). These people live in an organizational structure and form relationships based on "culturally defined" past experiences, present contexts, and future objectives. Complexity is best conceptualized as the means by which

societies organize and integrate within themselves to move in between the many different levels of interactions and multiple types of relationships and groups to allow for flexibility (Wynne-Jones and Kohring, 2007). Social complexity occurs in natural and dynamical social systems with distinct histories characterized by both sudden and gradual changes (Crumley, 2007). It also includes both horizontal and vertical differentiation in social, political, and economic structures (Blanton et al., 1993; Tainter, 2000).

A complex society refers to a formative or developed state-level civilization that is marked by distinctive characteristics such as subsistence changes, geographical expansion, territorial boundaries, maximized exploitation and domestication of resources, increased sedentism, significant population growth, nucleation of villages and cities, centralized political power, increased cultural florescence, and consequently, increased social hierarchy and stratification (Fried, 1967; Kushner, 1969; Carneiro, 1970; Tainter, 1975, 1980; Cohen, 2007; Smith, 2012; Cuellar, 2013). As such, socially complex civilizations require cultural adaptations to maintain stability, which may have contributed to the unequal redistribution of resources and goods due to increased centralization of political control and economic resources (Kushner, 1969; Service, 1979). The effects of social stratification may hinder the health and biological well-being of some individuals, especially those of lesser status. Thus, these cultural processes that were used to implement and regulate social inequality can be viewed as negative external social stressors on human biology (Schell, 1997). As a result, health disparities may develop among people of different ranking due to unequal access to resources (Fried, 1976; Peebles and Kus, 1977; Cohen, 2007).

Archaeological evidence for social complexity has focused on the materialization of individual decision making and human agency in three realms: food, objects, and work (Smith,

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2012). Food is a basic necessity and is used by people in many diverse ways. For instance, humans have developed preferences for certain dishes and often expend energy to produce more food. Aside from food, humans also make objects to manipulate the natural environment, interact with others, and express their identity. Lastly, work is the process by which humans make food and objects. Work involves labor and energy expenditure that require decision making and human cognitive capacity to consider time, space, and value. Decisions about food occur on a daily basis through individual and community thought processes, which can become more complex over time due to population growth, increased social diversity, and new demands where production takes place at the household level (Smith, 2012). Power relations and societal utilization of these three realms are also important to examine the overall degree of complexity in individual social relationships (Patterson and Gailey, 1987).

However, this is not to imply that states evolved from simple to complex societies or from equal to unequal structures (Service, 1979; Chapman, 2007). Instead, the adaptability and flexibility of a society to change demonstrates its already complex state because these interactions may occur at any point in time (Chapman, 2007). While Flannery (1972) has argued that complex societies tend to have more integrated and centralized structures because of higher levels of decision making and organization, DeMarrais (2007) and Souvatzi (2007) demonstrate that social complexity does not necessarily imply hierarchy or ranked order of social elements.

Social Variability: Hierarchy and Heterarchy

There are two types of social structures that can coexist within the same complex society: hierarchy and heterarchy (Crumley, 1995; 2005; Souvatzi, 2007). Both models resemble processual approaches that view change within a society as a direct response to external stress

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(Saitta and McGuire, 1998). Hierarchy refers to an organizational system in which elements are ranked and assigned values. Rank is the relative standing of an individual within a social order that reflects his or her value and authority among other members of a group (Daly et al., 2015). In a hierarchical society, individuals, groups, and institutions are ranked, and there is uneven access to power and resources, also referred to as social inequality (Crumley, 1995). The higher status authorities have more defined control over decision making and access to resources over their lower ranking counterparts. A complex society, however, can be organized in other ways beyond the traditional model of hierarchy. Heterarchy is one type of organizational system where elements are considered different instead of one element being ranked higher in prestige than the other (Crumley, 1995). In a society where the heterarchical structure is dominant, individuals may have approximately equal access to decision-making and resources, and interconnectedness exists among all individuals. However, a heterarchical society can eventually transform into a rigid hierarchical dominant society and vice versa because all societies are dynamic and open rather than stagnant and deterministic (Crumley, 1995; 2007).

While many studies consider hierarchy as a key component of social complexity, a heterarchical perspective is important because it explores the nuances of complexity and moves beyond an immediate, inherent bias towards social inequality and hierarchy. It forces researchers to consider whether economic, political, and social structures function independently or interdependently of one another (DeMarrais, 2007). The concept of heterarchy has been previously applied to examine ancient Maya socioeconomic structures and polities in the Three Rivers Region of the Yucatán peninsula (Scarborough et al., 2003) and food systems using stable isotopic data collected from burials at Chau Hiix, Belize (Metcalfe et al., 2009), and more recently to assessing complexity of the archaeological Tumanmarca and Borgatta polities in Peru

(DeMarrais, 2007). Practical approaches to distinguishing between hierarchy and heterarchy entail an established set of expectations within the archaeological record because while hierarchy models focus on individuals and subgroups, heterarchy models require a broader view of a society (DeMarrais, 2007). These expectations vary depending on the site, the sample under study, and research questions.

For instance, Metcalfe et al. (2009) compared isotopic values of individuals buried at Chau Hiix, Belize from the Early Classic to the Historic period. They found no differences in the diets of males and females and no changes from the time of birth to twelve years of age. A closer examination revealed that rulers from Chau Hiix, Lamanai, and Altun Ha had different diets from one another, but they also had very distinct diets compared to other individuals buried at the same locations. Metcalfe et al. (2009) concluded that hierarchy was evident between individuals of different social status, but heterarchy existed among elites from different sites, particularly during the Classic period.

On the other hand, DeMarrais (2007) explored the materiality of settings within a social order, specifically focusing on reserved spaces for community ownership and ritualized activities as well as individual ownership at the household level. She argued that the infrastructure and built environments of any community may institutionalize political centralization, status differences, and interdependence among subgroups. She argued that the household was the basic organizational unit in both polities from the Late Intermediate Period (AD 1350-1450) site of Tumanmarca in the central highlands of Peru and from Borgatta (AD 1000-1450) in the southern Andean region. According to DeMarrais (2007), the household was connected through broader structures within the community and shared burial settings, as seen in traditional *ayllus* of

Andean societies. These previous studies provide a foundation for exploring social complexity and structure in this thesis..

Gender Diversity

In the past, archaeological interpretations have generally centered on social ranking as opposed to exploring other ways in which society can be organized and how individuals interacted with each other at both the household and broader community levels (Conkey and Spector, 1984). The role of women, particularly, has often been neglected and undermined due to male dominance in archaeological research (De Lucia, 2008). In response to Western stereotypes and biases, gender archaeology has emerged to emphasize social relationships that transcend beyond preconceived notions about gender inequality and binary male and female domains (Brumfiel and Robin, 2008). Gender diversity is a vital part of exploring social variability because of the interaction that occurs at all societal levels through various channels. The interplay among individual members and subgroups helps shape a community's political and socioeconomical organization through decisions on power and resource allocation, which in turn can transform social structure and change how people are ranked within a group. Furthermore, sex differences in health can reflect gender equality or inequality and shed light on how men and women were treated differently within the same society.

Gender may be challenging to interpret in the archaeological record without placing one's own enculturated beliefs to what is categorized as masculine and feminine (Brumfiel and Robin, 2008). To avoid biases when interpreting the sample, this study emphasizes how cultural factors may augment present biological differences between males and females to reflect observable patterns in dental health.

Operationalizing of Disease and Health

To further explore the dynamics between social complexity and inequality and how these affect the biological well-being, the terms "disease" and "health" must be defined. Disease refers to pathological conditions that impair a person's biological well-being and disrupt normal functioning of physiological functions (Mascie-Taylor, 1993; Loustaunau and Sobo, 1997). Diseases are classified as chronic or infectious and are the result of complex etiologies, such as genetics, the external environment, cultural influences, sex, age, and microscopic agents (Mascie-Taylor, 1993). If the pathological condition progresses to an advanced stage, the organism may eventually succumb to death (Mascie-Taylor, 1993; Waldron, 2009; Ortner, 2012). Additionally, the concept of disease may vary from person to person because culture influences individual and group perceptions of disease (Loustaunau and Sobo, 1997; MacLachlan, 1997; Lock and Nguyen, 2010). These beliefs may become altered over time as culture changes. Thus, disease can be best understood from a life course perspective where health is explored at various life stages as people undergo unique individual experiences and have different biological capacities depending on intrinsic and extrinsic factors, such as age, sex, and the external environment (Pickin and St. Leger, 1993; Loustaunau and Sobo, 1997; MacLachlan, 1997).

Health can be conceptualized as a comprehensive state of well-being that is determined by physiological status, individual perception, culture, and lived disease experience (Loustaunau and Sobo, 1997; Kleinman and Petryna, 2001). Although these factors may not be easily observed in ancient populations, health can be implied based on specific skeletal indicators (Temple and Goodman, 2014). There are also differences in how health is explored across disciplines. In biological and medical studies of modern populations, health is often defined

qualitatively in relation to dimensions of social inequality and disparities (Davey, 2003; Lock and Nguyen, 2010). Conversely, in bioarchaeology, health may be defined quantitatively as the total amount of stress and frequency of skeletal lesions observed in ancient human remains (Goodman and Martin, 2002; Cohen, 2007; Temple and Goodman, 2014; Wilson, 2014). This binary view of health assumes that individuals who died before disease manifested in their skeletons were healthier because of the absence of lesions. However, it also presupposes that those who lived long enough to fully manifest the disease were considered less healthy due to a higher number of skeletal lesions (Siek, 2013). This is perceived as the "osteological paradox", first defined by Wood et al. (1992).

The osteological paradox suggests that because many diseases take time to manifest in the skeleton, affected individuals who lived long enough for skeletal and/or dental lesions to appear were essentially healthier than those who died quickly before the pathological condition became apparent (Wood et al., 1992). In other words, the presence or absence of lesions does not necessarily imply good or bad health (Wood et al., 1992). Thus, when studying health at the individual and population levels, the osteological paradox must be taken into consideration (Wright and Yoder, 2003). Detailed information on each pathological indicator's presence in the individual will be provided as Wood et al. (1992) has suggested for better evaluations of heterogeneity in frailty for lesions (caries and AMTL) or tartar (calculus) formation. Analysis of pathological lesion by age-at-death was also recommended for examining the significance of disease formation in regards to morbidity and mortality (Wright and Yoder, 2003). To further test for patterns in disease conditional expression, I will assess an individual's biological sex because inherent biological factors can also affect pathological susceptibility and manifestation.

Health Differences and Disparities

A person's well-being varies because there are intrinsic and extrinsic factors that all play a role in compromising someone's health. In particular, health differences refer to variations in disease susceptibility and experience due to intrinsic factors such as age, biological sex, genetic disorders, and pre-existing conditions (Braveman, 2006; 2014). Conversely, health disparities are differences caused extrinsically by unequal access to resources in which the economically or socially disadvantaged groups have poorer health (Braveman, 2006; 2014). Health differences are present in both hierarchical and heterarchical societies, but health disparities are the direct result of social inequality.

Intrinsic biological differences in health between males and females can be primarily attributed to dissimilar rates of development, differential immune responses, hormone secretions, and other physiological factors (Covington, 1996; Institute of Medicine, 2001). For example, caries is a progressive decay of tooth tissues by bacteria found in dental plaque. This pathological condition has been examined extensively in dental anthropological literature because carious lesions reflect both intrinsic biological changes to the human body and nuances in behavioral practices (extrinsic factors) over time (Turner II, 1979; Lukacs, 1996; Larsen, 1998; Watson et al., 2010). Teeth tend to erupt earlier in females, which according to anthropological literature (Larsen, 2015) and clinical literature (Fédération Dentaire Internationale, 1988; Antunes et al., 2003), allows more time for lesions to develop. Figure 2.1 displays the intrinsic and extrinsic factors that can influence dental health and disease manifestation and susceptibility during an individual's life history.

INFANT

Developmental Factors — *Age of Eruption*

Occlusal Variation

Enamel quality

Hormonal Changes — **Physiological Factors (e.g. sex)**

Salivary flow rate and quality

Oral microbiology

Diet — *Carbohydrates vs. Proteins*

Food texture (sticky vs. non-sticky)

Amount of Consumption

Food Preparation — **Behavioral Factors**

Cultural habits (e.g. coca chewing)

Oral hygiene

Miscellaneous — *Cultural modifications*

Dental trauma and damage

Intentional extraction

OLD ADULT

Figure 2.1: Flowchart demonstrating factors that affect dental health, beginning from infant to old adult. Adapted from Lukacs (2008) and Hillson (1996; 2008).

In particular, hormones can drastically affect overall health, such as estrogens, which are said to enhance immune competence, and androgens, which decrease immune competence (Ahmed et al., 2010; Klein and Huber, 2010). Although females should have stronger immune responses, estrogen levels fluctuate frequently, especially during puberty and pregnancy, triggering certain physiological effects that inadvertently increase disease susceptibility (Lukacs, 2008). Changes in the salivary flow rate and the biochemical composition of saliva can lessen the removal of food particles as well as reduce an individual's antimicrobial functions and buffering capacity (decrease in pH level); these slight changes in the quality and quantity of saliva can ultimately increase a female's cariogenicity as her immune response has been compromised (Dowd, 1999; Dodds et al., 2005; Lukacs and Largaespada, 2006; Tabak, 2006).

Extrinsic factors that can cause health disparities between males and females are often culturally induced that lead to biological consequences. Referencing back to the caries example, the introduction and intensification of agriculture has been linked to increased caries prevalence and poorer overall dental health in adult females from many other ethnic groups from diverse environmental settings and cultural backgrounds (Hillson, 2008; Lukacs, 2008). The connection between caries and agriculture was first argued by Turner II (1979) when he closely examined the high incidence of caries and other dental pathological conditions in the Jomon people of prehistoric Japan and tied the findings to a plant-based diet of higher starch content and cariogenic potential. The intensification of both fertility and agriculture has increased caries prevalence in adult females because these rates were affected by dietary changes that caused physiological disruptions in female sex hormones and saliva, especially during pregnancy (Lukacs, 2008). As such, health differences and disparities can be used to establish expectations in patterns of disease prevalence among demographic subgroups of a sample or population.

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Social Inequality in the Past

Research on social inequality in the past can broaden our understanding of social complexity and human agency as it allows us to examine how individuals were impacted by unequal access to resources and power. While these processes cannot be observed directly, scientists can derive inferences based on hypothesis testing and multiple lines of evidence from biological and material remains. The subfield of physical anthropology that investigates this kind of research is bioarchaeology.

Skeletal Analysis

Bioarchaeology refers to the contextualized analysis of human remains from archaeological sites of past societies, including skeletal elements, dentition, and desiccated soft tissues (Larsen, 2015). While previous physical anthropology research focused mainly on physical remains, bioarchaeologists incorporate archaeological data into their analyses for more contextualized and culturally-focused interpretations. The key component of bioarchaeology is the interaction between human biology and the environment, known as the biocultural approach, which highlights the dynamic nature of skeletal tissues as well as the cultural influences on human physiology, specifically the skeleton (Larsen, 2015). Since these biocultural processes cannot be directly observed, changes in the physical human body provide valuable insight about past daily lives and enables the interpretation of lifetime events in the past. At the individual scale, information can be obtained about the person's age-at-death, sex, diet, habitual behaviors, traumatic and disease experiences through the use of pathological indicators, and health (Buikstra 1979; 1981; Larsen, 2015).

From an analysis of multiple individuals (or a sample), inferences can be made about a population from a specific time and geographical location. Population studies allow for a more critical analysis of patterns identified in behavior, daily activities, physiological stress, and diseases (Larsen, 2015). These lines of evidence can then be used to draw broader interpretations about changes in overall health, lifestyles, and social structures. When contextualized with other material correlates, including grave goods, tomb size and architecture, skeletal and dental pathological indicators can be used to examine health differences and disparities in the past as cultural stressors negatively influence human biology (Sapolsky, 2004).

Dental Bioarchaeological Studies

While the human skeleton as a whole provides a wealth of information about the past, the bioarchaeological study of dental remains allows for a more specialized approach. In particular, teeth lack significant tissue turnover and remain unchanged throughout life unless they are affected by dental wear, trauma, or disease (Hillson, 1996; 2008). Teeth are also durable, often preserve better than bone, and reflect the interactions among the external environment, cultural behavior, and diet, which make them valuable for bioarchaeological analysis (Scott and Turner II, 1988).

Depending on the research design and questions, anthropologists can draw conclusions about diet, subsistence changes, health, and social structure (e.g., Turner II, 1979; Lukacs, 1996; Cucina and Tiesler, 2003; Eshed et al., 2006; Gagnon, 2006; Pezo Lanfranco and Eggers, 2010; Hubbe, et al., 2012; Novak, 2015). Implications can be made because different diseases affect teeth in identifiable ways and can be examined to provide valuable clues on foodways, differential access to resources, activities, and ultimately, implications for health disparities

(Hillson, 1996, 2008). Additionally, information about cultural practices can be inferred from dental health indicators, such as coca chewing habits in the Andes (Buck et al., 1968; Allen, 1985; 1988; Bastien, 1985; Cartmell et al., 1991). Thus, dental anthropological research contributes significantly to our understanding of the past and provides valuable insight into the past lives of individuals and more broadly, of the society from which they belong.

Overall, this thesis will contribute to current knowledge of dental health and paleopathology in the Andes. Although several studies have been published on the relationship between dental pathological indicators and social structure (e.g. Gagnon, 2006; Pechenkina and Delgado, 2006; Pechenkina et al., 2007; Pezo Lanfranco and Eggers, 2010; Gagnon and Wiesen, 2013), this thesis is the first to reconstruct dental health from the site of Kuelap and the broader Chachapoya cultural group while using a two stage analysis of three pathological conditions: caries, antemortem tooth loss (AMTL), and calculus.

Mortuary Analysis

When examined in conjunction with skeletal analyses, the archaeological study of mortuary contexts yields valuable insight about beliefs surrounding death and identity. These studies are crucial to a proper biocultural approach of skeletal analysis because they highlight the importance of context as mortuary sites are active places deeply connected and manipulated by the living even long after the body has been buried (Hertz, 1960; Goldstein, 2006). During the early 1900s, archaeologists undermined the importance of mortuary practices and discredited their connection within the larger society, but after paradigms shifts due to the work of Robert Hertz (1960) and the Saxe-Binford Approach (Gillespie, 2001), mortuary practices were comprehensively explored as a means to elucidate status differences in life based on individual

differential burial treatment. Furthermore, the analysis of the burial environment has changed significantly from early, simple archaeological interpretations of grave wealth and social ranks to more concrete, theoretically based explanations of the burial process (Goldstein, 2006).

The formation of the mortuary deposit is a chronological process that begins with death of one individual to the discovery of those remains by the archaeologist (Weiss-Krejci, 2011). Between these two events, natural and cultural post-depositional processes simultaneously shape the burial over time. Following the acceptance of an individual's biological death by the survivors, the process of social dying initiates, which comprises part of the larger funerary cycle. The survivors undergo a period of mourning that precedes deposit of the body (Hertz, 1960). The processes of corpse treatment range from bodily preparation and modification, temporary deposition for various ritualistic or practical reasons, to final deposition (Parker Pearson, 2000).

Burial Context

There are various types of burial contexts that are each created through these unique processes. First and foremost, these contexts can be categorized as primary or secondary interments (Fox and Marklein, 2014). Primary burials are permanent resting places where individuals are buried as complete, articulated bodies with all the skeletal elements present. Secondary burials, on the other hand, consist of individuals that have been previously removed from a temporary or initial interment and relocated to a different resting place. The body may be stored in temporary deposition for months or even years depending on ritualistic purposes, intended as part of an extended funerary cycle, or for practical reasons (Weiss-Krejci, 2011). Ethnographic research has suggested that temporary depositions may allow time for the survivors to gather the necessary resources for a final, proper burial (Tsu, 2000). Due to relocation, smaller

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and less preserved skeletal elements may become disarticulated and lost during transportation of the body, which complicate bioarchaeological analysis.

Primary and secondary interments can either consist of one or multiple individuals. Group burials, also known are collective burials, are further classified as synchronous or diachronous (Metcalf, 1991). Synchronous refers to the deposition of multiple individuals during a single event while diachronous consists of multiple individuals being deposited into a burial during separate occasions over a period of time. These burial contexts reflect how mortuary practices are intertwined with cultural identity of the deceased that was defined by the individual in life or ascribed during the funerary cycle by the living (Parker Pearson, 2000).

Social Rank through Mortuary Treatment

Mortuary analysis can yield valuable information about the cultural identity of the deceased that could be extrapolated to interpret degree of social ranking and organization in a society. Traditionally, burial type and architecture, embellishment, location, grave goods, and corpse treatment all reflect how individual identity was potentially expressed in life or manipulated by the living after death (Stutz and Tarlow, 2013). Peebles and Kus (1977) have argued that grave goods suggest status of the individual in life and that the range of variation in these materials can be used to infer about social ranking from an archaeological perspective.

The concept of energy expenditure also helps to elucidate differential burial treatment because it considers the amount of time, involvement and energy that was spent during the funerary cycle (Tainter, 1973). Thus, mortuary variability can reflect social inequality because these differences can be examined for complexity in architectural design and the resources that were exploited in burial construction (Tainter, 1975; Peebles and Kus, 1977). In particular, when

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there are few grave goods and the burial itself is plain with little embellishment, status becomes more difficult to assess as goods may not be present or have perished over time. In other words, it is important to examine not only the presence or absence of grave goods and the types of materials used but also how the materials were used as well as the costly effort and time to construct the tomb. Tainter (1973) asserts that higher ranking individuals will have greater energy expenditure from more group involvement in their funerary treatment than lower ranking members. The mortuary process, beginning with time of death to the point of discovery and excavation, warrants systematic interpretation of social ranking that can be attained with the incorporation of multiple lines of evidence, including a bioarchaeological analysis.

Overview of the Chachapoya Civilization

This study expands upon previous research on health and social variability to explore similar research questions on the Chachapoya civilization using dental pathological indicators and mortuary contexts. The Chachapoya occupied an area in the northern Andes region of Peru from the Late Intermediate Period (AD 900-1470) to the Inca invasion during the Late Horizon (AD 1470-1535) (Schjellerup, 1997; Muscutt, 1998; Church, 2006; Church and von Hagen, 2008) (Table 2.1).

Table 2.1: Accepted Andean Chronology based on Moseley (2001).

Period/Horizon	Time Range
Preceramic Period	3000 BC
Initial Period	2000-600 BC
Early Horizon	400-200 BC
Early Intermediate Period	AD 0-600
Middle Horizon	AD 600-1350
Late Intermediate Period	AD 1150-1350
Late Horizon	AD 1450
Spanish Conquest	AD 1532

The majority of Chachapoya occupational sites are situated on the eastern Andean cordillera between the two major north flowing rivers, the Marañón and Huallaga, with site altitudes reaching up to 4,000 meters above sea level (masl) primarily in the south (Church and von Hagen, 2008) (Figure 2.2). The western border of the Chachapoya has been identified as the Marañón River, and the southern boundary has been described as around the 8° south latitude, near the modern departments of La Libertad and Huánuco. The specific location of the Chachapoya in the valley west of the Upper Marañón River valley west may have served as a cultural crossroads for trade and migrations due to its strategic location among significant South American cultural co-traditions, such as the Central Andes and the Western Amazonia (Schjellerup, 1997; Church and von Hagen, 2008).
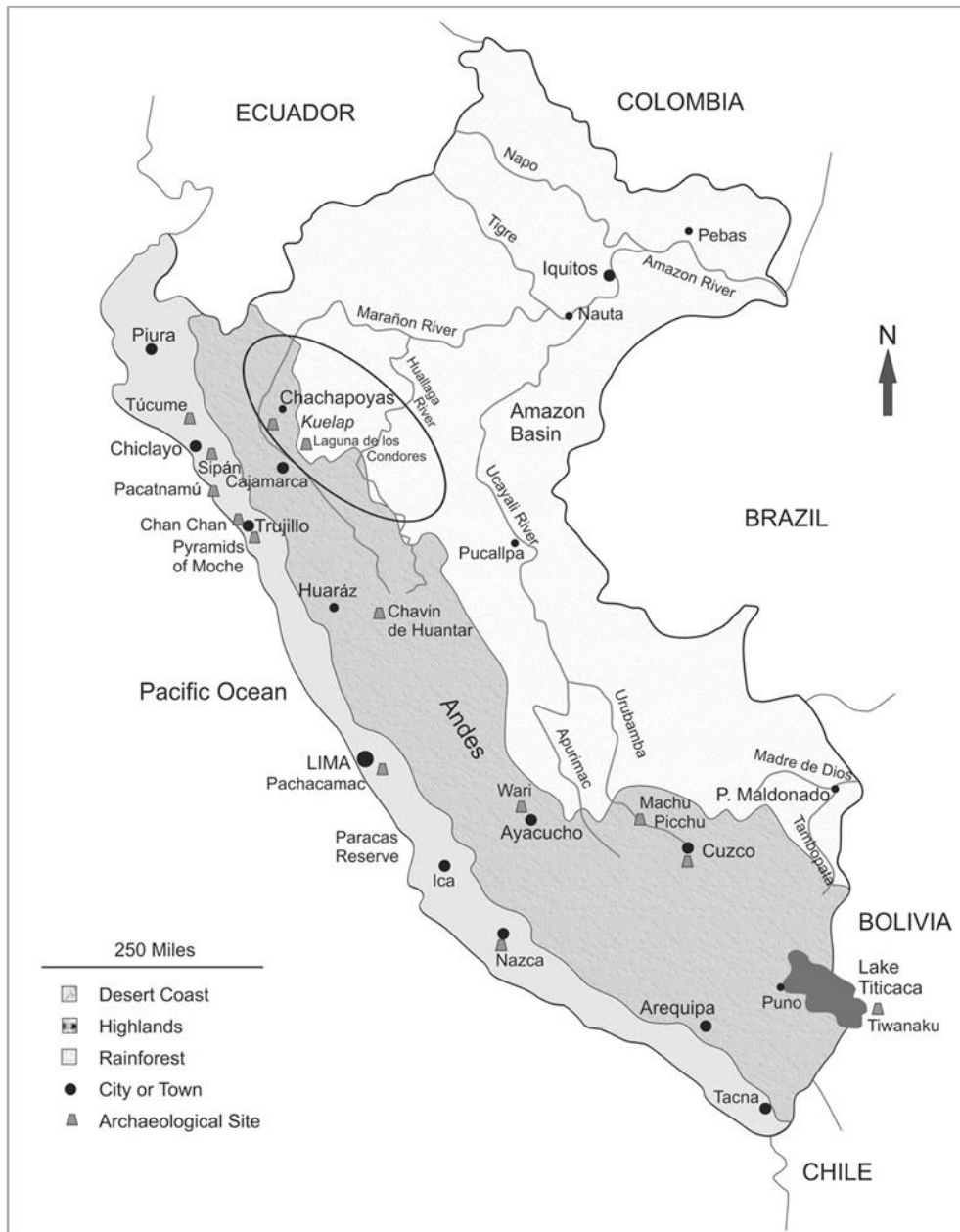
Figure 2.2: Map of Peru illustrating the general location of the Chachapoya cultural area. Courtesy of Dr. J. M. Toyne.

Due to its strategic location among these cultural co-traditions and the eastern slopes of the Andes that receive precipitation from the Amazonian plains climatological systems, there are various micro-climates that exist within the Chachapoya region, ranging from humid conditions

to relatively arid environments (Schjellerup, 1997). Minimal seasonal variation occurs with little distinction between the wet and dry seasons. The geographical terrain consists of deeply incised U-shaped valleys covered by alpine and sub-alpine grasslands and steep slopes that are separated by rocky peaks (Church and von Hagen, 2008)

Social Structure

Relatively little information is known about Chachapoya social structure, which has complicated interpretations of social complexity. According to Muscutt (1998), the population likely numbered over 300,000 inhabitants at their peak. Current research based on ethnohistorical accounts suggests that the Chachapoya region may have been inhabited by autonomous sociopolitical groups, community-based units that united to defend against a common enemy (Church and von Hagen, 2008). It is uncertain whether they collectively acknowledged themselves as a single people (Schjellerup, 1997; Church and von Hagen, 2008) or if they were hierarchically organized with a centralized power (Narváez Vargas, 1987). Schjellerup (1997), on the other hand, has suggested that the Chachapoya people were likely organized into nucleated hierarchical population clusters.

Some scholars have suggested that the Chachapoya people were possibly organized into kinship-based communities called *ayllus* (Muscutt, 1998; Church, 2006). The *ayllu* comprised of a small group of individuals who share a resource and are united by kinship whom were believed to have been descended from two individuals (Isbell, 1977; Henderson, 2013). In many past and modern Andean societies, *ayllus* may have functioned for important civic and organizational purposes, such as the reallocation of community property to adapt to population changes and maintain social stability (Henderson, 2013). However, around AD 1470, the Inca had conquered

the region and likely killed and relocated many Chachapoya individuals to different areas within the Inca Empire, significantly restructuring social and political organization of the Chachapoya (Muscutt, 1998; Church and von Hagen, 2008; Nystrom and Toyne, 2014). The concept of the *ayllus* provides a foundation for how the Chachapoya may have been socially organized in the past at residential sites throughout the region, including Kuelap.

Diet, Chicha, and Coca Chewing Habits

The ancient Chachapoya diet is currently under reconstruction, but other Andean studies (e.g. Finucane et al., 2006; Williams and Murphy, 2010) provide a foundation for exploring possible dietary options and foodways. For example, Finucane et al. (2006) demonstrated the use of widespread maize consumption in the Wari state by both humans and animals at the site of Conchopata, Peru during the Middle Horizon (AD 600-1350) through stable isotope analysis. Similarly, Williams and Murphy (2010) reconstructed diet using stable isotope analysis of skeletal remains from the central Peruvian coast based on published data from Finucane et al. (2006) and other papers (DeNiro, 1988; DeNiro and Hastorf 1985; Tieszen and Chapman, 1995; van der Merwe and Medina, 1991; van der Merwe et al., 1993; Williams, 2005). Williams and Murphy concluded that the diet for inhabitants at Puruchuco-Huaquerones during Inca rule in the Late Horizon (c. AD 1450) likely consisted of mixed C_3 and C_4 plants and lower tropic level terrestrial protein, such as guinea pig, llamas, and dogs.

Due to the high geographical terrain and diversity of microclimates, the Chachapoya would have had to efficiently maximize all available resources. Table 2.2 displays a list of possible plants indigenous during ancient Chachapoya occupation based on modern agricultural crops in the mountainous region. Animals could have also been consumed for protein, which

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possibly include horses, mules, sheep, pigs, guinea pigs and other rodents, dogs, cats, and llamas (Narváez Vargas, 2013). Thus, the Chachapoya likely consumed animal protein and common Andean staple plants including high altitudinal tubers, such as potatoes, and low altitude crops, such as maize and squash (Church, 2006).

Table 2.2: Possible Crops Available in the Andes (adapted from Schjellerup et al., 2005)

Tubers	Legumes	Vegetables and Spices	Fruits	Grasses	Other Crops
Sweet potato	Pea	Onion	Sugar Apple	Maize	Coffee
Potato	Pigeon Pea	Artichoke	Abiu	Rice	Cocoa bean
Yacón	Peanut	Celery	Cherimoya	Wheat	
Taro	Common Bean	Tomato	Granadilla	Kiwicha	
Radish	Horse Bean	Cauliflower	Guava	Lemon Grass	
Manioc	Lima Bean	Radish	Key lime		
Arracacha	Soybean	Garlic	Lemon		
Carrot	Poroto	Chili	Loquat		
	Andean Lupin	Chayote	Lúcuma		
		Mint	Orange		
		Lettuce	Mandarin		
		Oregano	Apple		
		Kaywa	Avocado		
		Squash	Cashews		
		Cilantro	Papaya		
		Parsley	Loquat		
		Cabbage	Passion Fruit		

The use of maize for alcoholic beverages should also be taken into consideration because *chicha* holds both cultural and economic significance that helps define social identity and gender roles in the Andes (Jennings and Bowser, 2009; Perlov, 2009). Chicha, also known as "corn beer", refers to indigenous fermented or non-fermented beverages derived from maize and is served during many community events, such as festivals and even when working in the field (Perlov, 2009). In the Andes, men are assumed to be more affiliated with chicha consumption while women control production (Jennings and Bowser, 2009). A man's identity is said to be tied to drinking and his ability to handle alcohol as relationships are established and kinships are

recognized through alcohol (Douglas, 1987). On the other hand, food and chicha production appear to define a woman's role in Andean society and allows her to manage her own source of income (Perlov, 2009).

Archaeological evidence for chicha production includes material correlates associated with production facilities, but carbon isotopic analysis of human bone has also been used to study corn beer consumption (Hastorf, 1991). In her dissertation, Gagnon (2006) compares carbon isotopic values and the frequency of pathological conditions (caries, abscesses, AMTL, and periodontal disease) between elites and nonelites as well as between males and females. Although there were no statistically significant differences between the higher and lower ranked individuals, she argues that men likely consumed more chicha due to less negative $\delta^{13}C$ signatures and lower frequency of dental pathological conditions in males than their female counterparts. She associated these differences to women consuming higher amounts of sticky, chewy carbohydrates, which are more likely to become trapped in the mouth and eventually cause decay.

The habitual chewing of coca leaves is also a common practice among ancient and modern groups of people in the Andean region (Buck et al., 1968; Allen, 1985; 1988; Bastien, 1985; Cartmell et al., 1991; Indriati and Buikstra, 2001; Dillehay et al., 2010; Murphy and Boza, 2012; Gagnon et al., 2013). Research from ethnographic and ethnohistorical accounts (Isbell, 1978; Allen, 1980; 1985; 1988; Murra, 1986; Netherly, 1988; Weismantel, 1988; Julien, 1998) have demonstrated the importance of coca in medicinal and therapeutic purposes as well as defining social relationships in the Andes. Coca chewing typically begins between the ages of 15 to 24 years in modern populations, but regular use becomes increasingly recurrent as people age (Carter and Mamani, 1986). While both men and women chew coca, men are more associated

with this habit and chew it more frequently because coca chewing is said to increase work capacity due to its therapeutic benefits at high altitudes (Allen, 1985; 1988).

Researchers have tracked early use of coca chewing in human remains recovered from various sites in Peru, including the earliest coca leaves found in house floors in the Nanchoc Valley (c. 8000 cal BP) (Dillehay et al., 2010), Cerro Oreja in the Moche Valley (1800 BC-AD 800) (Gagnon et al., 2013), four sites in the Moquegua Valley (AD 800-1350) (Buikstra and Indriati, 2001), and Puruchuco-Huaquerones in the Rimac Valley (Late Horizon c. AD 1450) (Murphy and Boza, 2012). Dental pathological indicators of coca chewing include periodontal disease and buccal caries on posterior dentition because users will add lime or *llipta*, a calcium carbonate powder, to activate the alkaloids in the leaves. In particular, lime irritates the gingiva, causing overall inflammation and reduction in the surrounding tissues (periodontal disease) and exposes roots to caries-causing bacteria (Gagnon et al., 2013). Increases in the mouth's alkalinity level from coca chewing also contributes to calculus formation. Table 2.3 presents the methodology established by previous researchers to identify evidence of coca chewing. From this background literature of for determining coca chewing in the human remains, and these predicted dental pathological indicators will be examined in this sample to identify evidence of coca chewing in the Chachapoya as no current studies have been published on this cultural group about coca chewing.

Table 2.3: Current Methodologies on Analysis of Coca Leaf Chewing

Site	Dates	Pathological Indicators	Additional Methods	Results
Nanchoc Valley (Dillehay et al., 2010)	c. 8000 cal BP	N/A	Microanalysis of coca leaves and chemical analysis of archaeological calcite samples	7 coca leaves identified in building floors
Cerro Oreja in the Moche Valley (Gagnon et al., 2013)	1800 BC-AD 800	Buccal caries based on Indriati and Buiksta (2001), alveoli for periodontal disease	Microfossil analysis of calculus deposits	18 coca chewers out of 173 individuals; sex differences tied to diet
Moquegua Valley (Buikstra and Indriati, 2001)	AD 800-1350	Strong: large, buccal caries near CEJ on lower molars Mild: buccal pit caries on maxillary molars and premolars Weak: Interproximal caries on molars and AMTL	Isotopic analysis of hair samples	35 coca chewers out of 86 individuals
Puruchuco-Huaquerones in the Rimac Valley (Murphy and Boza, 2012)	(Late Horizon ~AD 1450)	Buccal caries and AMTL based on Indriati and Buiksta (2001)	N/A	8 coca chewers out of 32 individuals

The Archaeological Site of Kuelap

Kuelap is one of the largest, best known Chachapoya sites, located at 3000 masl, with extensive agricultural terraces on the western flank of a long narrow ridge (Narváez Vargas, 1987; 1996; 2013). Kuelap may have been constructed as early as AD 500 during the Early Intermediate Period (Narváez Vargas, 2013). The site is built on a high mountainous ridge on a massive stone-built platform of over 600 meters from north to south, encompassing an area of around 450 hectares. There is an elevated platform that divides the site into lower and upper levels, Pueblo Bajo and Pueblo Alto (Figure 2.3). Overall, there are over 400 residential circular structures, and several buildings at Kuelap have also been identified as possible ceremonial and

administrative structures (Narváez Vargas, 1987; 1996). Aside from its impressive site and building architecture, Kuelap also has notable mortuary variation and a large excavated skeletal collection that are ideal for a bioarchaeological analysis of health and social diversity.
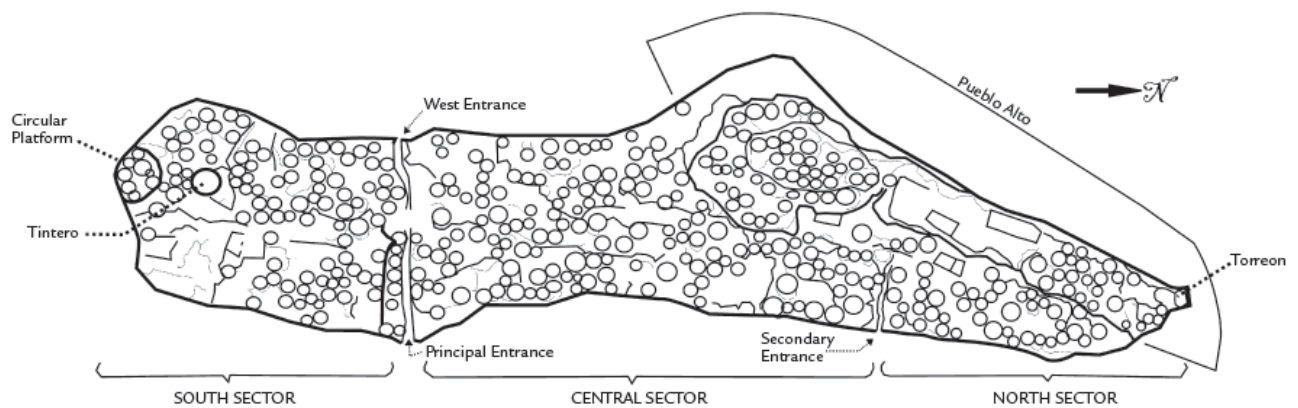
Figure 2.3: Plan drawing of Kuelap, showing site divisions, general layout of overall structures, and main entrances. Courtesy of Toyne and Narváez Vargas, 2014: Figure 13.2.

Andean Mortuary Practices and Mortuary Variability at Kuelap

Ancient general Andean mortuary views emphasized the importance of physical remains as they were believed to be crucial links to agriculture and social stability (Sillar, 1992; Isbell, 1997; Nystrom et al., 2010). These mortuary practices involved keeping physical remains of the deceased near or within homes and communities for regular contact between the living and dead (Sillar, 1992). In particular, Chachapoya mortuary practices demonstrate the dynamic relationship between the living and the dead that is deeply linked to social structure, as seen in other Andean societies. Crandall (2012) has argued that the Chachapoya people maintained an active relationship with the dead by publicly displaying the remains in sarcophagi and mummy bundles. He suggests that *ayllus* functioned to maintain these social relationships as the Chachapoya were likely organized based on kinship.

Furthermore, the dead are often manipulated by the living through these mortuary practices and marked with a specific social identity that may reflect their status in life (Parker Pearson, 2000). The variation in mortuary structures may suggest social ranking even though grave goods are rarely found in Chachapoya burials due to looting and poor preservation. Based on Tainter's (1973) concept of energy expenditure, more elaborate and a larger sized burial may indicate higher investment due to high standing of social elites while those buried in more humble and less elaborate funerary repositories were of lesser status. Chachapoya mortuary complexes generally consist of sarcophagi or *chullpas*, also referred to as mausoleums (Nystrom et al., 2010). The sarcophagus is a cane and plaster conical coffin where the body of one individual is seated with limbs tightly flexed in (Kauffmann Doig, 2009). *Chullpas* consisted of large, open collective masonry tombs located along the edges of the high cliff walls (Kauffmann Doig, 2009). Ongoing research by the Chachapoya Bioarchaeology Project explores how mortuary practices of the Chachapoya reflect social interactions among different groups living in the region and the complex relationship between the living and their ancestors.

Burial Types at Kuelap

Within and near Kuelap, there is notable mortuary variation that includes the sarcophagi, *chullpas*/mausoleums, cave deposits, wall niches, underground pits, collective tombs and an ossuary (Ruiz Estrada, 2009). The variation in mortuary contexts at the site represents the variation in burials observed throughout the region, which makes Kuelap unique among other known Chachapoya sites and the ideal location to explore the complex relationship between past Chachapoya health and social variability. All sarcophagi have been destroyed from looting at Kuelap, and remains from the *chullpas* and from the surrounding natural cave deposits could not

be assessed for this study (Ruiz Estrada, 2009). The four mortuary contexts that will be examined in this study include wall niches, underground pits, collective tombs, and an ossuary. Additionally, individuals from a non-burial context (massacre) will also be analyzed.

Wall Niches

The outer perimeter and high internal structural walls served as repositories for the dead (Toyne – personal communication). These burials contained secondary skeletal bundles of human remains. Individuals were likely wrapped in textile bundles and embedded into individual or collective niches. These spaces were then sealed with mud and small stones. According to Ruiz Estrada (2009), these burials were likely created when Kuelap was already built, suggesting that the remains may belong to the Chachapoya people.

Underground Pits

Another type of burial at Kuelap were the underground pits. These tombs are relatively small and shallow enough to fit one individual at a time with dimensions that never exceed one meter wide or deep (Ruiz Estrada, 2009). Underground pits were specifically built into the floors of circular residential buildings during occupation throughout the site. The pits likely reflect the active relationship between the living and the dead as the remains are stored within the living's space, as seen in other Andean societies (Sillar, 1992). However, these burials appear relatively simple and smaller when compared to the other mortuary complexes at Kuelap, and would have required less energy expenditure and resources.

Collective Tombs

Many primary collective tombs were found near residential houses in the Central sectors and southern end of the site (Toyne – personal communication). Approximately seven to nine

individuals were placed seated and flexed on top of each other in a stone walled hive shaped structure that was likely constructed during Inca occupation of the site. These individuals were likely wrapped in textiles that were no longer preserved by the time of discovery. Once filled, the top of this structure was sealed with stone. As a result, the contents were found *in situ*. These tombs are generally larger with a more complex architectural design than wall niches and underground pits.

Ossuary

The fourth burial context was the secondary ossuary found in the center of a large circular platform at the southern end of Kuelap, in the center of six large residential structures and the Tintero (Narváez Vargas, 1996). The ossuary was a stone-lined cylindrical crypt that is approximately 2 meters in diameter and 2.5 meters deep (Figure 2.4). It was excavated in eight arbitrary stratigraphic layers (levels 7-16) with most of the bone concentration at the top and the bottom levels, which indicates that this interment is diachronous with individuals deposited over time. There are no radiocarbon dates available for this ossuary. Analysis of the ossuary's contents revealed a highly commingled assemblage of approximately 28 subadults and 47 adults of both sexes (Tran, 2014). The formation of this burial context suggests more community involvement and energy expenditure than the wall niches or underground pits. Previous research indicated that this ossuary reflects a community identity as the remains appeared to have been intentionally transported from previous burials and commingled over time based on counts of the skeletal elements (Tran, 2014).

Figure 2.4: Photograph of Estructura 9 after excavation. Courtesy of Dr. J.M. Toyne.

Massacre Group

Lastly, a special context will be analyzed in this study, which includes the skeletal remains of unburied individuals found in an assemblage at the southernmost end of the site on the same circular platform as the ossuary and Tintero (Toyne and Narváez Vargas, 2014). The remains were found under toppled stones from house walls and identified as victims of a possible Early Historical massacre. These individuals were not buried according to traditional practices, but they will be analyzed because they provide a valuable opportunity to examine health from individuals that died suddenly from interpersonal violence rather than succumbing to disease or ill health.

Chapter Summary

This chapter provided the background information for this thesis in four main sections. The first section consisted of the theoretical framework for social complexity and variability, where important concepts were explained, such as a complex state, heterarchy and hierarchy, and

gender diversity. The following section examined health and how it has been conceptualized in the literature while also exploring the effects of social structure on health differences and disparities as well as biological factors that influence overall wellbeing. The osteological paradox was briefly addressed in this section to caution against overstretching interpretations of skeletal analyses of health. The third section focused on how social inequality has been studied in the past through bioarchaeological and mortuary analyses, which were the guiding framework for this study's analysis. In the last section, I described both the Chachapoya and the archaeological site of Kuelap by including important relevant information about the Chachapoya, Kuelap's architecture, and its diverse mortuary contexts. The next chapter will present and explain the materials and methods used to address the research questions and hypotheses introduced earlier in this thesis.

CHAPTER THREE: MATERIALS AND METHODS

To test the hypotheses introduced earlier, methods of data collection and analysis are employed to assess dental remains from the Kuelap skeletal sample. This chapter provides an overview of the materials examined in this study by characterizing the sample and defining the different categories based on age, sex, and mortuary context. Subsequently, methods of data collection will be explained, which include scoring procedures for dental wear, caries, antemortem tooth loss (AMTL), and calculus. Following these descriptions, analytical methods are described, which will cover how each disease is quantified and the application of the appropriate statistical tests.

Kuelap Selected Sample

This study includes the analysis of dental remains of individuals from the different burial contexts at Kuelap to record the frequency of dental pathological conditions. The total minimum number of individuals excavated at Kuelap is approximately 613. However, only 345 of those individuals were found with cranial remains, and of these, 217 were adults. To assess dental disease, a sample of 106 individuals was analyzed and selected based on representative age distribution, male to female ratio, and burial context. The sample consisted mainly of adult individuals because there were more complete adult human remains available for analysis than subadults. In addition, permanent teeth have been in the mouth longer and have increased exposure to disease causing agents. However, I also examined seven subadults (10-17 years) to assess the early possible stages and progression of dental diseases.

Only the teeth were assessed for each individual. Due to timing restraints, age and sex estimations were provided by Dr. J. M. Toyne who used morphological traits of the cranium and

os coxa based on methods outlined in *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker, 1994). Individuals were selected based on completeness of the dental arcade, preferably greater than 50% (at least a mandible or maxilla), and level of preservation, which ranged from excellent to fair.

Methods of Data Collection

Upon examination of each individual, data on attrition, dental anomalies, and pathological condition were visually observed via the naked eye or a low powered microscope and written on printed recording forms that contained a skeletal summary sheet and dental inventory. The data were then inputted into a database in an Excel spreadsheet and categorized into various subgroups. Previous studies pertaining to population have only focused whole unit for study (e.g. Cohen and Armelagos, 1984; Cohen, 1989), but subgroups allow for more detailed comparison into individuals of different demographics (Lukacs, 1996).

Demographic Categories

First, each individual was assigned to a broad age category based on estimations provided by Dr. J. M. Toyne from qualitative observations of skeletal features (Table 3.1). Age estimations can reveal changes over time in the development of pathological conditions as diseases take time to manifest and accumulate while the individual matures. Consequently, the pattern of development for many diseases is strongly correlated to age (Manji et al. 1991; Thylstrup and Fejerskov 1994; Hillson 2008; Siek, 2013). Therefore, an age cohort approach was used to test the sequential processes of caries, AMTL, and calculus.

Table 3.1: Definition of Age Categories

Category	Age Range
Subadult (SA)	10-18 years
Young Adult (YA)	19-34 years
Middle-age Adult (MA)	35-49 years
Older Adult (OA)	50+ years

The sex estimation of each adult was categorized as male (M), female (F), or indeterminate (IND). These observations were used to make inferences about gender roles during life because sex differences in health can be examined for evidence of social variability, specifically heterarchy, between males and females (Gagnon, 2006; Lukacs, 2008; 2011; Lukacs and Largaespada, 2006). I only examined teeth from five mortuary contexts due to limited access to some of the remains and poor preservation. These five contexts included the individual floor burials (underground pits) (n = 37), wall niches (n = 30), collective tombs (n = 25), the ossuary (n = 6), and the unburied massacre group (n = 8).

Inventory for Dentition of Each Individual

Each tooth or tooth socket was scored with an inventory code to distinguish between teeth that are present for a complete analysis and teeth that are fragmented or missing (Table 3.2). A detailed inventory coding system allows for ease with later data managing and statistical analyses.

Table 3.2: Dental Inventory Code Description

Score	Description
X	Missing sockets due to fragmentation
1	Present (and in occlusion)
2	Present, fragmentary
3	Postmortem Tooth Loss (PMTL)
4	Antemortem Tooth Loss (AMTL)
5	Present but unerupted
6	Congenitally missing

Dental Wear and Anomalies

Dental wear was scored for incisors, canines, and premolars using the system originally developed by Murphy (1959) and modified by Smith (1984). This system describes eight stages of wear (1-8) based on dentin exposure and horizontal reduction of the enamel crown through mastication and tooth on tooth contact (attrition) or grinding of other hard substances on teeth (abrasion) (Hillson, 1996). The scoring for molar wear was based on standards developed by Scott (1979) which incorporate a scale between 1 and 10. Scott (1979) considers a score of 0 for teeth that cannot be observed due to antemortem or postmortem tooth loss, unerupted, or congenitally missing teeth. However, since this study used a separate coding system for inventory, the score of "0" was not employed. The original system requires the molar to be arbitrarily divided into four quadrants (buccal-distal, buccal-mesial, lingual-distal, and lingual-mesial) with each quadrant receiving a separate score and then added together to yield a final score ranging from 4 to 40. However, this study provides an average overall score, ranging from 0 to 10, for the entire molar to maintain consistency with the scoring methods of other tooth types.

Wear was examined to assess for the progression of age and to determine the overall quality of the dentition. As individuals mature, their teeth become increasingly worn down and more dentin is exposed due to attrition and abrasion forces (Hillson, 1996). Thus, advanced dental wear can expose the pulp chamber, which could allow for bacteria to easily penetrate through the tooth and attack the living tissue (Clarke and Hirsch, 1991). However, dental abrasion from a tough diet can remove bacterial plaque and essentially file down teeth with less grooves and fissures and larger interproximal spaces, which may decrease cariogenicity as small food pieces are less likely to be trapped within the cheeks (Powell, 1985). Each wear grade was

considered an ordinal category, beginning with 1 to 8 for incisors, canines, and premolars, and 1 to 10 for molars. These grades were also grouped into ranked categories, such as minimal wear (1-3), moderate wear (4-6 for anterior teeth and premolars, 4-7 for molars), and advanced wear for (7-8 for anterior teeth and premolars, 8-10 for molars). Frequencies were collected for each dental wear score and further separated for tooth class (incisors, canines, premolars, and molars).

An average dental wear score was also calculated for each individual, which was used as an arbitrary index to compare abrasion and attrition across individuals. This calculation combines all dental wear grades from one individual or tooth class to produce an overall average score (Eshed et al., 2006; Hubbe et al., 2012). Even though the data are ordinal and this measure of central tendency is not recommended for categorical variables (Sokal and Rohlf, 1995), it is commonly employed in dental anthropological studies because a standard index has not been established for dental wear.

Dental anomalies, such as peg incisors, were also noted when present and listed in the comments section of the recording form based on criteria detailed in *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker, 1994). These anomalies were recorded in the event that the abnormal morphology of the tooth could have contributed to an unusual wear pattern or increased disease susceptibility, such as cariogenicity.

Pathological indicators

The use of more than one pathological indicator was necessary to explore an individual's susceptibility and frailty on a diversity of means to examine health at different age and sex categories in this study (Wright and Yoder, 2003). Furthermore, to address the implications of heterogeneity in frailty, Wood et al. (1992) has suggested that information should be provided on

lesion formation of a disease. Therefore, each pathological indicator was scored depending on the presence, size, and location.

Caries and Abscesses

Caries refers to the gradual progressive breakdown of enamel, dentin, and cementum by bacteria found in dental plaque (Silverstone 1981; Thylstrup and Fejerskov, 1994; Hillson 1996; Caselitz, 1998). The naturally occurring bacteria produce an acid that can slowly dissolve the enamel or cementum, forming a lesion or pit on the tooth surface. The lesion gradually enlarges to become a cavity over time. The location and size of the carious lesion varies by individual and by tooth as many factors can influence differential cariogenicity.

Dental caries epidemiology provides valuable information that can be used to reconstruct health in a past population because it is a slow progressive disease that is often affected by diet, physiological changes (e.g. pregnancy), tooth trauma, other pathological conditions, and crown morphology (Hillson, 1996; Caselitz, 1998; Pezo Lanfranco and Eggers, 2010; 2012). Teeth in this sample were observed for caries by direct examination via the naked eye and a sharp dental probe, but a low power microscope was also used to identify the first stages of decay (Hillson, 1996; 2008). Lesions were recorded by its specific location (Table 3.3) and approximate size (Table 3.4) on each tooth using a modified version of the coding system presented in Hillson (2001). The sizes were categorical rather than based on metric size due to the irregular and inconsistent shapes of carious lesions.

Table 3.3: Specific Locations of Caries on Tooth Surface and Root

Abbreviations	Description
CO	Caries on Occlusal surface
CI (m: mesial, d: distal)	Caries on Interproximal surface
CB	Caries on Buccal/Labial surface
CL	Caries on Lingual surface
CC (m: mesial, d: distal)	Caries on cement-enamel junction (CEJ)/Root caries

Table 3.4: Description of Carious Lesions by Size (adapted from Hillson, 2001)

Scores	Description
BLANK	Pit site not present or not visible (for any reason)
0	Carious site or sites present, but enamel is translucent and with a smooth surface
1	White or stained opaque area in enamel of pit, with smooth glossy or matte surface
2	White or stained opaque area, with associated roughening or slight surface destruction
3	Small cavity, where there is no clear evidence that it penetrates to the dentin
4	Medium cavity with discoloration of exposed dentin (For lesions located on the cervical surface (CC), the cavity penetrated past cementum & reached dentin)
5	Larger cavity, which clearly penetrates the dentin (For CC, the cavity has penetrated deeper through dentin)
6	Large cavity, which was clearly initiated in a pit site, within the floor of which is the open pulp chamber (For CC, more than half of the root dentin has been compromised)
7	Gross gross carious cavity, involving the loss of so much tooth that it is not possible to determine whether the lesion was initiated in the crown or root
8	Gross gross carious cavity, involving the loss of so much of the tooth that it is not possible to determine whether the lesion was initiated in the crown or root, and there is a clear opening into an exposed pulp chamber or root canal

For carious lesions with a size score of 7, the cavity was often large enough to manifest on more than one adjacent tooth surface and was recorded as CC/CI (caries on the cervical and interproximal surfaces) or CB/CI (caries on the buccal and interproximal surfaces). Cervical caries, or root caries, specifically target the CEJ and spread around the cervix (Hillson, 2001). Lesions with a score of 8 were recorded without the location because the tooth crown had been destroyed to the point where only a small portion of the enamel crown was present.

Abscesses were also recorded as buccal/labial or lingual perforations when present (Buikstra and Ubelaker, 1994). The relative location of each abscess was noted depending on the closest tooth socket. Advanced tooth decay exposes the pulp to bacteria, causing pulpitis and

eventual pulp death (Hillson, 1996). Following pulp death, the bacteria travel through the apical

foramen to attack surrounding tissues. If left untreated, a periapical abscess forms as pus

accumulates from the growing granulation tissue (Hillson, 1996; 2001). Detailed scoring was not

considered for abscesses because there is little information on how to accurately distinguish

between periapical granuloma and abscess, or between a healing and healed abscess. Data were

collected on abscesses to assess for comorbidity, which considers the relationship between two

pathological conditions within the same tooth or individual (van Schaik et al., 2014)

Antemortem Tooth Loss (AMTL)

Antemortem tooth loss describes the condition where the tooth was lost during life, and

there had been some degree of bone remodeling in the socket (Hillson, 1996). Advanced dental

caries can lead to AMTL in which there has been extreme damage to the tooth, and both the pulp

chamber and root canal have been penetrated. Consequently, the tooth can be intentionally

extracted to relieve possible associated pain, and the surrounding alveolar bone remodels to close

the socket. Extraction is the quickest treatment, especially for teeth that have become too

destroyed by caries to function (Hoffmann-Axthelm, 1981). However, it is important to note that

AMTL can also occur from extreme bone loss from periodontal disease and trauma to the

alveolar bone where tooth loss is attritional or accidental (Hillson, 1996; 2008).

To record AMTL, the missing tooth was denoted with an inventory code of 4 (Table 3.1)

to distinguish from postmortem tooth loss (PMTL). Degree of alveolar remodeling was also

observed and recorded using a modified version of Hillson's (2001) coding system in which

three categories were assigned to the missing tooth: minor, moderate, or full remodeling of

alveoli (Table 3.5). This system was used to help distinguish between AMTL and PMTL because

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it entailed more detailed data observation and collection as early bone remodeling can be difficult to assess.

Table 3.5: Description of AMTL by Bone Remodeling (adapted from Hillson, 2001)

Scores	Description
9	Tooth missing, leaving an empty socket in the jaw with minor signs of remodeling
10	Tooth missing, leaving an empty cavity in which there are signs of remodeling, but the bone is not fully remodeled to leave a leveled contour
11	Tooth missing, with full remodeling of the jaw to leave a leveled contour

Calculus

Calculus is mineralized plaque that has accumulated over a period of time on the surfaces of teeth depending on certain factors, such as diet and acidity of the oral cavity (Hillson, 1996; Lierverse, 1999). The oral sites most prone to calculus buildup are the lingual surfaces of the anterior teeth and the buccal surfaces of molars because they are closest to the salivary duct glands. The mineralizing agent derives from saliva but is also deposited from plaque fluid (Hillson, 1996). Calculus is categorized as supra-gingival or sub-gingival depending on its location on the tooth (Dobney and Brothwell, 1987; Hillson, 1996; 2008). Supra-gingival calculus attaches to the crown and may become lost in archaeological material. Sub-gingival calculus, on the other hand, forms on the root and has a similar color to the dental cement, which complicates observation.

Research on the quantity of calculus deposits in the mouth has been limited (Whittaker et al., 1998; Greene et al., 2005) as recent bioarchaeological studies of dental calculus have been more focused on stable isotope analysis and microfossils (Scott and Poulson, 2012). Scoring methods for the amount of calculus are less specific in the literature, although Buikstra and Ubelaker (1994) and a study by Dobney and Brothwell (1987) both provide distinct versions of how to rank calculus deposits. This study utilized a modified version of the coding system

provided by Dobney and Brothwell (1987) in which both the location (Table 3.6) and amount of

calcified plaque (Table 3.7) were recorded per tooth.

Table 3.6: Specific Location of Calculus on Tooth Surface

Abbreviation	Description
KB	Calculus on Buccal/Labial surface
KL	Calculus on Lingual surface
KI (m: mesial and/or d: distal)	Calculus on Interproximal surface
K	Calculus on all sides of tooth surface except for occlusal surface

Table 3.7: Description of Calculus Deposits by Amount (adapted from Dobney, 1987)

Scores	Thickness Range (mm)	% of Crown Covered	Description
0	0	None	No visible calculus deposit on crown or root
1	1	<20	Visible deposit, very thin, normally situated around gingival margin
2	1-2	20-50	Obvious with noticeable thickness often extending just below the CEJ
3	2-3	50-70	Very noticeable thickness, often extending some way below the CEJ
4	3-5	>70	Very thick deposit, extending some way below the neck, where it is usually thickest and often appears disorganized

Methods of Analysis

As demonstrated previously in Chapter Three, bioarchaeological studies on teeth are as

valuable to understanding health and social inequality in the past as investigations conducted

solely on skeletal remains. However, researchers have struggled with sampling issues in dental

analyses due to preservation. The primary challenge when conducting a dental anthropological

study is determining the unit of analysis, which could be either teeth or individuals (Gagnon and

Wiesen, 2013).

When teeth are considered as the unit of analysis, the sample size is greatly increased. To

do this, all teeth from each individual in the sample are pooled together. While this approach

yields a different interpretation for dental studies, it is not without drawbacks. When pooling all

teeth together, each tooth is considered independent as multiple teeth are from many individuals. The sample's heterogeneity is also increased, which can falter statistical analyses and produce spurious results (Gagnon and Wiesen, 2013). To address this problem, the large pooled sample was categorized into smaller groups, such as by tooth class (incisors, canines, premolars, and molars) and surfaces (e.g. buccal, cervical, interproximal, etc.) rather than by grouping the teeth into larger groups of anterior and posterior dentition. Categorization by tooth class and surfaces yields more informative explanations on etiology based on tooth morphology and location within the mouth.

With individuals as the unit of analysis, each person is described as having or not having the pathological indicator. This approach overgeneralizes the data as an individual with more than one affected tooth is not properly distinguished from someone with only one affected tooth. To combat this issue, individuals were usually assigned an index to denote the number of affected teeth, but by doing so, sample comparability may be undermined if there are significant differences in present, observable teeth among individuals (Hillson 1996; 2008). It is also important to note that each individual would be considered as only one datum, which may decrease the sample size. Therefore, this study used both units of analyses for a more complete, in-depth examination of dental health in the past.

Caries and AMTL

Following data collection, scores for caries and AMTL were quantified using various calculation methods per individual, such as the traditional dental caries rate, AMTL rate, the index of caries *et extratio*, and the caries lesion surfaces index. These methods provide a means of quantifying dental disease within an individual (Pezo Lanfranco and Eggers, 2010), and they

must be applied to archaeological samples with extreme caution. According to Hillson (2001), a single index cannot be used to fully express the true complexities of caries as differential preservation exists among tooth classes, age groups, and sexes. Rather, he suggests to organize data into different categories of carious lesions based on location on the tooth surface.

Statistics for each tooth type (incisors, canines, premolars, and molars) were differentiated for a more accurate assessment of dental health because tooth morphology and location in the mouth do affect susceptibility and decay rate (Hillson, 2001; Thylstrup and Fejerskov, 1994). However, side was not considered because caries and AMTL occurrence are typically symmetrical (Hillson, 2001).

In addition, the frequency of each surface affected by caries was calculated. Coca leaf chewing was also assessed in this study using the methodology developed by Indriati (1998) and further described by Indriati and Buikstra (2001), which looked at buccal carious lesions to determine strong, mild, or weak indication of the cultural practice.

Dental Caries Rate (DCR)

The traditional caries rate is calculated by the total number of caries-affected teeth divided by the total number of observed teeth and then multiplied by 100 to determine a caries index for each individual and tooth class (Erdal and Duyar 1999; Hillson 1996; 2008). However, this method does not consider actual caries per tooth prevalence within each individual. It also does not account for antemortem and postmortem tooth loss, which makes DCR difficult to apply to archaeological remains. Yet, DCR is the most commonly used frequency calculation of caries in both anthropology and modern dental studies because it provides the most conservative

approach to the caries rate (Hillson, 2001). The equations for DCR for each individual is determined by:

$$DCR = \frac{Total\ number\ of\ carious\ teeth}{Total\ number\ of\ observed\ teeth}x100$$

Antemortem Tooth Loss Rate (AMTL-R)

A separate AMTL rate is calculated for each individual and each tooth class that did not include carious teeth for each individual. This method was adapted from Cucina and Tiesler (2003). A tooth is recorded as absent when its socket is fully or partially closed due to some degree of remodeling (AMTL), but a tooth is considered present if the socket is still present with no signs of remodeling regardless of whether a tooth was still attached. For each individual and tooth class, AMTL rates are calculated by:

$$AMTL_{individual\ or\ class} = \frac{Total\ number\ of\ AMTL\ teeth}{Total\ number\ of\ sockets\ present}x100$$

Index of Caries et extratio (I-CE)

In samples where many individuals have an AMTL frequency that exceeds 50%, another caries procedure should be implemented for a better understanding of decay progression within each individual. The index of caries *et extratio* (I-CE), also known as the DM index (D for decayed and M for missing), includes both the number of carious teeth and the number of AMTL (Caselitz, 1998). The biggest critique of I-CE is the assumption that all AMTL is the direct result of advanced caries and intentional extraction as a treatment (Hillson, 2001). I-CE per individual is calculated by:

$$I\text{-}CE = \frac{Number\ of\ carious\ teeth + AMTL\ teeth}{Number\ of\ observed\ teeth + number\ of\ sockets}x100$$

Unlike DCR, I-CE considers both AMTL and PMTL, which may be better for less preserved, fragmentary samples. High AMTL frequencies will also skew the traditional caries rate, so I-CE is necessary for samples with older individuals who may have high rates of AMTL to assess for the appropriate caries frequency per individual.

Lesion-Surfaces Index (LSI)

Most of the literature on caries rates has been focused on the presence or absence of lesions on tooth surfaces, but none have considered lesion size or location on the tooth surface. Thus, this study introduces a new method for calculating caries experience, called the lesion surfaces index (LSI). While this procedure is similar to the decayed (D), missing (M), and filled (F) surfaces (S) (DMF-S) method that was originally developed by dentists to assess caries experience in modern living patients (Thylstrup and Fejerskov 1994; Broadbent and Thomson, 2005; Hillson 2008; Waldron 2009), LSI offers an alternative approach to examining the progression of tooth decay. The DMF-S index is essentially the sum of the number of lesions found on the surfaces of all decayed and filled teeth and the number of AMTL divided by the total number of teeth that would have been present during life. However, there are limitations with the DMF-S when applied to archaeological samples, while the LSI focuses on lesion size. Size is important because it assumes the advanced stage of caries and whether the individual has had lesion for an extended period of time, if the lesion is affecting his/her health, or which teeth have more advanced decay. In other words, LSI provides a quantitative assessment of disease manifestation that may be used to explore differences in health among subgroups, such as age, sex, and burial contexts.

LSI considers the five surfaces of the tooth: buccal/labial, lingual, occlusal (for pit caries), and the two interproximal surfaces (medial and lateral). Even though cervical caries were recorded distinctively because these lesions were specifically located on the CEJ, they will be counted as either interproximal or buccal/labial depending their location on the surfaces. LSI is calculated as:

$$\text{LSI} = \frac{Sum\ of\ 5\ scores\ of\ all\ carious\ teeth}{Total\ number\ of\ surfaces\ per\ tooth\ present}\ x100$$

Calculus

As stated previous, there are limited scoring methods on dental calculus compared to carious lesions. Even fewer studies attempt to quantify calculus to produce indices per individual and tooth class.

Calculus Rate

Calculus rate, which assesses the presence or absence of calculus on each tooth, for each individual and tooth class was determined by:

$$\text{Calculus Rate} = \frac{Total\ number\ of\ calculus-affected\ teeth}{Total\ number\ of\ observed\ teeth}\ x100$$

This calculation provides the most conservative assessment for the presence or absence of calculus on teeth. However, it provides relatively little information regarding the amount and location of the plaque and its distribution within the individual.

Simplified Calculus Index (CI-S)

Another procedure was employed to examine the amount of calculus deposits on the tooth crown and root surfaces within each individual. This method is known as the simplified calculus index (CI-S), which was originally developed by dentists (Nguyen, 1982). Instead of

assigning one score per tooth, each tooth is scored by surfaces (buccal/labial, lingual, mesial and distal interproximal), which is consistent with the scoring method used in this study. The first application of CI-S to an archaeological sample was published in a study by Greene et al. (2005). However, Greene et al. (2005) only considered three scores per tooth for the buccal/labial, lingual, and interproximal surfaces. They analyzed the interproximal surfaces as one score instead of two separate scores as there are medial and distal interproximal surfaces for each tooth. Therefore, this study is the first to consider four scores per tooth rather than three scores per tooth. The scores range from 0 to 4 depending on the size of the deposit (Table 3.7). The CI-S equation is written as:

$$\text{CI-S} = \frac{Sum\ of\ 4\ scores\ of\ all\ affected\ teeth}{Total\ number\ of\ surfaces\ per\ tooth\ present} \, x100$$

Descriptive Statistics

Descriptive statistics allow for a general, overall observation of the data to examine the distribution and prevalence of disease within the total sample. The summary statistics employed for this study included measures of central tendency, dispersion, and variance using the software Statistical Package for the Social Sciences (SPSS) version 20.0. These measures were specifically applied to the individual pathological frequencies and indices, such as the average dental wear score, DCR, AMTL-R, I-CE, LSI, CR, and CI-S values. The frequency of tooth surface type affected by caries and calculus was also calculated for each tooth class.

Inferential Statistics

The independent variables in this study included age, sex, and mortuary context while the dependent variables consisted of the frequencies and indices of dental wear and the three pathological conditions (caries, AMTL, and calculus). Various inferential statistical tests, such as

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the Mann Whitney *U* test, Kruskal-Wallis ANOVA procedure, Welch and Brown Forsythe procedures, simple linear regression, and MANOVA were used to fully assess differences in dental pathological indicators. Results from these tests were used to infer about disease manifestation and progression among subgroups of different ages, sexes, and burial contexts. All tests were run using a 95% Confidence Interval.

An independent sample t-test was employed to compare the differences in dental wear between males and females, while the Mann-Whitney *U* test was used to compare differences in pathological frequencies and indices between the sexes. This procedure is an alternative nonparametric test to the independent t-test because it can be applied to distributions that are not normally distributed (Lomax and Hahs-Vaughn, 2013). For comparisons of age and mortuary groups, which included more than two categories, a multivariate ANOVA test was employed. However, the Kruskal-Wallis, Welch and Brown Forsythe procedures were also used for variables in which the assumption of variance was violated based on results from Levene's test of homogeneity and for small uneven sample sizes (Lomax and Hahs-Vaughn, 2013). Cross tabulation analysis was not employed in this study because when the sample was divided into groups based on both mortuary context and sex, the subsamples were unbalanced and too small for a robust analysis.

This study also used a simple linear regression to analyze the possible correlations among caries, AMTL, and calculus frequencies for each tooth class. These relationships may provide insight on co-occurrence or comorbidity of disease expression and whether if one pathological indicator influences the expression of the other. Additionally, I examined the relationship between caries and dental wear using a simple linear regression test because dental wear can either accelerate decay (Clarke and Hirsch, 1991) or lower cariogenicity (Powell, 1985). A

simple linear regression test was also applied to assess the relationship between caries and AMTL, caries and calculus, and lastly, between calculus and AMTL. The regression model is chosen over ANOVA as it provided a more suitable explanation of how dental wear or one pathological condition predicted another. The regression model is still regarded as a bivariate analysis but a different statistical approach to the data. Lastly, a MANOVA test was run to compare all independent and dependent variables.

Chapter Summary

This chapter included an overview of the sample used in this study with a definition of the various categories based on sex, age, mortuary context, and disease. Methods of data collection were addressed through an explanation and justification of each method for dental wear, caries, AMTL, and calculus. Methods of analysis were also explored, which included the quantification of each pathological condition and the application of the appropriate statistical test. The next chapter will present the results of these analyses.

CHAPTER FOUR: THE RESULTS

This chapter presents the results obtained using methods described in the previous chapter. This includes the demographic profile of the sample, including final age, sex, and mortuary distribution of all individuals, as well as a brief examination of the reliability of the methods employed in this study. Afterwards, the chapter is divided into two major sections. The first part presents results descriptive statistics by tooth class. The latter part of this chapter provides descriptive summary statistics for dental wear and each pathological condition (caries, AMTL, and calculus) by individuals, followed by inferential statistical tests and multivariate analyses of dental pathology from age categories, sexes, and mortuary contexts. This chapter concludes with analysis of the relationships among the pathological conditions.

Demographic Distribution of Sample

The maxillary and mandibular dental arcades of 106 individuals analyzed for this study included 53 adult males (includes probable males), 46 adult females (includes probable females), and 7 subadults of indeterminate sex. Table 4.1 presents the demographic distribution of the Kuelap sample that separates the adults into age categories of young, middle-aged, and old adults. Individuals were also categorized based on burial context for further analysis of health. Table 4.2 displays the distribution of all individuals, separated by sex and mortuary context.

Table 4.1: Sex and Age Distribution of the Sample

Age Group	Male	Female	Indeterminate	Total
Subadult (10-18 years)	0	0	7	7
Young Adult (19-34 years)	26	18	0	44
Middle-aged Adult (35-49 years)	22	18	0	40
Old Adult (50+ years)	5	10	0	15
Total	53	46	7	106

Table 4.2: Number of Individuals in Each Mortuary Context

Context	Male	Female	Indeterminate	Total
Massacre	3	1	4	8
Ossuary	6	0	0	6
Pit	15	22	0	37
Tomb	15	8	2	25
Wall	14	15	1	30
Total	53	46	7	106

Intraobserver Error

Ten individuals were randomly selected from the sample and were re-examined to assess intraobserver error, which included a rescoring of the inventory code, dental wear, caries, AMTL, and calculus scores for each tooth of each individual. A Pearson's Correlation determined the reliability of the scoring methods by comparing all scores from the initial observation and the second observation. The correlation of the two scores is significant with a p-value of $< .001$ and is very high ($r = 0.995$), which strongly supports the observer reliability.

Analysis by Tooth Class

This type of analysis was conducted by pooling the teeth data together from all individuals and then using SPSS analytical software to calculate the scores for each variable. The total examined in this study are 1,563 teeth (782 maxillary and 781 mandibular teeth), including 324 incisors, 230 canines, 439 premolars, and 570 molars (Figure 4.1).
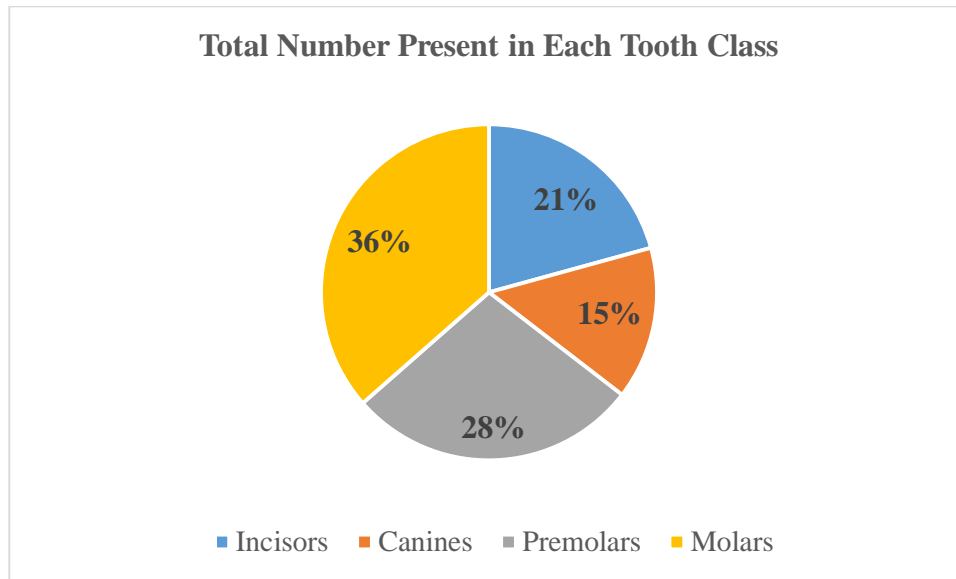
Figure 4.1: Pie chart displaying the distribution of tooth class by percentage.

In addition, no dental anomalies were found to have influenced disease susceptibility. Analysis by tooth was not divided into anterior and posterior teeth because tooth class provides a better assessment based on location and morphology. The pooled teeth were also not divided into groups based on age, sex, and mortuary context because this level of categorization was performed for individual scores, as presented later in this chapter.

Dental Wear

Of the 1,563 teeth, 1,540 were observed for dental wear as some teeth were too fragmentary for a complete analysis. There are 315 incisors, 224 canines, 436 premolars, and 565 molars scored for dental wear. Table 4.3 presents the summary statistics for the average dental wear grade by tooth class. Figure 4.2 illustrates the grades ranging from 1 to 8 for incisors, canines, and premolars, and from 1 to 10 for molars, which parallel the scores in the dental wear coding system. The distribution of the grades appeared consistently low for all tooth types.

Figures 4.3 to 4.5 demonstrate the various grades of dental wear: minimal, moderate, and

advanced.

Table 4.3: Summary Statistics of Dental Wear Grades by Tooth Class

Tooth Type	Mean	Mode	Median	Range
Incisor	3.97	4	4	7
Canine	3.97	2	4	7
Premolar	3.56	3	3	7
Molar	3.79	4	4	9
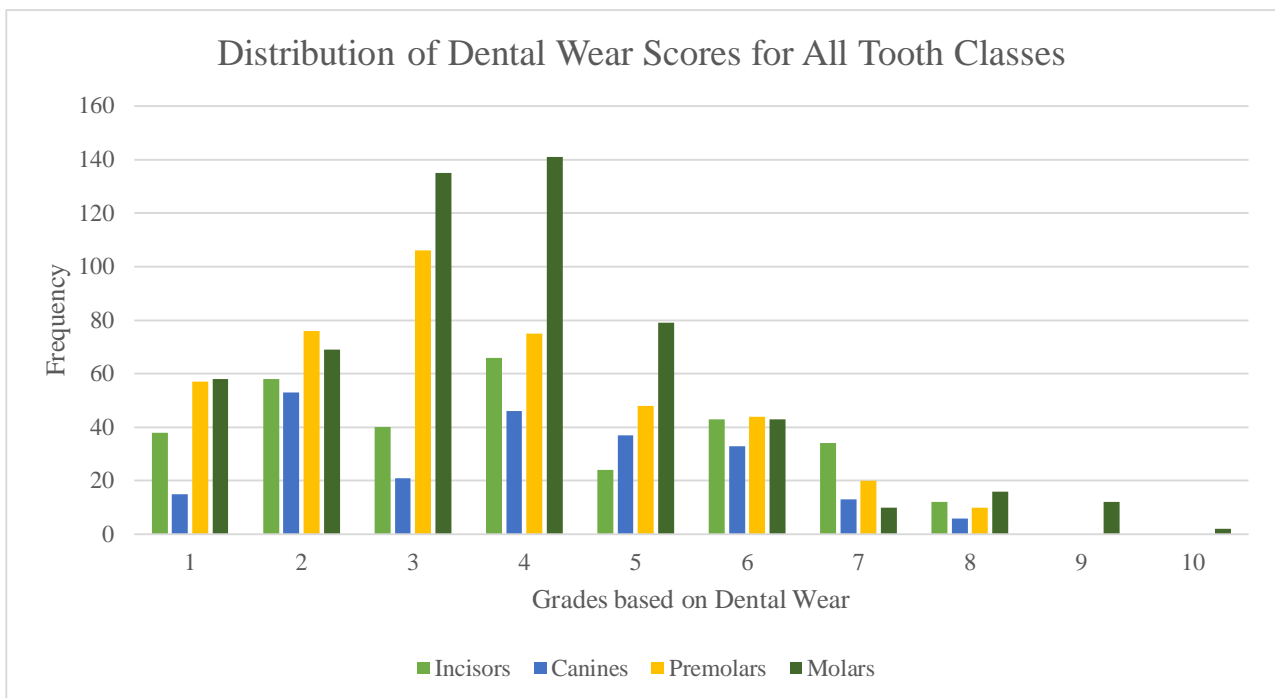
Figure 4.2: Bar graph illustrating the frequency distribution of average dental wear scores by tooth class.
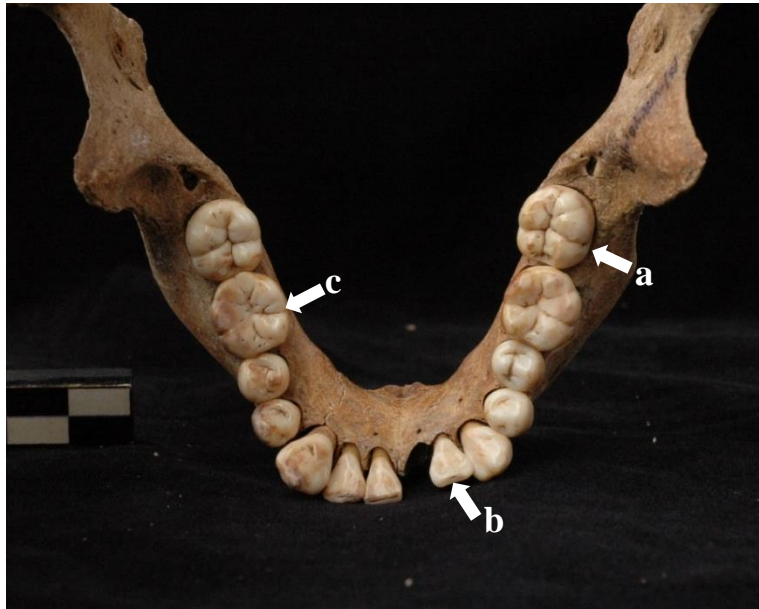
Figure 4.3: Occlusal view of a subadult mandible (individual #KSPlatC E2 -Vla' Ent22 from the massacre group), showing minimal dental wear with grades 1 (a), 2 (b), and 3 (c). This pattern of wear is typically documented on subadults and some young adults from this sample. Courtesy of Dr. J. M. Toyne.
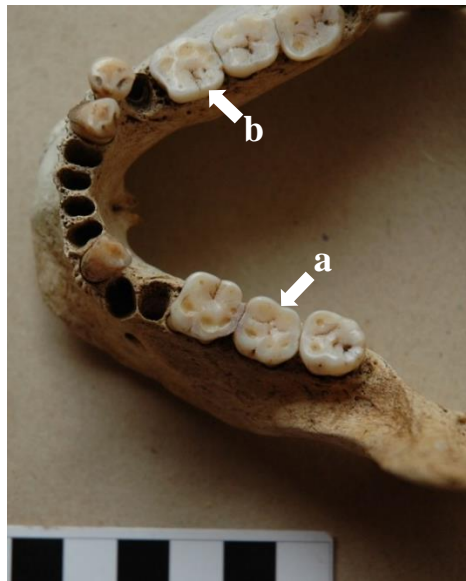
Figure 4.4: Occlusal view of a young adult male mandible (individual #K-SbPltII E1 -VIII S Ent1B from a collective tomb), demonstrating moderate dental wear with grades ranging from 4 to 6 for anterior teeth and premolars and 4 to 7 for molars. Grades 4 (a) and 5 (b) for molars are shown in the photograph. This pattern of wear is common among most young adults in this sample. Courtesy of Dr. J. M. Toyne.
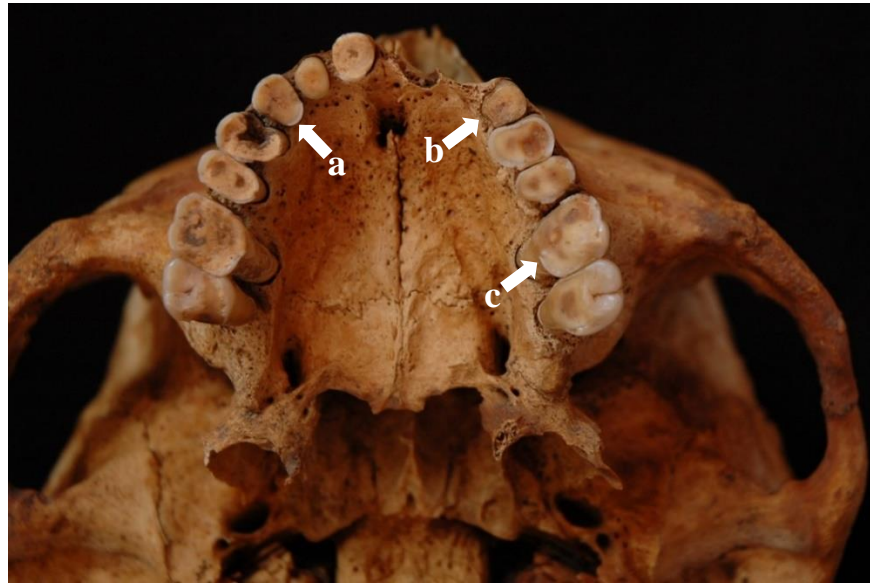
Figure 4.5: Occlusal view of a middle-aged adult male maxilla (individual #K-SbPltII E6 -VI U Ent2 from a collective tomb), demonstrating advanced dental wear with grades ranging from 7 to 8 for anterior teeth and premolars and 8 to 10 for molars. Grades 7 (a), 8 (b), and 9 (b) are shown in the photograph. This pattern of wear is common among middle-aged adults and some older adults in this sample. Courtesy of Dr. J. M. Toyne.

Caries

Each tooth was observed for caries and/or calculus, and AMTL. There are 249 teeth with at least one carious lesion out of the 1,563 total observed (15.9%). In particular, there are 23 incisors, 25 canines, 55 premolars, and 146 molars with at least one carious lesion. A total of 279 tooth surfaces (buccal, cervical, mesial and/or distal interproximal, lingual, and occlusal) were decayed to some degree by caries. There were also 19 teeth in which the crown had been completely destroyed (lesions from these teeth were categorized as gross gross caries). Table 4.4 provides a summary of all surfaces affected by caries. Figures 4.6 to 4.13 illustrate the various grades of tooth decay from 1 to 8 based on lesion size and loss of crown (See Appendix A for abbreviations).

Table 4.4: Total Frequency of Surfaces Affected by Caries per Tooth Type

Surface	Incisors	Canines	Premolars	Molars	Total
No crown	3	2	7	7	19
Buccal	0	1	3	11	15
Cervical	19	24	40	86	169
Interproximal	3	4	11	28	46
Lingual	1	0	0	3	4
Occlusal	0	0	1	44	45
Total Crown Surfaces	23	29	55	172	279
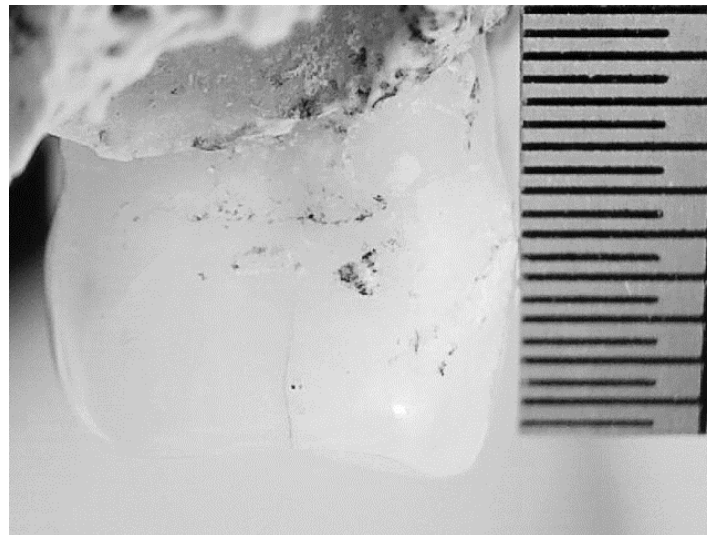
Figure 4.6: Grade 1 cervical carious lesion on mesial interproximal surface of LP[1] from individual #K-PAS MO-VIII U' ENT65. Magnification: 20x, scale: 1mm. Photographed by Tran.
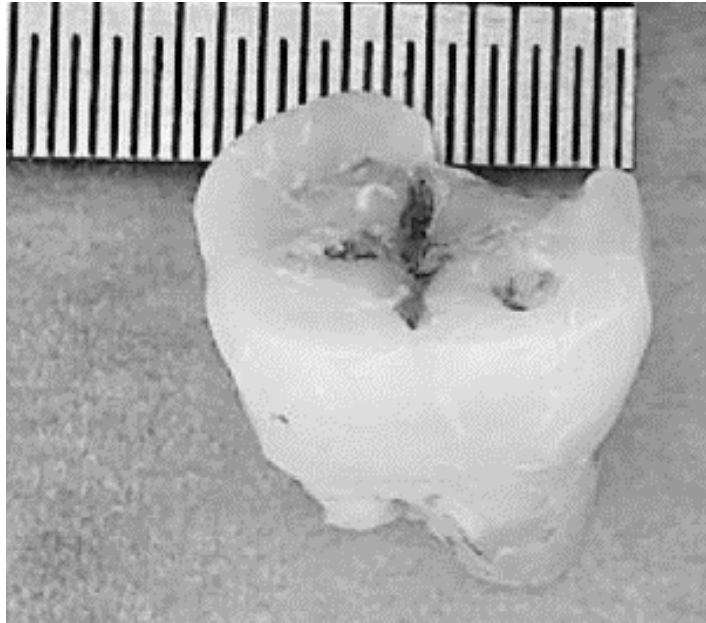
Figure 4.7: Grade 2 carious on occlusal surface of LM$_3$ from individual #KSPlatC E2 -Vlla'Vla' Ent06. Magnification: 10x, scale: 1mm. Photographed by Tran.
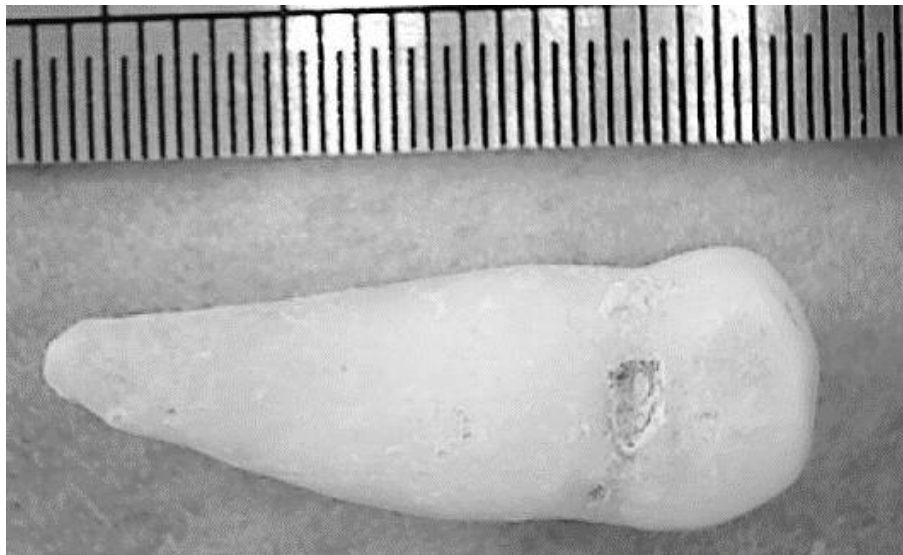
Figure 4.8: Grade 3 cervical carious lesion on distal interproximal surface of RC$_1$ from individual #K-PAS MO-VIII U' ENT63. Magnification: 10x, scale: 1mm. Photographed by Tran.
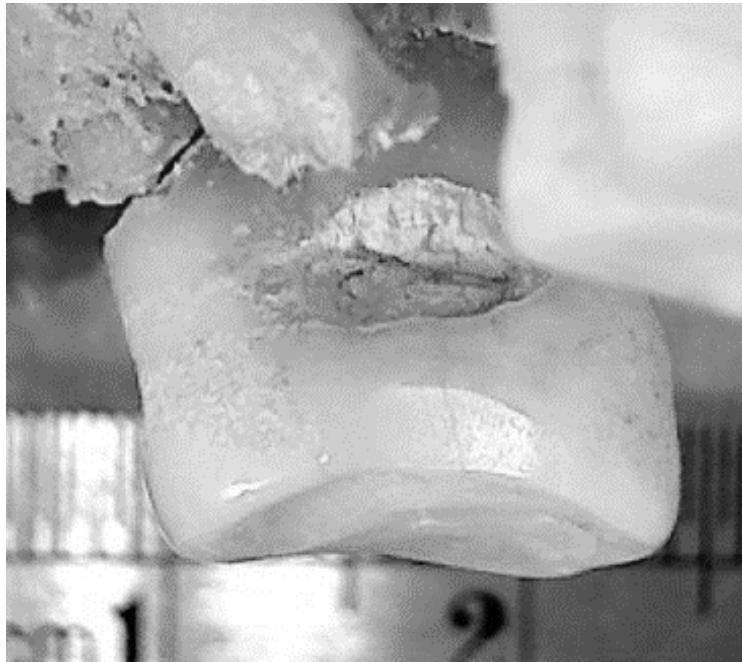
Figure 4.9: Grade 4 cervical carious lesion on the mesial interproximal surface of LM^2 from individual #K-PAS MO-VIII U' ENT73. Magnification: 20x, scale: 1mm. Photographed by Tran.

Figure 4.10: Grade 5 carious lesion on the buccal surface of RM^2 from individual #KSPlatC E9 - Vlz OS n13 Cr2. Magnification: 10x, scale: 1mm. Photographed by Tran.
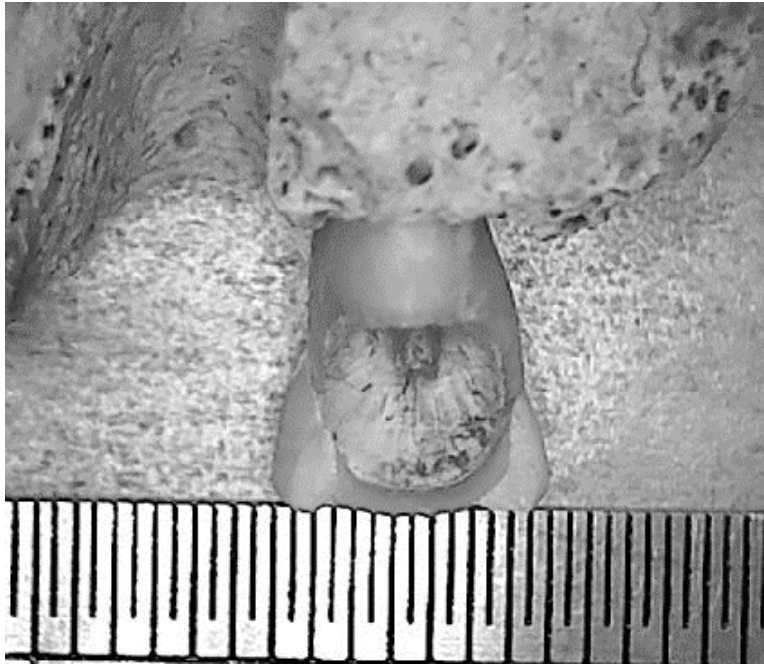
Figure 4.11: Grade 6 carious lesion on the buccal surface of LP[1] from individual #KSPlat1E6 - IIN -IIIN ENT1. Magnification: 10x, scale: 1mm. Photographed by Tran.
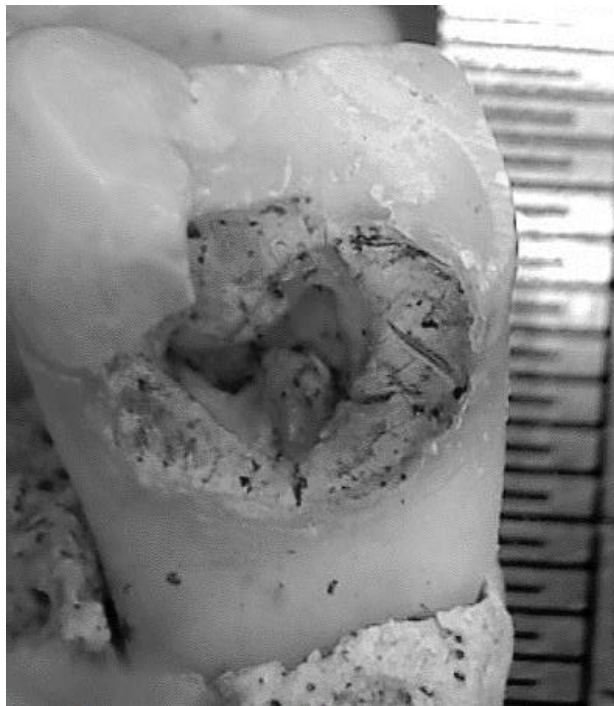
Figure 4.12: Grade 7 cervical carious lesion on the mesial interproximal surface of LM_2 from individual #K-PAC E1 -III G ENT2. Magnification: 20x, scale: 1mm. Photographed by Tran.
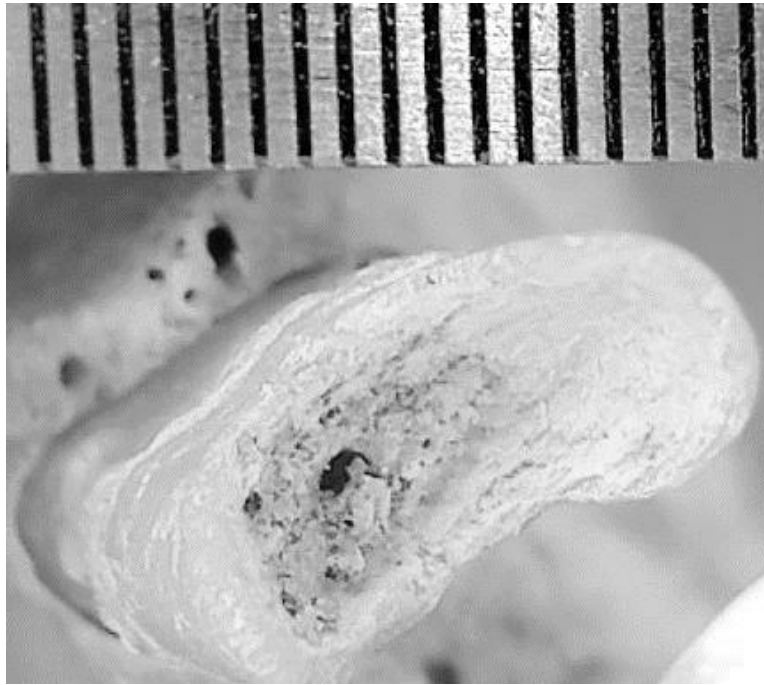
Figure 4.13: Grade 8 lesion in which most of the crown of LP_1 from individual #K-PAS MO-VIII U' ENT59 has been destroyed. Magnification: 20x, scale: 1mm. Photographed by Tran.

Lastly, teeth were also examined for evidence of coca leaf chewing as it is a common practice in ancient and contemporary Andean groups (Allen, 1985, 1988; Bastien, 1985; Buck et al., 1968; Cartmell et al., 1991). Following the methodology set by Indriati (1998) and Indriati and Buikstra (2001), only one middle-aged adult male was found with strong evidence for coca chewing with a large buccal carious lesion near the CEJ and brown staining on the buccal surfaces of the posterior teeth, from the ossuary, Estructura 9 (Figure 4.14).
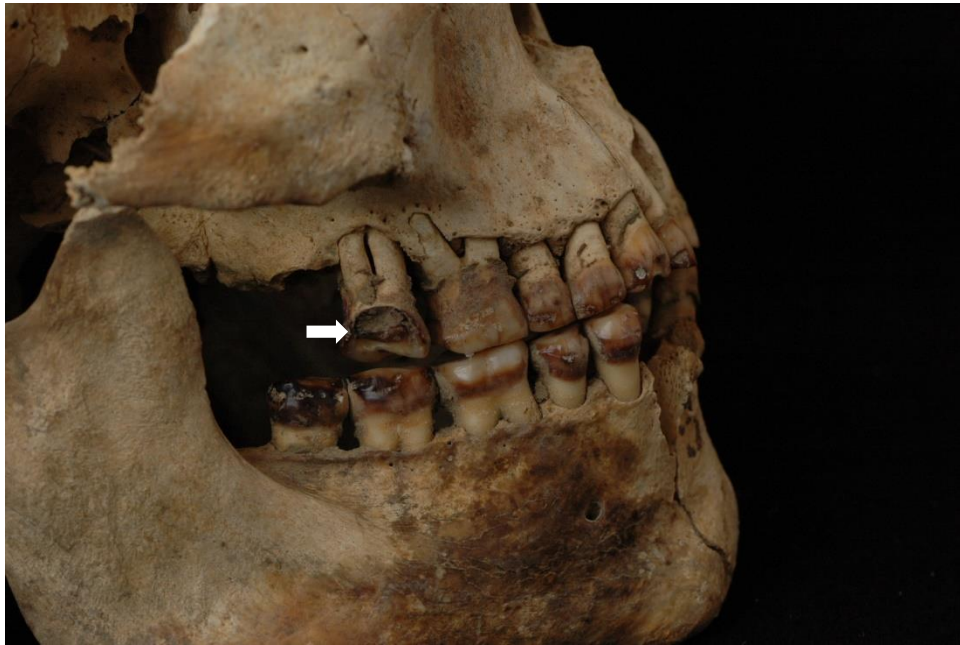
Figure 4.14: Right close-up lateral view of individual #KSPlatC E9 -Vlz OS n13 Cr2 showing the carious lesion (arrow) and brown straining on the posterior teeth that are consistent with coca chewing pathology. Courtesy of Dr. J. M. Toyne.

Antemortem Tooth Loss

A total of 2,778 empty sockets were examined and were denoted as either antemortem or postmortem tooth loss. Of these sockets, 639 are considered the result of AMTL out of all 2,778 empty (from AMTL and PMTL) and filled (with tooth still present) sockets. Table 4.5 displays the distribution of AMTL by tooth class. Figures 4.15 to 4.17 illustrate PMTL and the three degrees of AMTL as described by this study.

Table 4.5: Total Teeth Lost Antemortem by Tooth Type

	Incisors	Canines	Premolars	Molars	Total
AMTL	121	36	153	329	639
All empty sockets	740	354	698	986	2778
% AMTL	16%	10%	22%	33%	23%
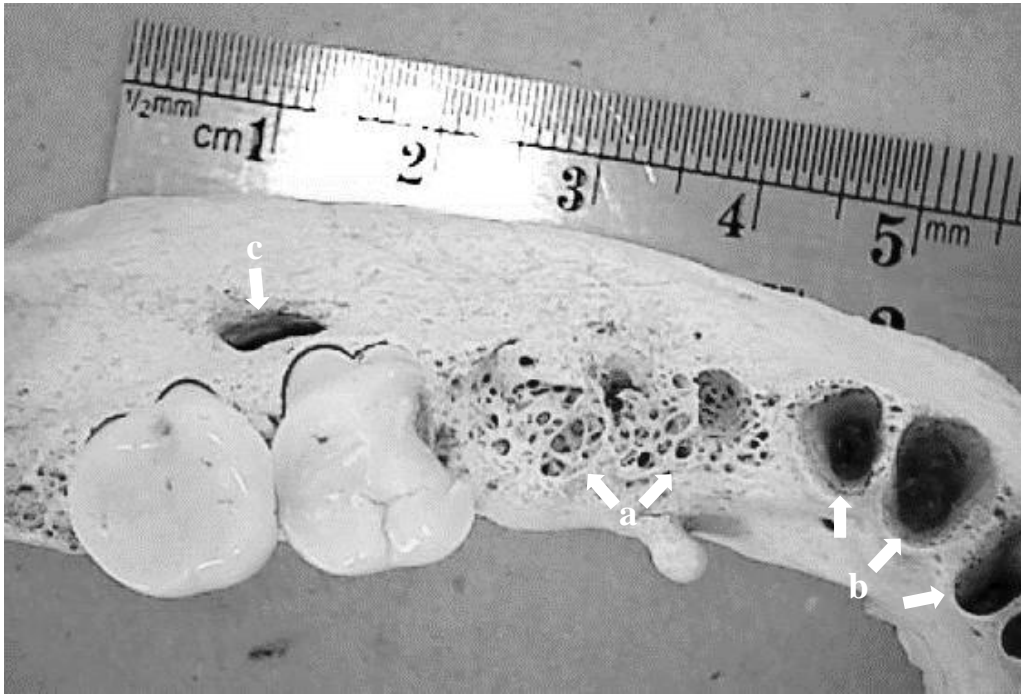
Figure 4.15: Grade 9 AMTL on LM_1 and LP_2 (a) of a left mandible from individual #K-PAC E1 -III G ENT2. This image also shows PMTL on LP_1, LC, and LI_2 (b). A buccal abscess near LM_2 which also has a grade 7 cervical caries lesion on the mesial interproximal surface (c). Magnification: 10x. Photographed by Tran.
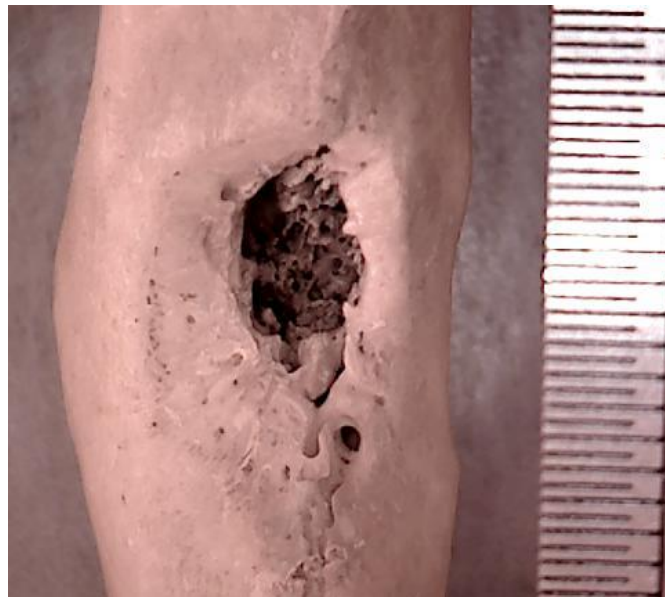
Figure 4.16: Grade 10 AMTL on RM_3 from individual #KSPlatC E6 -Vllz' -Vlla' ENT85. Magnification: 10x, scale: 1mm. Photographed by Tran.

Figure 4.17: Grade 11 AMTL on RM_1 to RM_3 to and LM_1 to LM_2 (arrows) from individual #K-PAS MO-VIII U' ENT63. Courtesy of Dr. J. M. Toyne.

Abscesses

Abscesses were only observed qualitatively, and while this pathological condition could not be quantified into an index for each individual, it was recorded because of its etiological relationship to caries (Hillson, 1996). Abscesses were observed near the roots or sockets, if the tooth was lost postmortem or antemortem, of 20 molars (e.g. Figure 4.15), 21 premolars, 5 canines, and 12 incisors.

Calculus

Of the 1563 total teeth observed, 344 had calculus accumulation on at least one tooth surface (22%). More specifically, calculus was found on 83 incisors, 59 canines, 82 premolars, and 120 molars. Table 4.6 presents a detailed summary of all surfaces affected by calculus. Figures 4.18 to 4.21 show the various grades of calcified plaque deposits.

Table 4.6: Total Frequency of Surfaces Affected by Calculus per Tooth Type

Surface	Incisors	Canines	Premolars	Molars	Total
Buccal	40	35	33	66	174
Interproximal	36	34	36	49	155
Lingual	32	10	26	27	95
Total	108	79	95	142	424

Figure 4.18: Grade 1 calculus deposits on RM_1 to RM_3 (arrows) from individual #K-SbPltII E6 - VI U Ent1. Courtesy of Dr. J. M. Toyne.

Figure 4.19: Grade 1 calculus deposits on RM^1 to RP^2 (arrows) from individual #K-SbPltII E6 - VI U Ent1. Courtesy of Dr. J. M. Toyne.

Figure 4.20: Grade 3 calculus deposits on incisors and canines (arrows) from individual #K-SbPltII E6 -VI U Ent1. Courtesy of Dr. J. M. Toyne.

Figure 4.21: Grade 4 calculus deposit on RM^2 (arrow) from individual # K-SbPltII E6 -VI U Ent2. Courtesy of Dr. J. M. Toyne.

Analysis by Individual Scores

For each individual examined (skull with the maxilla and mandible or either just the maxilla or mandible present), indices were calculated for dental wear and each pathological condition (see Appendix B: Table 1). Within the sample, there were seven individuals that did not have any teeth present due to AMTL and/or PMTL due to inconsistencies in preservation. Since final scores could not be calculated, these individuals were completely removed except for when analyzing AMTL rates. After removing those 7 individuals, the total sample consisted of 99 individuals, with 51 adult males, 41 adult females, and 7 subadults. Subsequently, the individuals were categorized into groups based on age, sex, and mortuary context for further statistical analysis.

Dental Wear

An arbitrary, average composite score for dental wear was calculated for each individual. These scores ranged from 1 to 8. The mean is 4.27 with a standard deviation of 1.73, the approximate median is 4.25, and the mode is 2.

To understand how dental wear is influenced by age, the scores were categorized into broad age groups and a one-way ANOVA test was employed. Results from the one-way ANOVA are statistically significant ($F = 32.601$, $p < 0.001$), the effect size is rather large ($h^2 = .549$); suggesting that about 55% of the variance of average dental scores are due to differences in age, and observed power is quite strong (1.00). The mean and standard deviation of the average dental scores for each age group are 1.78 (SD = 0.70) for subadults, 3.31 (SD = 1.03) for young adults, 5.42 (SD = 1.37) for middle-aged adults, and 5.87 (SD = 1.24) for old adults. The means suggest that with increasing age, there is a corresponding increase in the average dental wear scores, as expected. Figures 4.2 through 4.4 present the observational differences in attrition and abrasion among the age groups, providing an overall qualitative assessment of the correlation between age and wear.

An independent sample t-test was employed using dental wear data gathered from of 41 females and 51 females, with a female mean of 4.61 (SD = 1.77) and a male mean of 4.34 (SD = 1.52). The independent t-test indicated that the average dental wear scores were not significantly different for males and females ($p = 0.436$). Thus the statistical null hypothesis that the average dental wear scores are the same by sex is not rejected at the .05 level of significance. For assessment of dental wear among individuals buried in different contexts, an alternative ANOVA procedure was used because the assumption of variance was violated based on the Levene's test

of homogeneity (p = 0.026), meaning the variances were not equal across all groups. The Welch procedure (p = .052) indicated that the average dental wear scores did not vary by burial context.

Pathological Indicators

Caries was quantified as three different indices for each individual: dental caries rate (DCR), the index of caries *et extratio* (I-CE), and the lesion-surfaces index (LSI). These methods were important for understanding disease experience in the past because they each explored a different aspect of carious lesions. DCR calculates the presence of caries for each individual, and I-CE incorporated AMTL into the equation. LSI analyzes the manifestation of caries through size and number of lesions per tooth. Table 4.7 presents results from descriptive statistical analyses of central tendency and dispersion for DCR, I-CE, and LSI.

Table 4.7: Descriptive Statistics for DCR, I-CE, and LSI (n = 99)

Measure	DCR	I-CE	LSI
Mean	21.94	26.61	36.40
Standard Deviation	25.54	26.47	69.33
Median	13.33	16.67	9.87
Mode	0	0	0
Range	100	93.75	370
Maximum	100	93.75	370
Minimum	0	0	0

AMTL was examined separately from caries because it is the potential result of advanced tooth decay. AMTL rates ranged from a minimum of 0 to a maximum of 0.93, with a range of 0.93. The mean was 0.19 with a standard deviation of 0.27, the approximate median was 0.03, and the mode was 0.

Two indices were calculated for the presence and amount of calculus on teeth: calculus rate (CR) and the simplified calculus index (CI-S). Table 4.8 presents results from descriptive statistical analyses of central tendency and dispersion for these indices.

Table 4.8: Descriptive Statistics for Calculus Indices (n = 99)

Measure	CR	CI-S
Mean	0.20	0.09
Standard Deviation	0.25	0.15
Median	0.12	0.03
Mode	0	0
Range	0.93	0.84
Maximum	0.93	0.84
Minimum	0	0

Age

To understand the relationship between age, the independent factor, and disease experience, the dependent factor, a multivariate analysis was performed on the indices calculated for each person within the Kuelap sample. Individuals were categorized into broad age groups of subadult, young adult, middle-aged adult, and old adult. Figure 4.22 illustrates how each pathological condition is affected by increasing age.
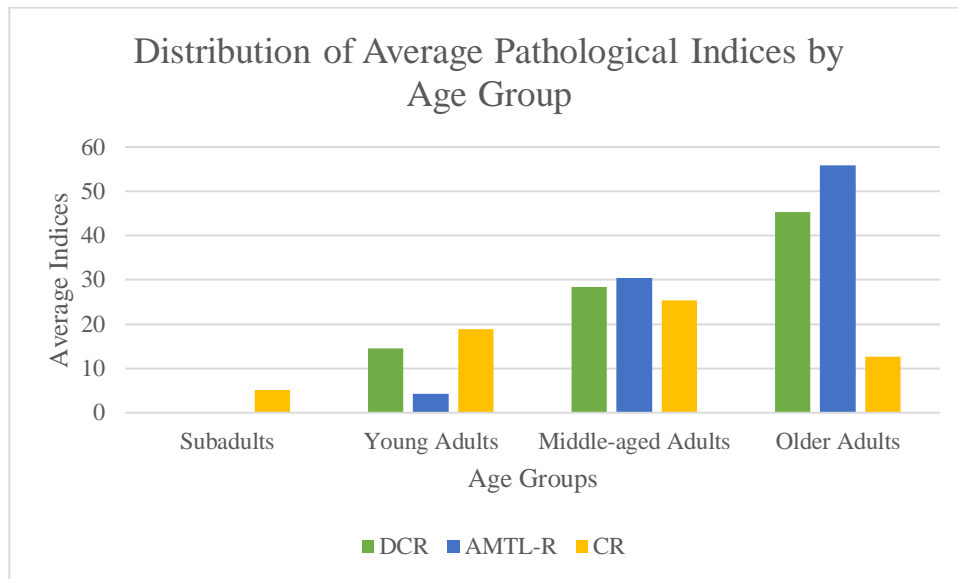
Figure 4.22: Bar graph displaying the age distribution of dental disease using the dental caries rate (DCR), antemortem tooth loss rate (AMTL-R), and the calculus rate (CR) which considers the frequency of each condition per individual.

Caries

A Levene's test of homogeneity was first applied using SPSS to determine whether equal

variances can be assumed for each of the indices. The Levene's test revealed that the variances

are not equal (p <0.001 for all three indices), and so the Welch and Brown Forsythe procedures

were used as alternatives to the ANOVA test. In addition, the variances for the subadult group is

0 as there are no carious lesions reported from these individuals (Table 4.9). Consequently,

robust tests of analysis could not be performed, so age analysis only focused on the adult groups.

Results from the Welch and Brown Forsythe procedures are statistically significant (Table 4.10).

The means also suggests that with increasing age, there was also an increase in caries occurrence

and lesion size (Table 4.9).

Table 4.9: Measures of Dispersion by Age Groups for Caries Indices

Index	Age	Mean	Std. Deviation	N
DCR	Subadult	0	0	7
	Young Adult	14.56	13.92	44
	Middle-aged Adult	28.37	28.05	38
	Old Adult	45.37	38.97	10
	Total	21.94	25.54	99
I-CE	Subadult	0	0	7
	Young Adult	12.30	13.34	44
	Middle-aged Adult	38.48	25.23	38
	Old Adult	63.13	23.16	10
	Total	26.61	26.47	99
LSI	Subadult	0	0	7
	Young Adult	11.78	13.99	44
	Middle-aged Adult	62.86	87.66	38
	Old Adult	69.61	107.86	10
	Total	36.40	69.33	99

Table 4.10: Robust Test of Equality of Means for Caries Indices by Age Group

Index	Procedure	Asymptotically F distributed Statistic	df1	df2	Significance (p-value)
DCR	Welch	6.200	2	21.261	0.008
	Brown-Forsythe	4.802	2	17.524	0.022
I-CE	Welch	33.875	2	22.575	0.000
	Brown-Forsythe	28.936	2	30.373	0.000
LSI	Welch	7.438	2	19.582	0.004
	Brown-Forsythe	4.245	2	17.960	0.031

AMTL

This age analysis only included adults because AMTL was not present on any of the subadults. Results from the Welch ($p < 0.001$) and Brown Forsythe ($p < 0.001$) procedures indicate that there is a significant difference among the AMTL rates of each age group. The means and standard deviations of ATML rates for each age group are as follows: 4.31 (SD = 10.16) for young adults, 30.41 (SD = 27.39) for the middle-aged adults, and 55.91 (SD = 28.17) for old adults. Thus, with increasing age, there is a corresponding increase in mean AMTL rates.

Calculus

To test the influence of age on calculus accumulation, the data were grouped into broad age categories for an analysis of variance. A Levene's test of homogeneity was initially conducted, and the results indicate that CR variances are not equal ($p = 0.023$), which requires an alternative to the ANOVA test, while CS-I variances are equal ($p = 0.059$). The Welch procedure indicated that there is a significant statistical difference in the mean calculus rates ($p = 0.001$) based on age group, which likely suggests age influence on the presence of calculus in the mouth. The means are 5.17 (SD = 6.49) for subadults, 18.88 (SD = 24.01) for young adults, 25.29 (SD = 26.91) for middle-aged adults, and 12.67 (SD = 20.77) for old adults.

Results from the one-way ANOVA test for CS-I, however, are not statistically significant ($F = 1.73$, $p = 0.165$), which suggest that age did not affect the amount or size of calculus

deposits. The mean and standard deviation of the CS-I scores for each age group are as follows:

1.82 (SD = 2.53) for subadults, 8.44 (SD = 15.71) for young adults, 12.51 (SD = 16.8) for

middle-aged adults, and 3.3 (SD = 5.16) for old adults.

Sex

This study examined sex as a potential contributing factor to disease experience. Data

were compared between 51 males and 41 females using a Mann Whitney U test, which is an

alternative to the independent samples t-test (Lomax and Hahs-Vaughn, 2013).

Caries

Results indicated that the average DCR (p = 0.25), I-CE (p = 0.044), and LSI (0.014)

scores were significantly different for both males and females. Overall, females had a

significantly higher caries frequency than males with more lesions and advanced tooth decay per

individual based on I-CE and LSI. Table 4.11 displays the means and standard deviations of

males and females for each index.

Table 4.11: Measures of Dispersion by Sex for Caries Indices

Index	Sex	Mean	Std. Deviation
DCR	Male	16.62	17.44
	Female	32.31	31.43
I-CE	Male	23.23	23.07
	Female	35.37	28.89
LSI	Male	17.51	23.85
	Female	66.11	97.33

ATML

Results show that AMTL-R scores are not statistically significantly different for males

and females as the p-value is 0.197, which indicates that both sexes had similar rates of AMTL.

The female mean is 27.1 (SD = 30.91) while the male mean is 15.55 (SD = 22.76).

Calculus

For CR, the difference between the sexes is statistically significant (p = 0.002), with a female mean of 11.99 (SD = 19.03) and a male mean of 27.98 (27.11). For CI-S, the difference is also statistically significant (p < 0.001), with the female group having a mean of 4.12 (SD = 8.34) and the male group having a mean of 13.94 (SD = 18.49). These results suggest that males had a higher calculus frequency than females with significantly larger number of deposits.

<center>*Mortuary Contexts*</center>

Individuals were also categorized in different groups based on mortuary context (wall niches, underground pits, collective tombs, ossuary, and massacre group). An analysis of variance test was employed to examine differences in dental indicators among these individuals.

Caries

An ANOVA test was employed for DCR and the Welch and Brown Forsythe procedures were used for I-CE and LSI because variances were not equal across all groups for these two indices based on a Levene's test of homogeneity. For DCR, results from the one-way ANOVA are not statistically significant (p = 0.569), which suggested that DCR scores are not affected by burial type. Results from the Welch procedures are statistically significant for I-CE (p = 0.016) but not for LSI (p = 0.073), while results from the Brown Forsythe procedures are not statistically for both I-CE (p = 0.056) and LSI (p = 0.267). Since the Welch procedure is considered the more robust test, results from this method were chosen for interpretation over the Brown Forsythe method. There are no differences among the mortuary contexts based on caries frequency (DCR) and lesion size (LSI), but there are differences based on number of lesions per individual. However, these differences may be due to a sampling error.

AMTL

An analysis of variance was conducted to examine AMTL rates among mortuary groups. Based on results from a Levene's test of homogeneity (p < 0.001), the Welch procedure was used instead as an alternative ANOVA test. Results from this test were statistically significant (p < 0.001). These results suggest that individuals have significant differences in AMTL rates among the groups.

Calculus

Lastly, a one-way ANOVA test was employed for CR and CI-S values, since the assumption of homogeneity was not violated. The results are statistically significant for calculus rates (F = 2.789, df= 4, p = 0.031) with a rather large effect size (0.106) and a moderate observed power of 0.744. The ANOVA results for CI-S, however, are not statistically significant (p = 0.704). These results suggest that there are differences in calculus frequency among these individuals.

Correlations among Dental Pathological Observations

Within the overall sample, only 9 individuals have no pathological indicators while 22 individuals have all three diseases present in their mouths. There are 37 people with caries and AMTL, 43 individuals with caries and calculus, and 27 with AMTL and calculus. When categorized by pathological indicators, 69 individuals are found with at least one carious lesion (65.1%), 55 people are affected by AMTL (51.9%), and 58 have calculus deposits in their mouths (54.7%). The relationships among the three indicators (caries, AMTL, and calculus) were furthered analyzed using a simple linear regression test on DCR, ATML-R, and CR values. The first test compared DCR, independent variable, and AMTL-R value, dependent variable. Based

on the results, caries is suggested to be a good predictor of the AMTL because a significant

proportion of the total variation in ATML-R values are predicted by DCR scores (p < .001).

Additionally, the unstandardized slope (0.504) and standardized slope (0.082) are statistically

significantly different from zero (t = 5.414, df = 97, p < .0001). The confidence interval around

the unstandardized slope does not include zero within its lower boundaries and upper boundaries

(0.319, 0.688), which further confirms that DCR is a statistically significant predictor of an

individual's AMTL rate.

The second test compared an individual's DCR score as the independent variable and CR

as the dependent variable. The p-value of 0.193 indicates that the correlation between the two

variables is not significant. Subsequently, a third test was run to assess the correlation between

calculus and AMTL, with CR as the independent variable and AMTL-R as the dependent

variable. The results suggested that calculus is not a good predictor of AMTL (p-value = 0.197).

The relationship between caries and dental wear was examined using a simple linear

regression test with the average dental wear per person as the dependent variable and DCR as the

independent variable. The results of the simple linear regression suggest that a significant

proportion of the total variation in DCR scores are predicted by average dental wear scores. In

other words, an individual's average dental wear is a good predictor of their DCR score (p <

.001). Additionally, the unstandardized slope (6.12) and standardized slope (-4.17) are

statistically significantly different from zero (t = 4.47, df = 97, p < .0001). The confidence

interval around the unstandardized slope does not include zero (3.40, 8.83) further confirming

that average dental wear is a statistically significant predictor of DCR scores. Lastly, a

MANOVA test was run to compare all independent variables (age, sex, and mortuary context)

and dependent variables (individual score per index), but no statistical difference was found.

Abscesses

Additionally, there were 39 individuals with at least one abscess. Table 4.12 displays the

demographic distribution of these individuals. Thirty-one had evidence of both carious lesions

and abscesses while 35 had AMTL and abscesses. Less individuals (n = 21) had evidence of both

calculus and abscesses, but these individuals also had carious lesions and/or AMTL present.

There were 15 individuals who had all 4 conditions present. Only a qualitative assessment of

abscesses was performed as an index has yet to be established.

Table 4.12: Sex and Age Distribution of Individuals with Abscesses

Age Group	Male	Female	Indeterminate	Total
Subadult (10-18 years)	0	0	0	0
Young Adult (19-34 years)	3	6	0	9
Middle-aged Adult (35-49 years)	12	11	0	23
Old Adult (50+ years)	1	6	0	7
Total	19	20	0	39

Abscesses were found in conjunction with only advanced carious lesions of grades 6 or

higher in 18 teeth. However, abscesses were also identified near 25 empty sockets and 15 closed

or partially closed sockets (AMTL).

Chapter Summary

This chapter detailed the results of qualitative observations and specific statistical

methods. First, a demographic profile of the sample, including age, sex, and mortuary

distribution, was provided along with an explanation on the reliability of the observations

gathered in this study. Results from the descriptive statistics of tooth class analysis were

presented. Next, results from individual analyses were detailed that included descriptive

summary statistics of individual indices for dental wear and each disease as well as the results

from several inferential statistical tests. Lastly, the possible correlations among dental wear and

the three pathological indicators were assessed using. The next chapter will further discuss these

data and interpret the results from a contextualized bioarchaeological perspective.

CHAPTER FIVE: DISCUSSION

This chapter discusses the results presented in Chapter Four, and is divided into two major sections to address the questions defined in Chapter One. This thesis argues that by recording and analyzing oral health indicators and mortuary data, it is possible to explore both specific and broad questions about health, social variability, and social complexity in the past. The first section includes an evaluation of the methodological approaches of dental analysis by teeth (class and surfaces) and by individuals as there is a discrepancy in the literature on which method is principally better for examining dental health in the past. The second section discusses the demographic and health profile of this sample by first examining the age progression of the disease process in these individuals and exploring age as a factor in the manifestation of these dental pathological conditions. Next, I will explore gender diversity based on the statistically significant results between males and females. Subsequently, I will discuss expected health differences in individuals buried in different mortuary contexts to draw inferences about social complexity at Kuelap. Lastly, this chapter concludes with a discussion on these patterns of health for Kuelap and of the broader Chachapoya cultural region.

Units of Dental Analysis: Teeth or Individual

Units of analysis are an integral part of any research design because they determine the type of data to be collected, studied, and interpreted. In dental studies, researchers have struggled with organizing and interpreting the data by teeth or by individuals. Both units of analysis answer different types of questions and provide alternative approaches to examining dental remains. This thesis demonstrates that both teeth and individual approaches provide information

on pathological expression in an individual and overall disease experience and health in a population.

Gagnon and Wiesen (2013) similarly questioned the appropriate unit for dental analysis. They also employed both levels because they viewed dental data as a two-stage sampling strategy. This thesis expanded on this approach by categorizing the teeth into classes based on type (incisors, canines, premolars, and molars) instead of grouping them as anterior and posterior teeth. Each tooth type has distinctive morphology and a specific location in the mouth that influences disease susceptibility, deterioration (caries and AMTL), or accumulation (calculus) (Hillson, 1996). In addition, this study used multiple indices to explore dental pathological indicators in each individual rather than only examining the ratio of affected to observed teeth or sockets.

Tooth Class and Surfaces

When examining teeth as the unit of analysis, the large pooled sample was further categorized into smaller groups by tooth class and surface to specifically assess how dental wear or pathological condition affected each tooth. Analyses of dental wear by tooth class showed that significantly more teeth, regardless of type, were moderately worn down (scores 3-5) as most of the sample (n = 84) consisted of young (18-34 years of age) and middle-aged adults (35-49 years). However, AMTL may have influenced this distribution as older adults (50+ years) had fewer observable teeth. The inverse relationship between caries and dental wear was expected as wear decreases cariogenicity (Powell, 1985) based on the results from the simple linear regression test. Dental wear can file down the grooves and fissures of teeth, limiting the number of small, available spaces for food particles to become trapped.

Patterns identified in the data for carious lesions followed expectations described in previous research (Hillson, 1996; Erdal and Duyar, 1999). For instance, there were more premolars and molars with caries than any other tooth class because these teeth were located posteriorly and functioned primarily to process food into digestible pieces. Food was more likely to be trapped in the interproximal surfaces of molars and premolars. Molars also had complex fissure systems that provided crevices for bacteria to accumulate in and slowly decay the teeth (Hillson, 1996).

Analysis by tooth surface indicated that caries was more likely to affect teeth at the CEJ on the mesial and distal sides than any other location because cementum is not as resilient as enamel due to its higher organic and lower inorganic composition. When the CEJ was exposed, it was likely that the individual also had some degree of periodontal disease as caries is commonly found with periodontal disease (Bignozzi et al., 2014). Periodontal disease refers to the inflammation of tissues surrounding the tooth, including alveolar bone, periodontal ligament, cement, gingiva, and mucous, which causes reduction in surrounding soft tissues and the gum line, leading to eventual gradual horizontal or vertical bone loss (Hillson, 1996; Irfan et al., 2001). Horizontal bone loss involves the equivalent loss in height of bone surrounding all teeth, while vertical bone loss describes localized bone reduction around individual teeth or groups of neighboring teeth, producing an intrabony defect. Periodontal disease typically affects the bone around the molars even though there may still be a substantial amount of bone near the anterior teeth (Hillson, 2008).

Similar to caries, AMTL affected the molars the most, followed by premolars, incisors and finally canines. A tooth can become lost during life due to several causes, such as trauma to the alveolar bone, extreme bone loss from periodontal disease, and intentional extraction

(Hillson, 1996; 2008). AMTL does occur in anterior teeth if there is significant trauma to the front oral region of the face because incisors and canines are single rooted; they are more likely to fall out since there is less attachment to the alveolar bone (Hillson, 1996). This first scenario of trauma is reasonable, but since there was a higher AMTL frequency for posterior teeth over anterior teeth, it is ruled out as the most plausible cause for AMTL in this study. While the amount of bone loss from periodontal disease was not observed and recorded due to timing restrictions, extreme vertical bone loss could have caused AMTL in the posterior teeth because this disease affects molars more than the anterior dentition. Since molars, in this study and in general, tend to develop more advanced carious lesions, they could have also been extracted as the quickest treatment for gross gross caries (Hoffmann-Axthelm, 1981). Results from the regression test also indicated a significant relationship between caries and AMTL frequency, suggesting that an individual's DCR score predicts their AMTL-R score. Thus, advanced carious lesions likely caused a higher AMTL rate for molars and premolars within the Kuelap sample.

As expected, calculus was observed mostly on molars, followed by the incisors, premolars, and canines. Calculus is typically found on the buccal surfaces of molars and the lingual surfaces on the incisors. These locations were more likely to be affected because they were situated closest to the salivary gland ducts where saliva would mix with food particles to form plaque (Hillson, 1996; 2008). Overall, calculus deposits were found mostly on buccal surfaces than interproximal surfaces for molars, and more calcified plaque was found on buccal than lingual surfaces for incisors.

Comorbidity/Multimorbidity

The presence of another pathological condition, in addition to extrinsic and intrinsic factors, can influence an individual's frailty and susceptibility to disease. Comorbidity involves the concurrent presence and correlation between two pathological conditions in the same individual; while multimorbidity refers to the presence of more than two pathological conditions (van Schaik et al., 2014). The relationship between the conditions is significant because it considers how one pathological condition may have increased the risk or susceptibility of the other. From results of the regression analysis, AMTL and caries appear related as advanced carious lesions may lead to AMTL via intentional extraction of the decaying tooth (Hoffmann-Axthelm, 1981). However, there was no significant correlation between calculus and AMTL as expected.

The comorbidity of two contradicting pathological conditions can also affect disease etiology. Both caries and calculus are plaque-related diseases in which dental plaque accumulates and eventually leads to tooth decay (i.e. caries) (Hillson, 2008). When the plaque becomes mineralized, it is referred to as calculus, or tartar. Archaeological studies have found caries and calculus to be inversely related to each other as caries involves demineralizing the tooth surface while calculus forms a mineralized deposit on the tooth surface (Hillson, 1996; 2008). Both conditions can exist on the same tooth but often on different surfaces (Thylstrup et al., 1989), but in some cases (Jones and Borde, 1987) and in two individuals in this study, they can form on the same location with a calculus deposit covering the carious lesion and even inhibiting further decay (Waldron, 2009). Despite these expectations of caries and calculus co-occurrence, the results did not a positive or negative correlation between caries and calculus.

While abscesses were only examined qualitatively in this sample, 39 individuals with

abscesses also had at least one carious lesion, AMTL, or both. The etiology of abscesses can be explained through advanced tooth decay in which large cavities expose the pulp and underlying tissues to bacteria which can cause inflammation, granulation of the tissues, and pus accumulation (Hillson, 1996). However, more abscesses were observed near empty sockets (n = 25) than caries-affected teeth (n = 18) and closed or partially closed sockets (AMTL) (n = 15). It is likely that the empty sockets had previously contained caries-affected teeth that were lost prior to archaeological recovery.

Additionally, periodontal disease may have played a role in influencing the pathological indicators. When the root is exposed by bone loss from periodontal disease, bacteria can decay the now exposed cement surface which would have been previously shielded by the gingiva and alveolar bone (Bignozzi et al., 2014). Extreme bone loss from periodontal disease can cause teeth to become loose in the alveoli and eventually fall out (Hillson, 2008). Periodontal disease was originally perceived to be caused predominantly by dental calculus (Wade, 1960), and while other factors can lead to this condition, calculus is still regarded as an important pathogenic factor to the development and progression of periodontal disease (Kieser, 1990; Whittaker et al., 1998; Dumitrescu and Kawamura, 2010). Overall, analysis at the tooth level allows for an examination and deeper understanding of comorbidity or multimorbidity among the conditions and how each affected the specific tooth type and class.

Indices for Dental Health Indicators

The level of analysis by individual was the main focus of this thesis. Each individual had been systematically examined for dental wear, caries, AMTL, and calculus and was assigned various indices. These included the average dental wear score, traditional dental caries rate

(DCR), index of caries *et extratio* (I-CE), lesion surfaces index (LSI), antemortem tooth loss rate (AMTL-R), calculus rate (CR), and the simplified calculus index (CI-S). In particular, past dental analyses have not been consistent and only recorded pathological indicators as present or absent. However, those studies that do utilize the binary approach have certainly provided a wealth of information about health in the past from different research questions.

While these multiple indices are arbitrary calculations and overlap, they each answered different questions about caries prevalence and assessed different perspectives on disease manifestation and experience. The traditional dental caries rate (DCR) was the most conservative calculation and was useful in understanding caries experience within an individual (Hillson, 1996; 2001; 2008). DCR is universally employed, so it can be compared to other published works, and is simple to calculate despite its shortcomings and the researcher can avoid the criticism of other methods that make huge assumptions about ATML. However, there is a void within dental anthropology in terms of understanding true caries experience because advanced caries can lead to AMTL via intentional extraction. While it cannot be definitively argued that caries directly causes AMTL, it is a reasonable assumption to consider. If only DCR were employed in a study, then an individual with a few small lesions and an individual with multiple large lesions would both be only considered present with caries. It is obvious that these two people have different caries experience as the first individual has a little tooth decay and the latter individual has more advanced decay.

The index of caries *et extratio* (I-CE), which takes antemortem and postmortem tooth loss into account, provided a more accurate assessment in the Kuelap sample than DCR due to the nature of preservation and high occurrence of AMTL. Aside from Caselitz (1988), there have been no other researchers that incorporate this method because the procedure makes assumptions

about AMTL that can be difficult to test (Hillson, 2001), but it is more appropriate for bioarchaeological studies than other methods.

In addition, this study introduced a new method called lesion surfaces index (LSI), which calculated the caries rate based on lesion size and location on the tooth surface. Unlike previous procedures, it assessed the extent of decay and frequency of lesions per tooth within each individual. The size of carious lesions is not generally addressed in dental anthropology research even though there are detailed, standardized procedures to scoring caries (e.g., Buikstra and Ubelaker, 1994; Hillson, 2001; 2008). This study is the first to quantify caries experience in this manner. When LSI was compared among the age groups, there appeared to be an increase in the scores that corresponded to age, which parallels the results from LSI. Differences between the sexes were statistically significant compared to DCR results, which were not significant, and I-CE results. These results suggest that the females in this sample had larger, more advanced carious lesions (higher rates of tooth decay) than their male counterparts, which would have been unexplored if only the DCR and/or I-CE were calculated.

Besides DCR, the decayed, missing, filled, surfaces (DMF-S) index is the other popular calculation of the caries rate and is a variant of the decayed, missing, filled (DMF) index that is employed by epidemiologists and dentists for contemporary studies (Thylstrup and Fejerskov, 1994; Broadbent and Thomson, 2005; Hillson, 2008). Other methods include Hardwick's Correction (Hardwick, 1960), the Caries Correction Factor (CCF) (Lukacs, 1995), and the Proportional Correction Factor (PCF) (Erdal and Duyar, 1999; Duyar and Erdal, 2003). However, all of these underestimate caries experience and do not distinguish among the sizes and locations of carious lesions.

Moreover, analysis of calculus tends to be qualitative and less studied than caries. There has been only one study that has attempted to quantify and calculate a calculus rate in archaeological remains (Greene et al., 2005). Aside from presence or absence, the size and location of plaque deposited needed to be taken into consideration because it would help assess differences in calculus prevalence. These distinctions were important because they allowed for better informed inferences about dental disease and potential oral health differences among different groups of people. However, these methods (both for caries and calculus) are not without shortcomings. For instance, in this sample, the results showed that the majority of individuals had no carious lesions in their teeth as they had indices of 0 for DCR, I-CE, and LSI. This was primarily due to inconsistencies in preservation because many teeth were lost in the postmortem environment. Thus, these methods should be used cautiously as they could limit interpretations if individuals within a sample are poorly preserved.

Demographic and Health Profile

This two stage analysis (teeth and individual) of dental wear, caries, AMTL, and calculus at Kuelap gave valuable insights about the population that inhabited the Chachapoya region from the Late Intermediate Period (AD 900-1470) to the Late Horizon (AD 1470-1535). In particular, this information sheds light on differences among the age groups, between sexes, and individuals buried in different mortuary practices in regards to health, gender diversity, and social ranking. While there have been informative articles published on dental pathology and health in the Andes (e.g., Indriati and Buikstra, 2001; Gagnon, 2006; Pechenkina and Delgado, 2006; Klaus and Tam, 2010; Murphy and Baza, 2012; Gagnon et al., 2013; Gagnon and Wiesen, 2013), no

dental investigations of the same caliber have been conducted on the Chachapoya, even though it is a dynamic and culturally rich area of Peru.

Age Groups and Disease Progression

The majority of the sample consisted of males and females aged between 20 and 49 years, which would be considered as young and middle-aged adults. Thus, the distribution of dental wear, caries experience, AMTL, and calculus followed expected patterns of disease expression as they are all considered age progressive conditions. In other words, the age progression of dental wear and of the indicators was consistent with the distribution of the sample for all indices. The ANOVA test results indicated that the average dental wear scores were not equal across age groups because there were significantly more young and middle-aged adults in the Kuelap sample than there were subadults and older adults.

Additionally, caries has a slowly progressive nature that is strongly correlated with age and as a result, a pattern of development can be identified (Manji et al., 1991; Thylstrup and Fejerskov, 1994). While there were only seven subadults examined, none had carious lesions or signs of AMTL, indicating that prior to 17 years of age, individuals likely did not have caries present on their teeth because visible lesions had yet to develop. Results from the analysis demonstrated that with increasing age, there was an increase in the size and number of lesions on teeth as well as an increase in AMTL. This was consistent with the expected age pattern of caries and AMTL for all teeth. It can be inferred that carious lesions begin to develop and AMTL occurs around the time of transition between subadult (10-17 years) and young adult (18-34 years). There were also three subadults with minimal calculus because calculus tends to accumulate over time as individuals age as demonstrated by the ANOVA results of calculus rates

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in this study and previous research (e.g., Beiswanger et al., 1989; Keenleyside, 2008; Dumitrescu and Kawamura, 2010). However, there appeared to be a decline in the amount of calculus deposits in older adults, but there were also less teeth observed due to extreme AMTL.

Thus, teeth of subadult and young adults are less prone to pathological conditions than older adults because diseases, such as the oral indicators used in this study, require time to manifest in the mouth. However, this does not imply that younger individuals are healthier because they still succumbed at an early age due to an unknown and possibly unrelated cause. In an article discussing the progress in bioarchaeology since the publication of the osteological paradox (Wood et al., 1992), Wright and Yoder (2003) wrote that analysis by age-at-death cohorts was crucial for evaluating the significance of lesions on morbidity and mortality. As this research has shown, age contributed to disease expression, particularly in lesion size and amount for caries, frequency and degree of bone remodeling for AMTL, and in the accumulation of calculus over time. In other words, the effects of age on the individual demonstrates the dynamic nature of an individual's frailty (Wright and Yoder, 2003). While heterogeneity in this population could not be assessed through biodistance at this time, this thesis does help address the osteological paradox by using demographic and health profiles based on detailed data collection of dental pathological indicators.

Sex Differences in Pathological Indicators

In addition to age, biological sex could also be a contributing factor in disease susceptibility and expression. There were no significant results for the average dental wear scores and AMTL rates of males and females in the Kuelap sample, which indicated that both males and females had similar rates of wear and tooth loss. There was no evidence that teeth

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were used as tools between either sexes, and although AMTL was somewhat more pronounced in females, the difference was not statistically significant. However, there were statistical differences in caries experience (I-CE and LSI) and calculus deposits (CR and CI-S). Females had a higher overall caries prevalence based on two of the three indices while males had a higher calculus prevalence for both indices. These differences in caries and calculus prevalence between males and females at Kuelap were likely caused by multiple intrinsic and extrinsic factors that could infer about gender diversity, particularly differential access to resources that could have led to observable variation in disease processes. Female overall health may already be compromised by inherent biological differences, but cultural factors (dietary practices, subsistence strategies, etc.) further influence health, specifically disease susceptibility and manifestation.

In particular, the introduction and intensification of agriculture has caused significant biological and culturally-induced changes to the human body, which include increases in fertility to meet labor demands of farming, a less diverse plant-based diet, decreased mobility, and rapid population growth (Cohen and Armelagos, 1984; Cohen, 1989; 2007; Eshed et al., 2006; Pechenkina et al., 2007; Larsen, 2015); all of which have contributed to a rise in caries prevalence. Overall, female dental health appeared to deteriorate at a substantially greater rate than male's with the rise of agriculture as seen in both New World (Larsen, 1998; Watson et al., 2010) and Old World (Lukacs, 1996) populations. Studies show that females had a higher frequency of carious lesions per individual and tooth as well as size of the lesions, which was expected in this sample, especially in agricultural communities like Kuelap and other Chachapoya sites.

This trend can also be observed in samples at various pre-Columbian sites in Peru and Mexico despite difficulties in cross comparison between dental studies as methods are not consistent or often well-explained. In one Andean study from the site of Cerro Oreja in the Moche Valley during the Salinar (400-1 BC) and Gallinazo 1-3 (AD 1-200) phases, females had higher caries prevalence, but males exhibited higher rates of dental wear in their molars (Gagnon and Wiensen, 2013). The researchers examined the dental remains of 176 skeletal individuals, including 49 females and 43 males, using a similar two stage analysis by tooth and by individual. Their cross temporal study indicated that 30 males and 32 females had carious lesions of the total pooled sample from 400 BC to AD 200. Despite the small sample sizes when categorizing by time period, they were able to demonstrate sex differences in dental health as there was a significant increase in caries among females by the end of the Gallinazo phase. Like this study, Gagnon and Wiensen (2013) did not find significant sex differences in AMTL in any of the phases.

Conversely, a study by Pezo Lanfranco and Eggers (2010) found only one significant difference between males and females among a sample of 263 individuals from the site of Los Pinos in Central Andes. Using a unit by tooth analysis, the authors noted that young adult males had more carious lesions than their female counterparts during the Late Intermediate Period (AD 1000-1470). Pezo Lanfranco and Eggers (2010) described the site as a highly stratified pre-Inca society with agriculture at its peak but attribute the lack of significant sex differences to unbalanced sample sizes.

In another dental study outside of the Andean region, Cucina and Tiesler (2003) analyzed oral pathologies in a sample from northern Peten urban sites of Calakmul, Dzibaché, and Kohunlich of Lowland Maya civilization in Mexico during the Classic period (AD 250-900).

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Social structures at these sites were considered hierarchically organized based the distinction between elite and nonelite burials from archaeological analysis of grave goods. Like Pezo Lanfranco and Eggers (2010), these authors conducted a unit by tooth analysis on a sample of 49 individuals, but they found sex differences in caries and AMTL rates.

Furthermore, sex differences in calculus are likely due to diet (Whittaker et al., 1998; Keenleyside, 2008) rather than biological differences (Christersson et al., 1992). However, the co-occurrence of caries and calculus is understudied as some articles have found higher calculus in females with high caries rates (Novak, 2015; Watson et al., 2010), while other studies (Bonsall, 2014), such as this one, has found the opposite to be true. The etiology of calculus is complex and often oversimplified by anthropologists (Hillson, 1979; Lierverse, 1999). The general consensus is that calculus formation is initiated by alkalinity, which increases mineral precipitation from saliva and other oral fluids (Hillson, 1979). It is proposed that diets high in protein would increase alkalinity of the oral cavity, facilitating calculus formation (Keenleyside, 2008). When coupled with caries rate, several bioarchaeological studies have indicated that a high calculus and low caries frequency is associated with a predominantly protein diet while a high calculus and high caries frequency is linked with a carbohydrate based diet (Keenleyside, 2008; Lieverse, 1999). Females did have lower calculus prevalence than males in this sample from the Chachapoya region. Males, on the other hand, had significantly more numerous and larger calculus deposits than females and thus likely had a higher protein diet (Keenleyside, 2008; Lieverse, 1999).

Aside from possible dietary differences, coca leaf chewing was examined in this study as a potential contributing factor to sex health differences. Coca chewing is a common habit in the ancient Andes (Indriati, 1998; Indriati and Buikstra, 2001; Murphy and Boza, 2012; Gagnon et

al., 2013), and it was hypothesized in these studies that a repeated pattern of buccal caries near the CEJ would indicate coca leaf chewing used in combination with lime or llacta regularly being placed there and held in the cheek. AMTL was considered a weak indicator of coca chewing because it could be caused by advanced caries or bone loss from periodontal disease (Indriati and Buikstra, 2001). Based on this criteria of buccal caries, only one middle-aged adult male (#KSPlatC E9 -Vlz OS n13 Cr2) from the ossuary, Estructura 9, had strong indication of coca chewing with large buccal caries and brown staining on the buccal surfaces of the posterior teeth (Figure 4.14).

This one example of coca chewing does not undermine the importance of coca chewing in the region as it is still possible that there were more individuals with similar indicators. Additionally, the criteria for identifying coca chewing in dental remains may need to be refined because the habitual practice also contributes to calculus accumulation. The addition of lime or llacta helps activate the alkaloids in the coca leaves. As a result, the alkalinity of the oral cavity increases, creating an ideal environment for calculus formation where the *quid* is held between the gums and cheek. Buccal surfaces of molars would be mostly affected, which was the pattern observed in this study, but calculus tends to accumulate in this region of the mouth because it is closest to the salivary duct glands (Hillson, 1996).

Mortuary Differences and Social Ranking

Individuals buried in different mortuary contexts showed no differences in dental wear or caries, except for index of caries *et extratio* (I-CE), AMTL-R, and the calculus rate (CR). However, even though there are no significant differences in dental health, inferences can be made about social structure and ranking as these individuals were buried in different tomb types.

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The mortuary contexts at Kuelap include various funerary repositories, and each are all unique in some way. One possibility for the diverse burial practices is due to changes in cultural groups residing in Kuelap, beginning with early Chachapoya occupation to Inca invasion.

While there were no grave goods in these tomb structures, size and tomb architecture provide rudimentary criteria for comparing energy expenditure and the ascribed socioeconomic status of the deceased (Binford, 1971; Tainter, 1973). A comparison of mortuary contexts reveals that the architectural and size differences among tomb types included in this study. The wall niche burials of Kuelap contained secondary skeletal bundles of human remains that had been previously placed in a primary burial, and the underground pits in the floors of the residential buildings at the site were simple in their construction as they are relatively small, shallow primary burials. On the other hand, the ossuary is larger compared to these two mortuary contexts and is situated in the center of a large circular platform near the Tintero at the southern end of the site (Figure 2.4). It is stone lined and would have required a higher energy expenditure to construct than wall and underground burials. The collective tombs, in particular, are also more elaborate than the wall and pit burials in its structure and design, with groups of individuals specifically placed together and originally sealed off with stone. This context would have also required more energy expenditure. However, this interpretation warrants a deeper exploration of cultural identity and Andean mortuary practices as this study is unable to address these issues.

The evidence of such mortuary diversity and the lack of significant differences in dental pathological indicators does suggest that individuals who were interred likely had similar access to resources and similar oral disease experiences. A hierarchical model assumes that higher ranking individuals had access to more diverse and higher quality food options and control over these commodities (Metcalfe et al., 2009), which would have negatively impacted health of

lower status people as these individuals would have had significantly higher disease prevalence. Conversely, a heterarchical model assumes that all individuals had similar access to resources, allowing for a more even distribution of resources and pathological frequencies in the sample. This bioarchaeological analysis is more consistent with a heterarchical structure was at Kuelap in which all members would have interacted with each other at both the household and larger community levels, there was a more homogenous distribution of goods, and social cohesion was tied to ancestral veneration of communal identity (Crumley, 1995). Hierarchical structure could have also existed in conjunction with heterarchy at Kuelap as the site layout and architecture suggest some distinctions between the upper and lower levels, but data are not consistent with a hierarchical society with explicit social inequality and stratification. Furthermore, while current research has yet to demonstrate that the Chachapoya were also organized into *ayllus*, which are the basic Andean social unit in both modern and past societies, different clan groups could have resided in Kuelap in the past, sharing the same space throughout the site.

Social Variability at Chachapoya

This study presented a bioarchaeological analysis of dental pathological conditions that provides a foundation for understanding gendered variation and social structure at Kuelap. These sex differences in health indicate that gender, coupled with inherent biological factors, demonstrated some differences in the social complexity at Kuelap. Additionally, the lack of explicit differences in oral health patterns and mortuary structures at this site also demonstrates that Kuelap may not have been socially organized according to hierarchical principles. Kuelap is an impressive archaeological site that has yet to be fully explored with its extensive agricultural terraces, numerous stone build structures, and large perimeter wall and platform. Additionally,

Kuelap represents a complex society with considerable variation in its social relationships and structure, regarding gender and mortuary treatment. The information acquired from this thesis yields a broader interpretation of the Chachapoya cultural group in that it deviates from traditional bioarchaeological expectations of a complex society.

Chapter Summary

This chapter discussed the application of a two stage analysis for ancient dental remains to explore how oral pathological indicators can inform about social variability and complexity in the past. Dental analysis by teeth and by individuals were both crucial for understanding various aspects of health that could not have been comprehensively understood with only a binary approach (present or absent) to disease expression. By examining age progression and sexual differentiation of dental wear and each pathological indicator, this study was able to construct demographic and health profiles of this sample as well as demonstrating the odd lack of evidence for a common cultural practice, coca leaf chewing, in the Andes. Through the integration of a biocultural approach to examine significant sex differences in health, this thesis was able to draw inferences about gendered differences at Kuelap. Additionally, comparisons of the mortuary context and lack of significant health differences enabled this study to infer that Kuelap was likely not a rigid hierarchical society with apparent social inequality among subgroups of the population. Rather, Kuelap demonstrates the complexity of the Chachapoya culture with its social and mortuary variability. The last chapter of this thesis will present conclusions, underlining the study's limitations and future considerations.

CHAPTER SIX: CONCLUSIONS

The main goal of this thesis was to explore health differences and social variability of the Chachapoya at the archaeological site of Kuelap, following three objectives. The first objective was to explore patterns in dental disease using pathological indicators (caries, antemortem tooth loss, and calculus) of a skeletal sample from Kuelap. The second objective was to investigate health differences between males and females and among individuals buried in the different types of mortuary contexts. Lastly, the third objective to explore evidence of gender inequality and social variability at Kuelap. This thesis hypothesized that there are no dental health differences among individuals from Kuelap, but by employing detailed data collection and a two stage analysis of oral pathological indicators, in conjunction with contextual mortuary information, the results suggested significant health differences between males and females.

All expectations were addressed by dental pathological data and mortuary information, which support the hypothesis. The results showed that caries, AMTL, and calculus were all present within the Kuelap sample, and the degree and location of each indicator varied by tooth type and individual. The utilization of a two stage analysis by tooth (class and surfaces) and by individual was made capable through detailed data recording of size and location of the lesion or deposit and the degree of bone remodeling. In particular, analysis by tooth proved to be a useful indicator of disease susceptibility and manifestation. Depending on the pathological condition, the type of surface affected varied, and patterns were identified depending on how the tooth was situated within the mouth, its size and morphology, and other extrinsic factors. Statistical analysis also indicated that there were some relationships among the three indicators as they may have influenced or inhibited each other due to multimorbidity.

Secondly, analysis by individual was important in determining health differences in age, males and females, and people buried in different mortuary interments. Multiple indices were employed because they each addressed differing approaches to understanding disease experience, specifically susceptibility and manifestation. Age appeared to be a significant factor in disease expression while gendered differences in health were likely due to both inherent biological causes and external influences, such as increased dependence on agricultural-based subsistence strategies and differences in cultural habits (e.g., coca chewing). Evidence of coca leaf chewing was apparent in only one adult male individual, but considering coca's importance in many past and modern Andean cultural groups, it is surprising that more individuals were not found with buccal carious lesions near the CEJ. This thesis was also the first study to document the evidence of coca chewing from the ancient Chachapoya site of Kuelap.

The data from this study were imperative to overall understanding of gender diversity and social structure at Kuelap, and broadly speaking, of the Chachapoya region. Until recently, archaeological research centered primarily on social ranking rather than exploring more inclusive concepts of gender variability (Conkey and Spencer, 1984; De Lucia, 2008). The role of gender in past societies requires a more in-depth analysis of how individuals specifically interacted with each other to construct social ranking within society. Additionally, heterarchical structures have been more recently explored as an alternative to the traditional rigid hierarchical models of most complex societies (Crumley, 2007). Dental analysis from this study suggested that social organization at Kuelap was not hierarchical based but more consisted with a heterarchical model. Other changes in cultural practices, such as diet and subsistence, may have dramatic effects on overall individual and community health in addition to inherent biological factors, which demonstrate that human control over resources, power, and decision making can be expressed

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biologically, such as health differences among individuals of various age, sex, and status, or even culturally, when the individual is placed in a specific type of burial. For the Chachapoya, this variation can be observed from the skeletons buried throughout Kuelap from the Late Intermediate Period to the Late Horizon.

Limitations and Future Considerations

Since time was a major constraint during field data collection, other dental pathological indicators, such as periodontal disease, could not be observed and recorded with the same rigor as caries, calculus, and AMTL. The skeletal remains of each person were originally stored in different facilities that had to be individually located and retrieved, which limited the complete access of all Kuelap individuals that have been excavated from the site. Preservation was a limiting factor as many remains were too fragmented or had no teeth present for analysis. Many of the teeth were also stained and had been exposed to the elements, so they were difficult to examine. To combat this issue, a low powered microscope was used to identify and score nuances in carious lesions as well as distinguish between postmortem tooth loss and early signs of bone remodeling.

Additionally, the calculations of multiple indices and percentages proved to be challenging as there were high rates of AMTL and PMTL within this selected sample. These calculations are more accurate for determining disease experience when more teeth are present for observation. The use of more than one type of index for each indicator allowed for an appropriate analysis of dental health as some methods considered the effect of AMTL on disease prevalence in association with another indicator, while others focused solely on how each tooth

was affected. The two stage approach also helped to explain disease experience by tooth class and surface based on how morphology and location could affect susceptibility.

Further research at Kuelap is necessary for exploring health and social variability in conjunction with the mortuary landscape in Chachapoya culture. Stable isotope analysis of both dental and skeletal remains would be particularly helpful in reconstructing diet at Kuelap and clarify differences between males and females. Additional microfossil analysis of plant remains from calculus deposits would prove particularly useful in identifying maize consumption and coca leaf chewing among the Kuelap inhabitants. Other pathological conditions, such as periodontal disease, would have provided additional information on multimorbidity. Future excavations need to be conducted at Kuelap because a large portion of the site remains relatively unexplored. An exploration of more areas within the site may allow for more individuals of all sexes and ages to be examined, thus increasing sample size, as well as additional contextual information about other mortuary interments at Kuelap. Lastly, dental remains from other Chachapoya sites should be analyzed and compared to the Kuelap sample to compare patterns of oral health.

Final Comments

This thesis was an analysis of dental remains that successfully explored questions regarding health, gender inequality, and social variability at the ancient site of Kuelap. While more information can always be gathered, this research was the first bioarchaeological investigation on teeth from this site and of the Chachapoya region. The data collected from this thesis contribute significantly to our current knowledge of ancient Chachapoya health and social structure. The two stage analysis proved to be an effective tool as it allowed for a comprehensive

assessment of health from the level of the tooth and the individual. As this thesis demonstrated, detailed data collection and analysis can provide a wealth of information about health beyond the basic binary methodology of dental disease, despite teeth's small size and complexity. Overall, this thesis presented a successful bioarchaeological dental analysis of teeth from multiple interments at Kuelap, demonstrating the importance of a systematic methodological approach and a holistic anthropological perspective for exploring gender diversity, social variability and complexity in the past.

APPENDIX A: ABBREVIATIONS

Abbreviations for Each Tooth based on the Anthropology Dental Recording System

RM^3 = Right upper third molar RM_3 = Right lower third molar

RM^2 = Right upper second molar RM_2 = Right lower second molar

RM^1 = Right upper first molar RM_1 = Right lower first molar

RP^2 = Right upper second premolar RP_2 = Right lower second premolar

RP^1 = Right upper first premolar RP_1 = Right lower first premolar

RC^1 = Right upper canine molar RC_1 = Right lower canine molar

RI^2 = Right upper second incisor RI_2 = Right lower second incisor

RI^1 = Right upper first incisor RI_1 = Right lower first incisor

LI^1 = Left upper first incisor LI_1 = Left lower first incisor

LI^2 = Left upper second incisor LI_2 = Left lower second incisor

LC^1 = Left upper canine LC_1 = Left lower canine

LP^1 = Left upper first premolar LP_1 = Left lower first premolar

LP^2 = Left upper second premolar LP_2 = Left lower second premolar

LM^1 = Left upper first molar LM_1 = Left lower first molar

LM^2 = Left upper second molar LM_2 = Left lower second molar

LM^3 = Left upper third molar LM_3 = Left lower third molar

APPENDIX B: SKELETAL INVENTORY OF ALL INDIVIDUALS IN THE KUELAP SAMPLE

Table 1: Final Inventory Listing Skeletal Identification Number, Sex, Age, Burial, and Pathological Indices for Each Individual

Sex: M = Male, F = Female

Age: SA = Subadult, YA = Young Adult, MA = Middle-aged Adult, OA = Old Adult

Pathological Indices: Avg DW = Average Dental Wear, AMTL-R = Antemortem Tooth Loss rate, #AB = Number of Abscesses, DCR = Dental Caries Rate, I-CE = Index of Caries *et extratio*, LSI = Lesion Surfaces Index, CR = Calculus Rate, CI-S = Simplified Calculus Index

*N/A = Not Applicable; score could not be calculated as there were no teeth present

Skeleton #	Sex	Age	Burial Type	Avg DW	AMTL-R	#AB	DCR	I-CE	LSI	CR	CI-S
KSPlat1E4 IÑ ENT2	F	OA	Pit	N/A	56.25	0	N/A	56.25	N/A	0.00	0.00
KSPlat1E4 IÑ ENT3	M	OA	Pit	5.55	31.82	0	52.63	53.13	56.84	5.26	0.03
KSPlat1E6 -IIN -IIIN ENT1	F	MA	Pit	5.67	13.33	0	66.67	31.58	83.33	0.00	0.00
KSTin E1 -VIV Ent7	F	OA	Pit	N/A	93.75	0	N/A	93.75	N/A	0.00	0.00
KSTIN -VU Ent1	F	YA	Pit	2.00	3.23	0	4.00	6.45	1.60	0.00	0.00
KSTIN -IIIT Ent4	F	YA	Pit	3.77	0.00	0	9.09	6.25	8.18	0.00	0.00
KSTIN -IIIT Ent5	F	OA	Pit	6.62	46.15	1	38.46	54.84	35.38	0.00	0.00
KSTIN -IIU -IIV Ent10	F	YA	Pit	5.17	0.00	0	4.35	3.33	1.74	0.00	0.00
KSTIN -IIU -IIV Ent11	F	MA	Pit	5.83	7.69	1	33.33	20.00	75.00	8.33	0.02
KSSbPlt1 -IIP Ent1	M	MA	Pit	6.75	32.26	0	25.00	36.67	25.00	0.00	0.00
KSSbPlt1 -IIP Ent2	F	OA	Pit	7.50	69.23	1	100.00	75.00	40.00	0.00	0.00
KSSbPlt1 -IP Ent2	M	YA	Pit	2.10	0.00	2	0.00	0.00	0.00	15.00	0.05
KSSbPlt1 -IO Ent1	F	YA	Pit	4.00	0.00	2	28.57	20.00	25.71	57.14	0.46
KSSbPlt1 -IO Ent1a	F	OA	Pit	4.73	41.67	3	72.73	56.25	58.18	0.00	0.00
KCAC1 IIM IIN Ent1	M	OA	Wall	7.50	81.25	0	0.00	81.25	0.00	0.00	0.00
KCAC1n E1 ENT1	F	YA	Pit	1.73	0.00	0	0.00	0.00	0.00	0.00	0.00
KSPlat2 E10 ENT2	F	OA	Pit	N/A	100.00	0	N/A	100.00	N/A	0.00	0.00
KSPlatC E1 -Vllz Ent04	F	YA	Pit	3.54	0.00	0	0.00	0.00	0.00	0.00	0.00
KSPlatC E2 -Vlla' Ent05	M	YA	Massacre	4.11	0.00	0	15.79	13.64	11.58	0.00	0.00
KSPlatC E2 -Vlla'Vla' Ent06	M	MA	Massacre	5.15	13.33	2	65.00	53.57	83.00	15.00	0.16

Skeleton #	Sex	Age	Burial Type	Avg DW	AMTL-R	#AB	DCR	I-CE	LSI	CR	CI-S
KSPlatC E2 -Vla' Ent13	-	SA	Massacre	1.36	0.00	0	0.00	0.00	0.00	0.00	0.00
KSPlatC E2 -Vla' Ent22	-	SA	Massacre	1.35	0.00	0	0.00	0.00	0.00	0.00	0.00
KSPlatC E2 -Vlla' Ent30	F	YA	Massacre	3.05	0.00	0	0.00	0.00	0.00	0.00	0.00
KSPlatC E4 -Vla' ENT47	-	SA	Massacre	2.37	0.00	0	0.00	0.00	0.00	11.11	0.06
KSPlatC E4 -Vla' ENT50	-	SA	Massacre	3.07	0.00	0	0.00	0.00	0.00	13.33	0.03
KSPlatC E4 -Vla' ENT57	M	MA	Pit	6.00	29.03	2	14.29	31.25	11.43	14.29	0.07
KSPlatC E4 -Vla' ENT65	F	YA	Pit	3.00	0.00	0	14.81	12.50	8.15	7.41	0.03
KSPlatC PatLib -Vlz ENT1a	M	YA	Massacre	2.00	0.00	0	0.00	0.00	0.00	0.00	0.00
KSPlatC E6 -Vllz' -Vlla' ENT79	F	YA	Tomb	2.67	0.00	0	9.52	6.25	5.71	19.05	0.06
KSPlatC E6 -Vllz' -Vlla' ENT80	M	MA	Tomb	7.29	23.33	0	0.00	23.33	0.00	57.14	0.25
KSPlatC E6 -Vllz' -Vlla' ENT81	M	YA	Tomb	3.79	0.00	0	0.00	0.00	0.00	75.00	0.31
KSPlatC E6 -Vllz' -Vlla' ENT82	M	OA	Tomb	N/A	84.38	0	N/A	84.38	N/A	0.00	0.00
KSPlatC E6 -Vllz' -Vlla' ENT83	M	YA	Tomb	3.00	0.00	0	11.11	6.25	6.67	0.00	0.00
KSPlatC E6 -Vllz' -Vlla' ENT84	M	MA	Tomb	N/A	37.93	1	N/A	37.93	N/A	0.00	0.00
KSPlatC E6 -Vllz' -Vlla' ENT85	F	OA	Tomb	N/A	68.75	5	N/A	68.75	N/A	0.00	0.00
KSPlatC E6 -Vllz' -Vlla' ENT86	M	YA	Tomb	4.00	0.00	0	0.00	0.00	0.00	0.00	0.00
KSPlatC E6 -Vllz' -Vlla' ENT91	-	SA	Tomb	1.48	0.00	0	0.00	0.00	0.00	0.00	0.00
KSPlatC E9 -Vlz OS n13 Cr1	M	YA	Ossuary	3.22	3.33	0	22.22	9.38	11.11	22.22	0.08
KSPlatC E9 -Vlz OS n13 Cr2	M	MA	Ossuary	4.86	3.45	1	13.04	12.50	9.57	56.52	0.22
KSPlatC E9 -Vlz OS n13 Cr3	M	MA	Ossuary	5.00	13.33	1	20.00	20.00	16.00	80.00	0.25
KSPlatC E9 -Vlz OS n13 Cr4	M	YA	Ossuary	3.33	0.00	0	33.33	12.50	6.67	0.00	0.00
KSPlatC E9 -Vlz OS n13 Cr5	M	MA	Ossuary	4.75	6.25	0	0.00	6.25	0.00	75.00	0.25

Skeleton #	Sex	Age	Burial Type	Avg DW	AMTL-R	#AB	DCR	I-CE	LSI	CR	CI-S
KSPlatC E9 -Vlz OS n13 Cr8	M	YA	Ossuary	3.86	11.54	1	42.86	28.13	32.86	28.57	0.09
K-PAS MO-VIII T' ENT3	M	YA	Wall	2.00	0.00	0	10.00	6.25	4.00	20.00	0.05
K-PAS MO-VIII T' ENT4	M	MA	Wall	4.47	4.76	0	20.00	16.67	21.33	46.67	0.22
K-PAS MO-VIII T' ENT11	M	MA	Wall	4.25	0.00	0	7.69	6.25	30.00	34.62	0.39
K-PAS MO-VIII T' ENT19	M	MA	Wall	3.60	52.94	3	0.00	52.94	0.00	0.00	0.00
K-PAS MO-VIII T' ENT20 (A/B)	M	MA	Wall	3.43	17.24	1	20.00	25.00	18.67	20.00	0.08
K-PAS MO-VIII T' ENT24	F	YA	Wall	4.86	0.00	0	42.86	33.33	45.71	0.00	0.00
K-PAS MO-VIII T' ENT27	F	YA	Wall	3.07	0.00	0	7.14	4.55	8.57	0.00	0.00
K-PAS MO-VIII T' ENT31	M	YA	Wall	3.19	0.00	1	30.77	25.00	32.31	50.00	0.17
K-PAS MO-VIII U' ENT44 (A/B)	F	MA	Wall	6.00	50.00	1	75.00	66.67	200.00	0.00	0.00
K-PAS MO-VIII U' ENT45	F	YA	Wall	2.85	0.00	0	11.11	9.38	6.67	0.00	0.00
K-PAS MO-VIII U' ENT48	M	MA	Wall	4.08	4.76	3	42.31	40.00	103.85	23.08	0.39
K-PAS MO-VIII U' ENT49b	F	OA	Wall	5.00	78.13	1	0.00	78.13	0.00	50.00	0.13
K-PAS MO-VIII U' ENT50	F	MA	Wall	4.00	0.00	0	45.45	20.83	105.45	45.45	0.14
K-PAS MO-VIII U' ENT53	M	YA	Wall	3.48	0.00	0	0.00	0.00	0.00	46.88	0.14
K-PAS MO-VIII U' ENT55	F	MA	Wall	5.55	26.09	2	27.27	34.62	125.45	0.00	0.00
K-PAS MO-VIII U' ENT56	F	YA	Wall	2.15	0.00	0	30.77	16.00	24.62	61.54	0.17
K-PAS MO-VIII U' ENT58	F	YA	Wall	4.85	24.00	0	38.46	36.67	24.62	0.00	0.00
K-PAS MO-VIII U' ENT59	F	OA	Wall	5.50	93.33	2	100.00	93.75	370.00	50.00	0.13
K-PAS MO-VIII U' ENT63	F	MA	Wall	4.63	83.33	0	100.00	87.50	97.50	12.50	0.03
K-PAS MO-VIII U' ENT64	F	MA	Wall	1.00	68.42	1	0.00	68.42	0.00	0.00	0.00
K-PAS MO-VIII U' ENT65	M	YA	Wall	3.52	0.00	0	16.00	12.50	8.80	36.00	0.10
K-PAS MO-VIII U' ENT69b	F	MA	Wall	6.10	50.00	1	60.00	59.38	170.00	0.00	0.00
K-PAS MO-VIII U' ENT70	M	YA	Wall	3.68	0.00	1	4.00	3.13	2.40	56.00	0.20
K-PAS MO-VIII U' ENT73	M	MA	Wall	4.91	3.23	0	4.17	6.25	3.33	50.00	0.14
K-PAS MO-VIII U' ENT75	M	YA	Wall	2.19	0.00	0	0.00	0.00	0.00	29.63	0.07
K-PAS MO-VIII U' ENT79	F	MA	Wall	5.73	32.14	2	26.67	40.63	96.00	20.00	0.08

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Skeleton #	Sex	Age	Burial Type	Avg DW	AMTL-R	#AB	DCR	I-CE	LSI	CR	CI-S
K-PAS E1 -VI Q' T1ENT1	M	YA	Pit	1.53	0.00	0	0.00	0.00	0.00	0.00	0.00
K-PAS E1 -VI Q' T1ENT2	M	YA	Pit	1.94	0.00	0	31.25	20.00	23.75	0.00	0.00
K-PAS E1 -VI Q' T1ENT5	M	OA	Pit	3.67	44.44	1	66.67	54.55	60.00	0.00	0.00
K-PAS E1 -VI Q' T1ENT6	M	OA	Pit	6.75	73.08	0	12.50	74.07	25.00	0.00	0.00
K-PAS E1 -VI Q' T1ENT6b	F	YA	Pit	1.92	0.00	0	3.85	3.45	1.54	23.08	0.06
K-PAC E1 -III G ENT1	M	MA	Pit	4.74	0.00	0	8.70	7.14	9.57	86.96	0.72
K-PAC E1 -III G ENT2	M	YA	Pit	4.80	13.79	1	20.00	16.67	28.00	0.00	0.00
K-PAC E1 -III G ENT3	M	MA	Pit	6.00	82.35	2	0.00	82.35	0.00	0.00	0.00
K-PBN AC3 ENT1a	M?	SA	Wall	1.12	0.00	0	0.00	0.00	0.00	11.76	0.03
K-PBN ME ENT1	F	MA	Wall	4.61	20.00	0	38.89	37.50	28.89	0.00	0.00
K-PAC E1 -II H' ENT1	F	MA	Pit	N/A	76.67	1	N/A	76.67	N/A	0.00	0.00
K-PAC E2 -IIN' Ent1A	F	YA	Tomb	2.84	16.00	3	36.84	34.38	62.11	36.84	0.12
K-PAC E2 -IIN' Ent1B	F	MA	Tomb	8.00	67.74	3	50.00	68.75	320.00	0.00	0.00
K-PAC E2 -IIN' Ent1C	F	MA	Tomb	7.50	75.00	0	0.00	75.00	0.00	50.00	0.13
K-PAC E2 -IIN' Ent2A	F	MA	Tomb	7.00	75.00	4	100.00	76.92	340.00	0.00	0.00
K-PAC E2 -IIN' Ent2B	M	MA	Tomb	7.17	74.19	0	16.67	75.00	13.33	33.33	0.08
K-PAC E2 -IIN' Ent2D	M	YA	Tomb	4.86	6.90	0	10.34	15.63	8.97	17.24	0.04
K-PAC E2 -IIN' Ent2E	-	SA	Tomb	1.70	0.00	0	0.00	0.00	0.00	0.00	0.00
K-PAC E2 -IIN' Ent2F	M	MA	Tomb	5.87	36.84	1	46.67	53.85	93.33	46.67	0.13
K-PAC E2 -IIN' Ent3A	M	YA	Tomb	2.66	0.00	0	16.67	15.63	21.33	16.67	0.05
K-PAC E2 -IIN' Ent3B	F	MA	Tomb	7.00	46.88	0	0.00	46.88	0.00	0.00	0.00
K-PAC E2 -IIN' Ent4A	M	YA	Tomb	4.89	28.00	0	38.89	43.75	32.22	55.56	0.39
K-PAC E2 -IIN' Ent5A	M	YA	Tomb	3.18	6.25	2	0.00	6.67	0.00	17.39	0.05
K-PAC E2 -IIN' Ent5B	F	YA	Tomb	3.15	0.00	0	15.38	7.14	12.31	0.00	0.00
K-PAC Est2 -III Ñ' ENT7A	F	YA	Pit	4.71	50.00	1	28.57	56.25	18.57	7.14	0.02
K-SbPltII E1 -VIII S Ent1A	M	MA	Tomb	6.00	32.14	1	36.36	40.63	32.73	27.27	0.07
K-SbPltII E1 -VIII S Ent1B	M	YA	Tomb	4.33	0.00	0	16.67	12.50	10.83	12.50	0.04
K-SbPltII E1 -VIII S Ent1C	M	YA	Tomb	2.00	0.00	0	6.67	6.25	4.00	26.67	0.10

Skeleton #	Sex	Age	Burial Type	Avg DW	AMTL-R	#AB	DCR	I-CE	LSI	CR	CI-S
K-SbPl II E5 -VII T ENT2	F	MA	Pit	3.62	0.00	0	3.85	3.57	2.31	3.85	0.01
K-SbPltII E6 -VI U Ent1	M	YA	Pit	3.79	0.00	0	0.00	0.00	0.00	93.10	0.84
K-SbPltII E6 -VI U Ent2	M	MA	Pit	6.69	13.33	0	7.69	18.75	9.23	76.92	0.60
K-TM E33 -IX W Ent1	M	MA	Pit	5.87	23.33	1	13.33	28.13	8.00	46.67	0.20
K-TM E38 -VIII V Ent1	F	MA	Pit	6.67	66.67	3	66.67	68.75	240.00	0.00	0.00
K-TM E40 -IX U Ent1	M	MA	Pit	4.83	0.00	0	0.00	0.00	0.00	13.04	0.07
K-TM MNO ENT1	M	YA	Wall	4.71	26.67	0	28.57	31.25	17.14	0.00	0.00
KSPlatC E1 -VIIZ ENT114	F	OA	Pit	5.86	0.00	0	10.71	10.34	50.71	21.43	0.05
KSSbPlt1 -IO Ent3	F	MA	Pit	5.47	7.14	1	23.53	18.75	16.47	17.65	0.06

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