RELATIONSHIPS BETWEEN DENTAL PATHOLOGY AND ANCESTRY FROM THE SANTA CLARA VALLEY MEDICAL CENTER PAUPER CEMETERY

A Thesis

Presented

to the Faculty of

California State University, Chico

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Anthropology

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by

Karin Wells

Spring 2019

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ACKNOWLEDGEMENTS

I would first like to thank my wonderful committee for all of their hard work and help with this project. Dr. Eric Bartelink, thank you for putting up with all of my questions and giving me the freedom to explore my research ideas. I definitely could not have done this without your guidance. Thank you to Dr. Ashley Kendell for reminding me to take things one step at a time and for all of the thoughtful edits and help with statistics. I also cannot express how much I appreciate the time spent with your dogs and baby Heath. It was through the hours of help and editing that you two put in that I am able to present this work. I am beyond thankful for you both. Also, thank you to Dr. Richard Scott and Dr. Marin Pilloud and the graduate students at the University of Nevada, Reno for teaching me how to properly score dental morphology and allowing me to spend three days with them at their boot camp.

Thanks are also in order to the many other professors I had the privilege to work with over the past three years, including Dr. P Willey, Dr. Beth Shook, and Dr. Colleen Milligan. Thank you P, for teaching me all there is to know about osteology and for only judging me a little when I got things wrong. Your stories always brighten my day! Thank you for your help with statistics and for giving me a hug when I had to collect more data. Your impact on my time at Chico has been immense. I would not have been nearly as successful without the guidance of Dr. Shook, who helped me through some of the tougher times these past few years. I appreciate your kindness and willingness to help those around you. Alex Perrone, you have been an incredible help through the years, in more ways than one. Thank you for giving me a chance in the lab and for seeing my passion and listening to me talk for hours. Our conversations helped me through many grad school and life issues and I cannot thank you enough for being a friend to me.

I would also like to thank my cohort, Sam Mijal, Vanessa Reeves, Mallory Peters, and Josh Nowakowski. Thank you for putting up with my antics in our various late-night seminars and for laughing along with me. Grad school would have been a lot harder without you all. I appreciate you and know you will all be successful! Special thanks to Sam Mijal for going over SPSS with me and helping me understand my results, and for answering various questions about teeth. I definitely could not have done stats without your help. Thank you to all the friends and colleagues I have met at Chico including, Valerie Sgheiza, Maria Cox, Martha Diaz, Matt and Lynsey Bond and family, Sarah Hall, Jacqueline Galimany Skupham, Alyssa Straub, Jess Hotaling, and Leigh Hayes. I learned something different from each of you and the amount of appreciation and friendship I have towards you all would be a thesis in itself, so simply, thank you!

Thank you to my colleagues at the Santa Clara County Medical Examiner-Coroner's Office for being my home away from home for almost four years. You have all been with me throughout this journey, from before my application to graduate school until now. I cannot express how much it means to me to have coworkers as wonderful and accepting as all of you. It has been my privilege to get to work with you all. Dr. Michelle Jorden, I could never thank you enough for every opportunity you have provided me. It is an honor to work with you.

I am immensely thankful for the support and friendship of my roommate and fellow grad student, Zhanna Kusmanova. I wish I could properly express what meeting you has done for me. Thank you for literally putting up with me all the time. We have laughed, cried, and spent hours

together and I still like you! Through some of my most difficult moments, you have been there, listening without judgement or criticism. My favorite thing about grad school was meeting you.

To my family. I am nothing without you. Thank you for pushing me to always do my best and to never give up. You three have supported all of my wildest dreams and helped me realize I could achieve them. Every happy moment, you all were there to share it with me, and every difficult or sad time was made more manageable with you. I very literally could not have done any of this without you all. Dad, thank you for teaching me that anything worth doing, is worth doing well. Mom, thank you for being my voice of reason. Madi, thank you for being my biggest fan. I love you all. Also, thank you Biscuit and Chester for giving me unconditional love every time I come home.

This work is dedicated to my grandparents. Even though they never got the opportunity to get an education, they all recognized the importance and privilege of receiving one. I hope I have made you all proud.

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ABSTRACT

RELATIONSHIPS BETWEEN DENTAL PATHOLOGY AND ANCESTRY FROM THE SANTA CLARA VALLEY MEDICAL CENTER PAUPER CEMETERY

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In order to assess variation in oral health, hygiene, and diet within the Santa Clara County Valley Medical Center pauper cemetery, pathological conditions of the teeth and jaws were analyzed by ancestry group. Utilizing a biocultural approach for analyzing pathological conditions, this study aims at understanding the interactions of sociocultural constructs and biology in a late 19th and early 20th century pauper cemetery. A total of 40 individuals from the Valley Medical Center (VMC) collection was analyzed for carious lesions, alveolar abscesses, dental attrition, and antemortem tooth loss. These individuals were separated into ancestry groups using dental morphological methods of ancestry estimation. As this skeletal collection is very poorly preserved, it was hypothesized that dental morphology would be a more reliable method of ancestry estimation than previously employed cranial methods. Analysis of the ancestry estimation results indicate that all of the previously indeterminate individuals were able to be estimated using dental morphology, though to what degree of accuracy is unknown.

It was hypothesized that there would be variation in the frequency and type of dental pathology between the estimated ancestry groups. It was predicted that the greatest

frequency of pathological conditions of the dentition would be seen among the non-white ancestry groups due to differences in access to healthcare and overall diet. Results of these data indicate that there is a significant difference in the number of carious lesions between white and non-white groups; however, the prediction was not supported. More significant dental pathology was observed among the white ancestry group, possibly indicating a lack of access to proper nutrition and healthcare, or diets more reliant on refined sugars. This project highlights the limitations of using dental pathology for indications of social status when working with a small sample size, as well as the inherent difficulty in estimating ancestry from skeletal remains.

CHAPTER I

INTRODUCTION

Studies of dental pathology in bioarchaeological collections provide insight on dietary habits, oral health, and hygiene. Many of these processes are biologically determined; however, cultural practices are the predominant cause of many pathological conditions of the mouth (Larsen 2015). Additionally, socioecomonic status plays a major role in access to proper nutrition and healthcare, potentially resulting in a greater susceptibility to dental disease. Understanding the social, cultural, economic, and biological aspects that can affect an individual's oral health provides us with a means to interpret skeletal manifestations of dental pathology.

Research Design

For this project, skeletal remains from the Santa Clara Valley Medical Center (VMC) pauper cemetery were analyzed. Biological profiles were created for each of the 40 individuals selected for analysis. Additionally, detailed dental inventories and data on pathological conditions were recorded for each burial. A new method for estimating ancestry using dental morphology and the beta version of the online database rASUDAS, an R-based statistics program modeling the Arizona State University Dental Anthropology System (ASUDAS), were used. The criteria for inclusion was simply the presence of at least one tooth. While those individuals who were edentulous during life provide interesting pathological information, they do not have any teeth to conduct ancestry estimation based on dental morphology. Therefore, these individuals were not included in the final sample.

As a way to demonstrate variation in dental pathology among the Valley Medical Center pauper cemetery collection, pathological conditions of the teeth and jaws were examined based on ancestry. The ancestry estimates were obtained using dental morphological traits that were input into rASUDAS for comparison with seven known biogeographic ancestry clusters. This program uses discriminant function analysis to estimate the probability of an individual belonging to one or more of the groups (Scott et al. 2018).

Ancestry was chosen for categorization in order to examine the relationship between dietary and cultural patterns and the frequency and types of pathological conditions of the teeth. Cariogenic foods high in carbohydrates, especially sugars, can lead to greater prevalence of carious lesions in groups that predominantly consume them (Larsen 2015). Frequency and lesion type were assessed for each tooth from each individual. Abscesses of the maxilla and mandible, as well as dental attrition and the presence of calculus were also recorded. These data, along with the ancestry estimates obtained from dental morphology were input into IBM SPSS (Version 25) for statistical analysis.

Hypotheses

The main hypothesis for this project is whether or not there is a statistically significant difference in the frequency and type of dental pathology between the ancestry groups. It was predicted that non-white individuals would have higher frequencies of carious lesions due to dietary differences and sociocultural marginalization. Another component of this project relied on the use of a contemporary collection associated with a church cemetery in Pittsburgh, Pennsylvania. The Voegtly Cemetery was in use during the same time period as the VMC cemetery; however, its association with a church and not a county infirmary makes it likely to be more representative of the general population at the time. Comparisons of the frequency of dental pathology between these two populations might indicate that differences in socioeconomic status are correlated with differences in dental pathology prevalence.

Thesis Organization

Chapter II of this thesis is a background overview of the Santa Clara Valley, the area where the cemetery was rediscovered in 2012 during a construction project. Historical information on the county, city, and hospital provides context to the burials. Additionally, the social, cultural, economic, and demographic components of the area and time period are presented, including a brief introduction to pauper cemeteries and workhouses. The comparative collection used for this project is also outlined here. Understanding the contexts in which these individuals lived and died helps inform analyses and interpretations of skeletal remains.

Chapter III outlines the theoretical perspectives which guide the interpretations of skeletal pathology in bioarchaeological collections. Models of stress and health allow for a holistic approach to understanding the skeletal manifestations of disease and inequality. Theories incorporating the cultural effects on biology yield insights into past lifeways. While complex, and at times controversial, the incorporation of biocultural theories into a thesis project such as this is imperative for analyzing results and forming conclusions.

The fourth chapter provides a literature review on the field of dental anthropology, including its applicability to bioarchaeological studies of health and disease. A detailed overview of dental morphology provides context for the methods used in this project for ancestry estimation. Finally, an extensive outline of pathological conditions of the teeth and jaws is included for a better understanding of the causes of these conditions, how they manifest themselves, and how to interpret them in skeletal remains.

Chapter V presents the materials and methods used to collect and analyze data for this project. This includes a project outline, sampling methodology, training, and data collection. The methods used for estimating the components of the biological profile along with the scoring protocols for dental inventory and pathology are provided. Also included are detailed outlines of the reference populations used for dental ancestry estimation, the dental traits used for rASUDAS, and the scoring procedure for these traits. The statistical tests conducted are outlined in this chapter to provide a framework for the results section.

Chapter VI applies statistical analyses to obtain results on the variation in dental pathology between the ancestry groups. While each burial is reported by their ancestry estimate, these categories were then aggregated into white and non-white categories. This was done in order to obtain more understandable results with more individuals falling into a category other than white, as much of the sample was estimated to be Western Eurasian. Finally, chapter VII discusses the results and outlines conclusions that can be drawn from them. It is hoped that these data will provide additional information on the lives of the individuals buried at the Santa Clara Valley Medical Center Infirmary Cemetery.

CHAPTER II

OVERVIEW OF SANTA CLARA COUNTY

Introduction

Background information on the demographics, socioeconomics, and landscape of Santa Clara County provides context for the cemetery, its function in the city, and its subsequent rediscovery. Santa Clara County, located in the south Bay Area region of California, has a rich history spanning the mission era and colonization to its current status as a leader in technology. This chapter will outline a brief history of the area, as well as the time periods during which the Valley Medical Center County Infirmary (VMC) was in use. Demographic information collected from census reports is used to illustrate the population of the county and the sociocultural interactions which shaped historical perspectives. An overview of historic period cemetery studies is also provided, along with background information on a comparative collection.

The History of Santa Clara Valley

California's Bay Area has long been a state hub for agriculture, trade, and technology. The area has a history of large native populations, Spanish missions, and Gold Rush era excitement. Because of these historical events, the population of the Bay Area has seen significant variation over the centuries. It is important to understand this variability in the context of this thesis project, due to the influence of historic, cultural, and socioeconomic factors that make a difference in how we perceive the time period surrounding the cemetery and the burials.

Mission Era

The mission era of Santa Clara Valley significantly impacted the population and cultural practices of the native groups living there. Mission Santa Clara de Asis, now located on the campus of Santa Clara University, opened in 1777 as Spanish colonizers laid claim to the area. The Native Americans were forced to live and work on these missions in an attempt to impart Christianity upon them. Following Spain's defeat against Mexico, California became a Mexican territory (URS 2015). Eventually, the United States would claim California as a state in 1848, effectively ending the Spanish and Mexican eras (URS 2015).

Agriculture

The Santa Clara Valley of the late 19th and early 20th centuries was an idyllic, fertile agricultural hub. Varieties of fruit trees grew in abundance, giving the area its nicknames: Garden of the World and the Valley of Heart's Delight (Tsu 2013). The areas within and around the valley were ideal for farming and large orchards, with fertile soil and a number of small creeks. Prior to the population and technological boom of the county's major cities, much of the land was used for apricot orchards, wheat fields, grapes, garlic, and prunes, among other produce and livestock (Munro-Fraser 1881; Sawyer 1924).

Insulated from the coastal winds of Santa Cruz and the fog of the San Francisco Bay, Santa Clara County's climate is mild and Mediterranean, a feature which allows for almost continuous growing seasons (Munro-Fraser 1881; Sawyer 1924). The proximity to the San Francisco Bay also provides access to ports for shipping and receiving goods (URS 2015; Munro-Fraser 1881). Many of the locally grown fruits and vegetables were packaged and canned in the county, providing further employment opportunities and setting the stage for Santa Clara County to become a major center for industry (Sawyer 1924).

As a result of this wealth of agriculture, Santa Clara Valley was cultivated by small family farms. Most of these farmsteads were owned and run by white Euro-americans; however, there was often a shortage of labor within families alone, and outside help became necessary (Tsu 2013). Therefore, laborers from Asian countries tended to do the majority of the labor required to run a family farm (Tsu 2013). As a result, a large portion of the population in this area was of Asian descent during the late 1800s and into the 1900s (Tsu 2013).

Mining

Along with agriculture, mining also employed a number of men in the area. In 1845, the New Almaden mine in south San Jose was discovered to contain quicksilver, cinnabar, and mercury, and quickly became a major source of income for the county (Munro-Fraser 1881). While the resources from this mine had been utilized by the Native Americans in the area, the discovery of the quicksilver located here gave Andres Castillero the land rights to the mine (Munro-Fraser 1881). With that came the employment of hundreds of men, many from Mexico, and the production of a large amount of quicksilver and mercury (Sawyer 1924). According to the historian Eugene Sawyer (1924: 87), the New Almaden mine was contributing more than half of the world's supply of quicksilver in the year 1887.

The Gold Rush

The state of California was completely changed in the year 1848. Gold was discovered in northern California, causing a massive influx of immigrants to the area, hoping to get rich. The proceeding Gold Rush saw men leaving the major cities of the state and heading for the mines (Sawyer 1924). The prospect of gold was so enticing that many of the crops in Santa Clara Valley died as their farmers quickly left the area. As a result of the Gold Rush frenzy, food prices drastically increased as resources were being brought in from outside (Sawyer 1924). Despite the momentary lapse in food production around this time, the valley was one of the state's leading producers of fruits and vegetables (Sawyer 1924). Additionally, the population boom that resulted from the Gold Rush saw San Francisco's population increasing from 600 to 100,000 within a single year (Milliken et al. 2009: 176).

The early influence of Spanish missionaries had a lasting impact on the native Californian tribes in the Bay Area specifically. California's admittance as a state, and the proceeding events of Western expansion by Euro-americans, again altered the culture, economics, and demographics of the area. Each passing decade saw variation in the population of the state and, more specifically, the county. The demographics of the area are important to understand because they have a significant impact on how we interpret sociocultural and economic differences in bioarchaeological studies.

Demographics of Early Santa Clara County

Santa Clara County has remained a diverse hub of the greater Bay Area region since its colonization by the Spanish in the 1700s. Many of the major groups present in the area today can be traced back to these historical beginnings, including the Spanish, Mexican, Native American, African American, Euro-american, and Asian populations. Each of these groups have differing histories within California and these will be further explored to provide context for the demographics seen within the cemetery. Because these burials have lost their identifying markers and records, it is necessary to gather data from external sources in order to piece together which groups were likely to be represented here. The major ethnic groups listed for the county of Santa Clara from 1860-1880 were white, black, Chinese, and Indian, or Native American (1880 US Census). Each of these groups saw an increase in population size over these three decades except for the Native American group, which underwent a significant population decline between 1860 and 1870 (1880 US Census). Subsequent census data demonstrate a similar trend, with native groups dwindling and Euro-american groups predominating. A brief outline of the histories of these major ancestral groups will inform further results gathered from this project.

The native tribe of the San Francisco Bay, the Ohlone, had been living in the area of present day Santa Clara County for centuries prior to European contact (Milliken et al. 2009). As is commonly known in American history, the colonization of the continent resulted in significant loss of land, culture, and life for many of the native populations. The introduction of previously unknown diseases such as small pox and syphilis further diminished these numbers. The California mission system was a unique attempt at forcing Eurocentric beliefs onto the Native Americans through labor and religious conversion. However, the end of the mission era did not bring with it the end of Native American suffering, ultimately contributing to the dwindling number of individuals present in Santa Clara County's population.

Following the end of the mission era in California, many native people found themselves without land or any place to go. They were met with hostility by other members of society, as well as by laws which deliberately excluded them from the community (Milliken et al. 2009). They were no longer allowed to live or work in areas they had previously inhabited and there were no formal reservations within the state (Milliken et al. 2009). After colonization, Native Californians did not have the means to maintain their previous ways of life, as they were met with Eurocentric beliefs from all sides (Milliken et al. 2009).

With an already significantly diminished native population, the time period in question for the burial and use of the VMC cemetery saw even further reduction in the number of Native Americans. According to census data from 1880, the Native American population of Santa Clara

County saw a significant decline between 1860 and 1870. In Santa Clara County in 1860 there were 157 Native Americans counted on the census. In the following decade the number of Native Americans dropped to only 12. While 1880 saw an increase up to 73 individuals, these numbers are shockingly low compared to other ethnic groups in the area (1880 US Census). The population continued to decline with the census data as follows: 1890 counted 19 native people; 1900 counted 9 native people; 1910 counted 16 native people (1910 US Census). In the last decade where the VMC cemetery was known to be in use, the 1930s, there were 45 native individuals counted on the census (1930 US Census).

The need for labor during major industrial periods in California's history was satisfied through immigration from across the globe. Asian men, many from China, came to California looking for work, leaving their wives and families behind (Fong and Markham 1991). The Gold Rush saw a huge number of immigrants arriving in California, including those of Asian descent (Chan 2000). These men immediately went to work for the mines; however, they were met with disapproval from Euro-americans who saw them as additional competition for jobs (Fong and Markham 1991). As a result, Chinese laborers were paid less than their Euro-american counterparts and were viewed as slaves (Fong and Markham 1991).

The decline of the Gold Rush led to another, equally dangerous, job opportunity for Asian laborers working on the railroads. Because they were essentially viewed as slave labor, many of the Chinese men working on the railroads were given the task of placing explosives into mountain sides for tunnels (Fong and Markham 1991). Following the end of the railroad, many of these men settled in California's larger cities where they worked in labor jobs, such as farming (Fong and Markham 1991; Tsu 2013). Racism and anti-Chinese sentiment gained more force during this time and the United States passed the Chinese Exclusion Act in 1882 to prevent further immigration from China (Fong and Markham 1991).

While this time period was wrought with racist ideology and the Chinese Exclusion Act prohibited more Chinese men from entering the country, many had already made it to the major California counties such as Santa Clara. Perhaps surprisingly, the farm and land owners of Santa Clara were not opposed to using Chinese laborers on their farms, as it became necessary for family farms to hire outside help (Tsu 2013). Regardless, the politics of the time viewed Chinese immigrants unfavorably and there was a desire for reform back to the idealized family farms owned and operated by Euro-americans (Tsu 2013). Given the demographics of the state as a whole and the county in particular, it is likely that many of the individuals uncovered at the county infirmary cemetery are of Asian descent.

Many of the early Euro-american settlers to the area began fruit orchards or worked in mines and factory jobs. A number of streets in San Jose now bear the names of these individuals, as they played instrumental roles in making Santa Clara County the top fruit producer in the state (Sawyer 1924). The main canning, packing, and preservation factories set up in response to the overwhelming amount of fruit production offered employment for many county laborers (Sawyer 1924). Following the Gold Rush, Santa Clara County saw a dramatic increase in population, as with the rest of the state. The white Euro-american population of the county increased each decade following the discovery of gold. This is demonstrated through census data which indicates that there were 80,000 Euro-americans living in the county by 1910 (1910 US Census).

While they did not make up a substantial part of the population at this time, African Americans did have a place in Santa Clara County. Unfortunately, the censuses during these decades had separate distinguished categories of “colored,” “black” and “negro” and did not provide definitions for these distinctions. The earliest census data from 1860 until 1880 classified these individuals into the "colored" category (1880 US Census). The black population in 1860 was 87 individuals, and these numbers increased slightly to 161 in 1880 (1880 US Census). Beginning in the 1900s, the "colored" category was divided into "negro" and "black" (1910 US Census). The "negro" population decreased from 989 in 1890 to 251 in 1900 but increased slightly again in 1910. The "black" population was counted as 175 in 1910 (1910 US Census). It is likely, even with a small population, that some of these individuals are represented in the VMC infirmary cemetery.

It is with the historical context of the demographics of the county that we can attempt to understand the ancestry groups present in the cemetery population. Though a diverse area at the time of the infirmary, Euro-americans dominated much of the politics and economics of the period, therefore making up a substantial portion of the community. Regardless, Santa Clara County's demographics represent ethnic and cultural diversity during the late 19th and early 20th centuries and discovery of this historic cemetery provides a unique opportunity to study past lifeways for an array of individuals.

The Valley Medical Center Infirmary Cemetery

The Santa Clara County Valley Medical Center is located in the city of San Jose. Prior to 1871, what was considered to be the county hospital was located in the center of San Jose and was seen as out-of-date and lacking the accommodations necessary for a rapidly expanding city. Land was purchased just outside the city in 1871 to build a more amenable infirmary (Munro-Fraser 1881). At this time the hospital was known as the Santa Clara County Infirmary. In 1875, the main infirmary building was erected as a way to better accommodate the sick poor of the county (Munro-Fraser 1881). The overall time period in which this cemetery was in use dates from 1871 until 1937 (URS 2015).

Building a county infirmary with tax-payer's dollars came as a result of the 1855 state hospital fund act, later amended to the state infirmary fund in 1860 (Hittell 1870). This act specifically authorized "the establishment of county infirmaries for the relief of the indigent sick" (Hittell 1870: 479). As a result, the Santa Clara County Infirmary was "dedicated to Sickness, Poverty, and Charity" (Munro-Fraser 1881: 148). In many ways, infirmaries or hospitals during the 19th and 20th centuries were much more than just a place for the sick (URS 2015; Marland 1991). These were institutions which aimed to uphold values of the community at large, including providing charity to the poor (Marland 1991). The infirmary also served as an almshouse or workhouse, where the poor were provided a place to stay if they were able to work, typically doing physical labor (URS 2015; Bell 1990).

Around the time that the hospital moved to its present-day location, a cemetery was also outlined for the burial of the indigent who died during their stay. There are very few remaining records of this burial ground, with little to no documentation of who was buried there and when. The only indication that it had been there at all comes from newspaper articles and building maps (URS 2015). For example, the only indicator that the cemetery stopped being used comes from a map of the area in 1937 which shows buildings on the land that previously encompassed the cemetery (URS 2015). Over the next few decades, maps would indicate a number of different structures built on the land and it eventually would be paved over for an employee parking lot (URS 2015). Subsequent construction projects on the hospital removed the parking area to find what is assumed to be only a small portion of the historic infirmary cemetery.

After the construction on the parking lot uncovered the coffins, archaeologists and osteologists began excavating the area with the aid of backhoes and hand troweling methods (URS 2015). Due to the fragmentary nature of these remains, various field applications were conducted in an attempt to maintain preservation. This included the use of polyvinyl acetate to keep elements together, as well as collecting measurements and biological profile information *in situ* (URS 2015). While useful, given the context of the burials, estimating aspects of the biological profile in the field is not typically done. Rather, laboratory analysis is required to get more specific, and to an extent, more accurate data. Laboratory analysis was conducted by anthropologists at San Francisco State University, as well as California State University, Chico. Data collection typically included estimates of the biological profile, photographs, inventory, and x-rays where applicable. A more specific outline of these methods and data collection protocols are outlined in the materials and methods chapter.

The remains of 1,004 individuals were uncovered from this forgotten cemetery between the years 2012 and 2014 (URS 2015). It is probable that there are more burials which have yet to be uncovered and likely will not be unless there is further construction at the hospital. Even though it was forgotten for decades, the cemetery associated with the county hospital holds historical significance, particularly in the way that the dead were perceived. Individuals buried in pauper cemeteries were stigmatized as the poorest of the poor, lacking both the financial and community ties necessary for a proper burial. By providing the lowest cost interment possible, infirmaries and almshouses perceived their actions as “humanitarian” (Bell 1990: 59). Regardless of the administrative motives, the stigma of being buried in a pauper cemetery still persists today.

Historic Cemetery Studies

Studies of burial and interment illustrate social and cultural perceptions of death. These may or may not be influenced by religious beliefs, socioeconomic status, or familial traditions. As an area of bioarchaeology, cemetery studies have proven to be unique repositories of historical data. Historic period cemeteries in the United States and Europe have demonstrated status differentiation and variations in cultural beliefs surrounding the dead and their final resting places. To illustrate the importance of historic cemetery studies, this section provides three examples, one of which serves as a comparative study for this thesis project.

One example of a pauper cemetery study comes from Bell (1990) at the Uxbridge Almshouse in Massachusetts. Similar to the VMC infirmary and cemetery, Uxbridge served as a workhouse for the poor and provided burials at low cost (Bell 1990). The graves were unmarked and the coffins were mass-produced. Archaeological evidence demonstrates that these coffins were a one-size-fits-all production, as many of the bodies within them did not fit properly (Bell 1990). Though all historical indications pointed towards this cemetery being used exclusively for the poor, some of the archaeological evidence proved anomalous. While the coffins were mass-produced, some were adorned with elaborate coffin hardware. This presented a particular challenge of interpretation, as the coffins were likely used because they were available at the time and status interpretations cannot be accurately drawn from decorations alone (Bell 1990). Ultimately, Bell (1990) argues that the display of mortuary decorations is not always indicative of social status and needs to be understood within the context of the time period.

The 19th century Golden Gate Cemetery, located near the Legion of Honor in San Francisco, was rediscovered in 1994 during a construction project at the cite. This cemetery is one of few examples of a historic cemetery on the West Coast of the United States and offers information on the early European settlers of California (Buzon et al. 2005). San Francisco's complicated history of disinterment of burials in the city limits provides contextual evidence for how and why this cemetery went undiscovered for centuries. The city banned any further burials in 1900 and many of the remaining graves were removed to nearby Colma, California (Buzon et al. 2005). Even though removal of burials was required by the city, many simply had their headstones removed and were forgotten (Buzon et al. 2005). The individuals interred here were considered paupers, with much of the osteological evidence demonstrating similarities to other indigent burials. The combination of historical and osteological findings helped reconstruct the sociocultural context of this forgotten cemetery.

Analysis done at the Voegtly Cemetery in Pittsburgh, Pennsylvania serves as a comparative collection for this project. Similar to Santa Clara County, the area surrounding the church and cemetery underwent a major transition into an industrialized center in the mid-to-late 1800s. With this expansion came cultural and ethnic diversity and an overall larger population size (Landers et al. 2003). Because this cemetery is associated with a church and not a county hospital, it is assumed that these individuals are more representative of the general population at the time. While it does predate the VMC cemetery by approximately a decade, the historical contexts of the cemeteries are similar.

The Voegtly church and cemetery were located in Old Allegheny Town in Pennsylvania, which was claimed from native tribes in 1787 (Landers et al. 2003). Many of the early settlers in this area were of German and Swiss descent and the town was mainly residential (Landers et al. 2003). However, around the 1880s, the area saw an influx of commercial businesses, including the Heinz factory which moved in across from the church (Landers et al. 2003). As a result, more workers began migrating here to live and work, diversifying the previously Swiss-German population (Landers et al. 2003). Data on the osteological analysis of these burials and their comparison with data from the VMC collection is discussed further in the results chapter.

Summary

The complex, diverse history of Santa Clara County makes it a unique area of bioarchaeological study. Providing a brief historical overview of the landscape and demographics during the 19^{th} and 20^{th} centuries adds contextual evidence for the study of the Valley Medical Center county infirmary cemetery. It is from these data that the results from the ancestry estimation methods and dental pathology studies come into perspective. While a lack of information in the form of burial records makes the task of studying this collection more difficult, it allows for the incorporation of historical and cultural data to help reconstruct the past.

CHAPTER III

THEORETICAL PERSPECTIVE

Introduction

Using a biocultural approach to assess the pathological variation of ancestry groups in the historic pauper cemetery of the Santa Clara Valley Medical Center allows for a holistic understanding of the ways cultural factors can affect biological processes. Further, this model can be used to demonstrate how pathological variation within and between ancestry groups is influenced by society and access to resources. Culture plays a major role in how different groups are perceived. This is particularly true of the poor and marginalized in society. As a result, we can study the biological ramifications of social and cultural systems. This chapter will outline biocultural theory, as well as address the osteological paradox and stress models and how these perspectives are used within the context of this thesis project.

Bioarchaeology and Biocultural Theory

Bioarchaeology began in the 1960s and 1970s as the New Archaeology and cultural ecology came to the forefront of archaeology (Buikstra 1977). Prior to 1960, osteologists were not included in field excavations and much of the skeletal analysis at sites was overlooked (Buikstra 1977). It was through the implementation of a multidisciplinary approach in both archaeology and physical anthropology that bioarchaeology was born. The relationship between biology, the environment, and culture makes bioarchaeology unique in its representation of skeletal remains and has proven to be a crucial aspect of methodology formation in the field

(Buikstra 1977; Wright and Yoder 2003). It is from this interdisciplinary approach that theories such as the biocultural theory have developed.

Biocultural theory has been used by anthropologists since the 1970s, particularly among medical anthropologists (Wiley and Cullin 2016). Generally, this term has come to describe the inclusive effects of culture and society, as well as the environment and genetics, on the biology and evolution of humans (Wiley and Cullin 2016; McElroy 1990). Just as epigenetics has demonstrated the effects of the external environment on the internal workings of human biology, sociocultural factors can have equally important biological outcomes (Goodman 2013). Taking each of these factors into account with regards to human adaptation, biocultural theory is largely concentrated on holistic aspects of humanity (Wiley and Cullin 2016; McElroy 1990). Many biocultural studies have focused on the adaptation of humans to varying environments, for example cold adaptation, and how these stressors culminate in human variation and diversity (Wiley and Cullin 2016). This approach has since been adapted to the study of stress markers of disease and illness on the human skeleton.

To properly utilize a biocultural model, culture must first be defined. Due to the inherently complex nature of human behavior, it can be challenging to define culture; however, a generally accepted definition states that culture is "learned, socially transmitted, symbolically mediated behavior" (McElroy 1990: 247). One of the ways in which humans have adapted to a multitude of environments is through culture. Therefore, as important as genetics and biology are for human evolution, culture must now be given equal attention as an evolutionary force (McElroy 1990). McElroy's (1990: 250) "integrated model" suggests that equal emphasis should be placed on the key features of biocultural theory. This includes gathering cultural data from historical and archaeological records, and combining this with biological observations of the skeleton. Alternatively, a "segmented biocultural model" places more emphasis on the biological aspect of a study and views other variables as supplementary (McElroy 1990: 252). For purposes of this study, and many other anthropological biocultural studies, an integrative model provides the most useful means of outlining and analyzing data from a late 19th and early 20th century pauper cemetery.

Though anthropology has placed increased interest on the biocultural model, in practice it can fall short. Interdisciplinary connections must be emphasized in order to avoid bias towards or away from any particular aspect of the biocultural model. McElroy (1990) suggests that in order to properly conduct biocultural studies, the researcher must be flexible in his/her approach and specific in their use of social, biological, and cultural variables. Goodman (2013: 637) even suggests altering the name to "cultural-biological research" in an attempt to more clearly represent what the model is really about. However, this does not necessarily fix the problems of defining variables and working within the model's framework. In coming to terms with the inevitable difficulties of placing equal emphasis on the variables required for using this model, anthropologists and bioarchaeologists can find this to be a practical means of data analysis and presentation.

Using a biocultural model to frame this thesis project allows for different aspects of the human experience to be given equal representation. It incorporates biology and genetics with culture and society to understand the implications these have on human health in a historic-period pauper cemetery. Social stigma, lack of access to proper care and nutrition, and the impacts of the environment all have the possibility of rendering negative biological effects (Goodman 2013). These can then be viewed on skeletal remains as the markers of chronic stress. Factors such as these cannot be ignored when working with a historic collection known to comprise individuals of low socioeconomic status, as the ramifications of cultural and social inequality can have negative effects on health.

Stress and Health in Bioarchaeology

Health and stress are not the same thing, though stress can play a role in the health of an individual. Health is a variable, continuous phenomena which cannot be easily studied in living or dead populations (Reitsema and McIlvaine 2014). Because of the difficulties present in trying to define health, the detection of whether or not someone is or was healthy is even more problematic. As a result, bioarchaeology focuses on stress as an indicator for health in a general sense (Reitsema and McIlvaine 2014). This is further complicated by the fact that stress is nonspecific, meaning that skeletal stress markers alone are not indicative of their cause. Therefore, even if we can say that stress is a useful proxy for health, we are still missing the causal factors of that stress.

How stress manifests as a bodily response is largely associated with hormones. Hormones are responsible for the maintenance of homeostasis, normal conditions, within the body (Seyle 1973). When an external factor attempts to alter this level of stability, the major glands secrete hormones as an adaptive response. According to Seyle (1973: 639), this adaptation is called a “non-specific” stress response, because regardless of the stress-event, the body’s adaptive response has the same end goal of maintaining homeostasis. However, the amount of time spent under high-stress conditions can lead to even greater physiological manifestations, such as illness and disease (Goodman et al. 1988). Because the body responds in similar ways to nonspecific stress, it can be difficult to diagnose any specific stimuli causing the response, particularly in skeletal remains.

While a large portion of the study of stress in bioarchaeology tends to focus on the paleopathological indications of illness, there are additional causes of stress which need equal representation (Goodman et al. 1988). Additionally, multiple stressors may be in effect at any one time and have the potential of exacerbating each other (Goodman et al. 1988). These can include environmental stressors such as sociocultural and political stress, psychological stress, and disease (Goodman et al. 1988). Diseases and illnesses are themselves even more complicated because there are often multiple pathogens and immune response factors that dictate them (Seyle 1973). Due to the multifactorial nature of stress and disease, it can be challenging, if not impossible in some ways, to account for multi-stressor events, particularly when relying on osteological samples. One of the many ways to account for the causal uncertainty of bioarchaeological studies of health and stress is to recognize and address the factors which could manifest themselves in a single pathological condition.

Researchers have found that the best way to study the effects of stress on the skeleton is by examining the perceived health of an individual and their actual health status in life (Reitsema and McIlvaine 2014). As with much of the study of stress and health in past populations, there are a number of factors responsible for any single bodily response. These factors include, but are not limited to illness, the environment, and genetics (Reitsema and McIlvaine 2014). Thus, negative stressors cannot be determined as the sole reason for particular phenomena, such as nutritional deficiency and shorter stature. This further implies the necessity of addressing all possible influences and refraining from making definitive diagnoses from skeletal remains.

Since health is so difficult to study, why do bioarchaeologists study it at all? Because stress can manifest itself in bones and teeth, anthropologists have argued that studying stress is the best way to approximate health (Goodman et al. 1988; Reitsema and McIlvaine 2014).

Bioarchaeology aims at studying the lives of past populations, with health being one of many factors of interest. Though this can be a frustrating task, an attempt at understanding is better than no attempt at all.

The Osteological Paradox

The 1992 paper by Wood and colleagues significantly impacted the way bioarchaeologists interpret skeletal stress. It had been the consensus that skeletal indications of illness, nutritional deficiency, and other external stressors implied that an individual was experiencing chronic stress and poor health during life. However, Wood et al. (1992) suggest that the process of skeletal manifestations of stress could be far more complicated. Looking at the amount and type of lesion activity on skeletal remains may actually be able to suggest more about an individual's resilience to stress and present further avenues of interpretation (Wood et al. 1992).

Skeletal pathology can be observed as active or inactive lesions, reflecting whether the infection was currently in the process of healing or had previously healed at the time of death (Wood et al. 1992). While either lesion type might indicate poor health or chronic stress, Wood et al. (1992) argue that it is more likely the case that individuals with inactive lesions were able to fight off the infection better than their active counterparts. Therefore, those individuals with healed lesions might be seen as comparatively healthier. To further complicate skeletal stress interpretations, individuals without skeletal pathology could be the ones who experienced the stress most strongly and were not able to survive to the point of lesion formation (Wood et al. 1992; DeWitte and Stojanowski 2015). Additionally, not all pathological conditions present as skeletal lesions, further illustrating the complexities of inferring health from skeletal remains (DeWitte and Stojanowski 2015).

While all of this research on the condition of an individual's life from skeletal remains has proven useful for interpreting stress in bioarchaeology, it is necessary to recall that health is inherently difficult to study in the past. Additionally, skeletal remains do not provide cause of death, therefore eliminating the possibility of determining whether or not an individual died as a result of their condition. Wood et al. (1992) provide steps to take in order to address the issues present in bioarchaeological studies of stress and health; however, these suggestions fail to solve all of the problems. The best option for remedying the issue of multifactorial causes of skeletal stress markers is by explicitly acknowledging those factors. This includes recognizing cultural, social, and environmental impacts on health, as well as the role of biology and genetics (Wood et al. 1992). Wright and Yoder (2003) argue that the debate brought forth by the osteological paradox is both necessary and useful, as the authors provide a framework for challenging our assumptions and recognizing our limitations (Wright and Yoder 2003).

A specific area of paleopathological research is the dentition. Due to the unique properties of teeth, information about diet and health can be obtained from studying them. Teeth are exposed to external, as well as internal factors which leave indications in the form of carious lesions, abscesses, and hypoplasia defects, among others (Larsen 2015; Ortner 2003). While generally indicative of dietary differences and access to oral health and hygiene practices, pathological conditions of the mouth and dentition can be influenced by genetics and specific disease processes (Larsen 2015). Studying stress markers left on the teeth will not allow for a definitive diagnosis, again demonstrating how skeletal stress is nonspecific.

Sociocultural implications can also be made from studies of dental pathology. Dietary differences due to culture or socioeconomic status may result in higher carious lesion rates for particular groups (Larsen 2015). For example, carbohydrates are highly cariogenic, and a diet mainly composed of foods such as corn could lead to a greater prevalence of dental caries among populations that consume a considerable amount (Larsen 2015; Lanfranco et al. 2010). Enamel hypoplasia defects are also indicative of early childhood stressors such as inadequate nutrition. However, there are a number of other diseases which can cause similar defects, such as congenital syphilis, tuberculosis, and rickets, each with their own sociocultural influences and repercussions (Ortner 2003). Again, the nonspecific nature of skeletal stress makes it difficult to identify any single causal factor, but does provided avenues for further data analysis.

Finally, bioarchaeological samples are inherently biased. They do not represent all individuals within a population, nor do they represent the variation in pathological conditions which could have been affecting the population (DeWitte and Stojanowski 2015). Small sample sizes and taphonomic damage also contribute to bias within bioarchaeological studies (Wood et al. 1992). To minimize overrepresentation of any particular pathological condition, this thesis very specifically states that the results do not represent the entire cemetery population, rather that they represent only the subsample population. Inferences about the rest of the cemetery sample could be gleaned from these data, but are by no means indicative of group trends as a whole.

Summary

Bioarchaeology paved the way for physical anthropologists to participate in archaeological study and debate. As an interdisciplinary perspective, it is no surprise that the methods and theories employed by bioarchaeologists draw from a number of disciplines. Many of these theories ultimately incorporate the cultural aspect of human life with biological processes, yet they also include perspectives from environmental, political, and social theories. While arguably a very challenging approach, bioarchaeology and biocultural perspectives have improved the way that anthropologists interpret data.

One of many complicating aspects of studying past lifeways is the endless number of ways in which to interpret the past. Through historical and contextual data, bioarchaeologists attempt to piece together concepts of health and livelihood – concepts which are inherently difficult to define. Many of the questions asked in these studies are left unanswered and are subject to various interpretations. Thus, while the task of recovering lost information can be frustrating and at times fruitless, it is the nature of the discipline to continually reformulate questions, hypotheses, and methods.

The pathological conditions identified in this thesis could have any number of causes. Lack of access to proper healthcare and nutrition plays a significant role in the formation of pathological conditions of the teeth and jaws; however, the reasons for inadequate care are multidimensional. For example, low socioeconomic status can result in insufficient access to social benefits, which can then affect the health of an individual. Utilizing biocultural theory and a cyclical model of cause and effect between social interactions and biological processes frames the interpretation of results from this project.

CHAPTER IV

A REVIEW OF DENTAL ANTHROPOLOGY

Introduction

This chapter focuses on the form, function, and application of the dentition to anthropological studies. An overview of the basic anatomy and composition of the dentition is discussed to provide a framework for how teeth can be used by anthropologists. Further, the history and study of dental anthropology applies these functional characteristics to the study of past human populations. Specific attention will be paid to the study of dental morphology and pathology, as these pertain directly to this thesis project. The background knowledge outlined in this chapter will help clarify methods and analyses carried out in later chapters.

Dental Anatomy, Preservation, and Applicability of Dental Studies

Teeth are made up of four main parts: enamel, dentin, pulp, and cementum. The main constituents are enamel, which covers the crown of the tooth, and dentin, the layer right beneath the enamel (Hillson 1979; Fuller et al. 2001; Scott 2008). Enamel forms incrementally during development but does not change or remodel over time, making it an ideal indicator of life history (Hillson 1979). The pulp chamber is the cavity within the tooth which holds blood vessels and nerves and is rarely exposed to oral bacteria, except in the event of severe attrition and dental caries. Finally, cementum lines the roots and helps to keep the tooth in place (Scott 2008). The composition of teeth makes them the strongest part of the human body. Therefore, the teeth are more likely to be preserved among fragmentary skeletal collections (Hillson 1979).

In addition to their durability, teeth have a unique interaction with the environment outside of the body, providing information on diet and disease in past populations (Hillson 1979). The dentition is also the most canalized part of the human body (Larsen 2015). This means that dental formation and eruption are less interrupted by stressors, such as nutritional deficiencies and disease, and are under stronger genetic control when compared to bone growth and development (Larsen 2015). While aspects of skeletal growth and development, such as height, may be stunted by external stressors, teeth are better correlated with biological age than bones (Ortner 2003; Larsen 2015). Because of the canalization of dental development, the teeth will continue to form even under significant stress and provide indications of these stress events early in life. For example, enamel hypoplasia defects are often the result of a lack of proper nutrition and illnesses, and present as linear bands in the enamel (Hillson 1979). Thus, defects such as these can provide indications of diet and general childhood health (Hillson 1979). Additionally, because the teeth are more genetically influenced than other morphological traits of the skeleton, they are ideal for use in ancestry estimation methods and examining gene flow and heritability (Edgar 2009).

History of Dental Anthropology

First outlined as a field of study by Klatsky and Fisher (1951), dental anthropology has since become a valuable source of data on human variation (Scott and Turner 1988). Dental anthropologists specifically focus on the ways in which teeth can provide information on life history, health, and growth and development (Scott and Turner 1988). This can then be applied to forensics, bioarchaeology, and human evolution to better understand ancestral, geographic, and cultural backgrounds.

One of the first major dental anthropologists was Albert Dahlberg. Though he was a dentist by trade, he pursued dental trait classifications and standardizations to demonstrate human dental variation over time (Scott and Turner 1988). Prior to Dahlberg, the study of morphological variation of the dentition was utilized by Hrdlicka (1920) in his graded scale of incisor shoveling among Asian and Native American populations (Hrdlicka 1920; Turner et al. 1991). Additionally, Hrdlicka (1920) provided an outline of the extent of variation for this specific trait, including the high likelihood that our earliest ancestors exhibited this trait to an extent greater than is seen in modern populations today.

To emphasize and better examine the variation seen by himself and other anthropologists, Dahlberg created the first plaster dental casts. Differences in dental shape and size between and within populations demonstrate that human teeth change over time. Though the overall process of genetic change is slow, Dahlberg (1945) found that it occurs differently among all populations. Thus, he suggested that we should be able to see variation in dental morphology based on geographic location (Dahlberg 1945). While this is an early, and somewhat outdated approach, Dahlberg's (1945) dental casts and traits provided the foundation for studying ancestry based on the dentition. Since Dahlberg's (1945) work, anthropologists such as Christy G. Turner and G. Richard Scott have advanced the field of dental anthropology exponentially, demonstrating the practical use of the dentition for reconstructing past lives.

Further building on these early studies of dental morphology, Turner et al. (1991) created the Arizona State University Dental Anthropology System (ASUDAS). This system allows researchers to more accurately score grades of morphological traits, rather than simple dichotomies of presence or absence (Turner et al. 1991). Additionally, this standardized scoring system helps reduce interobserver error. While the traits outlined in ASUDAS are not the only morphological traits that can be scored, Turner et al. (1991) chose those traits which were the least sexually dimorphic, the most readily viewable, and those that have proven to withstand time.

Dental Morphology

Dental morphology refers to the variation in shape and particular features, such as tubercles and accessory cusps, of the dentition (Scott 2008). These can be studied within and between populations, and are scored based on degrees of presence or absence. Understanding how morphological traits can provide ancestry estimates requires an understanding of the heritable component of dental variation. How to score traits and interpret morphological variation can then be addressed.

Dental morphology is used for ancestry estimation because these traits are between 60-80% heritable and they demonstrate within-group similarities (Hubbard et al. 2015: 295). However, some teeth have proven to be morphologically more stable, meaning they are more effected by genetic inheritance than by the environment (Scott 2008). The stable teeth are usually the first in the tooth category, such as the first upper and lower incisors, the first upper and lower premolars, and the first upper and lower molars (Scott 2008). Ideally, scoring morphological traits should be done on the stable teeth (Scott 2008). While there is a strong genetic component to dental morphology, these traits are complex and have not been related to any single gene (Scott and Turner 1988; Pilloud et al. 2016).

Using morphoscopic dental traits is a unique approach to estimating ancestry and eliminates some of the issues present in other ancestry estimation methods, particularly among poorly preserved skeletal collections. For example, ancestry estimation methods which utilize morphoscopic traits of the skull become problematic when remains are fragmentary and may result in inconsistent estimations. Additionally, morphological traits are independent of one another. However, there are traits which are more closely related and therefore a high frequency of one trait within a group could lead to a high frequency of another. An example provided by Scott and Irish (2017) is shoveling and double shoveling of the incisors, which have high frequencies together in certain populations. There also appears to be little to no sexual dimorphism present in morphological traits of the dentition, except for with certain traits of the canine; however, these traits are not present in the rASUDAS database (Scott and Irish 2017; Scott et al. 2018). According to Scott and Irish (2017), this allows for a larger sample size by combining the sexes into one sample and eliminates the need for distinguishing between the sexes.

Traits are scored and classified based on location and size, resulting in a scale based on the degree of trait presence or absence. Using this type of scoring system allows for the expression of inherent variation in morphological traits, something that Scott and Turner (1988: 100) characterize as "quasi-continuous" variation. Traits are commonly scored on one side of the jaw, since both sides are typically symmetrical; however, if there is a missing tooth on the side chosen for scoring, the other side can be substituted (Scott 2008).

While dental morphology provides a number of useful applications for skeletal analysis, there are some limitations. Antemortem and postmortem loss and damage impact the ability to observe and score traits (Scott 2008). Attrition and dental fillings also make scoring traits on the occlusal surfaces more difficult (Scott and Irish 2017). Age plays a significant role in this because age-related dental wear can hinder the researcher's ability to score a trait (Pilloud et al. 2016). In some cases, attrition and restorations can completely obscure a trait, making it impossible to score presence or absence (Scott 2008). If a tooth is worn to the point where the trait is unobservable, the common reaction is to exclude this trait. However, this results in either over or under-representation of morphological variants (Scott and Irish 2017). One of the ways in which to combat this issue is to address the possibility of bias based on dental wear, antemortem loss, and postmortem damage early on in the research process.

Dental Pathology

The study of dental pathology provides insight into the diets, health, and oral hygiene of past populations. The teeth are exposed to wear from the foods we consume, as well as cultural practices and modifications. While the use of dental pathology to infer subsistence strategies is complicated by the inherent individual variation in dental health and hygiene, it is still possible to use the dentition to help inform past dietary habits (Lanfranco et al. 2010). Some of the main pathological conditions of the dentition include carious lesions, attrition, antemortem tooth loss, abscesses of the alveolar bone, calculus, periodontal disease, and enamel defects. Analyzing dental pathology within a skeletal collection informs our understanding of how changing population structures, diet, and socioeconomic status play a role in oral health.

Carious lesions are the result of an infectious disease process called dental caries (Larsen et al. 1991). Colloquially, these lesions are referred to as cavities and are caused by oral bacteria, including *Streptococcus mutans,* as it ferments food particles (Ortner 2003). This microbacterium lives within the pits, fissures, and spaces between teeth where it ferments plaque and alters the pH levels of the oral cavity (Kolpan and Bartelink 2018). If teeth are not properly cleaned, plaque builds up on the tooth crown near the gum line, or gingivae. The bacterial activity that responds to this plaque accumulation is useful for studying past dietary habits and oral health (Hillson 1979; Hillson 2008). Dental caries manifests as mild discoloration to severe cavities within the tooth, which appear in the later stages of the disease (Larsen 2015; Ortner 2003; Hillson 2005; Hillson 2008).

There are internal and external factors which cause carious lesions including diet (e.g. sugar and carbohydrates), the build-up of plaque, the structure of the tooth, wear, natural bacterial flora of the mouth, and saliva (Larsen 2015; Ortner 2003; Larsen et al. 1991). Though there is a genetic component to the associated risk of developing caries, much of the disease is caused by food itself (Larsen 2015). Throughout the day, the mouth experiences different pH levels as a result of bacterial activity. When the level is acidic for a long period of time due to bacterial fermentation of food particles, the enamel dissolves, resulting in pits, or carious lesions, within the teeth (Hillson 1979; Featherstone 2004). This process is called demineralization, which can turn into cavities if left untreated (Featherstone 2004; Kolpan and Bartelink 2018). Bacteria which cause demineralization of the enamel tend to produce acidic by-products, which in turn leave the mouth with a lower pH level and acidic bacteria proliferate (Featherstone 2004). Therefore, the depiction of dental caries as a disease process can be seen when we consider how oral health leads to bacteria which can in turn lead to carious lesions and further bacterial proliferation.

When oral pH is more alkaline, there is little to no dissolving of accumulated food particles and hard deposits called calculus are formed around the gingivae (Hillson 1979). Calculus appears as a thick layer of brown or white mineral deposits on the lingual surfaces of the mesial teeth and buccal surfaces of the distal teeth (Hillson 2005). If the root is exposed below the cemento-enamel junction (CEJ), calculus and carious lesions may also occur below the gingivae (Hillson 2005). It is important to note that dental caries is a reversible disease when properly treated. The introduction of more alkaline substances can help remineralize the enamel and prevent the process from turning into a lesion (Featherstone 2004; Fejerskov and Kidd 2008).

Caries affecting the root of the tooth occur when the surface of the root is exposed at the CEJ, typically due to old age and periodontal disease (Hillson 2005). The root begins to demineralize upon exposure to bacteria and can lead to cavity formation. Hillson (2005) states that carious lesions of the root are most common in middle to older aged adults because of the time necessary for the exposure of the root. In order to accurately represent the number of root surface caries, the number of lesions present must be counted, as well as the number of teeth which could have potentially been effected (Hillson 2005).

The properties of particular foods, as well as their preparation, have an impact on the formation of carious lesions. For example, carbohydrates, particularly those from sugar and starch, are highly cariogenic (Larsen 2015). Therefore, diets high in carbohydrates result in individuals experiencing higher rates of carious lesions. These can penetrate into the dentin and may even cause exposure of the pulp cavity (Lanfranco et al. 2010). On the other hand, a lower carbohydrate diet typically results in fewer carious lesions, but when they do occur, they tend to affect the enamel only (Lanfranco et al. 2010). Diets high in fat and protein do not cause caries; however, the incorporation of refined sugar to this type of diet would increase the rate (Hillson 2005; Ortner 2003).

Dental attrition, or wear, also leaves the dentition more susceptible to bacteria and infection. Larsen (2015) states that the majority of studies have found a positive correlation between dental attrition and an increase in carious lesions. This positive correlation is seen predominantly among older individuals (Hillson 2005). The pulp chamber and dentin of the tooth may be exposed with excessive wear, allowing for bacteria to easily enter. Further, diets which are high in carbohydrates and abrasive in nature can leave the teeth worn and bacteria prone simultaneously (Larsen 2015). Cultural practices, as well as using the teeth as tools, can cause patterned attrition, which can be a useful indicator of lifestyle.

Caries rates based on socio-economic status have been widely studied, however with some discrepancies (Larsen 2015). Some studies find that higher status individuals tend to have more carious lesions due to greater variation in diet, while others find that lower status individuals experience higher caries rates because they lack protein rich diets and subsist on more cariogenic foods such as corn (Larsen 2015). An example of the variation in caries rate interpretation comes from Little et al.'s (1992) study on the Weir family cemetery in Virginia. Dating between the 1830s and 1907, the Weir family cemetery was used exclusively for family members. Much of the archaeological and historical data indicate that the family was of a higher status (Little et al. 1992). Little et al. (1992) conducted a comparative analysis of a pauper cemetery from Massachusetts during the same time period and found that the Weir family had higher rates of carious lesions. This they interpreted as an indication of access to more processed foods and healthcare, and thus higher status (Little et al. 1992). Regardless of the argument, diet has been correlated with caries rates and this may be explained by socioeconomic status and access to particular foods (Ortner 2003). It is imperative to mention that dental pathology alone is not a good indicator of social status, and therefore must be considered within the context of the site and the population as a whole.

Periodontal disease, a hypersensitive response to plaque, is another common pathology of the dentition, resulting in the loss of alveolar bone and eventual loss of the tooth (Hillson 2005;

Hillson 1979; Larsen 2015). What begins as gingivitis, an inflammation of soft tissue surrounding the tooth, can extend into the bone causing lesions and alteration of the tooth socket shape (Hillson 2005; Hillson 1979). It is at this stage that the infection becomes periodontal disease (Hillson 2005). According to Hillson (2005), this is a surprisingly painless process where the individual may not even know they are affected until the tooth becomes loose. The eventual result of this disease is the antemortem loss of teeth and alveolar resorption. While periodontal disease itself was not emphasized in this study, the resulting antemortem tooth loss was. Larsen (2015) argues that the comorbidity of caries and antemortem tooth loss is an indication of consuming a highly cariogenic diet. Although this has not been proven, it seems plausible that poor dental health overall would result in multiple pathological conditions.

Periapical inflammation causes the formation of abscesses on the alveolar bone, often exposing the roots (Hillson 2005). This is called periapical periodontitis and can present as acute abscesses, or small pockets of pus that typically do not destroy bone, or chronic lesions which do result in the loss of bone around the tooth socket (Hillson 2005). Based on the fragmentation of this collection, it is necessary to carefully analyze pathological conditions which affect the bone in order to not mistake taphonomic damage for pathological conditions. For instance, periapical lesions should be scrutinized for some demonstration of periosteal reaction in the form of small pits; however, these should not be mistaken for normal pitting of the bone (Mann and Hunt 2005).

The study of dental pathology provides evidence for the ways in which diet and lifestyle influence health. While they can be caused by a multitude of things, pathological conditions of the teeth indicate an individual or group’s access to proper nutrition, healthcare, and oral hygiene. By incorporating dental pathological data with ancestry estimates, sociocultural variation can be better understood.

Summary

Teeth are a unique way to understand more about a group's dietary and cultural practices, as well as provide an additional ancestry estimation method; however, there are limitations to these studies. Antemortem tooth loss results in the loss of information regarding possible carious lesions and attrition, making the interpretation of pathological conditions difficult. This also means that the number of teeth affected by pathological conditions might be over or underestimated. Another complication of combining the study of dental morphology with pathology is that the pathological conditions themselves obscure the morphological traits. Regardless, the study of dental anthropology has proven to be useful in studying the past. The following chapter discusses how the studies of dental morphology and pathology were used when analyzing a late 19th to early 20th century pauper cemetery.

CHAPTER V

MATERIALS AND METHODS

Introduction

This chapter discusses the materials and methods used for this project to outline the process of scoring dental morphology and pathology, and the statistical tests used. Additionally, the benefit of being trained on how to properly score dental morphology will be discussed, as well as the results of intraobserver error tests. The data collection methods follow the *Standards for Data Collection from Human Skeletal Remains* (Standards: Buikstra and Ubelaker 1994) and the protocol for scoring dental morphology outlined in the Arizona State University Dental Anthropology System (ASUDAS: Scott and Irish 2017). Statistical analyses address the prevalence of dental pathology among the ancestral groups represented in this sub-sample of the Valley Medical Center (VMC) collection.

Hypotheses

The main hypothesis for this project is whether or not there is a statistically significant difference in the amount and type of dental pathology between the ancestry groups. It is predicted that the prevalence of dental pathology between each ancestral group will be relatively equal given the overall low social status of this population. However, it is expected that types of dental pathology, such as carious lesions, will be more frequent within the non-white populations due to inadequate access to proper nutrition. The overall quality of dental health and hygiene is expected to be poor.

The second hypothesis relies on the use of a comparative collection from Voegtly Cemetery in Pennsylvania. This is a contemporary collection to VMC; however, the cemetery is associated with a church and therefore likely to be more indicative of the general population at the time. It is expected that there will be more dental pathology within the VMC collection based on the low socioeconomic status of these individuals.

In order to illustrate the applicability of training for properly scoring morphological dental traits, intraobserver error tests were conducted. It is expected that the scores from the trial prior to being trained will be the most different from the second trial after training and the third trial a few months later. Additionally, it is expected that the use of dental morphology for ancestry estimation will result in more of the sampled individuals receiving an ancestry estimate instead of being categorized as indeterminate.

Sampling Methodology

For this sample, 40 individuals (n=40) were selected from a set of remains determined to have good preservation. Initially, not all selected cases had teeth, either due to postmortem damage or antemortem tooth loss. Individuals missing the entire dentition due to postmortem damage were excluded from the final sample because they provided no useful information on dental morphology, a necessary aspect of this thesis. It is worth noting the presence of edentulous individuals for purposes of dental pathology; however, dental ancestry estimation could not be conducted. For purposes of this thesis project, the criteria for inclusion was that an individual had to have at least one tooth.

Training and Intraobserver Error

To aid in proper scoring of dental morphology, three days were spent with Dr. G. Richard Scott, Dr. Marin Pilloud, and graduate students from the University of Nevada, Reno. Training on proper scoring techniques is critical as traits can be difficult to score. This training also provided exposure to the array of expressions for each trait. After two days of lecture, each participant scored the same set of dental casts and compared these with the scores of Dr. Scott and one another.

To test the value of training for dental morphological trait scores, data collected from ten individuals prior to the training session. Following training, the same ten individuals were re-scored. Thirty additional skeletons were added to this sub-sample for an overall sample size of 40 (n=40). To further test the usefulness of training, dental traits from the initial ten skeletons were rescored. The ancestry estimations provided from each of these trials were compared to see if an entirely different ancestry was obtained. It is expected that the scores from the first and second checks will be different and that the third check scores will be more similar to the second check. Further, the ancestry estimates using dental morphology were compared to the estimates obtained using other methods such as cranial morphology and measurements. This will demonstrate the utility of proper training in scoring methodology for dental morphological ancestry estimation and whether or not it is a more useful method of ancestry estimation when working with a poorly preserved collection.

Data Collection

This thesis required that both dental pathological data and morphological ancestry data be collected. Data collection sheets for dental inventory and pathology were modified from

Standards for Data Collection from Human Skeletal Remains (Buikstra and Ubelaker 1994). Additionally, I created paper data collection sheets for dental morphology based on the variables present in the rASUDAS database (beta version). Estimates of sex and age were obtained from data sheets that were previously collected by other graduate students and these also relied on the methods outlined in Buikstra and Ubelaker (1994). Ancestry estimation methods using the Forensic Data Bank cranial measurements, Howell's cranial measurements, postcranial measurements, and Hefner's (2009) cranial morphology were collected from data previously entered into FORDISC 3.1 (Ousley and Jantz 2015). The dental morphology data were entered into the online rASUDAS database for statistical analysis and probability estimates of ancestry. Additional statistical analyses were done using IBM SPSS (Version 25).

Dental Inventory

Each tooth was inventoried for presence or absence. This includes those teeth missing congenitally, antemortem loss, or postmortem loss or damage. The dental inventory was scored using codes corresponding to the level of presence or absence. These data were also recorded visually using dental charts, which allowed for illustrating various pathological conditions and dental wear. The data scoring sheets used for inventory are included in Appendix A. The scores for inventory are found in Table 1.

Dental Pathology

Carious lesions were recorded using a numeric code based on the size and location of the lesion (Table 2). The data collection form provided space to record up to three lesions per tooth, and is provided in Appendix A. Carious lesions commonly occur on the occlusal surfaces of the molars, where the bacteria are protected and can easily propagate in the natural pits and fissures of these teeth (Hillson 2005). To determine whether a pit on an occlusal surface was carious, a dental probe was used. If the probe became caught on the edges of the pit, the lesion was

Table 1. Criteria for dental inventory

Numeric Score	Inventory Criteria
1	present, but not in occlusion (not erupted)
2	present, development complete, in occlusion (with wear facets and >/=2mm root present)
3	absent, without associated alveolar bone (unknown when it was lost)
4	absent, with the alveolus remodeled or remodeling, antemortem tooth loss
5	absent, without alveolar remodeling, postmortem loss
6	absent, congenital, alveolar bone indicates that tooth never formed
7	present, damaged, little information recorded (or less than 2mm below crown)
8	present, but not observable (e.g. tooth in crypt, or impacted)
9	root is present, but fractured, crown is absent

Source: Data for table modified from *Standards* (Buikstra and Ubelaker 1994).

considered carious. If not, the pit was deemed to be non-carious (Hillson 1996). Another common location for carious lesions is the interproximal surfaces between teeth. Bacteria easily become trapped in between the teeth, resulting in lesions at times involving the entire interproximal area of the affected tooth and root (Hillson 2005). Scores for caries were recorded as follows in Table 2.

Abscesses were also recorded using a numeric code (Table 3). Again, these numbers correspond mainly to the location of the abscess, for example, periapical lesions located at the apex of a tooth root. An abscess presents as a hole in the alveolar bone with smooth margins and signs of periosteal reaction surrounding the lesion. In addition to the above-mentioned pathological conditions, the amount of calculus present on the teeth was noted generally, as well as the presence of restorations and periodontal disease. The data collection form for abscesses are included in the Appendix, with the scores as follows in Table 3.

Table 2. Criteria for carious lesion scores

Numeric Score	Caries Prevalence
0	no caries
1	occlusal surface, including the pits, fissures and exposed dentine
2	cervical regions, mesial and distal (excluding interproximal points of contact)
3	smooth surfaces of buccal and lingual aspects, excluding fissures
4	cervical regions, buccal and lingual, excluding interproximal points of contact
5	root caries, below the cervical area
6	large caries, have destroyed so much of the crown that point of origin is unclear
7	interproximal surfaces at the contact points between teeth
8	caries of the protosylid pit or circular caries (of hypoplasia)
9	pulp exposed by attrition, not really caries

Source: Data for table modified from *Standards* (Buikstra and Ubelaker 1994).

Table 3. Criteria for abscess scores

Numeric Score	Abscess Location
0	no abscess, alveolus is complete
1	buccal or labial channel
2	lingual perforation
3	evident pocket that extends from the buccal periodontal margin
4	evident pocket that extends from the lingual periodontal margin
5	periapical abscess
9	the alveolus is not observable

Source: Data for table modified from *Standards* (Buikstra and Ubelaker 1994).

Dental wear, or attrition, was scored using two methods. The molars were scored in quadrants, as outlined by Scott (1979). Additionally, the incisors, canines, and premolars were scored for their level of wear using Smith's (1984) scores for dental attrition. Because dental wear can diminish the appearance of morphological traits for ancestry, any tooth that was too worn for morphological data to be obtained was marked as missing/unobservable in rASUDAS (Scott and Irish 2017). Moreover, the presence of significant dental wear can impact the number of carious lesions scored. While a tooth may have had a lesion present at some point in the individual's life, significant wear can obliterate these and result in a misrepresentation of the number of carious lesions in the population. These factors will be considered in the results.

Dental Ancestry

Using morphoscopic traits for ancestry estimations, such as dental and cranial morphology, is a reliable method of estimating ancestry. These traits are scored based on a scale of trait variation, rather than using a dichotomized scale with only two options (Hefner 2009). Historically, morphoscopic and nonmetric traits for ancestry estimation were not replicable and, as argued by Hefner (2009), were based on experience and feeling rather than explicit scales. Studies of morphoscopic traits (Hefner 2009), have found great utility in statistically backed morphology scores; however, these are most useful when combined with other traits and not when one trait is relied on solely for an ancestry estimate. This is also the case when scoring dental morphology. It is best to include as many trait scores as possible, such as Hefner's morphoscopic traits of the crania, for an individual, as this strengthens the estimation output.

The morphological traits scored come from ASUDAS standardized scoring protocols; however, not all traits are present in the rASUDAS online database (beta version). Twenty-one crown and root traits are included in rASUDAS (Scott et al. 2018). A trait was scored as missing or unobservable if the tooth was lost postmortem, taphonomic damage was so great that the trait could not be scored, severe dental attrition prevented visible morphology, or the tooth was not able to be removed from the surrounding bone for analysis of the root traits. Dental casts created in conjunction with the ASUDAS scoring system were used for comparative assessment of each trait. The use of dental casts is helpful overall for comparing a sample to known dentition; however, casts can lack the detail seen on a real tooth, and it is therefore necessary to analyze real human teeth as well in order to familiarize oneself with the variation in trait expression.

Sex, Age, and Other Ancestry Estimations

The methods for estimating sex from these individuals come from previously collected data following the protocols outlined in *Standards* (Buikstra and Ubelaker 1994). Sex was estimated from traits of the pelvis, including the sub-pubic concavity, ischiopubic ramus ridge, ventral arc, greater sciatic notch, and preauricular sulcus, as well as cranial traits including the nuchal crest, supraorbital margin, glabella, mastoid process, and mental eminence. Traits of the os coxae were scored on a scale of blank for unobservable, 1 for female, 2 for ambiguous, and 3 for male, except for the greater sciatic notch which is scored from 1 to 5, with 1 being considered female and 5 considered male (Phenice 1969; Milner 1992). The preauricular sulcus was also scored from 0 to 4, with 0 being unobservable, 1 being wide, and 4 being narrow (Milner 1992). All of the cranial features were scored from 1 to 5, with 1 considered female and 5 considered male (Acsadi and Nemeskeri 1970). Based on these combinations of scores, a sex estimation was assigned as undetermined, female, probable female, ambiguous, probable male, or male.

Age estimation methods following those presented in *Standards* (Buikstra and Ubelaker 1994) included the fourth sternal rib end, the pubic symphysis, and the auricular surface. Additional methods outlined by Hartnett (2010) were also used. The auricular surface was scored in phases from 1 to 8, with the eighth phase indicating the most age-related degeneration of the bone (Lovejoy et al. 1985). The pubic symphysis was scored based on Hartnett's (2010a) phases from 1 to 7. Each phase corresponds with an age range, with phase 7 showing the greatest amount of degeneration. Similarly, the sternal end of the fourth rib was also scored between phases 1 through 7, and analyzes the amount of pitting and irregularity of the rib rim (Hartnett 2010b).

Scoring Methods for Dental Morphology

Scoring morphological traits for ancestry estimation follow those outlined by Scott and Irish (2017) and were collected based on the breakpoint scores used in the rASUDAS database (beta version). A breakpoint is the threshold for trait presence or absence (Scott and Irish 2017). If an individual demonstrates a score above the threshold, they would be considered as having the trait to a specified degree (Scott and Irish 2017). Scores for each trait were input into rASUDAS for comparison between known biogeographic clusters, providing the probabilities of the sample individual belonging to any of the reference sample ancestral groups (Scott et al. 2018). The reference samples include Western Eurasian, Sub-Saharan African, Southeast Asia and Polynesia, American Indian, East Asian, Australo-Melanesia and Micronesia, and American Arctic and Northeast Asian (Scott and Irish 2017; Scott et al. 2018). The specific populations comprising each group are listed in Table 4.

Morphological trait scores were input into rASUDAS to obtain an ancestry estimate. Each burial was initially run against all seven of the biogeographic clusters available in the database. However, upon review of census data from Santa Clara County during the time period proposed for the cemetery, four particular ancestry groups appeared to be the most common.

Additionally, selecting fewer ancestry clusters improves the output estimate of the program (Scott et al. 2018, 27). Therefore, each individual burial was re-run against the four main ancestry groups of Western Eurasia, East Asia, Sub-Saharan Africa, and American Indian. See Appendix C for outputs from rASUDAS for each burial.

Table 4. rASUDAS biogeographic clusters

Cluster	Reference Sample Populations
Western Eurasia	Europe, North Africa, India
Sub-Saharan Africa	West, East, South Africa
Southeast Asia and Polynesia	Mainland and insular Southeast Asia and Polynesia
American Indian	North American, Mesoamerican, South American Indian
East Asia	China, Japan, Mongolia
Australo-Melanesia and Micronesia	Australia, New Guinea, Melanesia, Micronesia
American Arctic and Northeast Asia	Aleut, Inuit, Chukchi

Source: Data for table adapted from Scott et al. (2018: 22) reference sample data.

Descriptions of each trait, modified from Scott and Irish (2017) and their scoring procedures are found below. Photographs for illustrative purposes can be found in Appendix B.

- Winging of the upper central incisors is characterized as labial winging of the distal marginal edges of the teeth and is scored as absent, present with a score between 3 and 6, or missing/unobservable.
- Shoveling of the upper central incisors is scored as 0 and 1, 2 and 3, 4 to 7, or missing/unobservable. This trait is common among Asian populations and is a scoop or shovel shape on the lingual aspect of the incisors caused by more prominent marginal ridges.
- Interruption grooves appear on the marginal ridge of the upper lateral incisors as a distinct groove and are scored as 0, present, or missing/unobservable.
- The hypocone of the maxillary second molar is scored on a scale of 0 and 1, 2 and 3, 4+, or missing/unobservable. This is also known as cusp four on the distal lingual edge of the tooth.
- Carabelli's trait is a projection found on the lingual edge of the maxillary first molars and is scored as 0 and 1, 2 to 4, 5+, or missing/unobservable.

- Cusp five, also called the metaconule, is located between the hypocone and metacone on the first maxillary molar. When present, it appears as a small additional cusp and is scored as 0, 1 to 5, or missing/unobservable.
- Enamel extensions of the maxillary first molars appear as extended lines of enamel into the area between the roots and are scored as 0 and 1, 2 and 3, or missing/unobservable.
- The lower second premolars can exhibit a range of cusp numbers along the lingual surface of the tooth. These multiple lingual cusps are scored as 0 and 1, 2 and 3, or missing/unobservable.
- Groove patterns of the mandibular second molar are scored as X and +, Y, or missing/unobservable. An X pattern is distinguished by cusps 1 and 4 touching in the center of the tooth, whereas a + pattern is all cusps 1 through 4 merging together. A Y pattern occurs when cusps 2 and 3 are touching.
- The cusp number on the mandibular second molar is scored based on a count of the number of cusps on the tooth. The options for scoring are 5, 4, or missing/unobservable.
- Cusp 6 of the mandibular first molar is scored as 0, 1 to 5, or missing/unobservable based on the presence and size of the cusp. In order for cusp 6 to be present, cusp 5 must also be present.
- Mandibular first molars are also scored for the presence and size of cusp 7, which appears between cusps 2 and 4 on the lingual side of the tooth and are scored as 0 and 1A, 1 to 4, or missing/unobservable.
- The protostylid of the lower first molar is a projection of the buccal side of the tooth and is scored as 0, 1, 2 to 7, or missing/unobservable.
- The final trait of the mandibular first molar, the deflecting wrinkle, is difficult to score when any type of wear is present. This trait presents as a groove on the occlusal surface of the tooth and is scored as 0 to 2, 3, or missing/unobservable.
- The 2-rooted maxillary premolar is scored as 1 root, 2 to 3 roots, or missing/unobservable.
- A 3-rooted maxillary second molar is scored as 1 or 2 roots, 3 roots, or missing/unobservable.
- The mandibular canine is scored for 1 root, 2 roots, or missing/unobservable.
- A 3-rooted mandibular first molar is scored as 1 and 2 roots, 3 roots, or missing/unobservable, and a 1-rooted mandibular second molar is scored as having 2 roots, 1 root, or missing/unobservable.
- Tomes' root of the mandibular first premolar presents as a root groove and is scored as 1 to 3, 4 to 7, or missing/unobservable.
- The maxillary third molar is scored for the traits of pegged/reduced/missing on a scale of absent, present, or missing/unobservable.

Scoring Limitations

Root traits are based on the number of roots present on the tooth. These traits can be scored even if the tooth is not present by looking at the tooth socket; however, they cannot be scored if the tooth was lost antemortem and remodeling of the bone occurred (Scott and Irish

2017). The third molar is extremely variable in terms of its presence, absence, and shape. In order to receive a score of absent, the tooth must not be pegged, reduced, or missing congenitally and is scored as present if any of these variations are observed (Scott and Irish 2017). A missing dental trait was scored if the tooth itself was not present, either due to postmortem damage or antemortem loss. A trait scored as unobservable could not be distinguished based on extensive enamel attrition, carious lesions, or the tooth could not be removed from the alveolus for observation of the root traits. While there is no separation of the missing/unobservable category in rASUDAS, this distinction was made on the paper data collection forms to explain why a tooth was not scored.

Statistical Tests

The rASUDAS database (beta version) uses a naïve Bayes algorithm to classify an individual into one of the seven biogeographical ancestry clusters (Scott et al. 2018). These clusters were created using pairwise analysis in order to combine groups with commonly shared traits (Scott et al. 2018). The probabilities for classification into each cluster are based on the Bayes probability algorithm and assumes that each trait is independent of each other, which is useful for scoring individuals with a number of missing teeth (Scott et al. 2018). The database output results include posterior probabilities for each selected ancestry cluster.

To test whether there is a statistically significant difference in the prevalence of dental pathology between ancestry groups the tooth count method was used. This method utilizes all teeth from each individual and encompasses a wider amount of data. The percentage of each tooth type affected by carious lesions out of the total number of each tooth was recorded to demonstrate the extent of lesions present among this sample. For this sub-sample, the majority of individuals were estimated to be Western Eurasian. In order to eliminate bias towards this population, all other ancestral groups were combined and compared against the Western Eurasian population. Chi-square and Fisher's exact tests were used to determine significance in carious lesion prevalence between Western Eurasian individuals versus all other ancestral groups.

Comparisons between the VMC collection and the collection from Voegtly Cemetery in Pennsylvania provide information on the relative frequency of dental pathology between the two groups. The Voegtly Cemetery is a contemporaneous collection dating from 1833 through 1861 (Landers et al. 2003). As these remains come from a church cemetery, it is assumed that they provide a better representation of the population at that time than the pauper burials comprising the VMC collection. Comparisons of these data were conducted to determine whether or not there is a statistically significant difference in the frequency of dental pathology between the two populations and whether or not this difference could be contributed to variation in socioeconomic status (Larsen 2015).

Cohen's Kappa was used to test intraobserver error rates of dental morphology scores. This statistical test looks for agreement between observations and eliminates those that occur by random chance (Cohen 1960; Pilloud et al. 2016). The ten individuals scored before and after the training session were included in this test. These ten skeletons were scored for dental morphology a total of three times each – once before training, once after training, and once a few months after training. Results of these intraobserver tests are discussed in the following chapter.

Summary

This chapter has outlined the skeletal collection and sampling methodology used in order to study the relationship between ancestry and dental pathology. Additionally, the scoring techniques implemented for purposes of estimating components of the biological profile are addressed. Detailed descriptions of the morphological traits scored for ancestry estimation, as well as the methods used to determine the type and extent of pathological conditions present, provide background on how results were obtained. Using the dentition for ancestry estimation in this collection has provided more specific ancestry estimates when compared to cranial morphology estimates, emphasizing the utility of these methods in fragmented skeletal collections. Statistical analyses combining these data with the dental pathology data illustrate the variation in pathological conditions present in the VMC collection, as well as the differences between it and a contemporaneous sample. The following chapter discusses the results obtained when implementing these methods.

CHAPTER VI

RESULTS

Introduction

This chapter will outline the statistical tests and software used for this thesis project, including data input and organization, as well as the results of these tests. Data on the individual skeletons used for data collection are also presented, including some burials of specific pathological interest. The inferences which can be made as a result of these analyses, as well as comparisons to the sample from the Voegtly Cemetery will be presented in chapter 7.

Intraobserver Error

In order to test the efficacy of training for scoring dental morphological traits for ancestry estimation, ten burials were scored a total of three separate times. These scores were done prior to and following training, and again a few months after training. Cohen's Kappa tests were conducted to determine if the estimates obtained during each trial were significantly different from one another (Tables 5-7).

Based on the results from the Cohen's Kappa tests, the value of agreement increased with each trial. This indicates that scoring did improve between the first and third, and second and third trials. The first and second ancestry estimates were in the least amount of agreement with each other, indicating that training did improve the overall ability to visualize and score dental traits.

Table 5. Cohen's Kappa test of first and second ancestry estimates

		Value	Asymptotic Standard Error	*p*-value
Measurement of agreement	Kappa	0.286	0.107	0.077
N of Valid Cases		10		

Table 6. Cohen's Kappa test for first and third ancestry estimates

		Value	Asymptotic Standard Error	*p*-value
Measurement of agreement	Kappa	0.400	0.059	0.011
N of Valid Cases		10		

Table 7. Cohen's Kappa test for second and third ancestry estimates

		Value	Asymptotic Standard Error	*p*-value
Measurement of agreement	Kappa	0.464	0.173	0.004
N of Valid Cases		10		

Examples of Pathological Variation

There were a handful of burials demonstrating interesting pathological conditions. These will be described along with photographic references in Appendix B. Presenting these cases demonstrates the type of variation seen within this collection in general and specifically within this subsample.

Many of the burials have dental restorations indicated by the presence of metal fillings. Two of the 40 burials in this subsample, however, had gold foil fillings located on the interproximal surface of the maxillary canines. Burial 294 also demonstrates congenital absence of both lateral maxillary incisors. Congenital absence of teeth is relatively common, particularly in the third molars, and was observed frequently in this subsample. Supernumerary teeth however, are less common in the general population and were not seen as frequently in the VMC collection. A supernumerary tooth was observed in only one burial in which there were five mandibular incisors present. All of the maxillary incisors of Burial 631 have holes which appear to be drilled into the pulp chamber and root. There are additional defects to the front of both central maxillary incisors which are likely carious lesions due to their irregular shape and jagged edges.

Third molars are typically variable in shape, size, and presence. Among this subsample, one individual had bilaterally pegged maxillary third molars. The maxillary first molars from Burial 671 display a trait known as mulberry molars (Ortner 2003). These molars have characteristic occlusal surface morphology which appears as no uniform cusp formation. Additional enamel hypoplasia defects are noted on the maxillary central incisors and canines, as well as on all mandibular incisors and canines. These defects are indicative of congenital syphilis, though this cannot be definitively determined for this burial (Ortner 2003).

Results

A total of 40 individuals were selected as a subsample from the VMC collection. Burials were included in the sample if they had at least one tooth present. A detailed explanation for sample selection and biological profile estimation methods were outlined in chapter 5. The results from each of the components analyzed for this project are reviewed below. See Appendix C for a comprehensive table for the age, sex, and ancestry estimates for each burial.

Sex

The majority of the sample were estimated as male or probable male, which follows the demographic seen in many pauper cemetery collections (Buzon et al. 2005). Males were estimated to comprise 50% of the sample, followed by 43% probable male, 2% female, and 5% indeterminate. Table 8 provides the number of individuals estimated for each sex.

Table 8. Sex estimation results

Sex Estimate	Number of Individuals (Frequency)
Male	20 (50%)
Probable male	17 (43%)
Female	1 (2%)
Indeterminate	2 (5%)

Age

Most of the individuals in this sample were estimated to be within the adult to older adult age categories. Only one individual was estimated within the mid-teens to mid-twenties range. Figure 1 illustrates the percentage of white and non-white individuals in each general age category. There are more white individuals in the middle to late adult age range, while the non-white individuals are spread throughout each age range. Regardless, the majority of individuals in this subsample fall into the late adult age category. Table 9 compares the number of individuals in each age range based on general ancestry and finds a statistically significant difference between white and non-white individuals. White individuals comprise a significant portion of the late adult age category.

Table 9. Mann-Whitney U test for age based on general ancestry

	General Ancestry	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Asymptotic Significance (2-tailed)[1]
General Age	White	23 (58%)	24.00	552.00	115.000	0.005
	Non-white	17 (42%)	15.76	268.00		
	Total	40				

[1]Significant if $p<0.05$

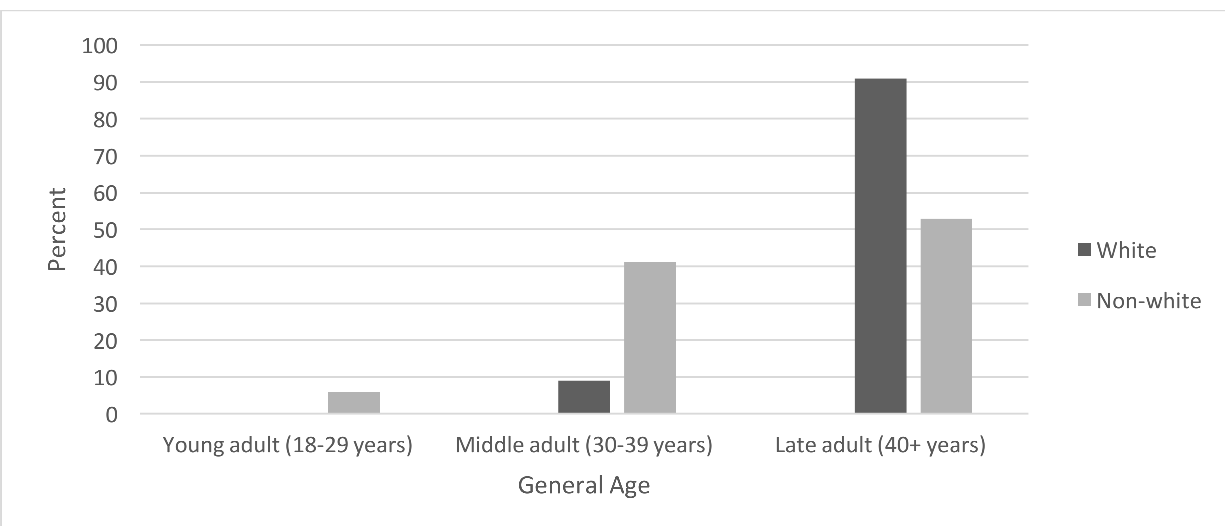

Figure 1. Percentage of individuals in each age category by general ancestry

Ancestry

The majority of individuals were estimated to be Western Eurasian. This is not surprising due to the corresponding census data indicating the Euro-American population in Santa Clara County to be the largest (1880 US Census). Fifty-seven percent were estimated as Western Eurasian, followed by 23% East Asian, 15% Sub-Saharan African, and 5% American Indian (Table 10). The percentages of each ancestry group corresponds with previously outlined census data.

Table 10. Number of individuals per ancestry group

Ancestry Estimate	Number of Individuals (Frequency)
Western Eurasian	23 (57%)
East Asian	9 (23%)
Sub-Saharan African	6 (15%)
American Indian	2 (5%)

Each burial had a previously estimated ancestry, based on postcranial osteometrics, cranial measurements, and cranial morphology. Appendix C provides a table of all burials including their initial ancestry estimates, and the estimates obtained using dental morphology.

Carious Lesions

All 40 individuals observed in this sample had at least one carious lesion. Of these 40, there were 30 individuals that had more than one carious lesion per tooth. Fifty-percent of these 30 individuals had more than one tooth with more than one carious lesion, with the maximum number of lesions per tooth being three. For example, Burial 620 had ten teeth with more than one carious lesion per tooth. The most common types of lesions observed on teeth with more than one lesion were occlusal surface, interproximal surface, and root caries, respectively. Of those 30 individuals with more than one carious lesion per tooth, 57% were classified as white and 43% were classified as non-white. See Appendix C for a detailed table of the number of carious lesions for each burial with more than one lesion per tooth.

The total number of carious lesions were counted for each individual in the subsample (n=40). The minimum number of lesions for any individual was two and the highest number of lesions was 32, found in a white individual. The individual burials were then separated by white (n=23) and non-white (n=17) subgroups. The total number of carious lesions within the white subgroup was 262, or 51% of all teeth within the white sub-group, and 121, or 37% of all teeth within the non-white subgroup. Table 11 outlines the results of an independent samples t-test comparing the number of carious lesions for each ancestry subcategory.

Table 11. Independent Samples T-test for total number of carious lesions by ancestry with equal variances assumed

Ancestry	N	Number of Carious Lesions	Mean	Standard Deviation	Sig. (2-tailed)
White	23	262 (51%)	11.4	7.2	0.033
Non-white	17	121 (37%)	7.1	4.0	0.021

There is a statistically significant difference between the mean number of carious lesions between the white and non-white categories. The mean number of carious lesions for the white sample is 11.4 with a standard deviation of 7.2 and the mean number of lesions for the non-white sample was 7.1 with a standard deviation of 4.0. The white sample had a significantly higher mean number of carious lesions when compared to the non-white sample, however the white sample were also significantly older than the non-white sample. There are two major outliers in the white sample, both of whom were in the middle to old adult age category, which skew these data; however, removing them from the sample did not change the mean significantly and also reduced the sample size even further. Figure 2 illustrates these outliers.

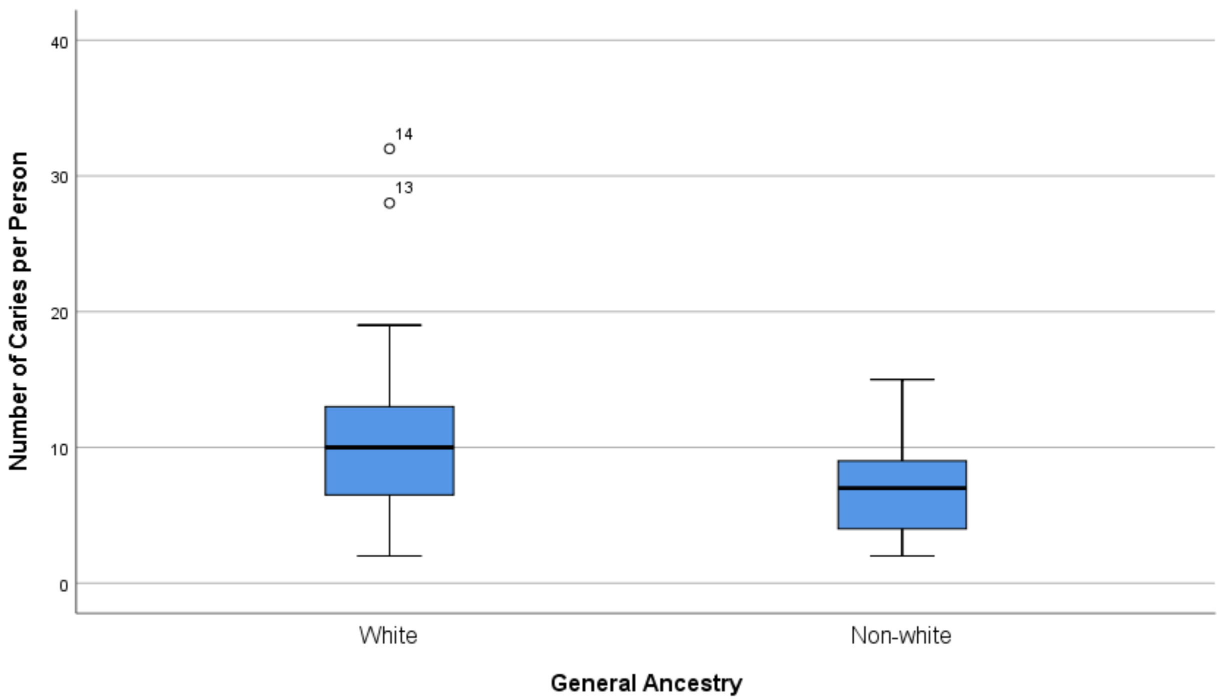

Figure 2. Number of carious lesions by general ancestry. Note the outliers in the white sample.

Out of a total of 841 teeth observed from these 40 individuals, there were 296 carious lesions (Figure 3). Therefore, 35% of all teeth observed had at least one lesion. The mean number of carious lesions for the combined sample was 18.5.

Each tooth from the left and right halves of the jaw was analyzed using Chi square and Fisher's exact tests to determine if there was a significant difference in the presence of carious lesions between whites and non-whites. Those teeth marked with an asterisk in Table 12 have the Fisher's exact results listed because one or more of the cells had an expected count less than five.

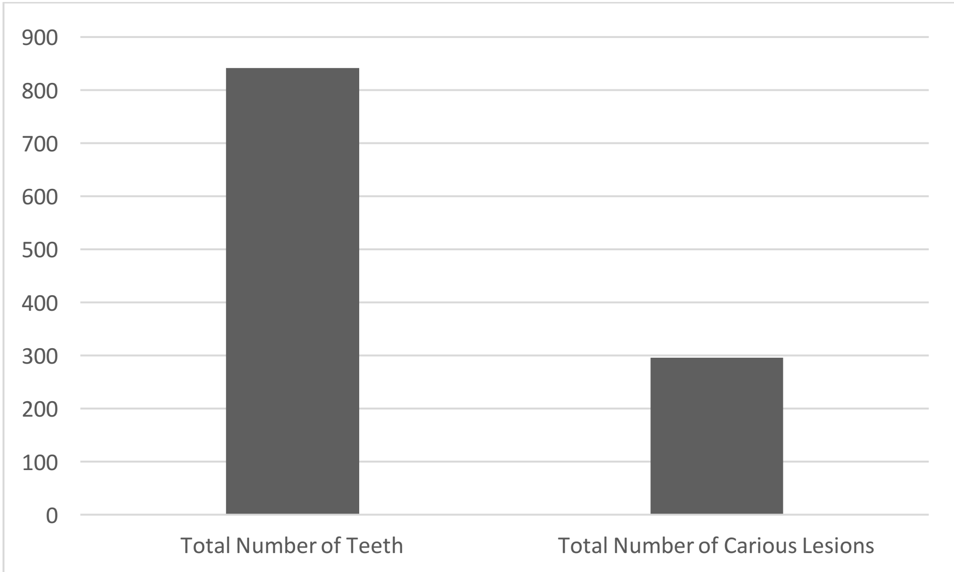

Figure 3. Total Number of teeth and total number of carious lesions present for all individuals

Table 12 indicates that there is no statistically significant difference in the presence of carious lesions for the majority of the teeth when separated by white and non-white ancestry categories. There is a significant difference in the presence of carious lesions based on general ancestry categories for the left second premolar, and right canine. This indicates that there is little significant difference between the ancestry categories and the presence of carious lesions.

In order to illustrate differences between carious lesion presence in the anterior and posterior teeth, Chi-square and Fisher's exact tests were conducted. Anterior teeth include the central and lateral incisors and canines, while the posterior teeth include the first and second premolars and the first, second, and third molars. Overall, there were more posterior teeth (n=477), than anterior teeth (n=364) in this sample. Table 13 outlines these results for the maxillary and mandibular anterior and posterior teeth.

Table 12. Chi-square and Fisher's exact test results for carious lesion presence on each tooth by general ancestry

Left Teeth		Value	Degrees of freedom	*p* value[1]
	Third Molar	1.799	1	0.180
	Second Molar	2.316	1	0.128
	First Molar	0.354	1	0.552
	Second Premolar	7.816	1	0.005
	First Premolar	0.014	1	0.905
	Canine*			1.000
	Lateral Incisors*			1.000
	Central Incisors*			0.458
Right Teeth				
	Third Molar*			0.444
	Second Molar	0.744	1	0.388
	First Molar*			0.052
	Second Premolar	0.245	1	0.620
	First Premolar	0.139	1	0.709
	Canine	3.909	1	0.048
	Lateral Incisors*			1.000
	Central Incisors*			0.172

[1]Significant if $p<0.05$
*These results are reported as Fisher's exact because one or more of the cells have less than the expected count of 5.

The results of these tests indicate that there is a significant difference in the frequency of carious lesions on the maxillary anterior teeth between whites and non-whites. There is a higher percentage (78.9%) of carious lesions present on these teeth among the white ancestry group than the non-white, while a higher percentage (60.0%) of non-white individuals had no lesions on these teeth. Therefore, white individuals have significantly more carious lesions present on the anterior maxillary teeth. All other results are not statistically significant.

Table 13. Chi-square and Fisher's exact results for anterior and posterior maxillary and mandibular carious lesion presence by general ancestry

		Value	Degrees of freedom	*p* value[1]
Anterior	Maxillary	5.384	1	0.020
	Mandibular	0.727	1	0.394
Posterior*	Maxillary			1.000
	Mandibular			0.294

[1]Significant if $p<0.05$

*These results are reported as Fisher's exact because 50% of the cells have less than the expected count of 5.

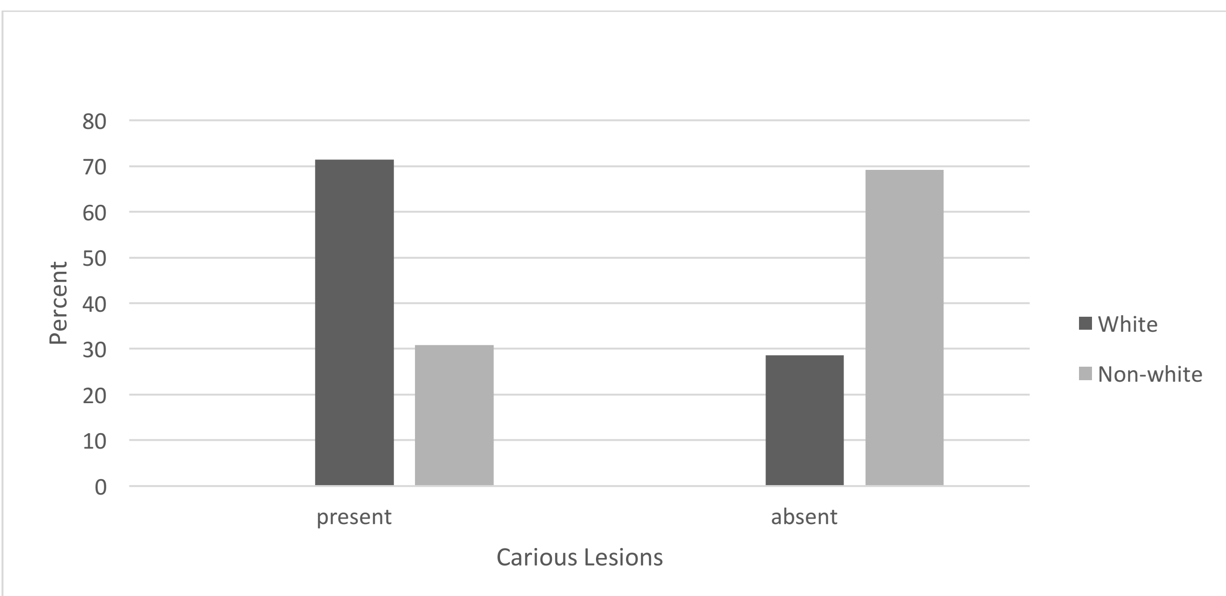

Figure 4. Percentage of carious lesions on maxillary anterior teeth

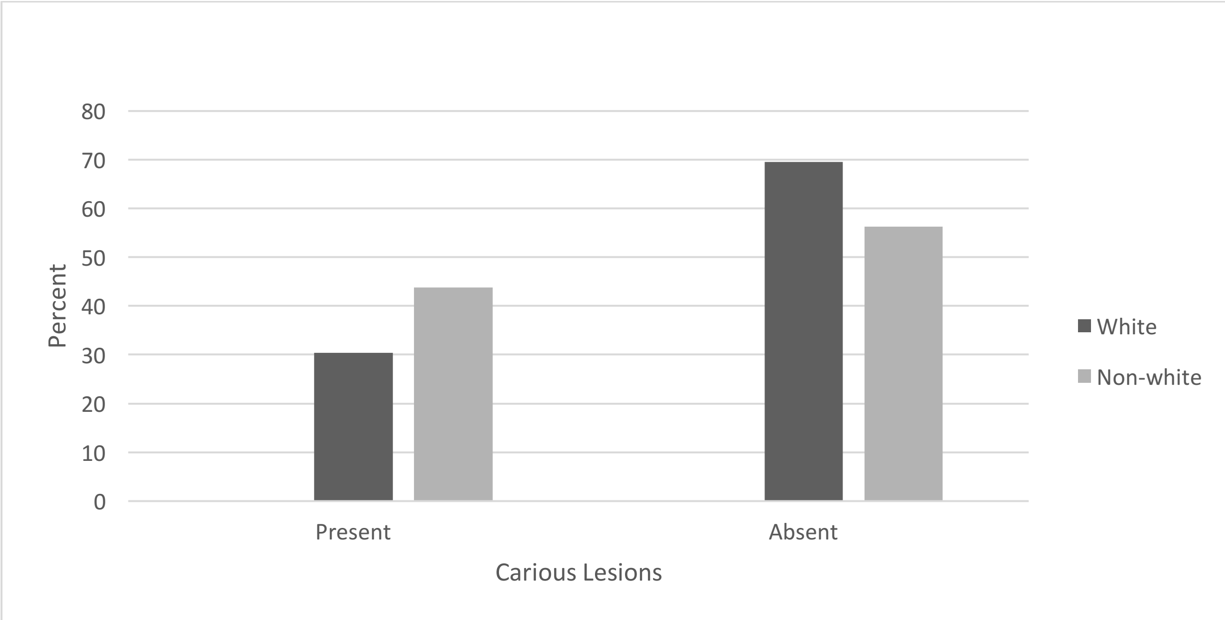

Figure 5. Percentage of carious lesions on mandibular anterior teeth

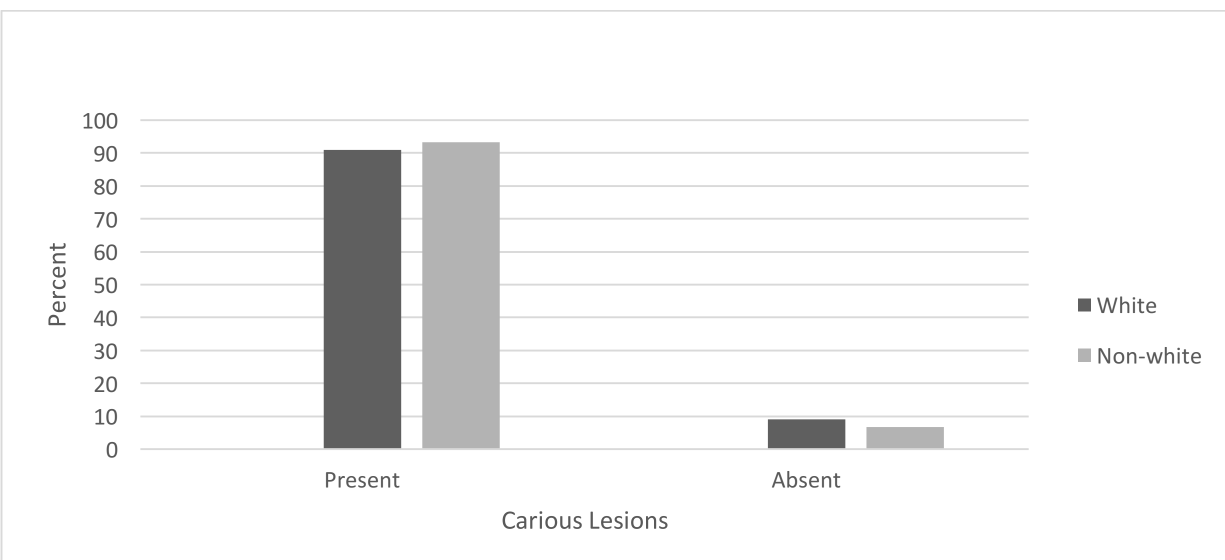

Figure 6. Percentage of carious lesions on posterior maxillary teeth

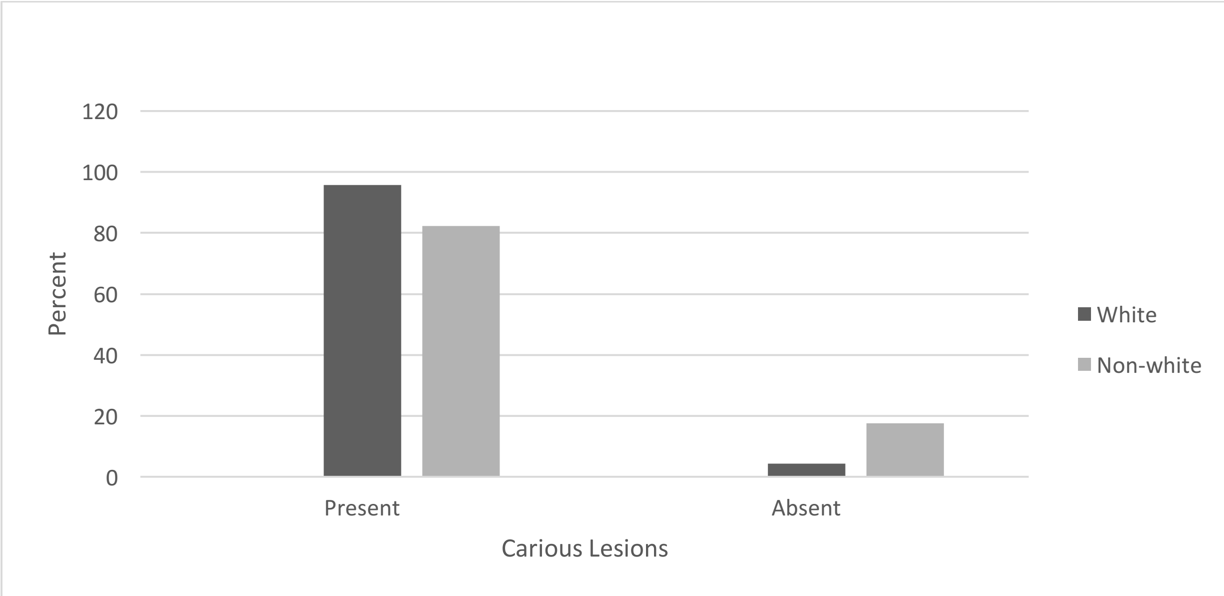

Figure 7. Percentage of carious lesions on posterior mandibular teeth

Additional Chi-square and Fisher's exact tests were done on just the incisors and the first molar to see if there is any difference between the general ancestry categories and the frequency of carious lesions on these teeth. Table 14 and Figures 8 and 9 indicate that there is no significant difference in the frequency of carious lesions between white and non-white groups for either first molars or incisors.

Table 14. Chi-square and Fisher's exact results for incisor and first molar carious lesion presence by general ancestry

	Value	Degrees of freedom	*p* value[1]
Incisor Carious Lesion Presence	0.354	1	0.552
First Molar Carious Lesion Presence*			1.000

[1]Significant if $p<0.05$
*These results are reported as Fisher's exact because 50% of the cells have less than the expected count of 5.

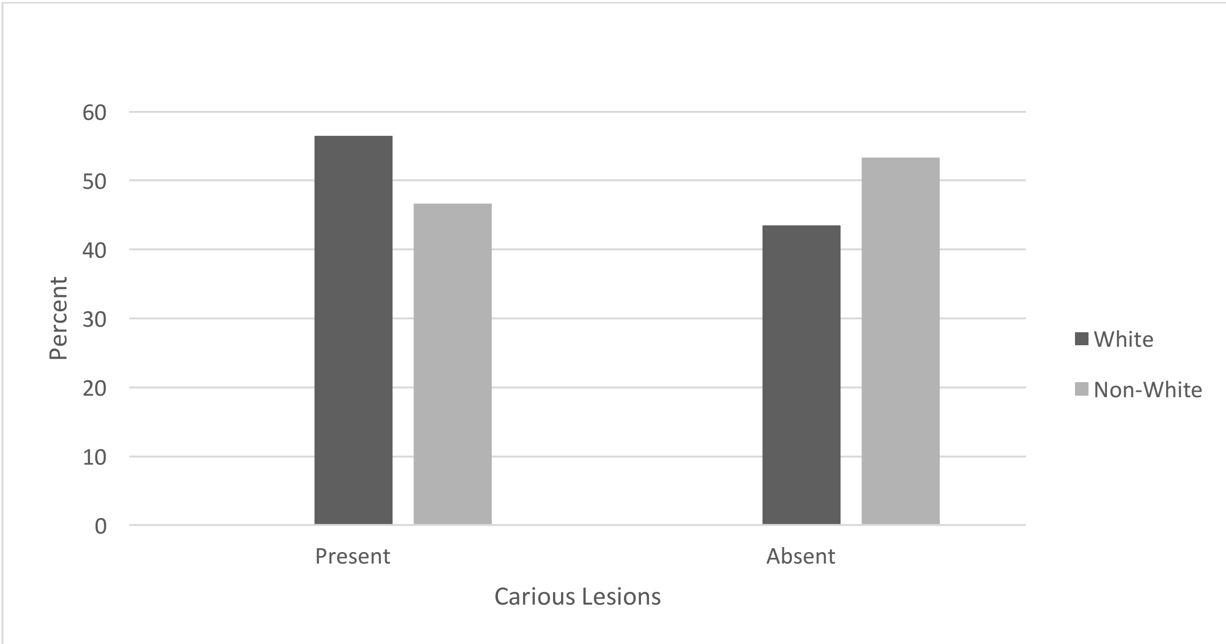

Figure 8. Percentage of carious lesions on maxillary and mandibular incisors

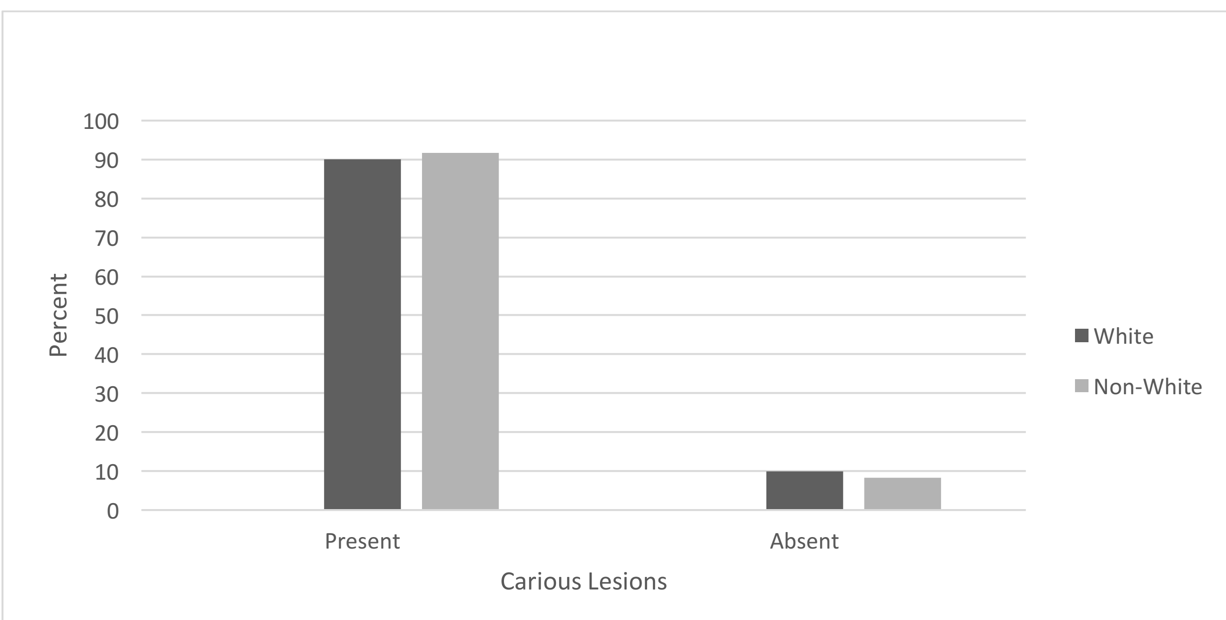

Figure 9. Percentage of carious lesions on maxillary and mandibular first molars

Abscesses

Often associated with large carious lesions, alveolar abscesses are significant pathological conditions. Figures 10-13 illustrate the type and frequency of various alveolar abscesses present between white and non-white individuals for the right and left first molars and the right and left first premolars. Many of the individuals either had no alveolar abscesses present, or had no alveolar bone associated with the remains. This is due to the fragmentation of the collection. Periapical abscesses are noted at each tooth position predominantly among white individuals.

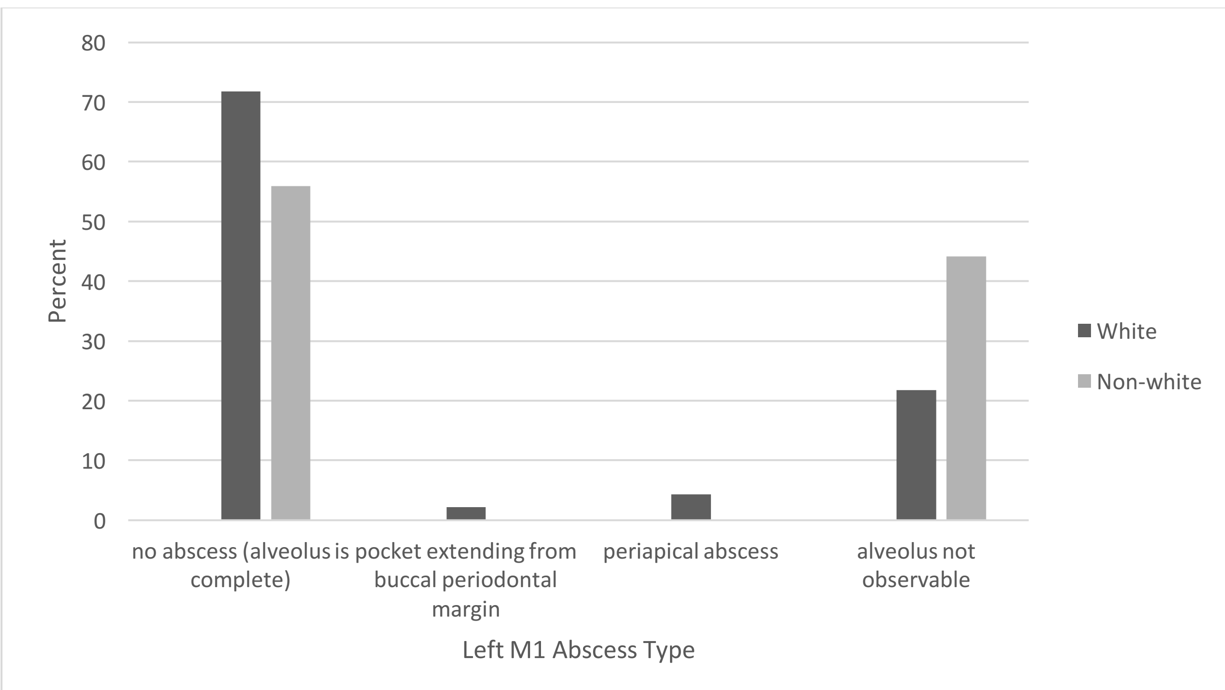

Figure 10. Percentage of left first molar alveolar abscesses

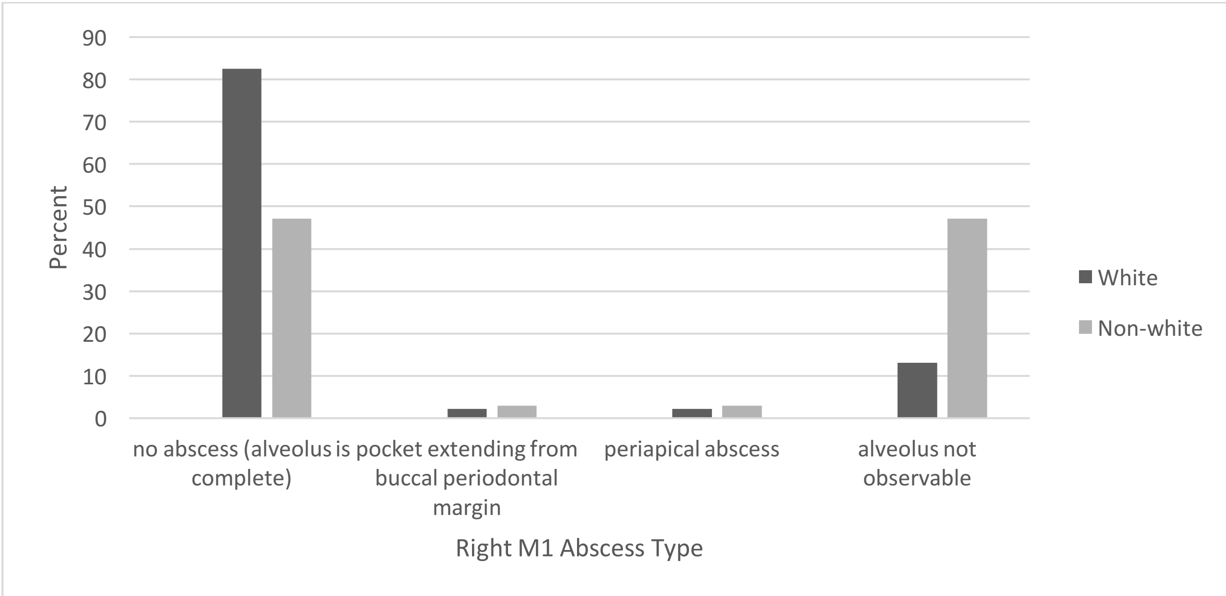

Figure 11. Percentage of right first molar alveolar abscesses

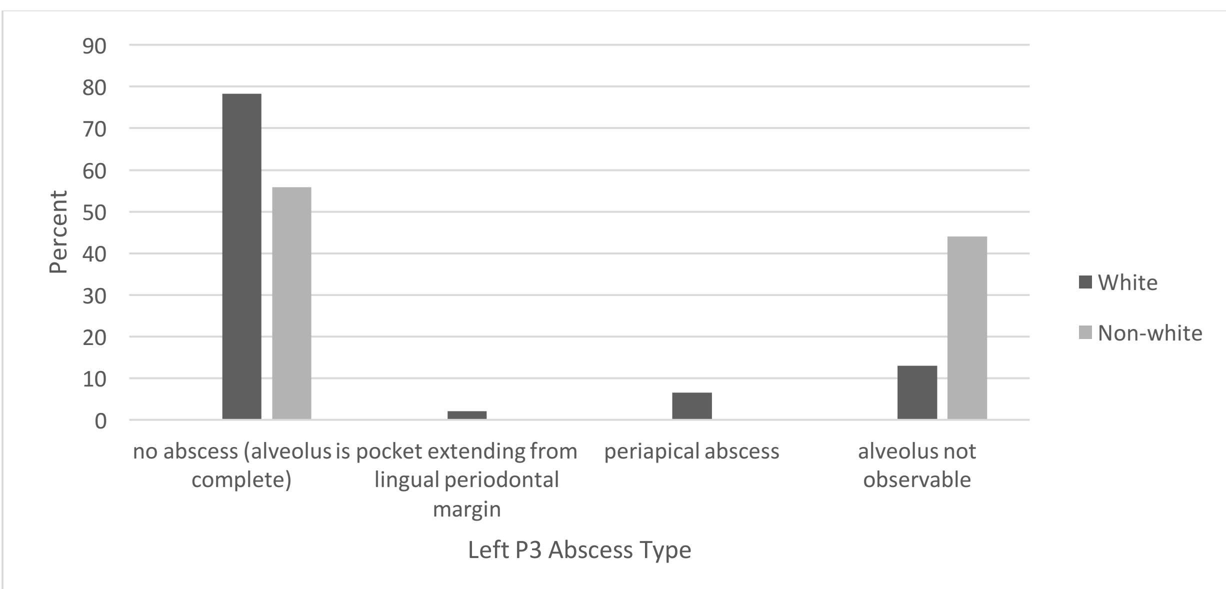

Figure 12. Percentage of left first premolar alveolar abscesses

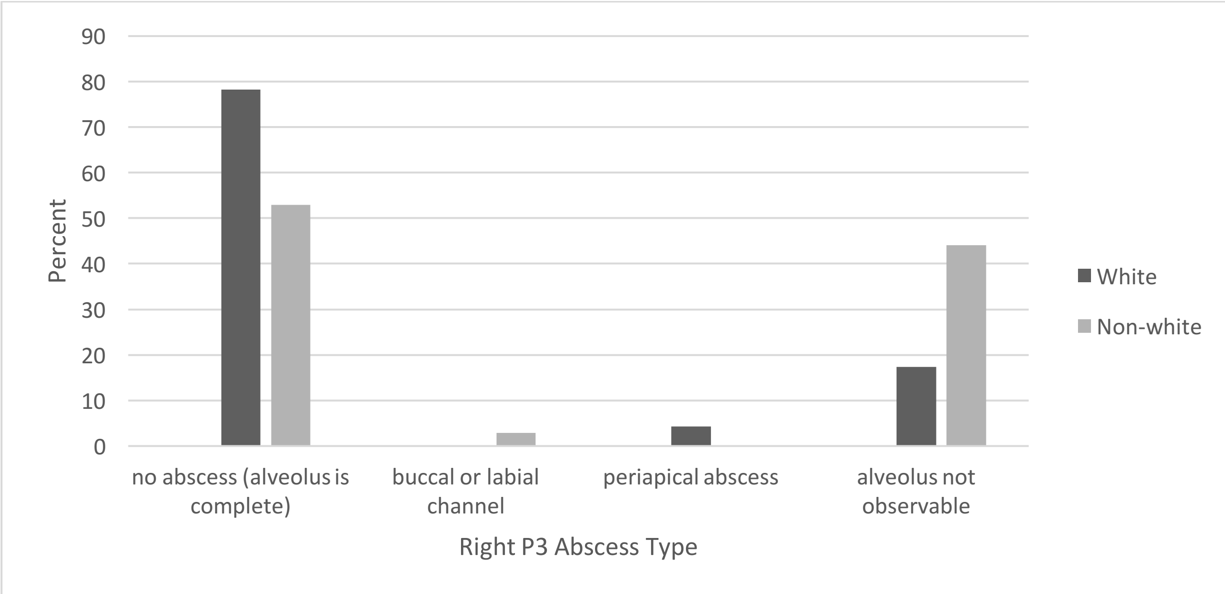

Figure 13. Percentage of right first premolar alveolar abscesses

Attrition and Calculus

The amount of dental wear seen in this collection is significant, though not as severe as one might see in a pre-contact Native American collection. There is some evidence of patterned wear, possibly associated with the use of teeth as tools. Additionally, calculus was noted for those burials which were severely affected. Photographs of these cases are included in Appendix B. Periodontal disease was noted in some of the burials, though this was not recorded in any systematic fashion due to the extent of postmortem fragmentation.

To visualize the amount of occlusal wear present for each of the two ancestry categories, the three molars were chosen for representation because they are typically involved in heavy chewing. The majority of the teeth from both ancestry groups could not be scored for attrition, largely attributed to antemortem or postmortem loss. From those individuals that could be scored, there is a relatively even distribution across all attrition types (Figures 14-16).

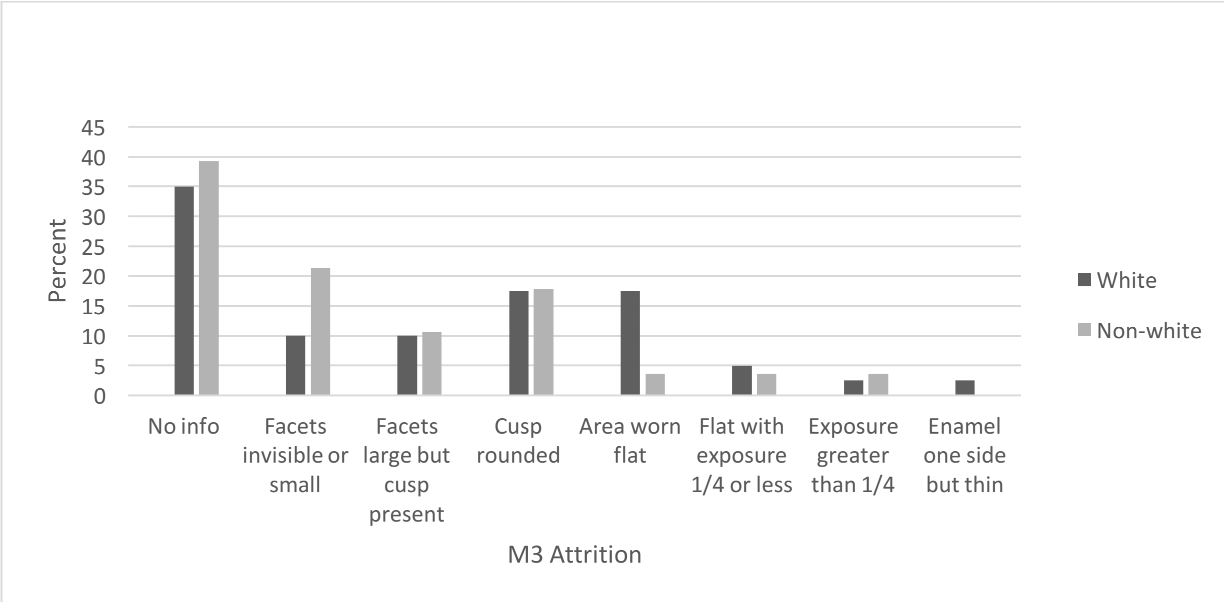

Figure 14. Percentage of attrition type for third molars by general ancestry

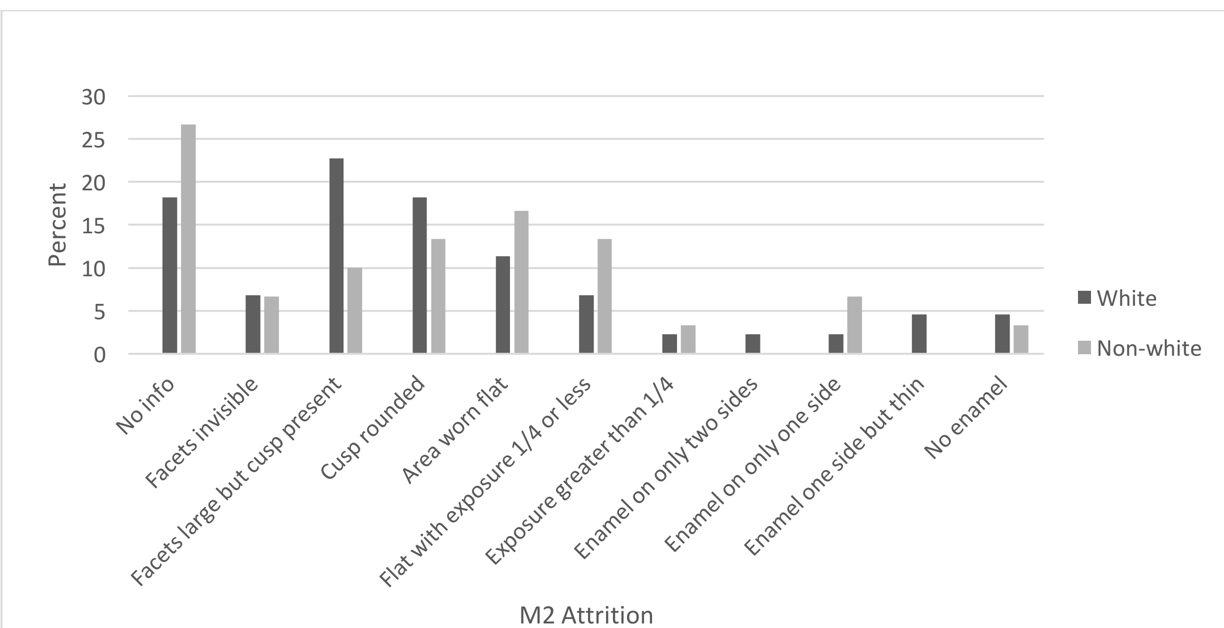

Figure 15. Percentage of attrition type for second molars by general ancestry

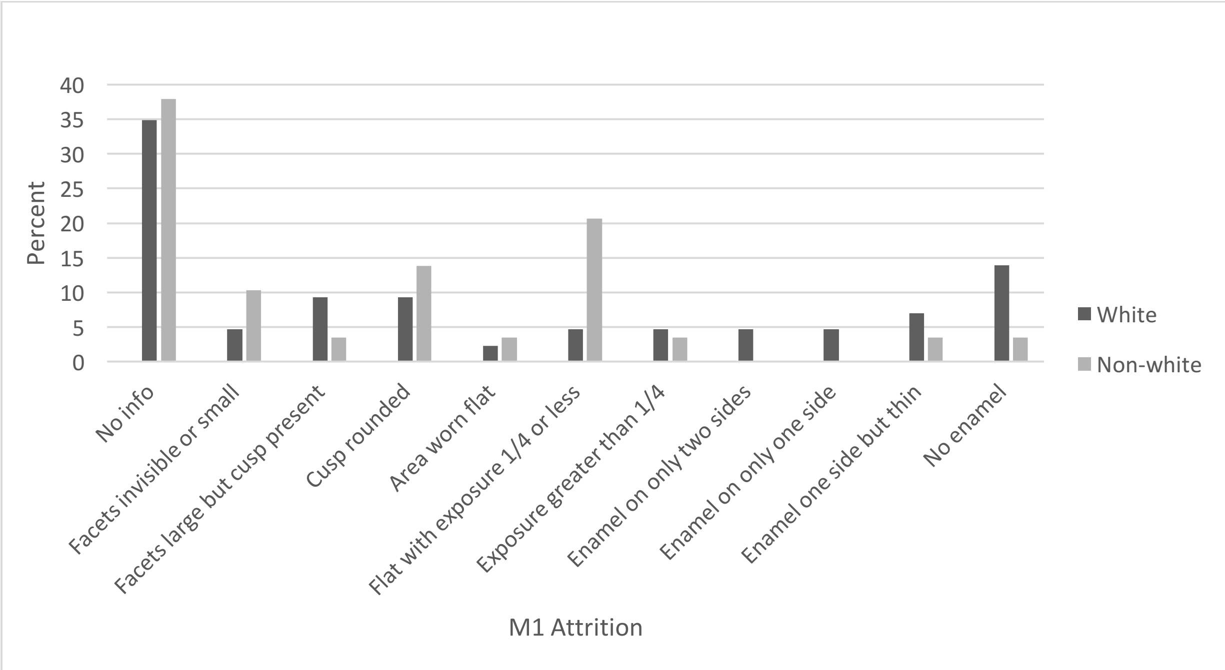

Figure 16. Percentage of attrition type for first molars by general ancestry

Summary

The above results indicate that many of the observations were not significant when compared between white and non-white ancestry categories. There was no significant difference between anterior and posterior maxillary and mandibular carious lesion presence by white and non-white ancestry categories. Left second premolars and right canines were significantly different in terms of carious lesion presence, though the majority of the teeth were not significantly different from one another. Interestingly, across both ancestry categories, there was a higher percentage of posterior maxillary and mandibular lesions, as well as a greater percentage of anterior maxillary lesions; however, the anterior mandibular teeth show fewer carious lesions. While abscesses were not common in the VMC collection, periapical abscesses are more commonly seen among the white individuals.

The Cohen's Kappa tests for intraobserver error indicate that training did improve scoring accuracy. The second and third trial scores were more consistent with each other, and the first and second trials were most dissimilar, indicating that training was useful. The implications for this, and the rest of these data, are discussed in the following chapter.

CHAPTER VII

DISCUSSION

Introduction

This chapter discusses the results presented in the previous chapter. The conclusions and implications of this study will also be addressed. Additionally, a comparison between the results obtained from this project and those obtained from the contemporaneous Voegtly Cemetery are discussed. Limitations and future studies, along with overall conclusions, will conclude this chapter.

Ancestry Estimates

Of the 40 individuals in this sample, 23 of them were estimated as Western Eurasian. The remaining 17 were estimated as either East Asian, Sub-Saharan African, or American Indian. For ease of analysis, and to have a comparably sized sample to compare with the Western Eurasian group, these 17 individuals were combined into a non-white subcategory. Four biogeographic clusters from rASUDAS were chosen as the most likely groups to be present in the collection based on a review of census data. Fourteen of the ancestry estimates changed when only four clusters were selected, as opposed to the seven available in the database. The major difference between the first and final ancestry estimates comes from the elimination of Australo-Melanesia and Micronesia. Those individuals who originally were estimated as belonging to this group were either estimated as Sub-Saharan African, Western Eurasian, or East Asian. That these Australo-Melanesian and Micronesian individuals were dispersed into three other ancestry groups after elimination could be due to the variability of the reference sample for that geographic location.

The high number of white individuals in this sample corresponds with census data from the years in which the cemetery was in use. There were significantly more Euro-american individuals living in the area at the time (1880 US Census; 1910 US Census). It is also not surprising that East Asians make up the next most populous category, as many of the Asian immigrants who came to California during the Gold Rush ended up settling in the Bay Area (Fong and Markham 1991).

One of the questions proposed by this project is whether or not dental ancestry estimation will provide more accurate or consistent ancestry estimates for a poorly preserved collection such as VMC. While it cannot be determined whether or not the ancestry results obtained from the teeth are more accurate, as there are no known records for these individuals, the method did provide an estimate for all of the sampled individuals. Some of these estimates match those obtained from other methods previously implemented, such as cranial morphology and metrics. Others are drastically different. Variations in estimates between dental morphology and alternative methods of ancestry estimation can be seen in Appendix C.

Where dental morphology for ancestry estimation in this collection has been most useful is in obtaining estimates for otherwise indeterminate individuals. Five of the 40 individuals in this sample were previously estimated to be of indeterminate ancestry due to a lack of measureable or observable traits. While ancestry could not be estimated from cranial or post-cranial methods, these individuals were classified through the use of dental morphology because each trait was considered independent of the others, allowing for an ancestry estimate to be made from only a single trait (Scott and Irish 2017). Additionally, the teeth are the best preserved element in this collection, meaning that more burials are likely to have teeth than other skeletal elements.

Sex and Age

The majority of the individuals in this subsample were estimated as male or probable male, with only one individual estimated as female and two as indeterminate. This distribution also follows the demographics seen in other pauper cemetery collections (Buzon et al. 2005). It is probable that there are more females within the entire collection; however, they likely make up only a small percentage of the population based on the demographics seen within other pauper cemetery collections.

The age ranges seen within this subsample are also in accordance with other pauper cemetery studies, with the majority of individuals falling into the middle to older adult ranges. White individuals represent the majority of the late adult individuals and a small portion of the middle adult age range, but are not represented in the young adult category. The non-white individuals are represented in each age range, indicating a greater age distribution for this group. There is a statistically significant difference between the ancestry groups and the age ranges, which could have an impact on dental pathology. With age comes prolonged exposure to the bacteria causing caries (Hillson 2005). Because the majority of the sample were estimated as white and they also represent the majority of the older individuals, this could have a significant impact on the number of carious lesions present among these individuals, as age correlates with longer exposure to the processes which cause carious lesions (Hillson 2008).

Pathology

Carious lesions were the most significant pathological condition of the teeth and jaws seen in this sample. Every individual sampled had at least one carious lesion, and seventy-five percent had more than one lesion on a single tooth. The maximum number of lesions on a single tooth was three and the most common location for lesions was on the occlusal surface. Occlusal surface lesions occur most frequently on the posterior teeth in the pits and fissures of the chewing surfaces. This provides an ideal environment for microbacterium to live and to ferment food particles that remain in hard to reach places on the teeth (Kolpan and Bartelink 2018).

The interproximal surfaces were the next most common location for carious lesion development. Again, the environment between the teeth allows for bacteria to ferment food particles. Interestingly, the third most common type of lesion occurred on the roots, a location that Hillson (2005) attributes to individuals of older age. With age comes the increased exposure to various pathological conditions of the teeth, including periodontal disease, which causes inflammation of the gingiva and eventual loss of teeth (Hillson 2005; Hillson 1979). Processes such as these result in exposure of the tooth root, allowing bacteria to enter regions otherwise protected by bone and soft tissue. The fact that many of the individuals in this sample were estimated in the middle to older adult ranges, and that carious lesions of the root were fairly common, coincides with Hillson's (2005) observations of these lesions and provides an explanation for their relative abundance within this sample.

The results from data on alveolar abscesses indicate the impact of taphonomic damage on this collection. Many of the individuals from both general ancestry groups did not have observable alveolar bone and therefore could not be examined for abscesses. Of those individuals who could be examined, the majority did not have any abscesses. When they were observed, periapical abscesses commonly appeared in conjunction with carious teeth, particularly those with very destructive lesions of the crown.

Dental attrition was observed on most of the teeth from both general ancestry groups, with specific attention paid to the first, second, and third molars as these teeth are typically involved in heavy chewing. Many of the non-white individuals did not have enough of the crown for dental wear to be assessed, either due to postmortem damage, destruction by carious lesions, or antemortem tooth loss.

Based on the results from these pathological data, I can reject the null hypothesis that there is no statistically significant difference in the prevalence of dental pathology between the two ancestry subgroups. The white individuals had significantly more carious lesions than the non-white individuals. While I can accept my alternative hypothesis, my predictions were incorrect. The non-white group did not have more lesions than the Euro-american individuals, as previously expected.

The mean number of carious lesions for the white and non-white subgroups were significantly different, with whites having a much higher mean than non-whites (11.4 compared to 7.1). There are a number of possible explanations for why the white subgroup had more carious lesions than the non-white subgroups. Because the white individuals make up the majority of the older adult category, the high number of lesions could be attributed to their older age. Diet also impacts the prevalence of carious lesions, as previously outlined in chapter IV. Foods high in carbohydrates and refined sugar are more cariogenic (Larsen 2015). The white subgroup in this sample could have been eating relatively abundant but not very nutritious foods such as corn, or they could have had access to more processed foods and refined sugars, potentially indicating higher status (Little et al. 1992).

The high percentage of posterior carious lesions for both general ancestry groups corresponds with the greater frequency in occlusal surface lesions. The occlusal surfaces of posterior teeth are very commonly affected by carious lesions because these areas are ideal for microbacterium to live (Kolpan and Bartelink 2018). The overall number of carious lesions within and between both white and non-white groups is high. This could indicate an overall lack of access to healthcare and low socioeconomic status.

It is clear from these results that it is difficult to determine social status from dental pathology alone. The overall high frequency of pathological conditions within this sample could indicate limited access to healthcare, poor concepts of oral hygiene, using the teeth as tools, and highly cariogenic diets. Where this becomes increasingly more complicated is in trying to assess whether or not the frequency of dental pathology between two general ancestry groups is due to access to convenient but less nutritious foods or highly processed, refined foods. As outlined by Little et al. (1992), the higher frequency of carious lesions within the wealthy Weir family cemetery when compared to a contemporary pauper cemetery indicates the difficulty of attributing dental pathology to sociocultural or socioeconomic status. Therefore, while there is a significant difference between the ancestry groups observed for this project, the causal relationships cannot be definitely determined.

Voegtly Cemetery Comparison

The excavation at the Voegtly Cemetery uncovered around 800 burials dating from between 1833 and 1861. In many respects, this cemetery is remarkably similar to VMC. Both are from contemporaneous time periods and both were forgotten for nearly a century before being uncovered during construction projects (Landers et al. 2003). Ultimately, however, these two cemeteries represent very different populations. Voegtly Cemetery was located in Old Allegheny Town in Pennsylvania and the population was predominantly German and Swiss. Additionally, this cemetery was associated with a church, making burial here exclusive to those belonging to the congregation. Coffin decorations from Voegtly Cemetery also indicate differences in social status within the burial population. Contrary to this, Santa Clara County during this time was far more diverse, even with the majority population being Euro-american. Demographic differences, along with the fact that the VMC cemetery is associated with an infirmary and used to inter the county's poor, are the major points of variation between the two cemeteries.

Many of these individuals found at Voegtly Cemetery were infants or children, a demographic not seen in the VMC collection. Only 28.8 percent of individuals were estimated to be 20 years or older (Landers et al. 2003, 21). Additionally, the number of females and males were very similar to each other, at 47.2 percent and 52.8 percent respectively (Landers et al. 2003, 21). This is another major difference between the demographics of the Voegtly Cemetery and the VMC cemetery, with the former having a significantly higher female population and thus being more representative of a normal population. It is also worth noting that the sample size from the Voegtly Cemetery and the sample size of this project are drastically different. In order to do a more comprehensive comparison between them, more individuals from the VMC collection would need to be analyzed.

Landers and colleagues (2003) found that carious lesions of the maxillary teeth were the most common within their sample. Additionally, interproximal lesions were the most frequent, followed by occlusal surface lesions. These results are similar to those obtained from the VMC sample used in this study. Both indicated high rates of interproximal and occlusal surface lesions, likely indicative of these locations being ideal for bacterial fermentation. The fact that the

Voegtly individuals also had significant amounts of dental pathology across the different socioeconomic divisions further indicates the difficulty of using pathology as a means for estimating social status.

As was seen by Little et al. (1992), the results of these types of studies can be surprisingly contradictory. The Voegtly Cemetery sample was expected to have lower frequencies in dental pathology than the VMC cemetery because the former is representative of the general population, while the latter represents individuals of lower socioeconomic status. On the contrary, both cemetery samples indicate high frequencies of carious lesions. One explanation could be that the general population at the time, including all socioeconomic levels, simply had poor oral health and hygiene. This could be due to a lack of knowledge about the importance of cleaning and caring for teeth and gums, resulting in a population with high levels of pathological conditions of the mouth. Another explanation could be that higher status individuals were eating more processed foods high in refined sugars while lower status individuals were subsisting on abundant cariogenic foods such as corn, resulting in high carious lesion frequencies for both groups. While the answer is unclear, the results do indicate similarities between two otherwise different populations.

Limitations of Study

There were many limitations to this study, most significantly the lack of preservation of the remains. Postmortem damage to the teeth and bones made it difficult, and in some cases impossible, to see pathological conditions and morphological traits. Because of this, it is likely that much of these data were lost, potentially skewing the results. Another limitation to the scoring of dental morphology and pathology comes from the presence of dental wear and restorations. Significant attrition removes cusps used for estimating ancestry and obscures carious lesions.

Another limitation of this study involved the efficacy of training for properly observing and scoring dental morphology for ancestry estimation. Ten individuals were scored before and after training, and then again a few months later. The values obtained between the first and second trials were the most dissimilar, which is not surprising because they occurred before and after training. Results also show that there was slight improvement between the second and third trials. However, the sample size used for testing intraobserver error was very small and therefore these results could be due to random chance.

Training was imperative for gaining confidence in scoring methods and obtaining exposure to the variability in trait presence. Forty percent of the initial sub-sample had different ancestry estimates following the second analysis, indicating that training did have an impact on the resulting estimates. Additionally, following the training, more traits were determined to be unobservable due to wear, dental restorations, and postmortem damage. After observing the types of pathological teeth that professionals felt comfortable scoring, it became clear that many of the previously scored traits were likely too difficult to see.

This type of ancestry estimation method requires training along with continued practice because the traits can be difficult to see and damage or wear to the teeth can further obscure them. It is necessary to be exposed to variation in morphology, as well as how other observers would score these, in order to feel confident that scoring will be consistent every time.

Further limitations include a lack of burial records for comparison, small sample sizes for each ancestry group, and the inevitable challenge of estimating ancestry from skeletal remains. The records from the VMC cemetery were lost some time between the last year of cemetery operation and the rediscovery of the burials decades later. This makes it difficult to determine the accuracy and applicability of using dental morphology for ancestry estimation within this collection as there are no records for comparison. The small sample size for each ancestry group could be remedied through more data collection; however, it would be very difficult to collect an equal number of individuals for each ancestry since the results obtained through this method do not always match results from other ancestry estimation methods and there may not be equal representation across all ancestry groups.

Estimating ancestry is one of the main parts of the biological profile in bioarchaeology and forensic anthropology, yet it is one variable that is extremely difficult to qualify and validate. Many of the ancestry estimation methods commonly employed have variations of different ancestry categories that do not always align with one another. Therefore, results obtained from these methods could be extremely different from each other, as was seen for some of the burials in this study. Due to the inherent biological diversity of humans, ancestry is one of the most complex aspects of the biological profile.

Future Research

This study has opened the door for future studies incorporating dental morphology for ancestry estimation within the VMC collection. As so many of the burials in this collection are in various stages of preservation, it would be useful to employ a single method for ancestry estimation that could be used for the majority of the burials. Obviously, a lack of dentition would require alternative estimation methods to be used, but dental morphology could be used as the primary ancestry method for this collection. DNA analysis of each burial would help to determine the accuracy of this method.

Increasing the number of individuals sampled in this study would help illuminate other trends in pathological conditions of the jaws and teeth for each ancestry group. Having a larger sample of each ancestry category would also negate the need to combine groups into a single, less informative category such as non-white, as used in this project.

There is still much to learn about the relationship between dental pathology and socioeconomic status and social hierarchies. Perhaps it will continue to be an unreliable indicator of either variable, but teeth do provide valuable information regarding diet and oral hygiene. Future studies involving the VMC collection should not neglect the implications of dental pathology while also analyzing additional pathological conditions of the skeleton.

Summary

While a useful method of ancestry estimation for poorly preserved skeletal collections, dental morphology does have its limitations. Many of the traits are difficult to see and easy to remove, both during life and after death. Ancestry as a variable estimated for the biological profile should be considered in light of extensive human variation and should not be used for definitive classifications.

Pathological conditions of the teeth and jaws provide bioarchaeologists with a vast repository for information on disease, oral hygiene, and diet. To some extent, socioeconomic status can also be deduced; however, dental pathological data must be considered as one of many possible variables influencing social status. Based on the results obtained from this study, there can be differences in the amount of dental pathology between ancestry groups in a collection, yet these results can be indicative of any number of factors.

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APPENDIX A

Winging UI1	Absent	Present, Grade 3-6		Missing/Not observable
Shoveling UI1	0 and 1	2 and 3	4 to 7	Missing/Not observable
Interruption grooves UI2	0	Present		Missing/Not observable
Hypocone UM2	0 and 1	2 and 3	4+	Missing/Not observable
Carabelli's Trait UM1	0 and 1	2 to 4	5+	Missing/Not observable
Cusp 5 UM1	0	1 to 5		Missing/Not observable
Enamel Extensions UM1	0 and 1	2 and 3		Missing/Not observable
Multiple Lingual Cusps LP2	0 and 1	2 and 3		Missing/Not observable
Groove Pattern LM2	X and +	Y		Missing/Not observable
4-cusped LM2	5	4		Missing/Not observable
Cusp 6 LM1	0	1 to 5		Missing/Not observable
Cusp 7 LM1	0 and 1A	1 to 4		Missing/Not observable
Protostylid LM1	0	1	2 to 7	Missing/Not observable
Deflecting wrinkle LM1	0 to 2	3		Missing/Not observable
2-rooted UPM	1 root	2 to 3 roots		Missing/Not observable
3-rooted UM2	1 or 2 roots	3 roots		Missing/Not observable
2-rooted LC	1 root	2 roots		Missing/Not observable
Tomes' root	1 to 3	4 to 7		Missing/Not observable
3-rooted LM1	1 and 2 roots	3 roots		Missing/Not observable
1-rooted LM2	2 roots	1 root		Missing/Not observable

P/R/M UM3 Absent Present Missing/Not observable

PERMANENT TEETH: Mandibular

Site: __________ Catalogue Number: _____________

Date: __________ Burial Number: ______________

	Tooth	Inventory	Development	Attrition Smith	Scott	Caries 1	2	3	Abscess Type	Periosteal Reaction?
Mand	M3	______	_______		_____	_____	_____	_____	_____	_________
Left	M2	______	_______		_____	_____	_____	_____	_____	_________
(L)	M1	______	_______		_____	_____	_____	_____	_____	_________
	P4	______	_______	_____		_____	_____	_____	_____	_________
	P3	______	_______	_____		_____	_____	_____	_____	_________
	C	______	_______	_____		_____	_____	_____	_____	_________
	I2	______	_______	_____		_____	_____	_____	_____	_________
	I1	______	_______	_____		_____	_____	_____	_____	_________
Mand	I1	______	_______	_____		_____	_____	_____	_____	_________
Right	I2	______	_______	_____		_____	_____	_____	_____	_________
(R)	C	______	_______	_____		_____	_____	_____	_____	_________
	P3	______	_______	_____		_____	_____	_____	_____	_________
	P4	______	_______	_____		_____	_____	_____	_____	_________
	M1	______	_______		_____	_____	_____	_____	_____	_________
	M2	______	_______		_____	_____	_____	_____	_____	_________
	M3	______	_______		_____	_____	_____	_____	_____	_________

Dental age estimate:

By dental development (Ubelaker) ________________________

By attrition/tooth loss ________________________

Notes & Comments:

PERMANENT TEETH: Maxillary

Site: __________ Catalogue Number: _____________
Date: __________ Burial Number: ______________

	Tooth	Inventory	Development	Attrition Smith	Scott	Caries 1	2	3	Abscess Type	Periosteal Reaction?
Max	M3	______	_______		_____	_____	_____	_____	_____	_________
Left	M2	______	_______		_____	_____	_____	_____	_____	_________
(L)	M1	______	_______		_____	_____	_____	_____	_____	_________
	P4	______	_______	_____		_____	_____	_____	_____	_________
	P3	______	_______	_____		_____	_____	_____	_____	_________
	C	______	_______	_____		_____	_____	_____	_____	_________
	I2	______	_______	_____		_____	_____	_____	_____	_________
	I1	______	_______	_____		_____	_____	_____	_____	_________
Max	I1	______	_______	_____		_____	_____	_____	_____	_________
Right	I2	______	_______	_____		_____	_____	_____	_____	_________
(R)	C	______	_______	_____		_____	_____	_____	_____	_________
	P3	______	_______	_____		_____	_____	_____	_____	_________
	P4	______	_______	_____		_____	_____	_____	_____	_________
	M1	______	_______		_____	_____	_____	_____	_____	_________
	M2	______	_______		_____	_____	_____	_____	_____	_________
	M3	______	_______		_____	_____	_____	_____	_____	_________

Dental age estimate:
By dental development (Ubelaker) ________________________

By attrition/tooth loss ________________________

Notes & Comments:

APPENDIX B

Figure 17. Burial 498 demonstrating bilaterally pegged maxillary third molars

Figure 18. Burial 511 with gold foil restoration on the maxillary left canine

Figure 19. Burial 294 with gold foil restoration of maxillary canine

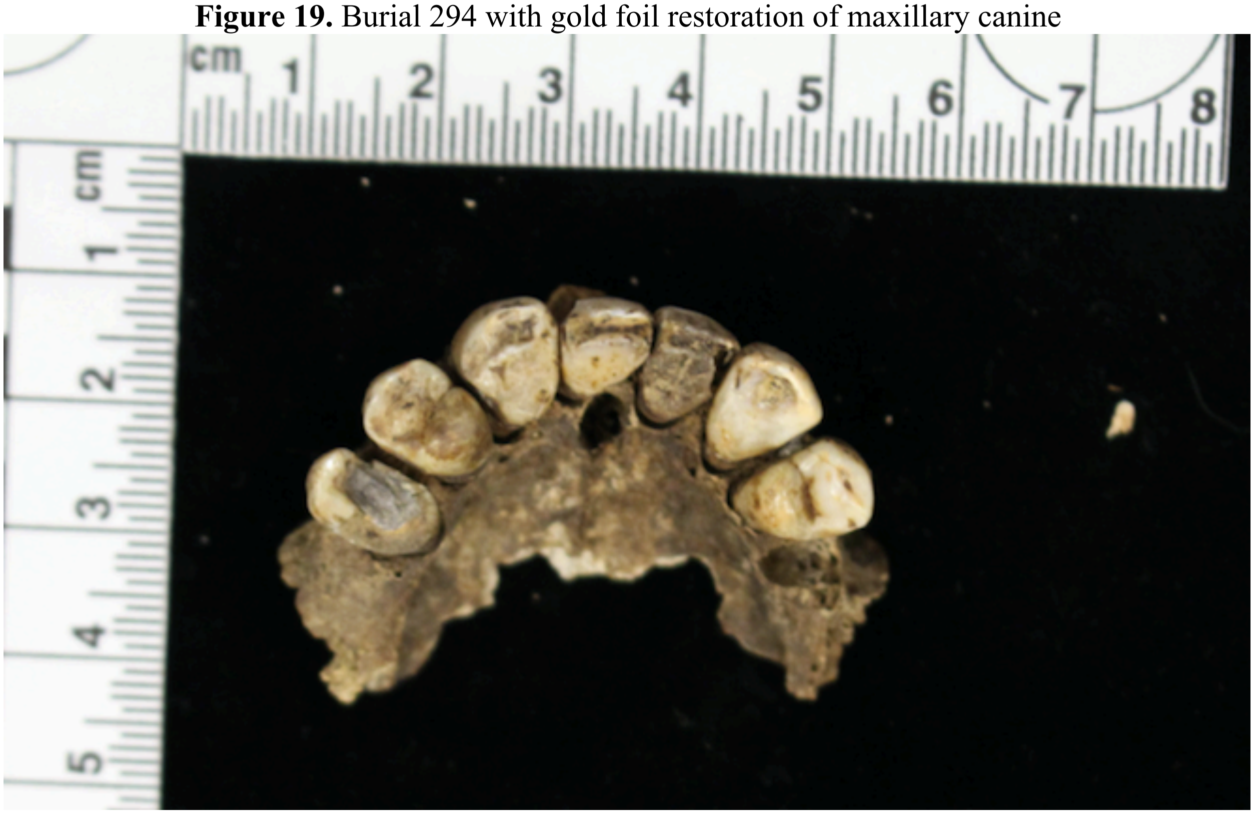

Figure 20. Burial 294 maxillary dentition. Note the absence of both lateral incisors and the dark discoloration.

Figure 21. Burial 443 demonstrating a supernumerary incisor

Figure 22. Burial 631 maxillary incisors with carious lesions of the root

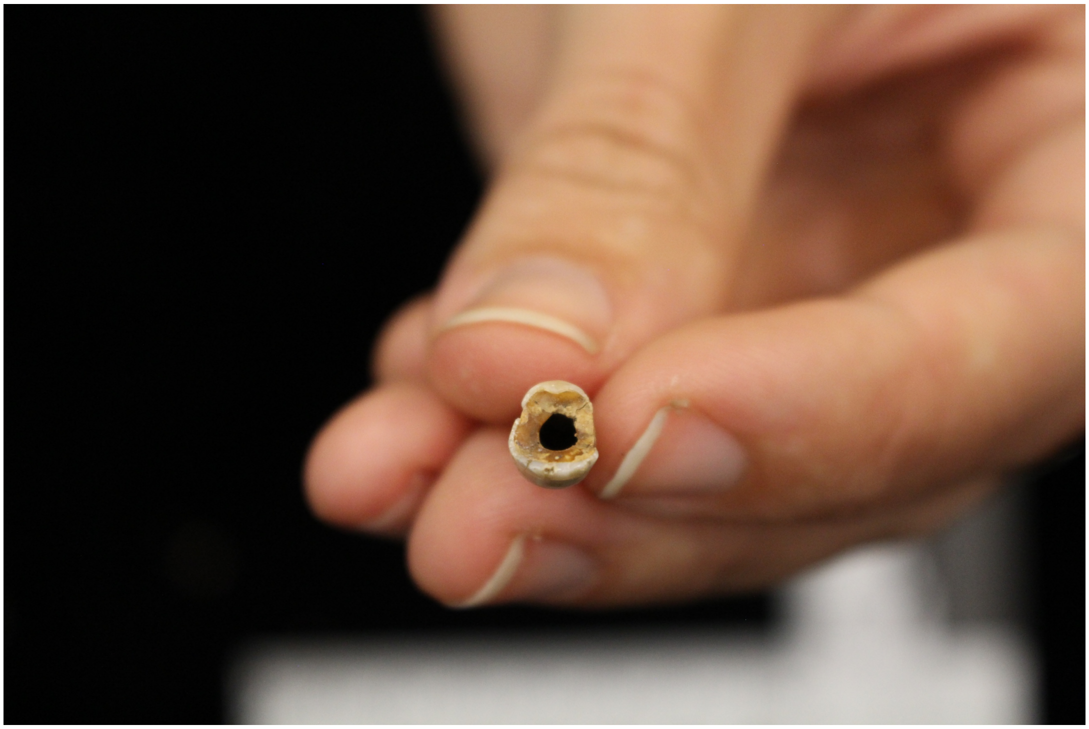

Figure 23. Burial 631 maxillary incisor occlusal surface view demonstrating circular defect

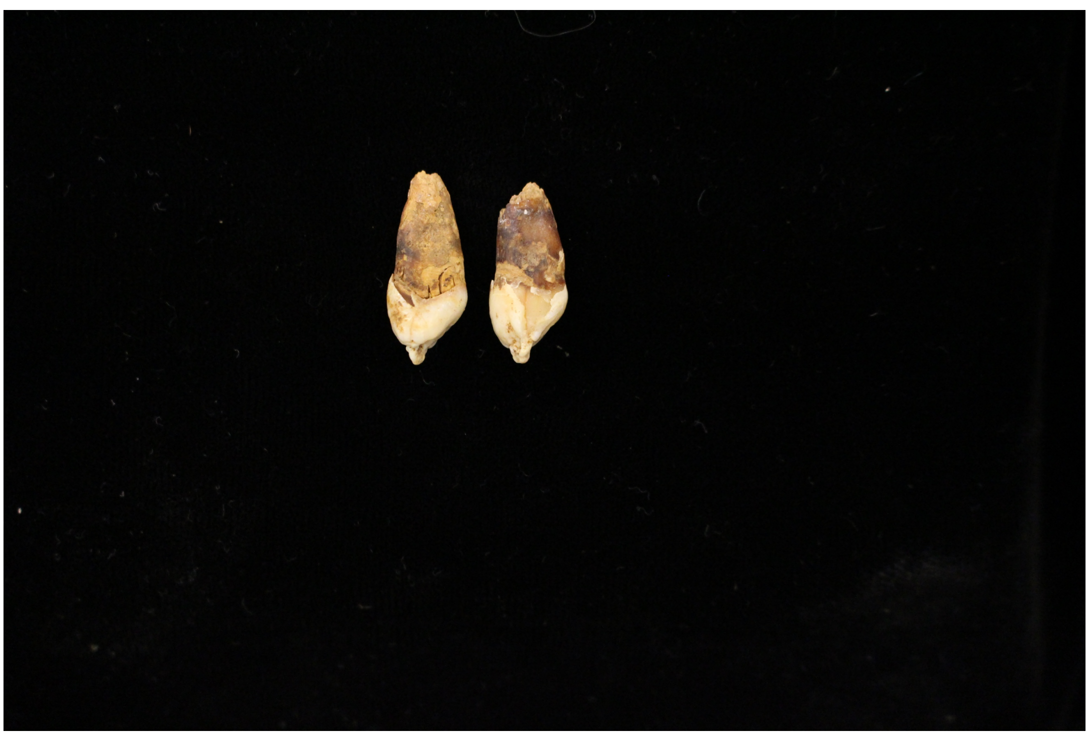

Figure 24. Burial 671 maxillary canines with enamel defect

Figure 25. Burial 671 close up view of the enamel defect to the maxillary canine

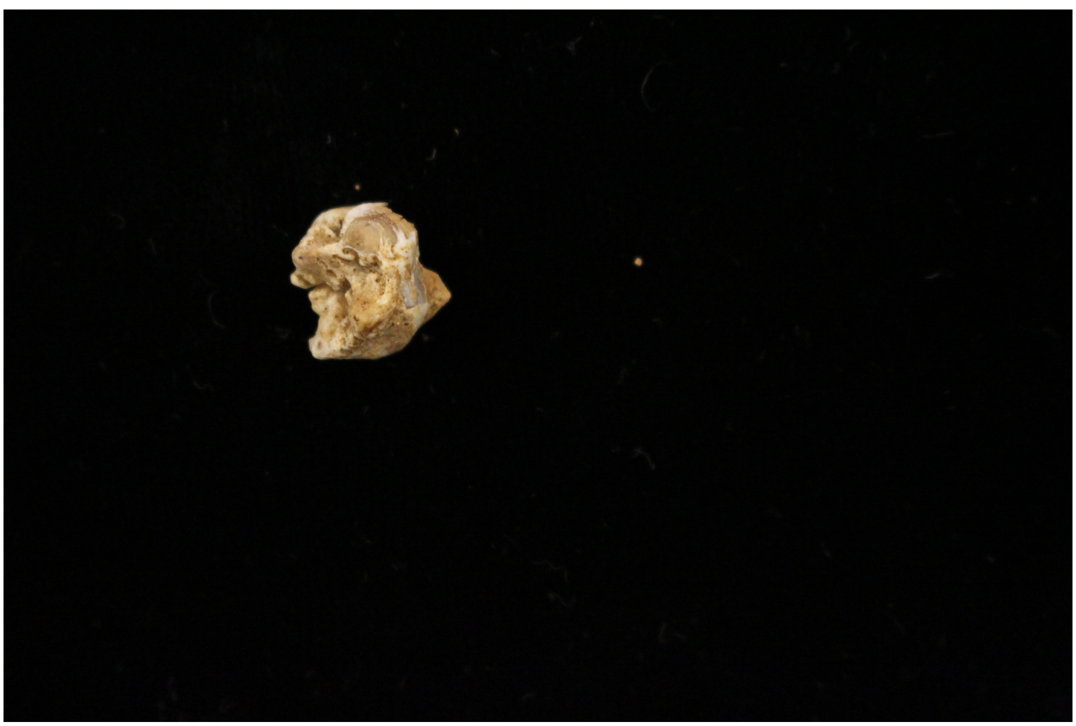

Figure 26. Burial 671 maxillary molar demonstrating characteristics of mulberry molars

Figure 27. Burial 446 maxillary teeth with extensive calculus. Note the large carious lesion of the second molar and associated periapical abscess.

Figure 28. Burial 271 with extensive antemortem tooth loss of the mandible. Note the wear on the remaining molar.

Figure 29. Burial 440 crowding of the maxillary dentition and taphonomic damage to the bone

APPENDIX C

Table 15. Sex, age, and ancestry for each burial

Burial Number	Sex	Age	Ancestry Estimate	General Ancestry Category
446	Male	20-45	Western Eurasian	White
294	Male	45-60	Western Eurasian	White
453	Probable male	35-50+	Western Eurasian	White
434	Probable male	30-45	East Asian	Non-White
511	Male	35-55+	Western Eurasian	White
175	Probable male	30+	Western Eurasian	White
631	Probable male	30-50+	Western Eurasian	White
278	Probable male	40-60+	American Indian	Non-White
415	Probable male	40-60+	Western Eurasian	White
611	Probable male	23-57	Western Eurasian	White
680	Male	30-45	East Asian	Non-White
591	Probable male	40+	Sub-Saharan African	Non-White
281	Male	45-60	Western Eurasian	White
271	Probable male	40-60+	East Asian	Non-White
635	Probable male	30-50+	East Asian	Non-White
440	Probable male	27-55	Western Eurasian	White
599	Indeterminate	25+	Western Eurasian	White
108	Male	35-45	Sub-Saharan African	Non-White
298	Female	45+	Western Eurasian	White
443	Male	30-45	Sub-Saharan African	Non-White
620	Male	35-55	Western Eurasian	White
545	Probable male	30-60	East Asian	Non-White
596	Probable male	35-50+	East Asian	Non-White
597	Probable male	40-60+	East Asian	Non-White
671	Indeterminate	14-26	Sub-Saharan African	Non-White
475	Male	30+	American Indian	Non-White
498	Male	30-50	Western Eurasian	White
688	Probable male	30+	Sub-Saharan African	Non-White
634	Probable male	30-50	Western Eurasian	White
116	Male	25-45	Western Eurasian	White
312	Probable male	35+	Western Eurasian	White
668	Male	35-50	Western Eurasian	White
613	Male	35-60	Western Eurasian	White
487	Male	60+	Western Eurasian	White
445	Male	30-39	Sub-Saharan African	Non-White
585	Male	40-44	Western Eurasian	White
295	Male	50-60	Western Eurasian	White
485	Male	40-44	East Asian	Non-White
227	Male	40+	Western Eurasian	White
426	Male	30-45	East Asian	Non-White

Table 16. Burials with more than one carious lesion per tooth

Burial Number	Number of Affected Teeth with More Than One Lesion	General Ancestry
511	1	White
434	3	Non-White
278	1	Non-White
597	1	Non-White
545	1	Non-White
596	3	Non-White
680	1	Non-White
415	2	White
631	3	White
453	2	White
175	1	White
671	1	Non-White
688	2	Non-White
440	2	White
634	1	White
116	3	White
599	1	White
281	8	White
271	1	Non-White
620	10	White
635	1	Non-White
443	3	Non-White
498	2	White
298	5	White
312	1	White
295	2	White
426	1	Non-White
445	1	Non-White
668	1	White
613	2	White

Table 17. Ancestry estimates from dental morphology and alternative methods

Burial Number	Previous Ancestry Estimate	Initial Dental Ancestry Estimate	Final Ancestry Estimate
446	European	Western Eurasian	Western Eurasian
294	Vietnamese or White	Western Eurasian	Western Eurasian
453	Hispanic	Western Eurasian	Western Eurasian
434	White	East Asian	East Asian
511	Hispanic	Western Eurasian	Western Eurasian
175	Hispanic	Western Eurasian	Western Eurasian
631	Hispanic	Western Eurasian	Western Eurasian
278	Asian	East Asian	American Indian
415	Asian	Australo-Melanesia and Micronesia	Western Eurasian
611	African	Western Eurasian	Western Eurasian
680	Hispanic	American Arctic and Northeast Asian	Western Eurasian
591	Asian, Amerindian, Black	Australo-Melanesia and Micronesia	Sub-Saharan African
281*	Indeterminate	Western Eurasian	Western Eurasian
271	Hispanic	East Asian	East Asian
635	Amerindian	Australo-Melanesia and Micronesia	East Asian
440	Hispanic	Western Eurasian	Western Eurasian
599	Asian	Western Eurasian	Western Eurasian
108	Asian	Sub-Saharan African	Sub-Saharan African
298	White	Western Eurasian	Western Eurasian
443	Asian	Australo-Melanesia and Micronesia	Sub-Saharan African
620	White	Western Eurasian	Western Eurasian
545	Asian, possibly Native American	American Arctic and Northeast Asian	American Indian
596*	Indeterminate	East Asian	East Asian
597	Hispanic	American Arctic and Northeast Asian	East Asian
671	Black	Australo-Melanesia and Micronesia	Sub-Saharan African
475	Black	American Arctic and Northeast Asian	American Indian
498	White	Western Eurasian	Western Eurasian
688*	Indeterminate	Australo-Melanesia and Micronesia	Sub-Saharan African
634	Black	Western Eurasian	Western Eurasian
116	Chinese	Western Eurasian	Western Eurasian

312*	Indeterminate	Western Eurasian	Western Eurasian
668	European	Western Eurasian	Western Eurasian
613	African	Western Eurasian	Western Eurasian
487	European	Western Eurasian	Western Eurasian
445	Asian	Sub-Saharan African	Sub-Saharan African
585	Asian	Australo-Melanesia and Micronesia	Western Eurasian
295	African? Not European	Western Eurasian	Western Eurasian
485	Hispanic	Southeast Asia and Polynesian	East Asian
227*	Indeterminate	Western Eurasian	Western Eurasian
426	African	American Arctic and Northeast Asian	East Asian

*Indicates a burial that had a previously indeterminate ancestry but was able to be estimated using dental morphology.