DENTAL ANALYSIS OF THE PREVALENCE OF CARIES AND INFECTION IN THE ANCIENT MAYA OF K'AXOB, BELIZE

A Thesis

Presented to

The Faculty of the Department

of Anthropology

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Meghan C. Harmon

December 2018

DENTAL ANALYSIS OF THE PREVALENCE OF CARIES AND INFECTION IN THE ANCIENT MAYA OF K'AXOB, BELIZE

_____

Meghan C. Harmon

APPROVED:

_____

Rebecca Storey, Ph.D.
Committee Chair

_____

Kenneth Brown, Ph.D.

_____

Dirk Van Tuerenhout, Ph.D.
Houston Museum of Natural Science

_____

Antonio D. Tillis, Ph.D.
Dean, College of Liberal Arts and Social Sciences
Department of Hispanic Studies

DENTAL ANALYSIS OF THE PREVALENCE OF CARIES AND INFECTION IN THE ANCIENT MAYA OF K'AXOB, BELIZE

An Abstract of a Thesis
Presented to
The Faculty of the Department
of Anthropology
University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Meghan C. Harmon

December 2018

ABSTRACT

Remains of humans recovered in modern and archaeological contexts provide a wealth of information regarding an individual's life history and that of the society itself in which they lived. Individuals that have been excavated from burials at K'axob, Belize, an ancient Maya site have yielded a skeletal population dating from the Preclassic to Classic periods. Through examination of the dentition of these remains for caries, infection, and wear, this study aims to analyze the prevalence of these dental pathologies and their correlations to one another among other factors. Caries were found to be present in 80 (76.2%) of the 105 individuals and infection was seen in 16 (15.2%) of the individuals. Tooth wear was seen to have not occurred in 13 individuals (12.4%); light wear was seen in 17 (16.2%), moderate in 39 (37.1%), and severe wear occurred in 36 (34.3%) of the 105 individuals. It was found that tooth wear and caries prevalence of individuals were not interconnected, while infection and tooth wear were related with more wear of the teeth resulting in the presence of infection.

ACKNOWLEDGMENTS

I would like to thank my committee members, Dr. Rebecca Storey, Dr. Dirk Van Tuerenhout, and Dr. Kenneth Brown, for their insight, advice, and support throughout the process of conducting research and bringing my work to life in writing this thesis. I would like to thank Dr. Storey for not only serving as my advisor and committee, but for allowing for access to studying the individuals of K'axob. Dr. Brown, for offering his perspective and additional insight based on his experience. Also, Dr. Dirk Van Tuerenhout, who was an invaluable source of humor and insight, which made this process far less painful and terrifying than it could have been.

Without the love and support of my family I would not have been able to have my determination in pursuing this degree. I have received words of encouragement and love that helped push me along to reach my goals. I would specifically like to thank my parents, Wayne and Donna Harmon, who always provided ever constant support and encouragement to follow my dreams and be myself. Without their love and guidance, I would not be where and who I am today. And for this I will never have the words to thank them enough. I would also like to thank Zack Wilkerson, who was always available to act as a sounding board and help me keep my sanity as best he could during my undergraduate and graduate careers.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter One: INTRODUCTION

Since archaeological sites of the Ancient Maya were discovered they have captivated the minds of researchers and laymen alike, and prompted decades worth of research. In attempting to understand the culture and individuals who inhabited these regions that were once thought to be "collapsed civilizations," researchers have undertaken a variety of excavations and developed a wide array of ways in which to analyze these sites. An important factor in attempting to better understand the people of an archaeological site is through population studies. In performing demographic studies, and learning in depth about a population, new information can be added to the narrative beyond that of cultural artifacts left behind on a more personal/individualized level of the peoples who once lived and died at a particular site.

One of the key factors in understanding the diet and health of a population as a whole and on an individualized level, is through bioarchaeological studies. Utilization of bioarchaeological methods allows for inferences about key factors relating to the health and nutrition of ancient populations. In looking at the population of one ancient Maya site of K'axob, one such available resource for bioarchaeological studies was that of the dentition and looking at the prevalence of caries, infection, and wear of the population. The teeth are utilized in a two-step process of eating, from the initial "preparation" of food via biting, and followed with the breaking down of the

food through chewing. In performing these two processes, the teeth are worn down over time, either through contact of the teeth against each other through the chewing process, or from the texture of the food itself (Larsen 2015). These two different acts – the process of chewing (mastication) and the abrasion that occurs between the teeth and the food or other materials present in the food (attrition) account for the wear seen in teeth of past and present populations. For individuals at K'axob, tooth wear occurred not only as a result of mastication, but also from attrition due to the food preparation methods and food sources available at the time. Food preparation methods greatly affected the texture of the food consumed, and will be discussed in further detail in later chapters. Wear of the teeth plays a role in the instance of caries and infections present in the dentition of individuals. By understanding the processes of wear, better insight can be gained in terms of understanding the prevalence of caries.

The Maya lived in the areas of the countries we now know as modern-day Belize, Honduras, Guatemala, El Salvador, and southern Mexico (Coe 2005). The Maya timeline is broken down into the Preclassic period, ranging from around 2000 B.C. to A.D. 250; the Classic period, which went from A.D. 250 through 1000; and to the Postclassic period, from A.D. 1000 to the Spanish conquest that occurred in the early 1500's (Coe 2005).

K'axob is a Maya site of moderate size situated in northern Belize, with the site showing signs of occupation dating from 800 B.C., occurring during the

Middle Formative through the Classic period (McAnany and Lopez Varela 1999). The community of K'axob is one of ten residential communities situated in the area of Pulltrouser Swamp (Henderson 2003). Due to where it was situated geographically, K'axob residents had access to the variety of plant and animal resources made available by the nearby wetlands and riparian ecosystems[1] (McAnany and Lopez Varela 1999). Research has shown that in the region of K'axob, farmers began an intensification of their agrarian production through means of more intensively maintaining fields through hoeing, weeding, constructing raised beds, drained field plots, and forming larger households as a response to the growing population (Henderson 2003).

The increase of the population resulted in more individuals needing to be fed, and so a reliance more on crops rather than that of the wild animal resources which had already been overexploited began to occur at K'axob (Coe 2005). Alterations to the diet based on the availability of resources would have an effect on nutrition and in turn affect the teeth of individuals based upon the types of food being consumed. Excavations of the site occurred over six field seasons taking place starting in 1990, with the largest being Operation 1, a 6 x 8-meter excavation unit (McAnany 2004; McAnany and Lopez Varela 1999).
Human teeth are one of the remains that typically have been found to survive the best in an archaeological context. , Teeth provide an important source of

[1] Lands bordering streams, lakes, and rivers (National Academy Press, 2002)

information about dental disease, but also the use of teeth as tools, and social habits such as artificial modifications (Waldron 2009). The teeth of an individual can be some of the most informative evidence available regarding a past populations' health, diet, and in some instances, cultural practices. The most telling aspects about nutrition and health in a population when looking at the teeth is gathered from the presence of caries, infection, and wear. These three factors allow for a better understanding of a populations' diet and nutrition. The importance of identifying caries and infection in a population is that it allows for better insight to the diet and nutrition in a region, as certain food types can be the cause of caries and wear of the teeth, and resources vary in their regional availability. Another factor to be considered is that of food preparation processes, which will be discussed later on, that can also have an effect on the wear of the dentition.

Skeletal analysis is one of the principal ways of gaining an understanding of an individual and a population, whether it be in an archaeological context or in the use of modern-day forensics. Through studying the skeleton researchers can be able to not only reconstruct the past, but also see firsthand aspects of everyday life as it plays out in the human body. Evidence of illness or injuries experienced, physical activity, cultural modifications, and even trauma that could have resulted in death are all recorded on the skeleton. Population demographics can be achieved by looking at remains that are found in an archaeological context (Larsen 2015). By studying the teeth of a

population, insight can be gained regarding the makeup of the diet and nutritional stressors that occurred during the lifetime of individuals in a specific population group. Some of the best evidence provided regarding diet and nutrition of a society comes from examining teeth for the prevalence of dental caries and infections. Even in modern day cases we can see how nutrition and health are contributing factors to the teeth and their formation and in some cases, their decay. With human remains from ancient societies, we can learn not only about the way individuals were treated in death, but also what they would have endured in life. Wear that can occur on teeth allows also for the ability be able to age the skeleton, as signs of severe wear indicates a longer exposure to a diet of foods which are coarse or less finely ground (Larsen 2015).

Dental caries are the most common cause of oral pain and tooth loss and have affected humans throughout time. Changes in diets of humans throughout time have altered where caries are seen to occur on the surfaces of the teeth (Waldron 2009). Diseases of the dentition, although much more prevalent in past populations, still occur in our modern setting for much of the same reasons. Other major dental diseases that can occur aside from caries are infections that begin in the tooth but eventually move down through the root and into the mandible or maxilla (Waldron 2008).

PROBLEM AND HYPOTHESES

Varying food types can have a marked effect on the state of dentition based on the wear that can occur due to mastication, coupled with the coarseness of the food itself or grit present in the food from the preparation process. Sources of food in K'axob were highly varied and did not consist solely of agriculture; plant and animal resources available through the environment also supplemented much of their diet. Residents' crops were raised fields located in Pulltrouser Swamp, done so with the use of a canal system, which aided in terms of cultivation of the soil by enhancing runoff and lowering local water levels (Pope and Dahlin 1989). By providing channels and a canal system to their raised fields, residents of K'axob were able to manipulate the water flow so that the soils in the field were never overwatered or dried out, allowing for cultivation of crops yearlong (Turner II and Harrison 1983). With having available food sources from crops year-round, there is the potential for more of the sustenance at K'axob to come from agriculture rather than the environment's plant and animal resources. While this was beneficial for the people of K'axob, there was also the instance of more wear of the teeth from the consumption of ground maize and other foods. Pollen analysis has been performed in the region of Pulltrouser Swamp, and it has been found that evidence for maize pollen and cotton is found in the lower aspects of the canals, which indicate these are from when

the Ancient Maya were cultivating the fields and not recent pollen (Wiseman 1983). Wear of the teeth can also be attributed to dental attrition, which is the wear of the teeth due to tooth-on-tooth contact, which produces wear points on the surface contact points between the teeth (Hillson 1996). With keeping this in mind, it must be recognized that diet alone is not wholly responsible for tooth wear, but that dental abrasion produced the act of chewing also produces a marked effect on the morphology of the teeth overall.

The main focus of this study in analyzing the teeth from the K'axob sample is to examine the impact that not only diet had on dental health, by examination of the caries and infection, but also if the presence of caries and infection has any correlation with the amount of wear observed. As it has been observed in dental anthropology works that wear of the teeth can aide in the prevention of carious lesions from forming as wearing of the teeth eliminates the initial caries before it can continue to grow (Hillson 1996). And if there are not correlations between wear and caries and infection prevalence is there any correlation with other factors such as age, sex, status, or time period lived of the individual?

The hypotheses are as follows:

1. The prevalence of caries and infection within a population will be lower in individuals exhibiting signs of significant wear of the surfaces of the teeth.

2. The prevalence caries of the dentition in a population will be significantly higher in individuals of the population that are of the older age group.
3. The prevalence of infection and caries of the population will be lower in Preclassic burials versus that of the Classic burials.

The null hypothesis for all cases will be that there will not be any observable correlations or difference in the presence of caries, infection, or wear based on the different factors. These hypotheses will be tested by observing the individual teeth associated with each burial and assessing the wear, number of observable caries, and if infection is found to present in any of the associated teeth or mandible/maxilla when available. In examining these hypotheses, the study will also evaluate differences among sex groups.

RELEVANCE

Caries and infection of the dentition have a profound effect on the overall health of an individual, as the presence of either or both of these can have a large impact in an individual's ability to eat and chew due to the levels of pain one would experience. With the Ancient Maya, dental technology available was not like that of what we have today to be able to rectify issues such as this. For individuals suffering from caries and infection, their quality of life would have diminished and also an increase in their mortality rate would occur in the cases of some. Undertaking a study on K'axob will allow for representation of smaller

sites in term of understanding paleopathology of the Maya, which will be done with my own research.

Research on aspects affecting health of the ancient Maya has implications for studies regarding dental health in the modern world also by adding to the body of knowledge in dental anthropology itself. Better understanding can be achieved if there is a correlation found between the presence of caries and infection of the teeth in relation to their wear. This has implications for studies in modern-day applications of dental anthropology also, in that dentition is versatile in the ability to provide information of past and present populations in areas regarding diet, use of the teeth as tools, and food preparation. Based on the wear that can be observed which occurs over time, specific aspects of the food consumed can be better understood as wear in many cases can indicate food which is much more coarse and gritty in texture, which over time will erode and wear down the cusps of the teeth during mastication. Wear also can occur due to humans often utilizing the teeth as tools themselves, lending a pattern of wear on the certain teeth over time in cases of prolonged use (Eshed et al 2006). Patterning of wear of the teeth in the case of the K'axob sample has shown that the presence of wear is that of occlusal wear from mastication and attrition. In the observed cases of wear on the teeth occurring from the use of tools, there is distinctive angling of certain teeth, while with the K'axob sample, this is not observed to be present.

Chapter Two: ANCIENT MAYA

The culture area attributed to the Maya consists of extensive portions of Mesoamerica, which includes the modern-day countries of Belize, Mexico, Guatemala, Honduras, and El Salvador. The Maya, unlike the other peoples within Mexico and Central America, were confined to a single, unbroken area in Mesoamerica (Coe 2005). The Maya and the other indigenous cultures in the region shared traits that were distinctive and unique to them and absent or rare elsewhere in the New World – such as hieroglyphic writing, a complex calendar system, knowledge of planetary movements, extremely specialized markets, and a complex, pantheistic religion which included divinities from nature as well as deities of royal descent (Coe 2005). Other culture groups that existed in Mesoamerica throughout other periods of history included the Olmecs, the Toltecs, the Teotihuacanos, and the Aztecs.

The ancient Maya occupied two regions, broadly defined by archaeologists as the highlands and the lowlands. The highlands are areas that are above one thousand feet elevation, with the lowlands consisting of areas with an elevation below that (Coe 2005). The highlands occupied by the Maya include western Guatemala, Honduras, El Salvador, and the southern portion of Chiapas, Mexico; while the lowlands' ancient Maya occupation encompass the areas of Belize and the Yucatan Peninsula, which can be further broken down into the northern and southern lowlands (fig. 2.1). The northern Maya lowlands area

consists of the Yucatan Peninsula, while the southern lowlands are made up of Campeche, Mexico, Petén, Guatemala, and Belize. The lowland climate is one that is tropical, consisting of rainforests and swamp regions, while the highland climate is characterized as having drier and more arid environments (Coe 2005).

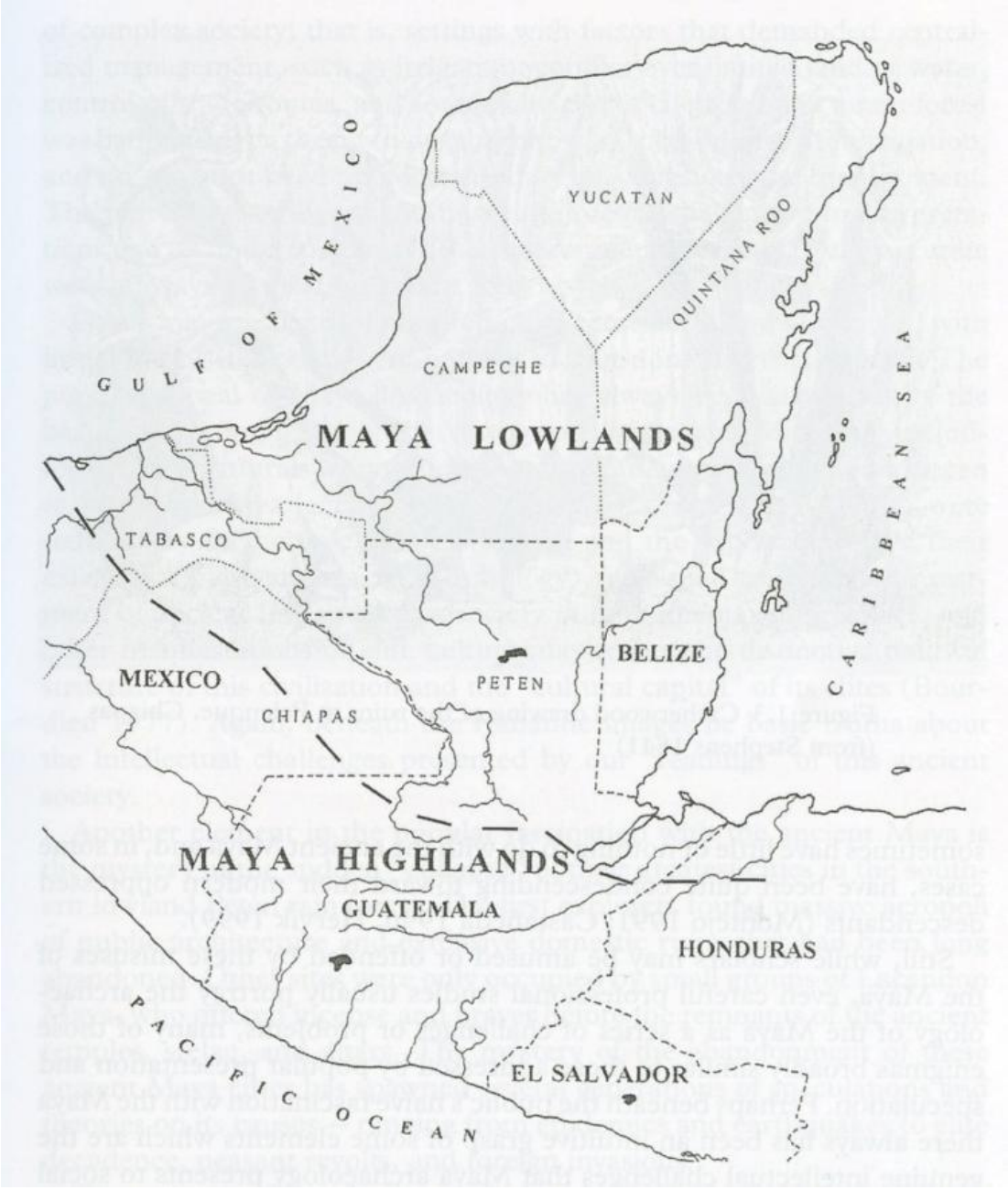


Figure 2.1: Map of Maya Highlands and Lowlands (Adapted from Demarest 2004, p. 3)

BRIEF HISTORY OF THE MAYA

Studies have shown that the ancient Maya population was able to flourish from 900 BC to 900 AD (Wright & White 1996). In the understanding and reconstruction of ancient Maya politics/polities, researchers have utilized a combination of epigraphic, ethnohistorical, and archaeological data (Foias 2013). The first Maya settlements occurred as the seasonal campsites in the region during the archaic period shifted to more permanent settlements. The chronologies of focus for this study regarding the ancient Maya will focus on the Preclassic and Classic periods as they are what have been observed and recorded to have been present at K'axob. In reviewing the literature related to the Maya, a great amount of attention is focused on the Classic period as that is where a great deal of the information in regards to the Maya in their own words is found. The Classic period is where the full emergence of hieroglyphic writing is seen in the Maya, along with the Long Count calendar, and grander styles of architecture (Coe 2005).

The Preclassic period is broken down into three stages: early, middle, and late; it is during the Preclassic, in the early stage, that we see the beginnings of agriculture as a means of subsistence, with the early Preclassic Maya growing domesticated maize, fruit, cacao and some root crops ("Preclassic Period," 2010). Politically, we see the introduction of chiefdoms in the middle to late Preclassic, which would have occurred as a shift from solitary villages to that of a multi or

supravillage polity (Marcus 2003). With the Early Preclassic Maya, the invention, or at least introduction, of pottery is seen around 1,800 BC on the Pacific coasts of Chiapas and El Salvador (Demarest 2004); this first pottery marks the Barra phase. During this phase ceramics are observed to contain thin-walled, neckless jars and deep bowls, as well as the first clay-fired figurines. The subsequent phases are the Locona (1,600 – 1,500 BC), which is where we see the introduction of vessels specifically for cooking and village organization under a single polity with a "capital" village after the Early Classic in the Maya region, and the Ocós (1,500 – 1,400 BC), which is a continuation of the Locona phase with the addition of a pottery decoration style known as cord-marking (Coe 2005). During the Middle Preclassic period is when the beginnings of buildings considered to be monumental architecture are observed, which brings the implications of large-scale labor mobilization, as well as villagers partaking in shared ritual practice and craft specialization (Doyle 2012). While there is evidence of monumental architecture during the Middle Preclassic period, villages in the Maya lowlands are limited in scale, complexity, and their architecture (Demarest 2004). By the Late Preclassic period, population growth is detected based on the findings of vast quantities of pottery at sites in many of the early components of the areas (Demarest 2004).

The Classic period in the chronology of the ancient Maya marks the beginnings of many innovations that are thought of as distinctly "Maya." The Classic period has been defined as the span during which the lowland Maya

were using the Long Count calendar on their monuments, and it was during this time period that the Maya began leaving vivid evidence of a new kind of society (Coe 2005). During this period is when we see the ancient Maya populations flourish in eastern Mexico, Guatemala, El Salvador, and western Honduras. It is also during this time that geographic variability is seen among the Maya in terms of material culture, agricultural practices, and socio-political structures, which is suggestive of a degree of regional isolation allowing for **variations to occur** (Scherer 2007). The Classic period also features courts in the Maya kingdoms, which separate the rulers from those under them, which was achieved by the heightening of inequality and diminishment of ease of access to the ruler. With this introduction of courts, there would also be a greater focus on the sorting of individuals based on rank or status, through assigning various titles, tasks, and positions (Coe 2005).

Maya Political Structure

Early on for the Maya, particularly in the Preclassic, there would not have been major distinctions of class or politics. It is believed that in the beginning, based on the equidistant spacing of major centers that the Maya in the lowlands did not see other centers as adversaries to be concerned by, but rather as political equals. Initially these distinctions between individuals in a population would have been understated, and not until the expansion and growth that occurs during the Late Preclassic/Early Classic periods, will social and political

distinctions be seen among individuals who would be those that ruled and controlled the wealth and influence throughout the region (Sharer and Traxler 2006). With the introduction of the ruling elite in the Maya regions, social distinctions would become more apparent and enacted in everyday life in terms of housing situations for the Maya in settlement centers. Particularly so when those ruling would utilize their community as a means of providing sustenance for themselves while effectively taking from them, in instances of areas that have limited resources. Although at sites situated such as that of K'axob, the region is plentiful enough that even with the ruling elite having the rural farmers provide for them might not affect the amount of food or nutrition that those who are not of the elite would have access to (Siemens 1982; Lentz 1991; McAnany 2004).

For some settlements, the reach of the ruling elite would not have been beyond that of their own settlement area, while others were able to expand into other settlements and centers allowing for greater growth and sustainability of their home center (Sharer and Traxler 2006). The importance of being able to have reach would not only allow for those in power to have a wider range of a "kingdom" but also that they would be able to acquire resources from farther locations that potentially they did not have access to in their environment. It would also allow for the establishment of trading systems, keeping a relationship open with not only those that they ruled, but with other rulers.

Landscape of Maya Lowlands

For the region of the Maya lowlands, environmental history has indicated that episodes of droughts were experienced, although the exact length, nature, and intensity are not known. It can be assumed though that these instances of droughts would have affected the types of plants available to the Maya in the lowlands regions, but could also have accounted for adaptations and developments, with some being related directly to food production (Valdez and Scarborough 2014). The lowlands' climate is that of having high heat with lakes and rivers being a rarity compared to that of the highlands. Agriculturally, the lowlands are not known for being uniform, as some soils are deep and fertile while others are lacking in fertility due to a lack of forest cover. In instances such as the latter, the Maya employed the use of a slash-and-burn system where the forest is able to regenerate at intervals as one area is cut down and that remaining wood and brush is burned at the end of the dry season, allowing for a cover to form from the smoke obscuring the sun and allowing for the planting of maize (Coe 2005).

Settlement of the Maya in the Lowlands

The presence of architecture throughout the Maya lowlands is wide and varied. In some settlements, there are grand palaces and city centers, while others tend to have more modest structures. For places that possess different

architectural types in one settlement, differentiation in class status can be seen, as there would be larger dwellings with multiple levels, while those in the more rural areas or those not on the same social ranking would live in dwellings of related family members that would surround a plaza of sorts that would keep them all connected (Demarest 2004, Houk et al. 2015).

It is not until the Classic period that evidence of expansion and what we know as distinctively "Maya" in terms of architectural structures and settlement patterns begin to occur. During the time of the Preclassic the Maya would have been in much more ruralized settlements in areas that would have provided adequate resources making the region desirable to set up a permanent structure. Having a steady supply or an environment that allows for the acquiring of food, whether it be plant or animal, would be a main factor in deciding where to establish a community for the Maya of the region, particularly in the lowlands where the unique environment and climate would allow for this in a variety of areas.

ANCIENT MAYA DIET

Diet for the Ancient Maya, specifically in the areas of the lowlands would have provided individuals with a diverse array of food sources. While not only being dependent on their natural surroundings for plant and animal resources, the ancient Maya also cultivated and grew their own food through agricultural

means and the raising of domesticated animals. In varying areas, different types of agricultural methods were practiced. Archaeological excavations and bioarchaeological studies provide evidence regarding agricultural methods practiced and what was cultivated and consumed by the population at the site. Based on evidence yielded by decades of research in the Maya area, it is understood that the Maya not only practiced a wide variety of subsistence methods, but also that this was in response to the complex landscape and available resources (Coe 2005; Killion 1992).

Animal Resources

An important part of Maya diet was the fauna of the region. Protein sources of meat for the Maya included breeds of dogs cultivated for food, along with wild turkeys, deer, peccary, partridge, wild pigeons, quail, wild duck, and armadillo. Evidence of these varying animal resources have been found at different sites and identified through analyses of the remnants of their remains. Fishing was also a means of acquiring meat for the ancient Maya; this was done offshore and inland. Depending on the location, aquatic fauna was used in varying amounts, based on availability and accessibility. Offshore fishing methods included sweep-and-drag nets, hook and line, as well as shooting fish with bows and arrows in the lagoons. While inland fishing was achieved by adding stupefying drugs into the water via pounding, with the fish floating into artificial dams where they were then taken by hand (Coe 2005). Evidence of

mollusks, terrestrial and aquatic, having supplemented the diet has also been found at some sites, such as that of K'axob itself (Masson 2004).

Agricultural Resources

The staple crop present for the ancient Maya was maize, and even in modern Maya households, maize has been documented as accounting for nearly 70% of the calories and proteins consumed (Coe 2005). Other crops that were also cultivated included beans, squashes, chile peppers, cotton, various forms of root crops, and fruit trees. These other foods would have served as a complement to the maize produced and used in the food. Having a diet heavily reliant on maize has been said to be unable to meet nutritional requirements, as researchers have argued that maize is deficient in iron, niacin, and certain amino acids, but that this would have been supplemented by the additional food sources available, particularly beans. With diets including processed maize and beans, adults are able to overall meet the nutritional requirements of their bodies. (Coe 2005; Gerry and Krueger 1997; Wright and White 1996).

Food Preparation

Ancient Maya diets were, and to date are still, high in the reliance on carbohydrates such as that of maize. Cucina et al (2011) discusses historical sources that have mentioned maize specifically as the staple crop of the area and prepared and consumed in a variety of ways. Foods such as that of tortillas,

tamales, drinks of either ground maize with spices and water, or fermented to make alcoholic drinks. Within groups, diets that are more varied are an indicator of the elite who would have greater access, while diets heavy in carbohydrates have been observed in the poor individuals (Cucina et al 2011). During the Preclassic period, human population density was lower and the availability of wild animals was higher, diet is characterized by lower maize percentages (Marcus 2003). The Mesoamerican diet is still reliant on the main food components of maize, chile peppers, and squash, with the specific process of maize preparation being distinctive to Mesoamerica. In this process, hard, ripe kernels of maize are boiled with a mix of water and white lime creating what is known as *nixtamal,* which is then ground on a *metate* (quern) with a *mano* (handstone) (Coe 2005). The importance of the *nixtamal* process is that maize is naturally deficient in essential amino acids and niacin, but the cooking with lime is able to enhance the balance of the essential amino acids and frees the niacin, which would not be available from the maize otherwise (Coe 2005). While the *nixtamal* process is important in what it provides for nutrition, the physical grinding of the maize through the use of a *metate* and *mano* allow for food types that are not going to be finely ground which will account for the wear seen in the dentition of the ancient Maya. By understanding the diet of not only the ancient Maya, but also that of K'axob specifically further on, we can better understand what types of substances were coming into contact with the teeth, which would in turn affect their overall health – including wear and caries formation.

SUMMARY

A variety of food sources were available to the ancient Maya throughout the region. Dietary variation in the Maya regions is based on the different environments the Maya occupied, which would allow for differing sources in terms of fauna and flora (Scherer, Wright, and Yoder 2007). By exploiting these different regions and their available resources, the Maya were first able to move into the area and settle in. It was once this was achieved that we see the emergence of forms of agriculture, allowing for the ancient Maya to become more sedentary, but to also be able to provide for themselves from the landscape. In undertaking a more sedentary lifestyle, the ancient Maya were able to focus on perfecting the practice of food production, but also to begin to work on experimenting with different types of architecture for their domestic structures and eventually for grander scale architectural endeavors.

Chapter Three: K'AXOB

K'axob (fig. 3.1) is the location of what was a pre-Columbian Maya village located in the northern wetlands of Belize between Pulltrouser Swamp and the New River (McAnany and Lopez Varela 1999). The wetlands of northern Belize include areas that are floodplains, lake margins, and tenuously connected swampland that is surrounded by terra firma (Siemens 1982). K'axob is situated in an area of Belize that is considered to be the wetlands. With the diversity available in the area of resources and mollisols, the area would have been very attractive to those who moved into the region. With the region being a wetland area, it is also very humid, which, as observed in the excavations, has made the preservation of the bone poor and what skeletal remains found have deteriorated or were never interred in the first place (McAnany et al 1999). Of these remains that have been preserved, many are incomplete skeletons, or very fragile, which has made studying of the teeth one of the options, as they are some of the best-preserved remains that can be studied. Even with the dentition being some of the best preserved, some teeth show evidence and signs of postmortem breakage and loss.

Figure 3.1: Map Detailing Location of K'axob, Belize (Adapted from McAnany and Lopez Varela

HISTORY OF K'AXOB

Two of the periods associated with K'axob that I will be examining are that of the Preclassic (Formative) and the Classic. K'axob's chronology is based upon the analysis of the types of ceramics that have been found as stratified deposits at the sites of domiciles. These phases for K'axob were established as the Formative, Classic, and Postclassic, with corresponding complex names for each. The complex names for the Middle and Late Formative periods are that of Chaakk'ax and K'atabche'k'ax, while the Early and Late Classic are known as Nohalk'ax and Witsk'ax, with the Postclassic being that of Kimilk'ax.

Domicile construction gives insight into the number of individuals living in the area and if the population was growing. Analysis performed on the excavation data resulted in the findings that construction of domiciles was most active during the K'atabche'k'ax complex (Late Preclassic), with 67% of these residences being built during this time (McAnany 2004). Examination of the Preclassic period architecture/structures has yielded that not many elite residences or palaces were present at K'axob during this time period. This is suggestive that there was not an intensive amount of class distinctions among individuals (McAnany 2004).

Test excavations at K'axob first began in 1981, with Patricia McAnany surveying and mapping the Eastern sector of Pulltrouser Swamp as part of the Pulltrouser Swamp project (McAnany 2004). This led to excavations over multiple field seasons from 1990 through 1998. Units excavated were given a

series of numbers, beginning with Operation 1 in 1990. During the initial field seasons of 1990, 1992, and 1993 the focus was on the Formative Period. The 1995 field season focused on the Classic Period, where pyramid building is seen to have occurred with the two pyramid plazas – Plazas A and B (McAnany 2004). Later field seasons, 1997 and 1998 focused on gathering information regarding the utilization of the wetlands (McAnany 2004). For each operation, archaeological deposits were grouped into construction phases and assigned numbers in ascending order (Fig. 3.2). The largest of these operations was that of Operation 1, which yielded the oldest materials and greatest volume of artifacts – this operation also included the highest number of burials with all the remains belonging to individuals from varying periods of the Preclassic.

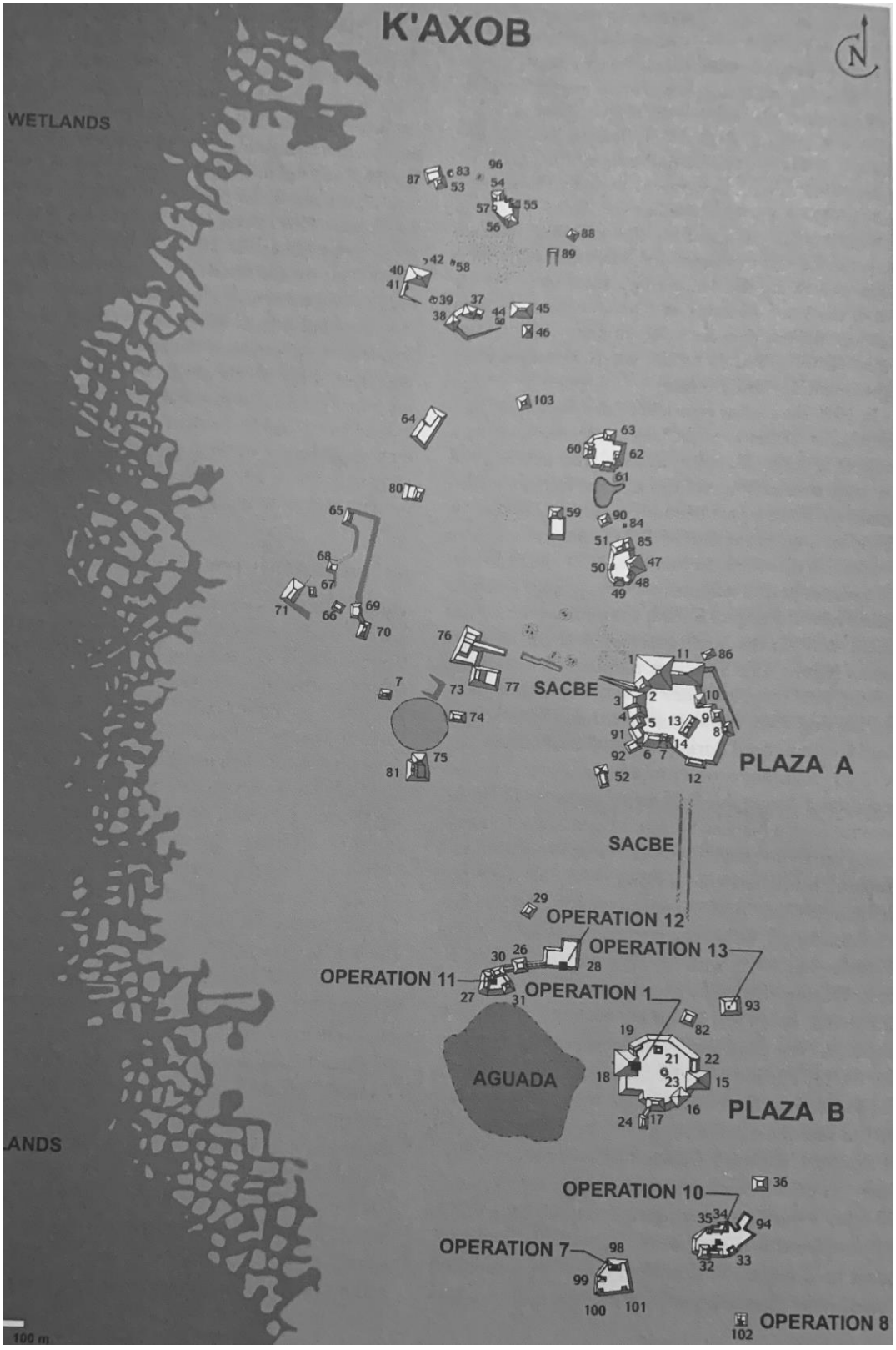


Fig. 3.2: Map of Operations at K'axob (Adapted from McAnany 2004)

Burials/Mortuary Treatment

Burials at K'axob not only span across time periods, but also in the differences in burial types found. Storey (2004) makes note of two basic types of interment seen at K'axob, primary and secondary. With primary interments, the individuals are placed in their burial location shortly after death and the skeleton has remained in the position of that at time of burial. With secondary interments, we see remains of individuals represented by that of a partial, disarticulated skeleton (Storey 2004). For burials at K'axob, a large amount were found to have been placed under domestic structures or in simple pits which were backfilled, and it has been discussed by McAnany that in these instances, such burial types cannot be considered representative of the population as a whole in terms of sex and age distribution This type of burial, in that of placing individuals under or close to living spaces in the subfloor of structures is reminiscent of ethnographically documented home-dedication rituals that take place among the Maya (McAnany, Storey, and Lockard 1999).

Of the burials (fig. 3.3), there were three different types of primary interments that were observed: extended, found on their left or right side or supine with the lower legs crossed; flexed and on either their left or right side; and seated with the legs crossed and arms resting on the knees of the individuals – these types of interments make up 58% of those excavated, with secondary and indeterminable burials making up 42% (McAnany, Storey, and Lockard 1999).

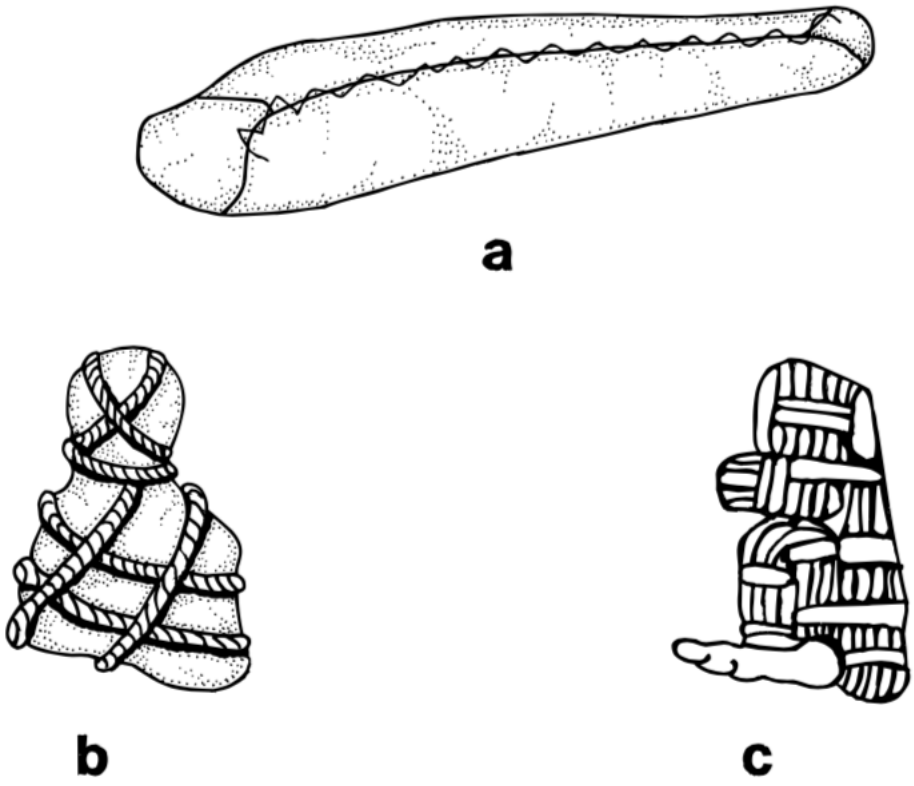


Figure 3.3: Depictions of burial positions observed - extended (a), seated (b), and flexed (c) (Adapted from McAnany, Storey, and Lockard 1999)

The importance of identification of the burial types found at K'axob is that this made it possible to ascertain as to why some individuals had a proportionately higher number of teeth present versus others. In the cases of secondary burials, these individuals have been relocated from their primary interment, which can account for the absence of bones and teeth associated with a burial. In many instances, the secondary interments were burials that individuals did not have an entire set present of teeth, and in some cases, none at all. Acknowledging these two interment types allows for being able to

understand the variability among burials, which would could otherwise have been overlooked and affected how the data was interpreted.

Politics at K'axob

In regards to political systems and modes of governance, not much is known for the early systems of the Maya region itself, although, there are typically two sets of "camps" regarding opinions for the origin of and organization in regards to the exact form and time span that Olmec governance would have taken place (Clark in McAnany 2004). These two are that either Maya principles of statecraft could have existed from the beginning in the Mirador Basin, if Maya principles were grafted from the Gulf Coast, or that rulership was reinvented based upon Olmec motifs – resulting in the independent emergence of a rulership institution during the Preclassic period (McAnany 2004).

Ancestor veneration through means of burying deceased relatives beneath the household structures could have served the purpose of strengthening not only the family lineage, but the rights to material property (Gillespie 2002). This practice of burying ancestors beneath the domestic structures and patios is seen to occur at K'axob. For residents of K'axob it is believed that lineage was an important factor in having more control in the community and access to the best agricultural lands (McAnany 2004; McAnany and Lopez Varela 1999).

Landscape of K'axob

The earliest evidence from K'axob comes from the Middle Formative period deposits recovered from the site. Based on these findings of faunal and floral deposits, residents that initially arrived in the region would have probably been attracted to the diverse resources. As observed in the faunal (aquatic and terrestrial) and floral remains. K'axob's soil makeup, which is a tropical variant of rich mollisols allowed for greater desirability of the region as this made for soils that were more drought-resistant than those of other regions. (McAnany and Lopez Varela 1999). Much of K'axob's farming was performed in Pulltrouser Swamp, allowing for unique methods of agricultural practice. Certain features that were useful in farming at Pulltrouser Swamp was that of a canal system to allow for the crops to attain adequate amounts of water, but also allowed for the collection of food from the canals themselves, such as that of a variety of mollusks and fish. To get the most of the swampy region and annual flooding, sloping areas were fitted with raised or drained fields that allowed for better crops that would not be flooded out for extended periods of time. Other benefits to the agricultural system of having raised fields is that of the associated canals which provided added nutrients that could be mucked into the field to better facilitate better crops (Siemens in Flannery, 1982).

Pulltrouser Swamp itself has a variety of vegetative associations (fig. 3.4); the *botan* forest, *escoba* forest, saw grass community, and grass savanna, which

seem to correlate to the spatial variability of available local water (Darch in Turner II & Harrison, 1983). Each of these vegetative associations plays a unique part in the areas in which they are found. The *botan* forest association is seen to occur on the border of the area that is Pulltrouser Swamp, with this section of the swamp featuring palm species as the dominant vegetation. In the *botan* forest association, there is a high number of trees, with it having been estimated at .44 trees per square meter. Further inward of the swamp is the *escoba* forest which features and is dominated by leguminous trees and shrubs, while even further inward of the swamp is the saw grass community. The saw grass community features a dense ground cover, which allows for the soil to remain saturated as it impedes excessive evaporation from the soil. The grass savanna association is confined to the region referred to as Pulltrouser-West, which is made up of herb coverage of grasses and scattered savanna trees (Darch in Turner II & Harrison, 1983; Scarborough 1985). Having a variety of vegetative associations in Pulltrouser Swamp allowed for differing methods of agriculture and use of the land itself, as the changing of available vegetation and soil moisture levels in the swamp allowed for varying crops to be grown, and for the utilization of more than one method of agriculture.

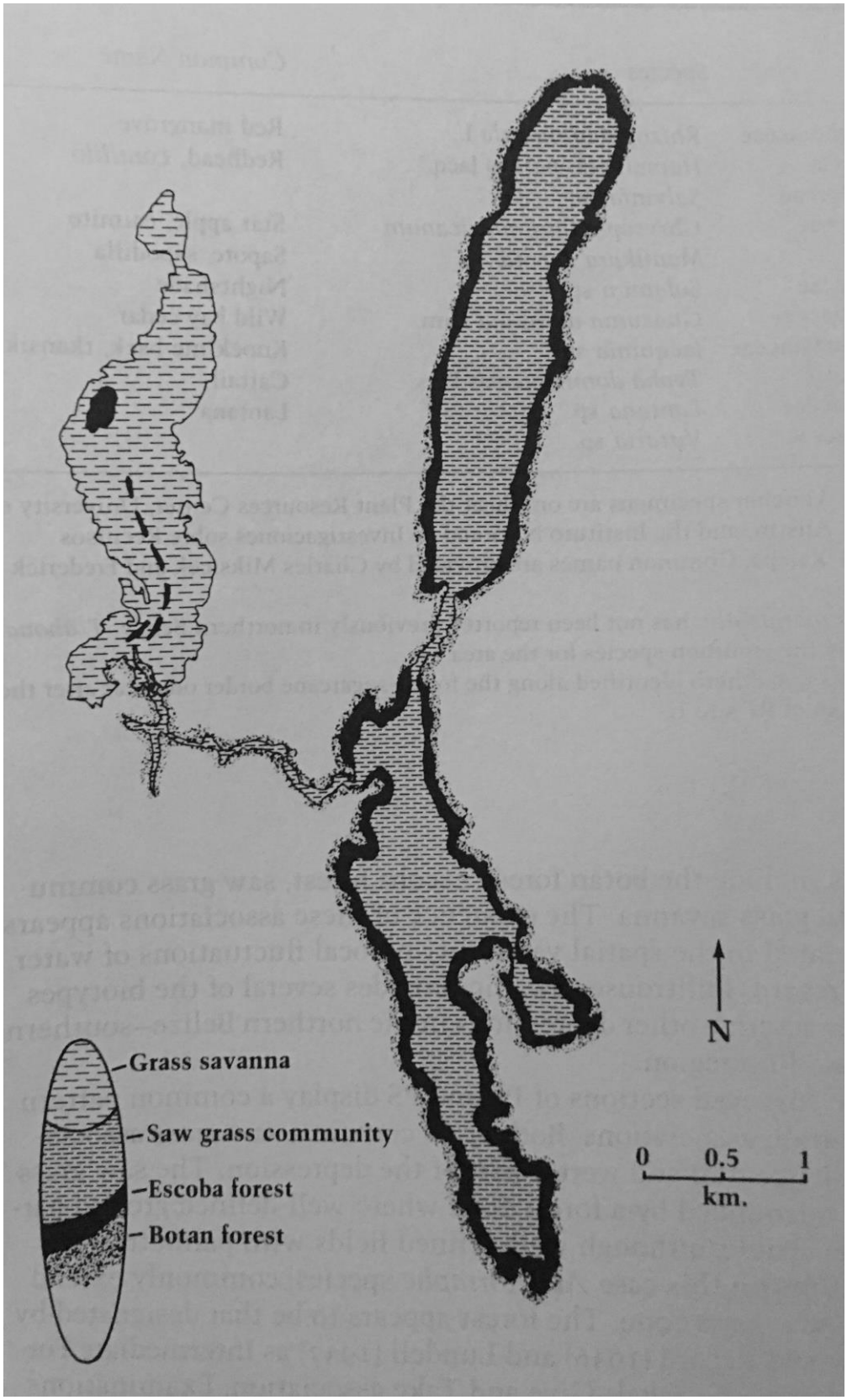


Figure 3.4: Map of Vegetative Associations of Pulltrouser Swamp; adapted from Turner II and Harrison

RESOURCES

Plant Resources

Remains of plants and plant spores have been found throughout many lowland Mesoamerican sites. The earliest of which have been found in 3,000-year-old deposits at the Cuello site in Belize, along with other Formative sites such as that of Copan, Pulltrouser Swamp, and Cerros (Miksicek et al, 1991). Particularly in relation to Pulltrouser Swamp, certain remains of plant matter have been found that allude to the type of diet and agriculture individuals would have partaken in. Types of plant matter remains found have included bean, squash, cacao seeds, maize corncobs, avocados, and cotton. While most of these were plants that were grown as a means of sustenance, cotton was used for its fibers and its seeds for a source of oil (Lentz 1991). With understanding the plant resources that were available to the Maya, it is best to take into consideration the benefits of the combination of certain plant food items in terms of nutrition. The combination of beans and maize in the diet provide essential amino acids for human nutrition, with the beans providing where the maize is deficient in terms of proteins available (Lentz 1991).

The importance of understanding these types of plant resources is that it allows for a better understanding of the available diet of the individuals of K'axob, but also certain types of plants have observed methods of preparation as discussed earlier, which can affect the dentition as well as nutrition. Different plant food sources provide a variety of nutrients, sometimes more when eaten in

conjunction with one another as one source will complement or provide where the other food source cannot.

Animal Resources

Findings throughout all periods at K'axob have yielded evidence of animal exploitation patterns of a variety of aquatic and terrestrial animals (Masson 2004). Based on K'axob's unique location, situated between the New River and Pulltrouser Swamp, residents would have had access to a wide variety of aquatic animals for a means of sustenance. This is also including the canals utilized in their agriculture at Pulltrouser Swamp as they would have provided an environment that was beneficial for certain small fish and freshwater bivalves. Not only is there a recorded presence of freshwater mollusks, there is also that of the land species of snails that are available in the region. Although it is noted by Covich in Turner II and Harrison (1983) that it is not possible to evaluate the cultural exploitation of mollusks as food, ornamental usage, or as ritual items until the predation by nonhuman predators/consumers in the region is well understood. This is due to certain nonhuman predators/consumers inflicting markings on mollusks' shells during the process of attempting to catch, kill, or even eat the mollusk.

Masson's research found that freshwater fish and turtles were the most abundant remains found in relation to aquatic species. Terrestrial mammals were also present in the faunal remains found, which included small and large game

animals such as that of armadillos, foxes, dogs, deer, and peccary (Masson 2004). Diets consisted highly of fish during the Early K'atabche'k'ax and Early Nohalk'ax periods based on Masson's research of the faunal remains at K'axob. The secondary highest source of animal protein came from that of medium and small animals, with common species identified as canids being present in all samples taken and armadillo in five out of six, along with agouti in two of the six samples (Masson 2004). Other food sources at K'axob observed by Masson included that of reptiles and amphibians, although this was typically turtles, with small amounts of amphibians and other small reptiles such as that of snakes having been found. By supplementing the diet with protein of terrestrial and aquatic sources, the inhabitants of K'axob were able to have a varied diet that could adjust to the changes of present fauna in the area and not be dependent on one sole source of protein. This allowed for the ability to not only adjust to fluctuations of availability, but to also hunt for the animals that would have been more abundant and avoid overhunting/fishing of their resources, allowing for a regular source of food.

Chapter Four: PALEOPATHOLOGY AND DENTAL CARIES/INFECTION/WEAR

DENTAL CARIES, INFECTION, AND WEAR

Caries are lesions of the teeth that are much like caries, but are irregular, being found typically on the contact points between the crowns of the teeth, in the fissures of the occlusal surface of the molars, and around the cervix of the teeth. In some instances, the caries can progress in combination with wear that occurs due to the abrasion of the tooth surface due to small abrasive particles found in the food, such as grit from bones or grinding stones, soil or dust, or even microscopic particles found in plants (Hillson 2008). With the progression of wear from abrasion from particles in the food or the attrition of the teeth that occurs during chewing, underlying dentine of the teeth can become exposed (Hillson 2008).

Caries and infections of the mandible and maxillae give insight to what the diet could consist of in terms of food being high in sugar, as the introduction of sugar in the diet has allowed for more caries to occur (Hillson 2008). Teeth are especially prone to carious lesions when carbohydrates comprise a significant portion of the diet (Navia 1994). It can also allow for understanding the nature of the food consumed, in that teeth will show signs of wear based on the varying degrees of coarseness of foods consumed.

What Caries/Infection Tell of Diet and Nutrition

In most cases of looking at the dentition of individuals as a means of learning about a society's diet and health, the main area that is looked at first is that of linear enamel hypoplasia, as the occurrence of such indicates periods of stress and lack of adequate nutrition in the diet. Many have looked at this as a first indicator of gathering information regarding a society's health and nutrition, as it allows for being able to see if individuals experienced nutritional stressors during their growth and development stages and on through the emergence of adult teeth. The presence of linear enamel hypoplasia takes the form of lines seen to occur either horizontally or vertically in the enamel of the teeth. What these tell specifically are of systemic stress endured by an individual during a specific time in their life when the teeth would have been developing, and also make it possible to date the defects as to when they happened in an individuals' lifetime by matching the defects in the crowns of different teeth (Waldron 2009).

Another means of understanding the health and nutrition of a population based upon the evidence found in the dentition is that of examining and looking for the presence of caries and infection, along with the wear of the occlusal surfaces of the teeth. When examining this aspect of dental health, interpretations regarding not only the health of the individuals can be made, but also as to the types of sustenance that were available at the time. The presence of caries in the teeth provide evidence of the types of foods that would have been available in that caries development, which will be discussed more in depth

later, occurs based on the bacteria present in the mouth and on the teeth. These caries can further develop into infections of the tooth, which also affect individuals' overall health and wellbeing. Other causes for infection can be observed, and will be discussed in the section covering the formation of infections of the teeth. When certain bacteria are present in the mouth, it can begin to go through a fermentation process producing acid that will erode the mineral composition of an area of the tooth it is present on. Infections of the teeth occur in cases where the bacteria in the mouth has created a carious lesion, and continues to cause for the lesion to grow in size (Waldron 2009).

In the case of what can be a contributing factor to the propensity to develop caries, research has been done as to whether aspects such as that of sex, diet, and status can have an impact. Differences in terms of susceptibility to caries in a population based on sex have been examined by researchers. It has been observed that in comparisons of a wide range of populations of varying time periods and locations, that there is a pattern of a higher prevalence of caries in the adult females of the populations versus that of the males (Larsen 2015). This difference in terms of caries prevalence suggests that there is a food consumption in a population would have been different between the sexes, with the females of a group potentially ingesting more of the plant matter, which would account for a greater consumption of carbohydrates, versus that of the males. Although as mentioned by Larsen, there is another factor to consider in terms of the differences between the prevalence of caries in men and women in

an archaeological context – it has been observed that in females, the teeth tend to erupt earlier than those of males, which would make for the teeth having longer exposure time to caries causing factors (Larsen 2015). In analyzing the difference among statuses, research has provided evidence to suggest that the dichotomy between the food consumption patterns of a society based on social ranking can also have a profound effect on the prevalence of caries in a population. As in some populations, the marked difference among social status would mean that individuals of varying status would have access to different foods. In terms of the Maya of the Classic period, Larsen (2015) makes note that it has been observed that elites show differences in caries prevalence versus that of the non-elites, with the elites showing lower levels of caries prevalence at certain sites. It is suggested that these findings indicate that the elite consumed less maize than the non-elite on a regular basis, with a greater amount of access to animal protein and diversity in the diet itself versus that of non-elite individuals (Larsen 2015).

Based on these findings regarding status differences as well as with the differences that have been observed between sexes, the individuals at K'axob present an interesting case. The burials at K'axob mostly come from the Preclassic period, which is when there was not as much of marked difference between elites and non-elites as is seen in late Classic period centers. So in the case of K'axob, the assumption can be made that more of these caries and infections would have been due to the factor of the sex of an individual and what foods overall were available to the population as a whole.

Formation of Caries and Infection

Dental caries are a result of the demineralization of the dental hard tissues by fermentation. These can manifest in various stages from enamel opacities to partial or complete destruction of the crowns and roots of the teeth (Hillson 2008). There is known to be an extensive process that occurs in the mouth due to pH levels working to stay balanced and helping in the prevention of caries. The saliva in the mouth has a buffering effect on the pH levels, which is lowered during the day because of the organic acid produced during fermentation of bacteria present in plaque, which in turn causes the mineral component to start to dissolve as pH is lowered (Waldron 2009). With the buffering effect of the saliva, pH levels are raised to a neutral state that allows for remineralization to occur in the teeth allotting for the prevention to an extent of caries production and demineralization of the teeth from plaque bacteria (Hillson 2008). To have caries formation, there are three main factors to consider in terms of how they occur. These include – the surfaces of the teeth themselves which are exposed to the oral environment; the presence of complex aggregates of oral bacteria (particularly *Streptococcus mutans and Lactobacillus acidophilus*), salivary glycoproteins, and inorganic salts adhering to the tooth surfaces; and diet itself (Larsen 2015).

In terms of the diet's effect on the prevalence of caries, it has been found that foods higher in carbohydrates like that of plants would have caused for a greater presence of caries. This is due to the nature of how the saliva breaks

down the carbohydrates during the process of mastication, which causes for bacteria in the mouth to be able to have a food source. In the breaking down of carbohydrates by the body, sugars are produced which in turn feed bacteria present, allowing for their growth and ability to be able to thrive and cause for destruction of the teeth in the form of caries (Larsen 2015; Hillson 2008; Lanfranco and Eggers 2012; and Waldron 2009). There is also the factor of grit present in the food available that can lead to extensive wear of the teeth during chewing. Wear such as this is much more prevalent in an archaeological context as today we now have greater access to machines which allow for our diets to have food that is much softer than what would have been allowed previously. Tooth wear has its benefits and drawbacks when it comes to caries and carious lesion prevalence, in that wear has been found to remove areas of the that were affected by carious lesions, but more so that is can also allow for new areas of carious lesions to develop (Hillson 2008). In the cases of these areas where the tooth has already been weakened by wear and a carious lesion is still able to form, we see infections sometimes begin to occur as the bacteria has done more than affected the enamel opacity, but has worked its way down into the root of the tooth. In these cases, the tooth can become infected and swollen, causing a great deal of pain for the individual. Some of the teeth present at K'axob showed signs of infection such as that of a swollen root (fig. 4.1) or through abscesses where the tooth has developed a hole and would have drained pus from the inside of the tooth (figs. 4.2 and 4.3)

Figure 4.1: I² with evidence of infection present in root

Figures 4.2 and 4.3: Molars with abscess of root

Chapter Five: MATERIALS AND METHODS

K'AXOB BURIAL SAMPLE

The sample being used will be that of a population from K'axob, Belize. This sample population is currently (mostly) housed at the University of North Carolina at Chapel Hill and contains individuals of varying ages, sexes, and social status. This allows for a wide scope of what I can look for in terms of learning about a population directly through analysis of the dentition. Certain factors regarding the population sample that I will be using have already been cataloged in an inventory in access and excel documents in terms of the remains found, burial positions, sex, age, and grave goods found. These factors were important in being able to analyze what I was able to find in terms of caries and infection prevalence in association with tooth wear in the group. The sample population from K'axob consists of 147 individuals recorded, spanning from the Chaakk'ax complex and ending with the Nohalk'ax burials. As with many other pre-Columbian groups of Central and South America, burials underneath or near the residences were a common practice (Storey 2004).

Burials with high associations of grave goods are thought to be those belonging to individuals of importance within the society, as more offerings either can equate to being of a wealthier class or that of an individual who is revered by those who lived in their society. Importance of understanding the burial samples on a societal level is that it allows for examination of whether or

not class played an important role if any in the overall health of an individual based on what foods they may or may not have had access to. In some societies, individuals of higher rank have access to the best foods available while those who are not as highly ranking do not. In the case of this it allows for those that are higher ranking socially to be able to maintain proper nutrition throughout their life and will show evidence of such in their skeleton. As individuals who would have grown up not having access will show indications of such on their skeleton, whether it be that the lack of nutrition only occurred during childhood and they were able to have greater access as they grew older, or if their lack of access to proper nutrition was maintained throughout their entire life.

Through the use of the K'axob burial sample, analyses could be performed regarding this variety of factors associated with the dentition that was found and processed from the site.

Methodology

Data was collected using methods for observing and notating caries, infection, and wear by initially performing an overall count of the caries observed for each tooth, along with notating whether or not infection was present and the scoring of wear based on a system of none, minimal, moderate, and severe, along with taking photographs of each individual tooth to document wear patterns and caries and infection. Wear that was indicated as being severe

was noted for the teeth that were present and had complete obliteration of the cusps of the teeth and in some cases down to the dentine. In these cases, it was possible that individuals may have at one point had caries or carious lesions that afflicted them during life but it would be indeterminable at the point of observation to see if these caused any issues for the individual.

Newer methods of studying teeth have emerged as scientific advances have been made, one of the most important being that of isotopic data analysis done with a mass spectrometer (Waldron 2009). Mass spectrometry allows for the ability to profile the elements found in the teeth and bone matter of individuals, which can then be compared to known elemental profiles based on available water in areas. Not only does this help in terms of understanding the available nutrients available when the child was first developing, it also allows for researchers to pinpoint where an individual is from, as in some cases it has made it so that instances of migration into areas can be documented. Unfortunately, this has not been able to be done for the teeth recovered from K'axob.

The goal of this research is to analyze and discuss not just the prevalence of observable caries and infection of the teeth in relation to tooth wear in Preclassic and Classic K'axob. Other aspects that will be analyzed and discussed in conjunction with caries and infection in relation to wear is that if there is any marked difference between age, sex, and time period. These extra factors could also help in understanding if there was any inequality in terms of nutritional

access during the Preclassic when it is believed to have been fairly equal, or if any changes can be noted between the Preclassic and Classic periods.

After all data was recorded and entered into SPSS along with supplementary data detailing burial position, grave goods, and ceramic complex that the burials were found to be buried in, courtesy of an excel spreadsheet from Dr. Storey, tests were able to be run in SPSS. With the remains being poorly preserved due to the environment of K'axob, this document was extremely helpful. Along with reviewing the field notes taken regarding each burial, which indicated if in the field of immediate observations regarding sex, age, number of individuals found, and if the individual appeared to have any infection present on the bone. In undertaking this study, the resources of Bioarchaeology by Clark Spencer Larsen, Paleopathology by Waldron, and Human Osteology by White, along with the works in McAnany's book, K'axob.

Burials from K'axob were from 11 different excavations, also called operations, during such, each excavated burial was given a number beginning with 1 and in the instances of burials including multiple individuals, letters were placed after to differentiate between individuals. For example, the first burial found during Operation 1 was labeled as that of 1-1a through 1-1g, indicating that in one burial, remains of seven individuals had been found.

Dentition Sample

Without the use of the available dataset and field notes, I would not have been able to make accurate determinations regarding sex and age, due to the degradation of the remains themselves. In total, there were 105 individuals in the burial sample that I analyzed from K'axob, 13 burials that did not have teeth present to be used in the analyses of the state of their dentition, but are useful in understanding the sex and age variation present in the burials of those in the region and time periods. For some of the tests regarding caries and infection rates, those with no teeth found with the burial will be excluded so as to have a better test for caries and infection prevalence. Other burials which did have information present from Dr. Storey's excel spreadsheet, but were not able to be observed during the initial research process were also excluded; it is unclear at this time where these teeth/burials were sorted as they were not present during initial research.

The Preclassic period, K'atabche'k'ax, (including the early, late, and terminal facets) had the greatest number of remains represented, with 40.9% (N=76) of individuals being associated with this period. While the early facet of Nohalk'ax has the fewest represented with 2.9% (N=3) of the population sample coming from this period. The remaining complexes are the early and late facets of the Chaakk'ax period and early and late facets of the Witsk'ax period, with 13.3% (N=14) and 11.4% (N=11) respectively (table 5.1).

Period

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	e chaa	8	7.6	7.6	7.6
	e katab	23	21.9	21.9	29.5
	e nohal	3	2.9	2.9	32.4
	e wits	10	9.5	9.5	41.9
	l chaa	6	5.7	5.7	47.6
	l katab	39	37.1	37.1	84.8
	l wits	2	1.9	1.9	86.7
	t katab	14	13.3	13.3	100.0
	Total	105	100.0	100.0	

Table 5.1: Frequencies of Ceramic Complexes

Upon examination of the dental remains of the burials, it became apparent that most were not found with complete dentition and that the teeth were loose and not situated in the mandible or maxillae. Fortunately, many of these were labeled as to what they had been identified as and their location in the skull during previous research. With looking at the dentition, many were examined and probed with a dental probe to check areas where caries were believed to be observed. In some instances, these were not actual caries as the probe did not "stick" and were more than likely superficial holes in the teeth, but it is uncertain whether these occurred ante or postmortem. Some of the teeth found were fractured postmortem and had already been put back together and bonded, while others were still in a fragmentary state. This shows precisely how hard on the skeleton itself that the environment of K'axob and its soil is on the preservation of human remains – if the teeth, which have been found to be the strongest and best lasting in terms of an archaeological context, are showing

signs of degradation, then the soil's pH levels and the overall environment itself must not be conducive to providing a conservatory situation.

Many of the samples did not include the full dentition for an individual. Full dentition was only seen in the case of burials 1-40, 11-7, 12-6, and 14-9, 14-10, and 16-4. Although burials 11-7, 14-9, and 14-10 had the presence of more teeth than the human mouth possesses (32), these were all identified as juvenile remains, which would mean this includes the presence of deciduous teeth in the overall count. Most of the other burials did not possess high amounts of teeth, but it must also be taken into account that many of these burials were deemed to be secondary interments rather than primary, so the allowance for teeth lost during the moving of individuals to their secondary interment must be taken into consideration.

VARIABLES/MEASUREMENTS

As mentioned previously, individual burials within an operation were given an identification number, with the single graves that included multiple individuals having a letter placed afterward. Estimates were made by Dr. Rebecca Storey of the University of Houston regarding the age and sex of the individuals, although based on the degradation of remains, some were left to be deemed indeterminable in regards to sex and/or age. Age estimation for determining juveniles versus adults was possible based on the eruption of the dentition, as there is a general timeframe that teeth begin forming and erupting

in the mouth which allows for the ability to be able to age a skeleton based on the teeth themselves when situated in the jaw or if all are present (White 1999; Waldron 2009). Although accuracy in determining an age range is possible from the dentition, there is still a "range" which is utilized, as narrowing down to an exact age is not feasible. For adult teeth, aging is made possible by making this determination based on the wear of the occlusal surface of the teeth (Waldron 2009).

DATA ANALYSIS

Data collected for caries was input into SPSS as a total number of caries observed on all the teeth of the individual. While a scoring system was utilized for the wear of the teeth: 1) no wear observed, 2) light wear, 3) moderate, and 4) severe. When it came to recording observations for infection, it was either yes or no, as those who did present signs of infection had advanced, readily seen infections of the tooth, while others may have had infection but did not show any outward symptoms on the tooth itself of an infection having abscessed (fig 5.1). Caries were also input into SPSS as "yes" or "no" for if they were present overall in the burial to allow for simpler tests to be run rather than seeing results based on the exact number of caries. Although running tests with exact numbers is also useful to be able to tell if there is a certain amount of caries present in the teeth across burials.

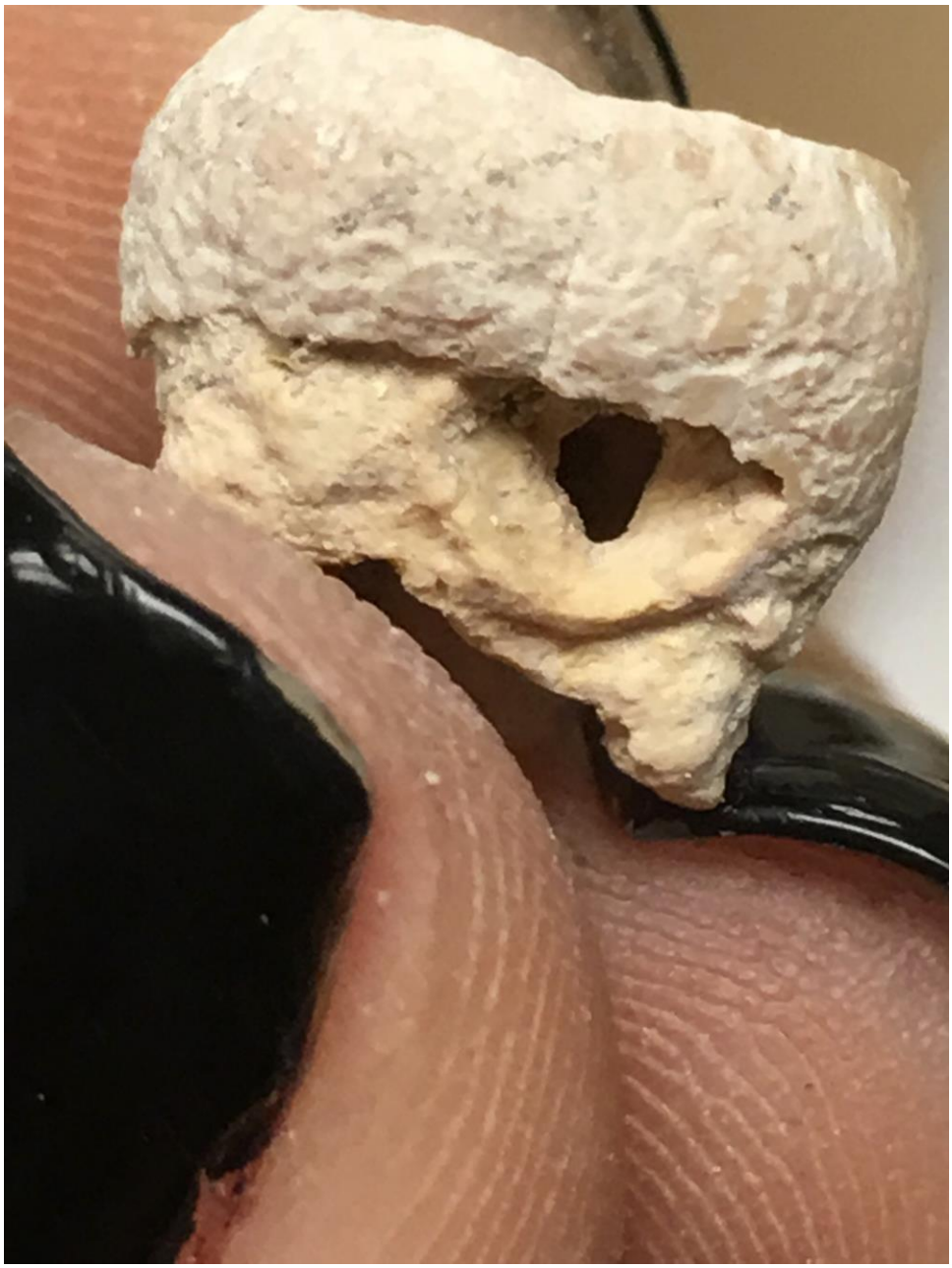


Figure 5.1: Image of Molar from Burial 16-4a

Upon initial input of data into SPSS, frequency tests were run regarding the population to be able to discern if there were any variables that occurred more than others. It was upon doing this that I discovered that the most prevalent sex was that of indeterminate, with 45.7% (N=48), followed by males with 31.4% (N=33), and females with 22.9% (N=24) (table 5.2). What this showed was that running tests based on sex with the data collected from the teeth alone would not be reliable, in that many of the individuals were not identified as male or female in supporting documents, which would make for an inaccurate assessment of sex distribution across complexes or in terms of understanding prevalence rates of caries, infection, or tooth wear. The high prevalence of indeterminate sex individuals is far greater than that of the identified male and female individuals, which would make for an inability to accurately determine factors associated with sex. The useful aspect appears to be that of testing by age, as the remains were able to be aged based on the skeleton and teeth present.

For age distribution, there were four categories assigned; Juvenile, which occurred at 28.6% (N=30), Young Adult 22.9% (N=24), Adult 37.1% (N=39), and Old Adult 11.4% (N=12). By running tests on age apart from sex, it allows for being able to see what the probable causation of the high number of indeterminate sex is due to, which is that of having skeletal remains of individuals that are juveniles – the ages that sexing the skeleton tends to be the hardest as it has not developed to the point of having distinctive indicators regarding sex. Among age groups, the highest number present is that of adults,

while juveniles account for the second greatest group, with young adult close behind in terms of numbers, and old adult have significantly lower levels of individuals present (fig. 5.2).

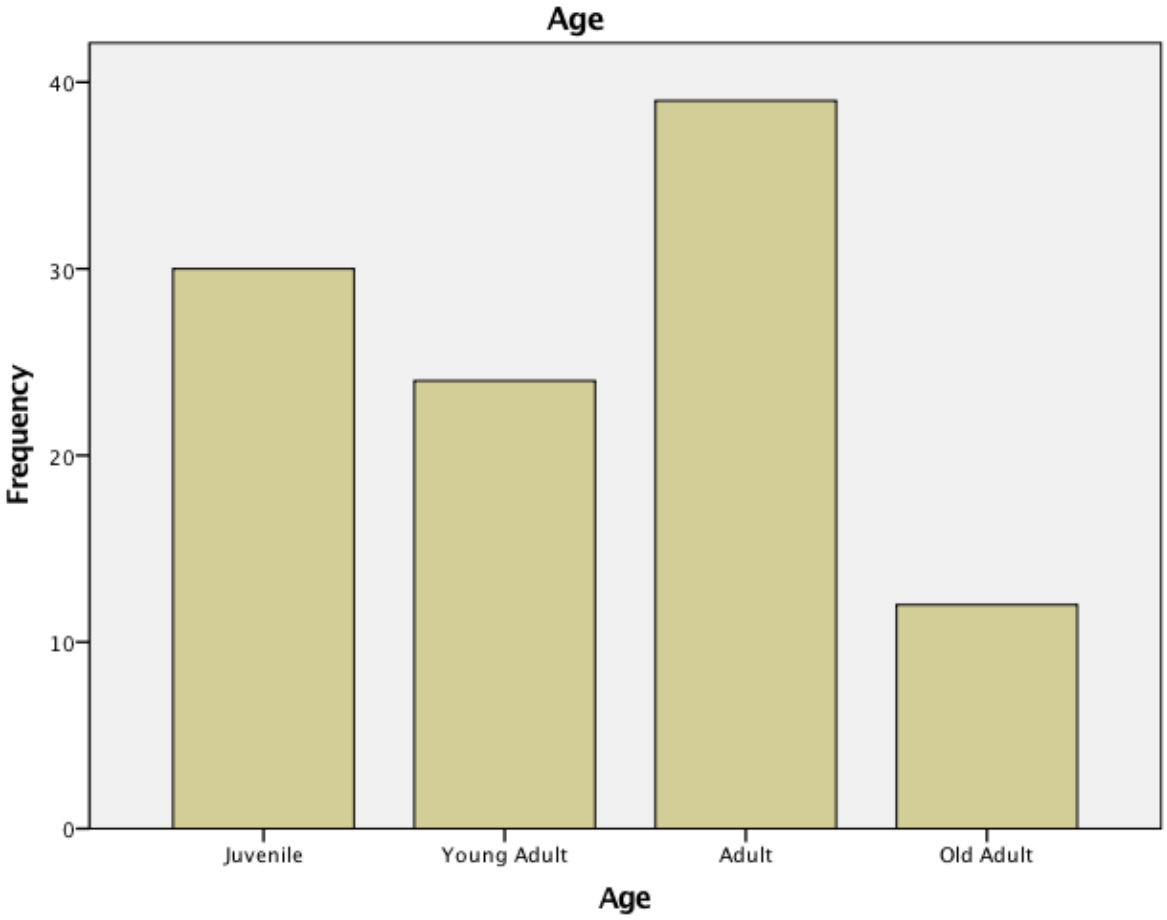


Figure 5.2: Frequencies for Age of Sample Population

A total of three tests were run on the data gathered to analyze if there is any significance and if any of the hypotheses presented are viable. These tests were first frequencies to be able to determine the overall occurrence of certain variables in the dataset and if they could be utilized in the other tests that would be run. Tests were run with the variable of sex for the sake of getting information regarding the known sexes. In running crosstabs on these groupings of

variables, my aim was to find if there was anything statistically significant associated among variables, such as with running crosstabs on age and tooth wear, age and infection presence, and age and caries presence. In running crosstabs, I also chose to include the variable of the number of caries recorded per individual, although this created a large chart and table, it allows for seeing if there is a certain amount of caries that seem to be the most common among individuals in K'axob.

Chi square tests were also of great use in analyzing the data recorded for the individuals. By running Chi square tests, I am able to test for statistical significance of variables, this is achieved by having a significance level of .05 or close to that in range.

SOURCES OF ERROR IN ANALYSES

Upon first running tests, I was including the burials which were present in the excel document I received from Dr. Storey, some of which included burials and information that I did not have the measurements of caries, infection, or wear for as these individuals were not present during my time of observation. Utilizing these burials as part of running tests was presenting results that did not allow for an accurate understanding of the data in terms of the variables. Another factor that was a source of error in analyses was the individuals who were considered indeterminate, as these burials were not able to make for

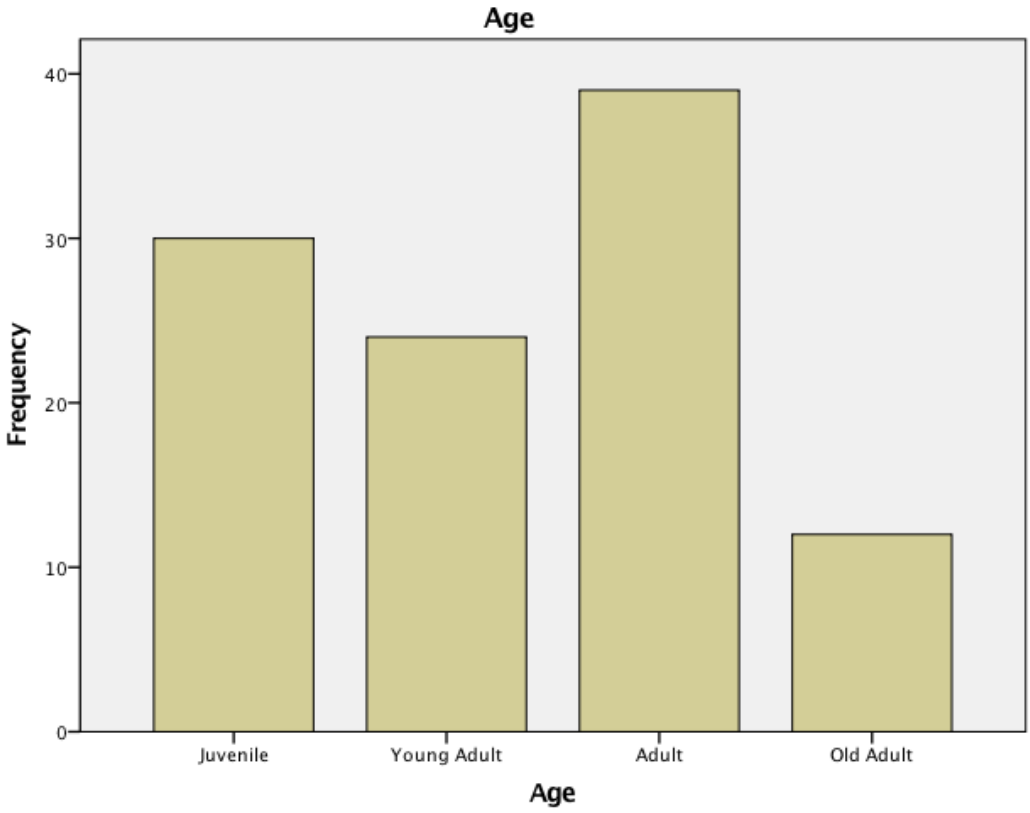
looking at sex in terms of understanding the population. When running tests with these two different aspects that caused for error, I was not able to get a more accurate picture of a sample population from K'axob in terms of caries, infection, and wear and what if any role sex or age plays in the prevalence.

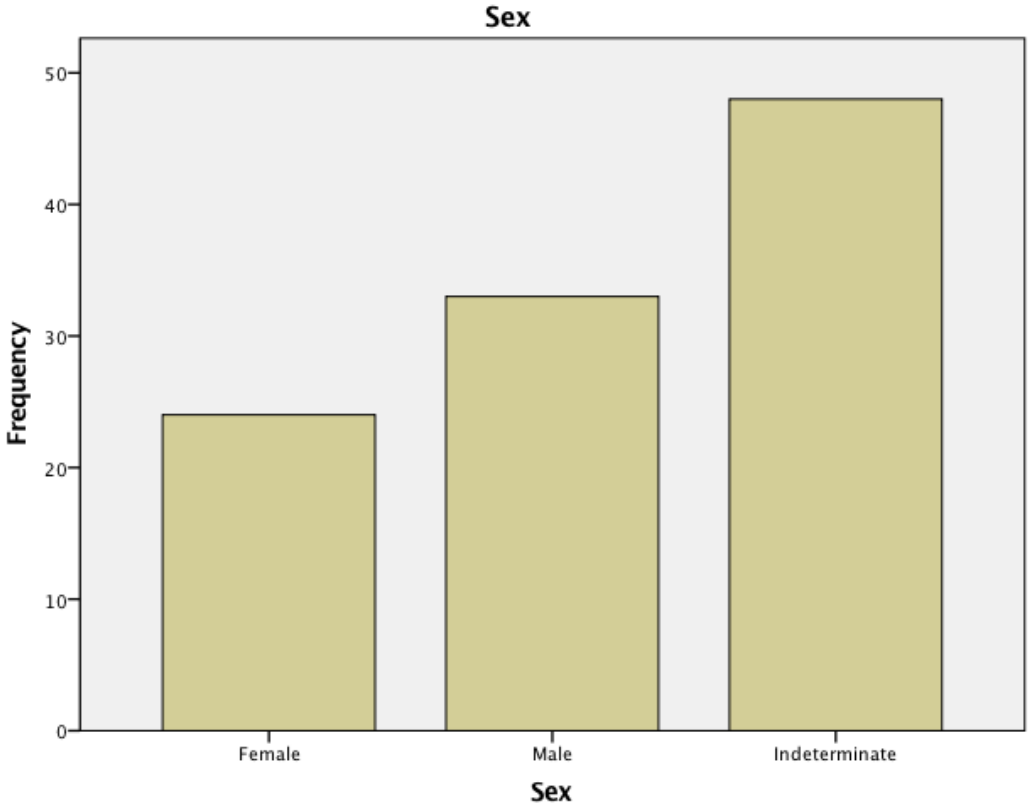
To examine this, I created a copy of the original dataset in SPSS and filtered out for the variables that had information for all cases first. In doing this I was able to filter out those that would give an incorrect reading during analysis as they were lacking information for caries, infection, and tooth wear.

When running the second set of tests this way, results were beginning to run more smoothly. It was after running the crosstabs for sex and other variables that I began to see a pattern emerging in terms of indeterminate sex skewing the data, as it is the variable with the largest amount. So for the sake of running tests to find out prevalence for known males and females, I decided to then select cases for those with known, identified sex, as this would allow for gaining a better understanding of the data in terms of sex being a factor. I believe many of the indeterminate sex scorings come from the fact that many of the individuals were identified as juvenile or young adult. For certain tests in regards to age rather than sex, these will not be omitted as it will give a clearer picture when analyzing and discussing age as a factor. The main issue with selecting for cases that only have been identified as male or female is that this brings the sample population down from 105 to that of 57. Which, while still greater than 30, which are an optimal size for a sample population for study, it does omit many

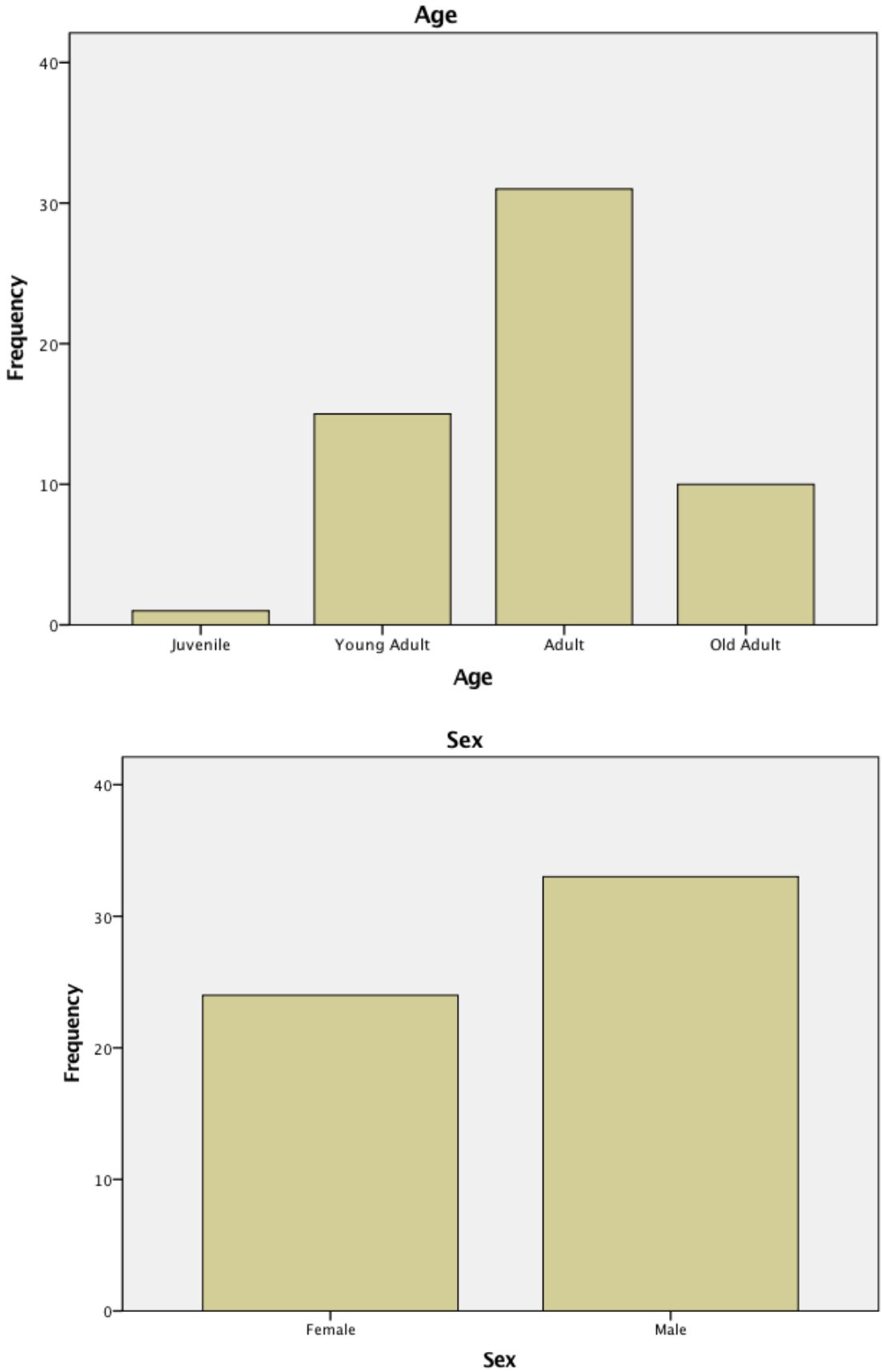
individuals that had the variables of caries, infection, and tooth wear.

For the sake of accuracy and to see the importance of the inclusion of the indeterminate for overall tests I will include the differences between age and sex variables with and without the omission of indeterminate which can be seen below in figures 5.3 and 5.4. As can be seen below between the two types of frequencies, omitting the indeterminate sex entirely for running of analyses is simply not feasible as the data would not be reflective or inclusive of the juvenile and young adults in the population. And to truly understand the population of K'axob as a whole, they must be included, particularly when running tests regarding age.





Figure(s) 5.3: Charts for Sex and Age Frequencies with Inclusion of Indeterminate Sex



Figure(s) 5.4: Charts of Sex and Age Frequencies with Indeterminate Sex Excluded

Chapter Six: RESULTS

DENTAL CARIES

Caries were observed in 80 individuals of the 105, or 76.2% (Table 6.1) that I had access to of the sample population from K'axob. Of these individuals, it is observed that there are 20 juveniles, 20 young adults, 31 adults, and 9 old adults that have the presence of caries. While 10 juveniles, 4 young adults, 8 adults, and 3 old adults did not have any caries observed. Total number of caries per tooth were recorded as well, the numbers of caries for individuals ranged from 0 in the instance of the 25 individuals who did not show signs of caries, all the way through to 39 in one individual, burial 8-2a, who was a young adult male that had 21 teeth recovered.

Crosstabs were also run on the caries present data and that of the operations and ceramic complexes to see if there was any significant correlation between operations and caries and ceramic complexes and caries. In running crosstabs on operations and caries presence, the results were that most of the caries observed were in individuals from Operation I, with 27 individuals from this operation having observed caries, accounting for 33.8% of the caries observed across operations. Operation VII had only 2 individuals, 2.5%, with caries observed, Operation VIII had 8 (10%), Operation X had 3 (3.8%), Operation XI caries observed was 10 (12.5%), Operation XII had 9 (11.3%), Operations XIII, XIV, and XV only had 1 (1.3%) individual with caries observed each, Operation

XVI had 11 (13.8%), and Operation XX had 7 (8.8%). This data can be seen in Table 6.3 as it also includes the totals and percentages of individuals that did not have caries by Operation. Performing crosstabs of these two variables ultimately showed that of most individuals observed to possess caries and to not all came from Operation I. Which could possibly be due to this operation finding the greatest number of individuals in a single excavation, while the following excavations did not yield as many individuals. An easier view of the dispersal of those with and without caries present is in the form of a bar chart attached below (Figure 6.1).

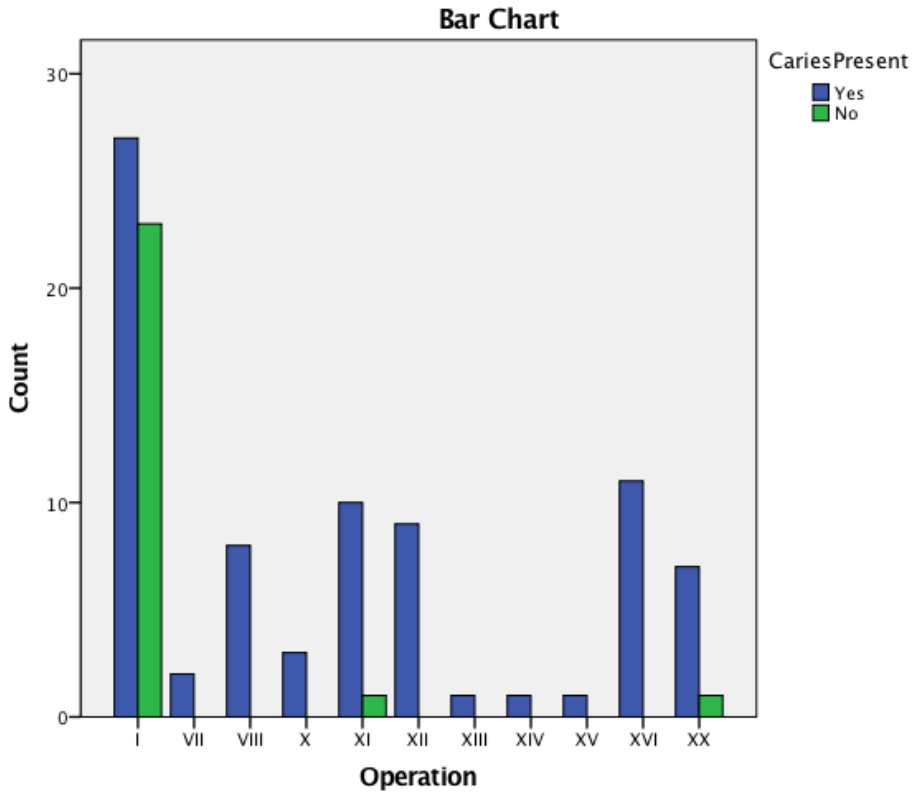


Fig. 6.1: Bar Chart of Caries Present by Operations

			Caries Present		
			Yes	No	Total
Operation	I	Count	27	23	50
		% within Operation	54.0%	46.0%	100.0%
		% within CariesPresent	33.8%	92.0%	47.6%
	VII	Count	2	0	2
		% within Operation	100.0%	0.0%	100.0%
		% within CariesPresent	2.5%	0.0%	1.9%
	VIII	Count	8	0	8
		% within Operation	100.0%	0.0%	100.0%
		% within CariesPresent	10.0%	0.0%	7.6%
	X	Count	3	0	3
		% within Operation	100.0%	0.0%	100.0%
		% within CariesPresent	3.8%	0.0%	2.9%
	XI	Count	10	1	11
		% within Operation	90.9%	9.1%	100.0%
		% within CariesPresent	12.5%	4.0%	10.5%
	XII	Count	9	0	9
		% within Operation	100.0%	0.0%	100.0%
		% within CariesPresent	11.3%	0.0%	8.6%
	XIII	Count	1	0	1
		% within Operation	100.0%	0.0%	100.0%
		% within CariesPresent	1.3%	0.0%	1.0%
	XIV	Count	1	0	1
		% within Operation	100.0%	0.0%	100.0%
		% within CariesPresent	1.3%	0.0%	1.0%
	XV	Count	1	0	1
		% within Operation	100.0%	0.0%	100.0%
		% within CariesPresent	1.3%	0.0%	1.0%
	XVI	Count	11	0	11
		% within Operation	100.0%	0.0%	100.0%
		% within CariesPresent	13.8%	0.0%	10.5%
	XX	Count	7	1	8
		% within Operation	87.5%	12.5%	100.0%
		% within CariesPresent	8.8%	4.0%	7.6%

Table 6.1: Crosstabs Results of Caries Present by Operations

Caries prevalence patterns were tested across the ceramic complexes as well to see if during certain complexes there is a prevalence of caries associated during certain facets of the Preclassic or the Classic periods of K'axob. In assessing this, crosstabs were again run to see if there was not only any correlation between caries and ceramic complex, but they were also run to see the associations of operations and complexes as well.

For the operations and complexes associated with them, crosstabs showed results (Table 6.4) that for Operation I burials excavated, 39 came from the K'atabche'k'ax complex, while the 11 other individuals accompanying with this operation are associated with the Chaakk'ax complex. Both of these are complexes associated with the Preclassic period. Operation VII had only two individuals and both were associated with the K'atabche'k'ax complex. Operation VIII had 8 individuals associated again with the K'atabche'k'ax complex. Only 3 individuals were associated with Operation X and all were of the K'atabche'k'ax complex. It is during Operation XI that we see again individuals from two complexes; again, this is K'atabche'k'ax and Chaakk'ax, with 8 and 3 individuals associated respectively. Operation XII is where we see a different ceramic complex has associated with burials, there is 1 burial associated with the Nohalk'ax complex, which is considered that of the Early Classic period, and 8 individuals from the K'atabche'k'ax complex. For Operation XIII there is only one individual and they are associated with the Nohalk'ax complex. By Operation XVI there is only one individual who is associated with the

K'atabche'k'ax complex, XV has 1 individual who is associated with the Witsk'ax complex, which is that of the Late Classic. Operation XVI has 11 burials associated with the Witsk'ax complex, and Operation XX has 1 burial associated with the Nohalk'ax and 7 with K'atabche'k'ax. Running crosstabs in this way showed that overall within the complex, 47.6% of the burials came from Operation I, which provides explanation as to why when running the crosstabs for caries by operation, the highest percentage came from Operation I as well. Doing this method of crosstabs analysis allows for further understanding of what period of time the individuals recovered came from. This also shows that many of the burials could be excavated during the first Operation.

The next crosstabs analysis that was run was that in regards to caries present in association with the ceramic complexes. This is to see if there is any correlation between period of time and caries prevalence. I found that the complex that had the highest number of caries present was that of the Late K'atabche'k'ax, with 41.3% (33) of the individuals with caries present having come from this facet. The complex with the lowest association of caries present was that of the Late Witsk'ax, with 2 individuals, accounting for 2.5% of what was recorded (Table 6.5).

After running crosstabs dealing with caries associations with the operations and complexes, I began looking to find if there were any correlations between sex and age and caries prevalence among individuals. This is important in understanding the dispersal of caries beyond the terms of time periods, but

rather on the individual level. For the age by caries present crosstab, I used the dataset, which includes those who have indeterminate sex, as this will provide a better view as to how caries are dispersed amongst age ranges that were present in the burials. The age ranges are that of juvenile, young adult, adult, and old adult. These were determined ahead of time during initial research by Dr. Storey and so her determinations are what will be utilized for the purposes of this research. In running of crosstabs, it was found that of the age ranges, those that exhibited the highest amount of caries was that of Adults, with 38.8% (N=31) showing signs of caries. While old adults accounted for only 11.3% (N=9) and juveniles and young adults had an equal percentage of 25% (N=20) each. This is not surprising in terms of the old adults having the lowest percentage of caries, as their group is the smallest in terms of representation among the burials. While the juveniles and young adults made up about half of the burials, which would be why they are evenly represented in terms of understanding the dispersion, and those in the adult range had the highest grouping, so based on percentages, it also makes sense that this age group had the highest prevalence rate (Table 6.6).

For the crosstabs tests run for caries presence by sex, the dataset with the excluded indeterminate was used to get an understanding of known male and female rates. For males and females, there was not as marked of a difference between one another in terms of caries present. For the males, 54.5% (N=24) showed caries present, while the females, 45.5% (N=20) showed signs of caries.

When comparing the two, overall there are more known male burials than females, with males being 33 and known females present totaling 24. While the percentages do show that overall the males tend to have shown caries more often, the percentage of men without caries versus that of women is also higher, as there are only 4 females who did not exhibit signs of caries and 9 males who did not. Which is an even higher percentage between the two than that of caries prevalence; 69.2% (N=9) for men, and 30.8% (N=4) for women in terms of no caries present.

The last test performed in crosstabs in relation to caries and infection presence was that of caries and infection presence in relation to the Preclassic versus the Classic periods. In running the initial crosstabs of the variables of caries present by the Classic/Preclassic variable. The results were that of the Classic burials, 100% (N=15) of individuals had caries present, while in the Preclassic, there were caries present in 72.2% (N=65) of individuals and no caries present in 27.8% (N=25) individuals. In running this test, risk estimates were also able to be run, allowing for understanding the associated risks of having caries based on the period. The results were that in terms of the risk of the outcome being caries, there was a 1.385% risk of either period developing caries. When the variables were reversed and a risk estimate was run, the outcome of Preclassic had a risk estimate value of .813%. These results show in both instances that, for the Preclassic and Classic periods, there is a risk of 1.385% of an individual developing caries in either period, while when ran in looking at which period

would show caries, there was a .813% risk associated with caries being dependent upon the Preclassic period as its outcome.

Crosstabs Summary for Caries Presence

Performance of crosstabs analysis for caries yielded results that allowed for being able to understand and see how caries are dispersed throughout K'axob, over time and across the ages and sexes. Running crosstabs for caries presence gave answers to some questions regarding the prevalence of caries and if they are evenly dispersed. By taking this data that has been produced from crosstabs, further tests can be run with this data as a supplement and helping in understanding the finding the rest of the tests present.

			Operation											Total
			I	VII	VIII	X	XI	XII	XIII	XIV	XV	XVI	XX	
Period	e chaa	Count	8	0	0	0	0	0	0	0	0	0	0	8
		% within Period	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Operation	16.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.6%
	e katab	Count	16	0	1	1	5	0	0	0	0	0	0	23
		% within Period	69.6%	0.0%	4.3%	4.3%	21.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Operation	32.0%	0.0%	12.5%	33.3%	45.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	21.9%
	e nohal	Count	0	0	0	0	0	1	1	0	0	0	1	3
		% within Period	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	33.3%	0.0%	0.0%	0.0%	33.3%	100.0%
		% within Operation	0.0%	0.0%	0.0%	0.0%	0.0%	11.1%	100.0%	0.0%	0.0%	0.0%	12.5%	2.9%
	e wits	Count	0	0	0	0	0	0	0	0	1	9	0	10
		% within Period	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	90.0%	0.0%	100.0%
		% within Operation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	81.8%	0.0%	9.5%
	l chaa	Count	3	0	0	0	3	0	0	0	0	0	0	6
		% within Period	50.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Operation	6.0%	0.0%	0.0%	0.0%	27.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.7%
	l katab	Count	15	0	5	1	3	8	0	0	0	0	7	39
		% within Period	38.5%	0.0%	12.8%	2.6%	7.7%	20.5%	0.0%	0.0%	0.0%	0.0%	17.9%	100.0%
		% within Operation	30.0%	0.0%	62.5%	33.3%	27.3%	88.9%	0.0%	0.0%	0.0%	0.0%	87.5%	37.1%
	l wits	Count	0	0	0	0	0	0	0	0	0	2	0	2
		% within Period	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%
		% within Operation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.2%	0.0%	1.9%
	t katab	Count	8	2	2	1	0	0	0	1	0	0	0	14
		% within Period	57.1%	14.3%	14.3%	7.1%	0.0%	0.0%	0.0%	7.1%	0.0%	0.0%	0.0%	100.0%
		% within Operation	16.0%	100.0%	25.0%	33.3%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	13.3%
Total		Count	50	2	8	3	11	9	1	1	1	11	8	105
		% within Period	47.6%	1.9%	7.6%	2.9%	10.5%	8.6%	1.0%	1.0%	1.0%	10.5%	7.6%	100.0%
		% within Operation	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 6.2: Complexes within Operations

			Caries Present		
			Yes	No	Total
Period	e chaa	Count	7	1	8
		% within Period	87.5%	12.5%	100.0%
		% within Caries Present	8.8%	4.0%	7.6%
	e katab	Count	11	12	23
		% within Period	47.8%	52.2%	100.0%
		% within Caries Present	13.8%	48.0%	21.9%
	e nohal	Count	3	0	3
		% within Period	100.0%	0.0%	100.0%
		% within Caries Present	3.8%	0.0%	2.9%
	e wits	Count	10	0	10
		% within Period	100.0%	0.0%	100.0%
		% within Caries Present	12.5%	0.0%	9.5%
	l chaa	Count	3	3	6
		% within Period	50.0%	50.0%	100.0%
		% within Caries Present	3.8%	12.0%	5.7%
	l katab	Count	33	6	39
		% within Period	84.6%	15.4%	100.0%
		% within Caries Present	41.3%	24.0%	37.1%
	l wits	Count	2	0	2
		% within Period	100.0%	0.0%	100.0%
		% within Caries Present	2.5%	0.0%	1.9%
	t katab	Count	11	3	14
		% within Period	78.6%	21.4%	100.0%
		% within Caries Present	13.8%	12.0%	13.3%
Total		Count	80	25	105
		% within Period	76.2%	23.8%	100.0%
		% within Caries Present	100.0%	100.0%	100.0%

Table 6.3: Caries Present and Ceramic Complexes

Age * Caries Present Crosstabulation

			CariesPresent		
			Yes	No	Total
Age	Juvenile	Count	20	10	30
		% within Age	66.7%	33.3%	100.0%
		% within CariesPresent	25.0%	40.0%	28.6%
	Young Adult	Count	20	4	24
		% within Age	83.3%	16.7%	100.0%
		% within CariesPresent	25.0%	16.0%	22.9%
	Adult	Count	31	8	39
		% within Age	79.5%	20.5%	100.0%
		% within CariesPresent	38.8%	32.0%	37.1%
	Old Adult	Count	9	3	12
		% within Age	75.0%	25.0%	100.0%
		% within CariesPresent	11.3%	12.0%	11.4%
Total		Count	80	25	105
		% within Age	76.2%	23.8%	100.0%
		% within CariesPresent	100.0%	100.0%	100.0%

Table 6.4: Caries Present and Age

Chi-Square Tests for Caries

The next test performed in regards to dental caries was that of the Chi-Square test, which tests for dependence and independence of variables in relation to one another. In running the chi-square tests, the first variables that I selected to test were that of caries presence and age, output of this test showed that age and caries presence were not related as the p-value for this test was .490, or 49%, well over the significance that we are looking for which is .05 or lower, which would allow for the rejection of the null hypothesis. After testing for the significance lambda was also looked at, with the approximate significance as .637, which again is not significant. This first test showed that age and caries presence was not dependent on one another. The next test performed was that of age by the total number of caries, again resulting in no significance, this time with a p-value of .738, meaning that in the case of age to total number of caries I still accept the null hypothesis that there is no correlation.

In running the tests regarding sex as a variable in terms of caries prevalence and also the total number of caries present, I used the dataset that had the inderminate variables omitted, to see if there was a direct correlation between sex and caries. Upon review of the chi-square test, the results were that there was a significance of .346, again causing for the acceptance of the null hypothesis that there is no correlation. The second test run in regards to sex with caries was that comparing sex and total caries counted, this had the lowest so far p-value with .231, but it is still too high to have an association. The second to last

chi-square test in regards to caries was that of tooth wear and its relation. Tooth wear was compared to caries presence as well as total number of caries observed, for the former there was finally a test that showed significance and required for the rejection of the null hypothesis, with a significance of .000 which shows that caries presence is dependent on the wear of the teeth, and with looking at Lambda, caries are dependent on tooth wear with a significance level of .048. The latter test being that of caries total and tooth wear, did not show signs of significance, with results for the p-value being .150, requiring for the acceptance of the null hypothesis.

Last of the chi-square tests run was that in relation to the presence of caries and the Preclassic or Classic periods. In doing this, the results were that of a p-value of 5.469 with a significance level of .019, which shows that there is an association between the Preclassic or Classic period and caries presence, meaning that the hypothesis can be accepted.

Chi-Square Summary for Caries

In running chi-square tests, it can be seen that in most cases in relation to caries presence there is no correlation to age or sex, but it does have an association to the wear of the teeth. While looking at the total number of caries counted, there is not an association in regards to sex, age, or wear of the teeth. So for running this test, only in one instance does the null hypothesis need to be

rejected and show that there is any correlation, while in all the other tests that were run in regards to caries showed that there was not an association.

DENTAL INFECTION

Of the 105 individuals, only 16 had evidence of infection present (Figure 6.2), to find out if there was a correlation in terms of infection, the same tests that were run for dental caries were run; frequencies, crosstabs, and chi-square. Again, risk estimate tests will also be attempted, with hopefully, results beyond that of being unable to complete the test. Dental infection was not scored but observed and recorded as yes or no for presence, as in the case of these teeth, and as mentioned previously, the only way that I was able to discern if there was infection present was if the tooth had abscessed, or in the case of one tooth, if the root was abnormally swollen and misshapen.

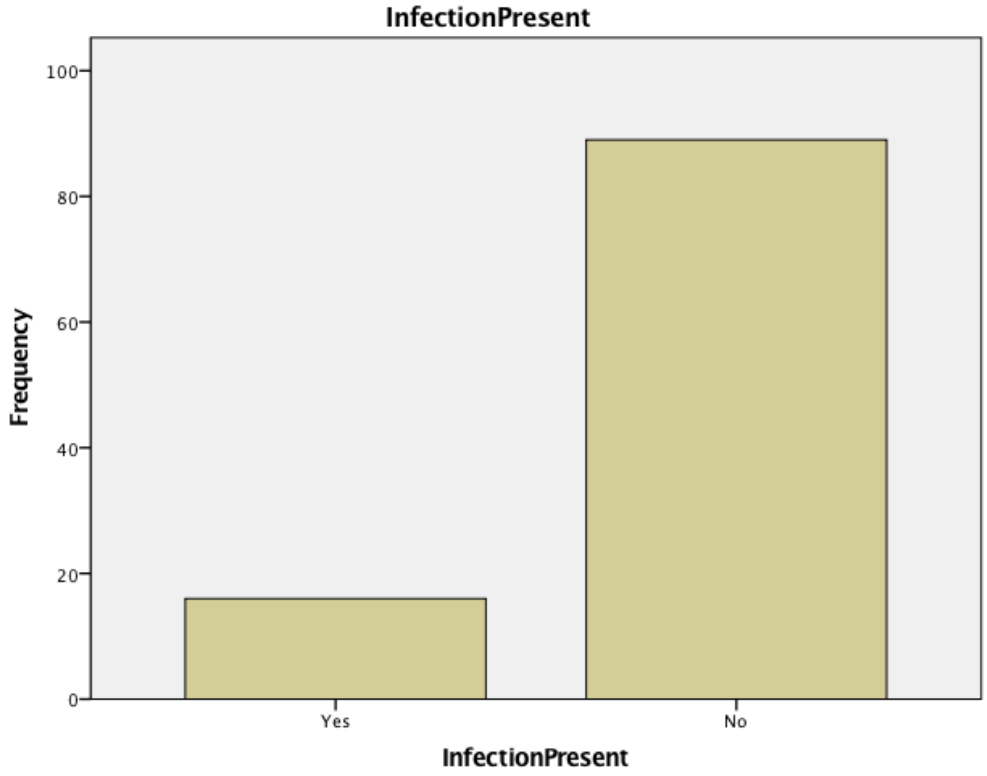


Figure 6.2: Infection Presence in K'axob Sample

After running the frequencies to find out how many infections overall were present in the teeth from the sample, the next test that was run was that of crosstabs, which included a variety of variables to test for. The first variables tested for in relation to dental infection were that of if there was any evidence of a correlation in terms of dental infection to the operations. Operations I, VII, VIII, XI, XII, XVI, and XX, all had instances of dental infection. The operation with the highest number of associated infections was that of Operation I having a total of 4 individuals with infection present, followed by Operations XI, XVI and XX having 3 individuals, while Operation XII only had one individual (Fig. 6.3). As to be expected, Operation I did end up having the highest recorded infections, but as the same with the caries, this operation yielded the highest number of

individuals, so it is not surprising that there would be a higher number of infections as there are more people to pull from.

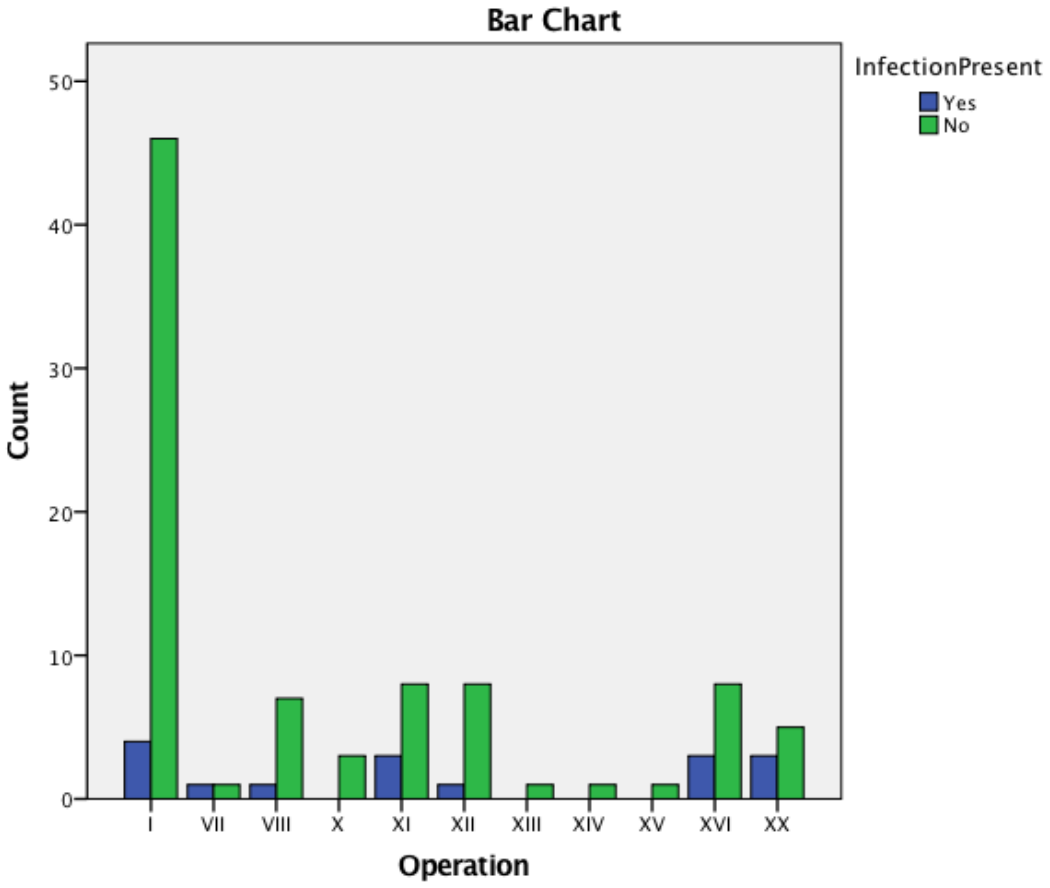


Figure 6.3: Infection Presence and Operations

The next comparison for crosstabs is that of infection present and the ceramic complexes. As mentioned in dealing with caries, the highest number of individuals excavated came from the facets of the K'atabche'k'ax complex of the Preclassic period, so it is not a surprise that the highest numbers of those with and without infection present have come from this complex either. For infection, 11 of the 16 individuals were from the K'atabche'k'ax complex, while 1 was

represented during the Chaakk'ax complex, 1 during the Nohalk'ax, and 3 during that of the Witsk'ax complex (Table 6.7).

			InfectionPresent		
			Yes	No	Total
Period	e chaa	Count	1	7	8
		% within Period	12.5%	87.5%	100.0%
		% within InfectionPresent	6.3%	7.9%	7.6%
	e katab	Count	4	19	23
		% within Period	17.4%	82.6%	100.0%
		% within InfectionPresent	25.0%	21.3%	21.9%
	e nohal	Count	1	2	3
		% within Period	33.3%	66.7%	100.0%
		% within InfectionPresent	6.3%	2.2%	2.9%
	e wits	Count	2	8	10
		% within Period	20.0%	80.0%	100.0%
		% within InfectionPresent	12.5%	9.0%	9.5%
	l chaa	Count	0	6	6
		% within Period	0.0%	100.0%	100.0%
		% within InfectionPresent	0.0%	6.7%	5.7%
	l katab	Count	6	33	39
		% within Period	15.4%	84.6%	100.0%
		% within InfectionPresent	37.5%	37.1%	37.1%
	l wits	Count	1	1	2
		% within Period	50.0%	50.0%	100.0%
		% within InfectionPresent	6.3%	1.1%	1.9%
	t katab	Count	1	13	14
		% within Period	7.1%	92.9%	100.0%
		% within InfectionPresent	6.3%	14.6%	13.3%
Total		Count	16	89	105
		% within Period	15.2%	84.8%	100.0%
		% within InfectionPresent	100.0%	100.0%	100.0%

Table 6.5: Infection Presence among Ceramic Complexes

Crosstabs were next run on infection presence and age (fig. 6.4), with surprising results of showing an affinity to an age group over the others, adults. In testing for age and infection presence, it was found that 68.8% (N=11) of the individuals that had infection present in their dentition were adults, while 25% (N=4) were old adults, and only one outlier of a young adult was present with 6.3%. This finding does fit that juveniles would not have the presence of infection in their teeth as there could be two reasons behind this, one is that they have not been exposed to as much food or environmental factors as adults and old adults have so their teeth are still quite hardy overall. While the other factor is that in the cases of if there was infection that occurred, it probably would have occurred in the deciduous teeth, which could easily fall out.

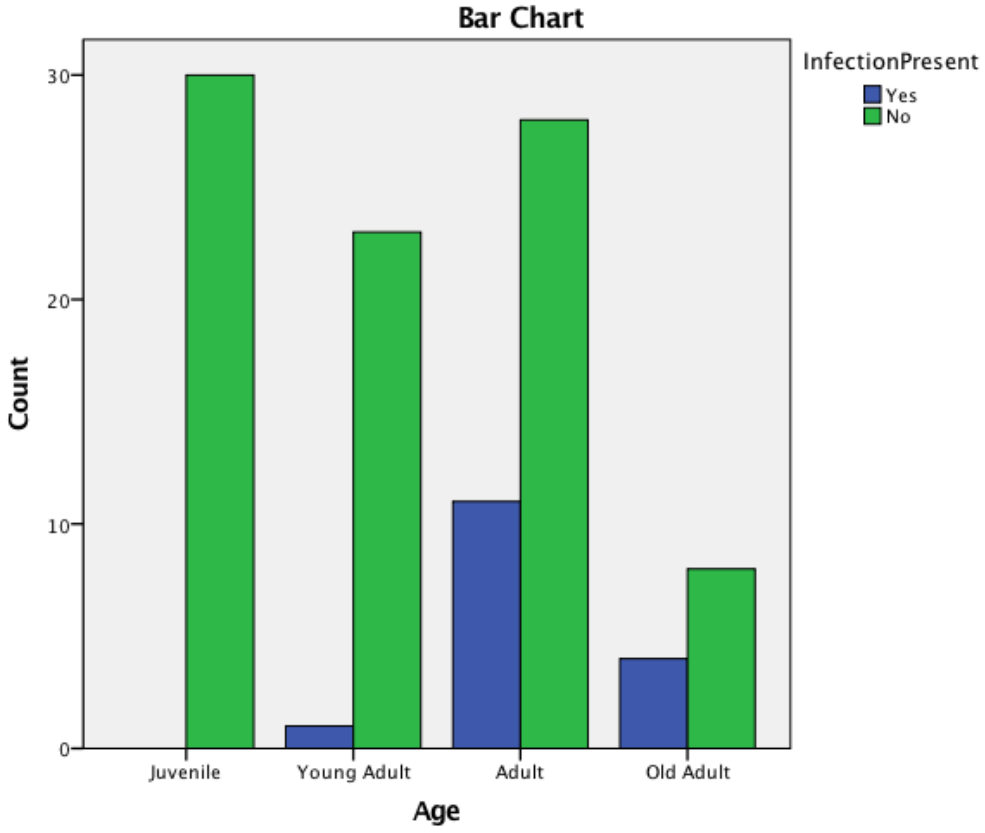


Figure 6.4: Chart of Infection Presence Prevalence and Age

The next test in terms of performing crosstabs was that of comparing infection presence with tooth wear. This crosstabs analysis showed that in the presence of teeth with moderate and severe wear, that the highest rates of infection were recorded, while those with none or light wear exhibited no infection. For those with infection, 25% (N=4) were those with moderate wear, which was a criterion set by myself that was teeth without complete obliteration of the cusps, while severe was flattening and obliteration of the cusps. In those with severe wear, the rate is that of 75% (N=12) (table 6.8), showing that in the case of tooth wear, it seems there is a definite correlation with severe wear and the infection present. To find if this assumption is true, chi-square tests were run as well.

			InfectionPresent		
			Yes	No	Total
ToothWear	None	Count	0	13	13
		% within ToothWear	0.0%	100.0%	100.0%
		% within InfectionPresent	0.0%	14.6%	12.4%
	Light	Count	0	17	17
		% within ToothWear	0.0%	100.0%	100.0%
		% within InfectionPresent	0.0%	19.1%	16.2%
	Moderate	Count	4	35	39
		% within ToothWear	10.3%	89.7%	100.0%
		% within InfectionPresent	25.0%	39.3%	37.1%
	Severe	Count	12	24	36
		% within ToothWear	33.3%	66.7%	100.0%
		% within InfectionPresent	75.0%	27.0%	34.3%
Total		Count	16	89	105
		% within ToothWear	15.2%	84.8%	100.0%
		% within InfectionPresent	100.0%	100.0%	100.0%

Table 6.6: Infection Prevalence and Tooth Wear

In running crosstabs, looking at sex is again important in understanding the distribution of infection among the population. For this test, the dataset that omits those that are indeterminable for sex will be utilized. In this test, it was found that males had the higher rate of infection with that of 77.8% (N=7), while females displayed 22.2% (N=2) (table 6.9). This number is down to 9 from that of 16, indicating that 8 individuals were omitted, and this was more than likely due to their being indeterminate young adults and/or adults resulting in indeterminable sexes.

			Infection Present		
			Yes	No	Total
Sex	Female	Count	2	22	24
		% within Sex	8.3%	91.7%	100.0%
		% within Infection Present	22.2%	45.8%	42.1%
	Male	Count	7	26	33
		% within Sex	21.2%	78.8%	100.0%
		% within Infection Present	77.8%	54.2%	57.9%
Total		Count	9	48	57
		% within Sex	15.8%	84.2%	100.0%
		% within Infection Present	100.0%	100.0%	100.0%

Table 6.7: Infection Presence and Sex with Indeterminate Sex Excluded

The last portion of the crosstabs run in relation to infection presence, was running infection present (yes/no) by that of the Preclassic/Classic variable. It yielded results of 26.7% (N=4) of Classic burials exhibiting signs of infection and 73.3% (N=11) having no observable infections. With the Preclassic burials, 13.3% (N=12) had observable infections, while 86.7% (N=78) did not have signs of infection. In running this, the risk estimate was also run in terms of infection and period, yielding the results that the chances of infection occurring in the Classic period over that of the Preclassic period was that of 2.36%, showing that the chances of infection occurring in the Classic versus that of the Preclassic are quite minimal. This tells me that the chances for infection being observed to occur are higher in the Preclassic period.

Crosstabs for Infection Presence Summary

In running crosstabs on the recorded infections for individuals, some results were able to be of great use in understanding the dispersal rate of infection among this sample population. With looking at the results for tooth wear, age, and sex, there is a definite pattern that appears to be forming in terms of which individuals of this population are susceptible to infection and which are not. For the adults and old adults, it is not surprising that they make up the majority of those who showed infection of the dentition as their teeth are older in age and have been exposed to more food items and stress in a lifetime compared to that of juveniles and young adults. For sex, it appears that there are simply more men than women in total for those who show signs of infection, and further study should be done in regards to the difference between males and females of a population and infection rates of the dentition. Ceramic complexes unfortunately did not shed much light on which individuals in certain time periods were more susceptible to infection as the K'atabche'k'ax complex had the largest number of individuals represented, which would make for a greater chance of those with infections being associated with that complex. The same can be applied to the varying operations that were undertaken at K'axob, as Operation I yielded the most individuals compared to all the following operations, which leads for a skew in terms of the amount that are able to be representative.

Chi-Square Tests for Infection Presence

While the crosstabs test allows for seeing if there is a general association between the presence of infection and the different variables, chi-square allows for being able to see if this is a significant enough correlation that it can be assumed that certain factors are dependent upon one another. For the first chi-square, I looked at the significance between infection being present and operations, the results yielded that there was not an association found between infection presence and operations. The test (Table 6.8) yielded a value of 10.68, a degree of freedom of 10 and a p-value of .383, leading to not rejecting the null hypothesis that the presence of infection is not dependent on the operation, but that there is not enough information present to make the determination. This is based on the p-value being greater than the significance level of .05 and also that if the cells show more than 20% cells are not valid, being sure of the true significance is not possible. The next test, which was of run in hopes of understanding infection across time periods was that of infection presence and ceramic complexes, which again yielded a result of not an association with the value being 4.726, having 7 degrees of freedom, and a p-value being .693, which again is greater than the .05 significance level we are looking for. These results along with the expected count of cells being above 20% at 56.3% makes for not being able to certain if truly significant (Table 6.9).

The first test to show some signs of significance was that of age and infection presence, with a value of 15.79, 3 degrees of freedom, and a p-value of

.001 (Table 6.10), but again this test did have 37.5% of cells having the expected count of less than 5, which again, being greater than 20% means that we cannot be certain of this significance. This tells that the null hypothesis of no correlation can be rejected and it must be accepted that infection presence is possibly dependent on the age of an individual in this population sample.

Tooth wear was also a significant factor in determining the presence of infection, with a value of 15.269, 3 degrees of freedom, and a p-value for this chi-square test of .002 (Table 6.11). These results indicate that the assumption that there is a significance between tooth wear and infection presence in the population must be accepted, but due to the cells having more than 20% as indicated below, we cannot be sure of the significance. The variable of sex in relation to infection presence did not show signs of significance and resulted in the acceptance of the null hypothesis that they were not related with a value of 1.814, 2 degrees of freedom, and a p-value of .404 (Table 6.12).

The results for running the chi square test on the infection presence and that of the Classic/Preclassic periods yielded a value of 1.77 with a p-value of .183, and 1 degree of freedom (Table 6.13) which would again show that there is not a level of significance found between period and infection presence.

Risk analyses, or Odds Ratio analyses, were run on the K'axob samples of males and females, infection presence, and caries presence. For using the analysis for sex, I needed to omit the indeterminate individuals to be able to have a 2x2 table to use in the risk analysis. In running the tests on these factors, all

lambda (λ) values were within the 95% confidence interval showing that there were not significant differences in the odds of having infection present between caries being present or not, between males and females, and between the Preclassic or Classic individuals.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10.680[a]	10	.383
Likelihood Ratio	10.308	10	.414
Linear-by-Linear Association	4.724	1	.030
N of Valid Cases	105		

a. 15 cells (68.2%) have expected count less than 5. The minimum expected count is .15.

Table 6.8: Chi-Square Results for Infection and Operation

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.726[a]	7	.693
Likelihood Ratio	5.058	7	.653
N of Valid Cases	105		

a. 9 cells (56.3%) have expected count less than 5. The minimum expected count is .30.

Table 6.9: Chi-Square Results for Infection and Ceramic Complex

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15.790[a]	3	.001
Likelihood Ratio	19.641	3	.000
Linear-by-Linear Association	14.038	1	.000
N of Valid Cases	105		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is 1.83.

Table 6.10: Chi-Square Results for Infection Presence and Age

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15.269[a]	3	.002
Likelihood Ratio	18.009	3	.000
Linear-by-Linear Association	12.525	1	.000
N of Valid Cases	105		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 1.98.

Table 6.11: Infection Presence and Tooth Wear

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.814[a]	2	.404
Likelihood Ratio	1.878	2	.391
Linear-by-Linear Association	.208	1	.648
N of Valid Cases	105		

a. 1 cells (16.7%) have expected count less than 5. The minimum expected count is 3.66.

Table 6.12: Chi-Square Results Infection Presence and Sex

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.770[a]	1	.183		
Continuity Correction[b]	.888	1	.346		
Likelihood Ratio	1.553	1	.213		
Fisher's Exact Test				.239	.170
N of Valid Cases	105				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.29.

b. Computed only for a 2x2 table

Table 6.13: Chi-Square Results for Infection Presence and Preclassic and Classic Periods

Chapter Seven: DISCUSSION AND CONCLUSIONS

This study's results indicate that caries were prevalent in individuals at K'axob, occurring at a rate of 76.2% of the 105 individuals that could be evaluated. For the distribution of the amount of caries present at K'axob among individuals, it was found that 23.8% of the sample population did not have instances of caries, while the remaining had caries ranging from 1 to 39, with the high range of 20 and 39 caries occur in single individuals. Otherwise the second highest level of caries based on percentage was that of individuals with 3 recorded caries in their present dentition for 8.6% of the population.

The prevalence of infection at K'axob was that of 15.2% of the 105 individuals examined from the population. Infection prevalence was found to have correlations with that of age and tooth wear among individuals in the sample population of K'axob, while all other variables were not related in terms of occurrences. There were found to be no significant associations between groups of caries presence and age, sex, ceramic complex, tooth wear, or operation, and with the same for the total number of caries observed. It was only with certain variables associated with infection that correlations could be seen, and only in certain factors. For sex, ceramic complex, and operation, there were not any associations with infection presence.

EVALUATION OF HYPOTHESES

The hypotheses for this study were:

1. The prevalence of caries and infection within a population will be lower in individuals exhibiting signs of significant wear of the surfaces of the teeth.
2. The prevalence caries and infection in a population will be significantly higher in individuals that are of an older age group.
3. The prevalence of infection and caries of a population will be lower in Preclassic burials versus that of the Classic burials.

Based on the results of the study and analyses performed, the null hypotheses cannot be rejected for either pathology for this study. For the case of caries and infection, these were not based on the factors examined of sex, age, tooth wear, and period. This is indicative that none of these factors alone are significantly a causation for caries or infection to occur, or that the variables of sex, age, tooth wear, or period affect the likelihood that an individual will or will not develop caries or infection of the teeth.

In performing this research on the individuals at K'axob it was found that factors which would normally have a predictable outcome, like that of the level of wear and caries present, do not seem to hold true for K'axob. This could be based on the different and varied diet that the individuals would have had access to which would affect the teeth differently than others in a similar setting.

DENTAL INFECTION AND CARIES AT K'AXOB

In undertaking this study, I have found that based on this sample population, only a few factors come into play when determining an individual's susceptibility to infection or caries. While food sources do play a part, it was found that in this instance, it is age and wear of the teeth that are the largest contributing factors for the prevalence of caries and infection at K'axob. These two aspects of causation for infection and caries seem to go hand in hand, due to as individuals age, their teeth are exposed for a longer time to certain foods that can wear down the surface, which in this instance opens the teeth up to the susceptibility of the formation of caries and even infection.

IMPLICATIONS AND DIRECTIONS FOR FURTHER RESEARCH

This study illustrated as to how factors surrounding aging and long-term exposure to particular food sources and preparation methods can have a profound effect on an individual's dental health. While it may be possible for certain factors such as different time periods which would in turn have an effect on the available resources to those in a population, in the instance of this study, that was not applicable as many of the individuals examined came from the Preclassic compared to that of the Classic period. If there were a more even distribution of individuals found from the Preclassic and Classic, there would be the option to be able to truly compare differences between these two periods. Unfortunately, in this case, more individuals from the Classic period would be

needed to make any determinations regarding the prevalence of and susceptibility to caries and infection among those at K'axob.

The field of bioarchaeology and the study of dental anthropology would benefit tremendously from the undertaking of more studies regarding the dentition and caries and infection rates of the Preclassic and Classic Maya from a variety of differing sites beyond that of K'axob. It would also be beneficial to the study to be able to pull from samples that are larger in size and diverse in terms of time periods associated with burials. By being able to examine more individuals from the Preclassic and Classic periods, new evidence could be found to shed light on the dental health of the ancient Maya. While it is an issue in terms of finding remains that are well preserved enough to perform studies, there is the benefit that the teeth are some of the hardiest and best preserved of remains found in an archeological context.

REFERENCES

Center, I.M.R.
2010 *Preclassic Period*. http://www.marc.ucsb.edu/research/maya/ancient-maya-civilization/preclassic-period.

Coe, M.D
2005. *The Maya*. New York: Thames & Hudson.

Cohen, M.N., Crane-Kramer, Mountford, Gillian Margaret.
2007. *Ancient Health: Skeletal indicators of agricultural and economic intensification*, Bioarchaeological interpretations of the human past. Gainesville, FL: University Press of Florida.

Cucina, A., and Tiesler, V.
2003. "Dental Caries and Antemortem Tooth Loss in the Northern Peten Area, Mexico: A Biocultural Perspective on Social Status Differences Among the Classic Maya." *American Journal of Physical Anthropology* 122 (1):1-10.

Cucina, A., Cantillo, Cristina Perea, Sosa, T.S, & Tiesler, V.
2011. "Carious lesions and maize consumption among the Prehispanic Maya: An analysis of a coastal community in northern Yucatan." *American Journal of Physical Anthropology* 145 (4):560-7.

Danforth, M.E.
1999. "Nutrition and Politics in Prehistory." *Annual Review of Anthropology* 28 (1).

Demarest, A.
2011. *Ancient Maya: The rise and fall of a rainforest civilization*. Cambridge: Cambridge University Press.

Doyle, J.
2012. *Architecture and the Origins of Preclassic Maya Politics*. Cambridge: Cambridge University Press.

Eshed, V., A. Gopher, & Hershkovitz, Israel.
2011. "Tooth wear and dental pathology at the advent of agriculture: New evidence from the Levant." *American Journal of Physical Anthropology* 130 (2):145-9.

Foias, A.E.
2013 *Ancient Maya Political Dynamics*. Gainesville, FL: University Press of Florida.

Gerry, J.P., and Harold W. Krueger.
1997 Regional Diversity in Classic Maya Diets. *In* Bones of the Maya: Studies of Ancient Skeletons. S.L. Whittington and D.M. Reed, eds. Pp. 196-207. Tuscaloosa: University of Alabama Press.

Gillespie, S.
2002 "Body and Soul among the Maya: Keeping the Spirits in Place." *Archaeological Papers of the American Anthropological Association* 11 (1): 67-78.

Henderson, H.
2003. "The Organization of Staple Crop Production at K'axob, Belize." *Latin American Antiquity* 14 (4):469-96.

Hendon, J.A., & Joyce, Rosemary A.
2004. *Mesoamerican Archaeology: Theory and Tractice*, Blackwell Studies in Global Archaeology. Malden, MA: Blackwell Pub.

Hillson, S.
1996. *Dental Anthropology*. Cambridge, United Kingdom: Cambridge University Press.

2001. Recording Dental Caries in Archaeological Human Remains." *International Journal of Osteoarchaeology* 11 (4):249-89.

2008. The Current State of Dental Decay. In *Technique and Application in Dental Anthropology*, edited by J.D. Irish, Nelson, Greg C. Cambridge, New York: Cambridge University Press.

2014. *Tooth Development in Human Evolution and Bioarchaeology*. Cambridge: Cambridge University Press.

Houk, B.A., Masson, M. A., Smith, M.E., & Janusek, J.W,. 2015. *Ancient Maya cities of the Eastern Lowlands*, Ancient Cities of the New World.

Killion, T.W.

1992. *Gardens of Prehistory: The archaeology of settlement; agriculture in Greater Mesoamerica*. Tuscaloosa, AL: University of Alabama Press.

Klaus, H.D.
2014. "Frontiers in the bioarchaeology of stress and disease: Cross-disciplinary perspectives from pathophysiology, human biology, and epidemiology." *American Journal of Physical Anthropology* 155 (2):294-308.

Lanfranco, L.P., and Eggers, S.
2012. Caries Through Time: An Anthropological Overview. In *Contemporary Approach to Dental Caries*, edited by M. Li: InTech.

Larsen, C.S.
1995. "BIOLOGICAL CHANGES IN HUMAN POPULATIONS WITH AGRICULTURE." *Annual Review of Anthropology* 24 (1):185.

2015. *Bioarchaeology: interpreting behavior from the human; skeleton /*, Cambridge studies in biological anthropology. New York, NY: Cambridge University Press.

Lentz, D.L.
1991. "Maya Diets of the Rich and Poor: Paleoethnobotanical Evidence from Copan." *Latin American Antiquity* 2 (3):269-87.

Marcus, J.
2003. "Recent Advances in Maya Archaeology." *Journal of Archaeological Research. Jun2003* 11 (2):71.

McAnany, Patricia
2004. *K'axob: Ritual, Work, and Family in an Ancient Maya Village*. University of California, Los Angeles: Cotsen Institute of Archaeology.

McAnany, P.A., & Lopez Varela, A.
1999. "RE-CREATING THE FORMATIVE MAYA VILLAGE OF K'AXOB: Chronology, ceramic complexes, and ancestors in architectural context." *Ancient Mesoamerica* 10 (1):147-68.

McAnany, P.A., Storey, R., & Lockard, A.K.
1999. "Mortuary Ritual and Family Politics at Formative and Early Classic K'axob, Belize." *Ancient Mesoamerica* 10 (1):129-46.

Pope, K.O., and B.H. Dahlin.
1989. "Ancient Maya Wetland Agriculture: New Insights from Ecological and Remote Sensing Research." *Journal of Field Archaeology* 16 (1):87-106.

Scarborough, V.L.
1985. "Archeology: Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize." *American Anthropologist* 87 (1):161-2.

Scherer, A.K.
2007. "Population structure of the classic period Maya." *American Journal of Physical Anthropology* 132 (3):367-80.

Scherer, A.K., L.E. Wright, and C.J. and Yoder.
2007. "Bioarchaeological Evidence for Social and Temporal Differences in Diet at Pedras Negras, Guatemala." *Latin American Antiquity* 18 (1):85-104.

Sharer, R.J and Traxler, L.P.
2009. *The Ancient Maya*. Stanford, CA: Stanford University Press.

Siemens, A.H.
1982. Prehistoric Agricultural Use of the Wetlands of Northern Belize. In *Maya Subsistence: Studies in Memory of Dennis E. Puleston*, edited by K.V. Flannery: Academic Press.

Storey, R.
2004. Ancestors: Bioarchaeology of the Human Remains of K'axob. In *K'Axob: Ritual, Work, and Family in an Ancient Maya Village* edited by P. McAnany. Los Angeles, CA: Cotsen Institute of Archaeology.

Turner, B.L., & Harrison, P.D.
1983. *Pulltrouser Swamp : Ancient Maya habitat, agriculture and settlement in northern Belize*. 1 ed, Texas Pan American series. Austin, TX: University of Texas Press.

Valdez, F., Scarborough, V.
2014. The Prehistoric Maya of Northern Belize: Issues of Drought and Cultural Transformations. In *The Great Maya Droughts in Cultural Context : Case Studies in Resilience and Vulnerability*, edited by Iannone and G. Boulder, CO: University Press of Colorado.

Waldron, T.
2009. *Palaeopathology*. Edited by G. Barker, Cambridge Manuals in Archaeology. New York, NY: University of Cambridge Press.

White, C.D.
1999. *Reconstructing Ancient Maya Diet*. Salt Lake City, UT: University of Utah Press.

White, C.D., Schwarcz, H.P.
1989. "Ancient Maya diet: as inferred from isotopic and elemental analysis of human bone." *Journal of Archaeological Science* 16:451-74.

Wiseman, F.M.
1983. "Subsistence and Complex Societies: The Case of the Maya." *Advances in Archaeological Method and Theory* 6:143-89.

Wright, L.E.
1997. "Intertooth patterns of hypoplasia expression: Implications for childhood health in the Classic Maya collapse." *American Journal of Physical Anthropology* 102 (2):233-47.

Wright, L.E., and White, C. D.
1996. "Human biology in the Classic Maya collapse: Evidence from paleopathology and paleodiet." *Journal of World Prehistory* 10 (2):147-98.