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DENTAL ARCHAEOLOGY OF THREE POPULATIONS OF CHRISTIANS AND NON-MUSLIMS IN POLLENTIA, MALLORCA

by

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A Paper Presented to the

Faculty of Mount Holyoke College in

Partial Fulfillment of the Requirements for

the Degree of Bachelors of Arts with

Honor

Department of Biological Sciences

South Hadley, MA 010175

May 2017

This paper was prepared
under the direction of
Professor Stan Rachootin
for eight credits.

DEDICATION

This paper is dedicated to my parents, Dr. Valerie A. Walters and Dr. Julio C. de Paula for their unending support and love, my sister for her inspiration, my friends at Mount Holyoke College for always cheering me on, and the citizens of Pollentia for being such good sports.

ACKNOWLEGDMENTS

I would like to acknowledge and thank the members of my thesis committee, Prof. Stan Rachootin, Prof. Sarah Bacon, and Prof. Janice Gifford. I would also like to acknowledge Dr. Francisca Cardona, Dr. Miguel Angel Cau Ontiveros, and Fr. Richard Rutherford whose mentorship would not have been possible without the University of Portland, the University of Barcelona, and the Bryant Foundation. Lastly, I would like to thank Mount Holyoke College for and the Lynk UAF Committee for granting me the Lynk UAF Award that allowed me to conduct my summer research.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

ABSTRACT

The diet, health, nutrition, and genetics of an individual leave unique and identifiable markers on dental remains. Those markers can be used to understand the diet and health of an ancient population. This study presents findings from an analysis of the dental remains of individuals from three Christian populations within the Roman city of Pollentia, located in Mallorca, Spain that was inhabited from 123 B.C. to 1229 A.D. The Christian populations of Ca'n Fanals and Sta. Ana are sites from the later Christian periods of the city, but the Forum is representative of the Islamic Period. My study compares the occurrence of hypoplasia, calculus, periodontitis, caries, occlusal wear, and agenesis to understand differences in diet and health between the three subsites. The comparison was conducted with One-Way ANOVA and Fisher's Exact Test. The result of this comparison is that there is no significant difference in the occurrence of the six pathologies between Sta. Ana and the Forum. Despite living during the Islamic Period, the Christians of the Forum had the same access to high quality food to which the Christians of Sta. Ana. This study presents the possible explanations for this interesting situation.

1. INTRODUCTION

Dental remains recovered from archaeological sites can reveal much about the life of an ancient population and assist in reconstructing the patterns of life for the entire ancient community. The marks left on dental remains by physical interactions with other teeth and the outside world, and biological responses to bacteria and food expand the understanding of the diet, the agricultural practices, and the environment of populations of the past (DiGangi and Moore 2013).

This study seeks to understand the dental archaeology of three populations of Christians within the larger context of the Roman city Pollentia, located on the island of Mallorca in Catalonia, Spain. Specifically, the following work examines the modifications and pathologies present on dental remains in the archaeological record of Pollentia.

1.1 *Pollentia, Mallorca*

The Roman city of Pollentia is located on the northern tip of the island of Mallorca in Catalonia, Spain. Mallorca (Fig. 1) is the largest of the four principal islands - Mallorca, Menorca, Eivissa (Ibiza), and Formentera - within the archipelago of the Balearic Islands (Rodriguez 2015a). The Balearic Islands are located off the eastern coast of Spain in the western Mediterranean Sea and are within the territory of Catalonia, but are also part of an autonomous community established in 1983 (Rodriguez 2015a). Mallorca encompasses two mountainous regions on the northwestern and southeastern sides of the island that are broken up by a lowland region (Rodriguez 2015b). The northern coast of Mallorca, where Pollentia is located, consists of large cliffs and two main bays, Badia Pollença and Badia d'Alcúdia (Rodriguez 2015b). Overall, the landscape is varied and the climate is mild, with low precipitation occurring in the fall and spring (Rodriguez 2015a).

Figure 1. Map of Mallorca.

Figure 1. Map of Mallorca, situated to the east of the Iberian Peninsula in the Balearic Islands archipelago. The location of Pollentia is indicated with a red dot (Image from Cau Ontiveros et al. 2015).

The best preserved Roman city on Mallorca, La Ciudad Romana de Pollentia was founded by Quintus Caecilius Metellus in 123 B.C., during the era of the Roman Republic, as a part of the Roman invasion of the Balearic Islands

(Ranieri et al. 2016; Cau Ontiveros et al. 2015). This invasion secured the Balearic islands for Rome (Márquez, Ontiveros, and Pons 2016). Pollentia is located next to the modern city of Alcúdia (Fig. 2), 1.5 km from the modern day Port d'Alcúdia and 2.5km from Porto Pollença, its northern limit merging with the southern limit of Alcúdia (Ranieri et al. 2016). The total area of the city is estimated at 180,000 m^2 with an orthogonal layout (Ranieri et al. 2016). From East to West, it is estimated to span 300 m and from North to South, it is estimated to span 600 m (Ranieri et al. 2016).

Figure 2. Map of the Location of Pollentia.

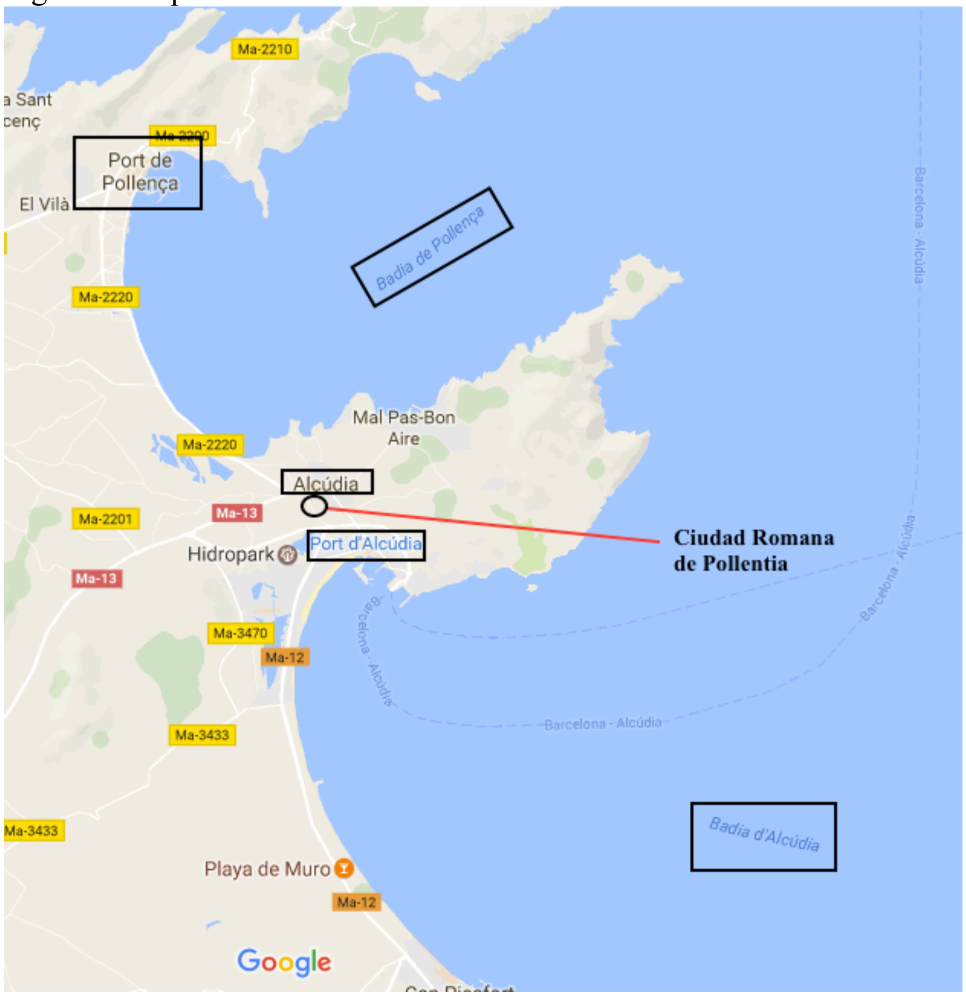

Figure 2. Map of the location of The Roman City of Pollentia within the Municipality of Pollença. Indicated on this map are Badia de Pollença and Badia d'Alcúdia, Port d'Alcúdia and Porto Pollença, the city of Alcúdia, and the Roman city of Pollentia (based on a map from https://www.google.com/maps/@39.8493243,3.1148984,12z).

Located so close to the main bays on the northern coast of Mallorca (Fig. 2), Pollentia was likely used for defensive purposes after the Roman invasion and later for commercial trade (Ranieri et al. 2016). Though the limits of the city are still under debate, two main walls have been discovered around the city, one built at the end of the 3rd century A.D. around the northwestern section and a second built in the Late Antique period in the area of the forum (Ranieri et al. 2016).

Before Roman settlements appeared in Mallorca, members of the Talayotic culture inhabited the Balearic Islands from 2500 B.C. until the Roman invasion in 123 B.C. (Mullen 2007, 72). When Metellus invaded the islands, he was said to have killed off all of the native Talayotic inhabitants claiming that they were pirates corrupting the area (Mullen 2007, 72).

Roman inhabitation of Mallorca took place over the subsequent century and culminated with the construction of the two important cities of Palma (40/50 B.C.), the modern day capital of Mallorca, and Pollentia (60/70 B.C.) (Orfila, Cau, and Chavez 2006, 133-145; Márquez, Ontiveros, and Pons 2016). Within Pollentia itself, construction began in the area of the Forum of the city around 70 B.C. (Ranieri et al. 2016).

The city remained in a state of construction until the dissolution of the city; the forum and the residential areas of the city show evidence of multiple building plans and construction of house on top of house (Orfila, Cau, and Chavez 2006, 133-145). Construction and development of the city carried on through Augustan monumentalism and imperial architecture until a large destructive fire swept the city in 260/270 A.D. (Cau Ontiveros et al. 2015).

Despite the destructive fire, the city survived through the fire and there is evidence of Roman occupation through the Late Roman, Vandal Period (455-534 A.D) and ending with the Byzantine Period (534-902/903) (Cau Ontiveros et al. 2015). In the area of the forum, there is evidence of an Islamic period beginning in 902/903 A.D. (Cau Ontiveros et al. 2015). The city remained under Islamic occupation until the Catalan conquest of Mallorca in 1229 A.D. (Cau Ontiveros et al. 2015; Ranieri et al. 2016). The Catalans continued to inhabit the city through Late Antiquity (Cau Ontiveros et al. 2015; Ranieri et al. 2016).

The excavated portion of the city of Pollentia encompasses the city center or the Forum (el Foro), the residential homes of Sa Portella and the House of Polymnia, an Amphitheatre, the Church of Santa Anna (Oratorio de Sta. Ana), the cemeteries of Ca'n Fanals, Ca'n Copido, and Ca'n Corro, and several necropolises that overlay the Forum and the Amphitheatre (Fig. 3) (Orfila, Cau, and Chavez 2006, 133-145; Cau Ontiveros et al. 2015). This study focuses on the Forum, the Oratorio de Sta. Ana, and Ca'n Fanals.

Figure 3. Site Map of Pollentia.

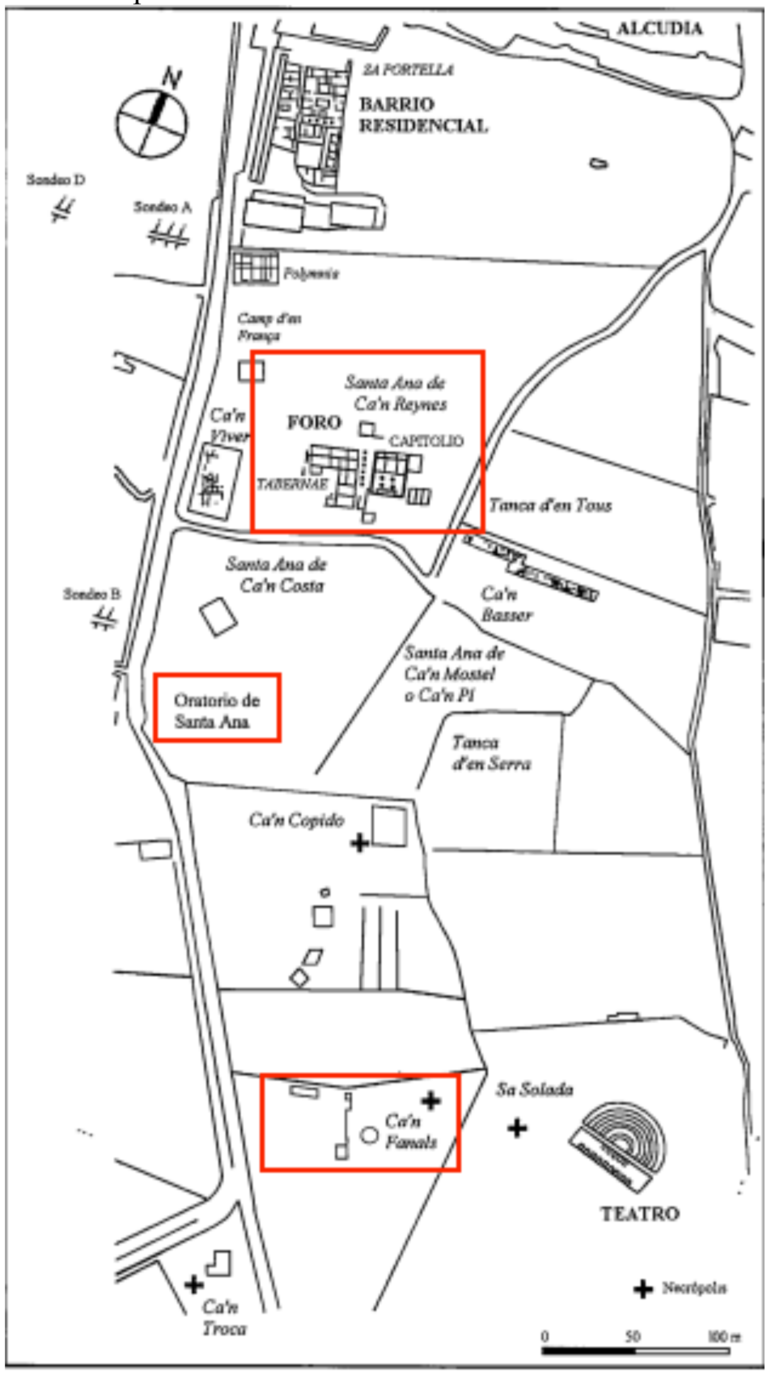

Figure 10. The map of the subsites within Pollentia. The Forum, Sta. Ana, and Ca'n Fanals are highlighted with a red box (based on an image from: Orfila, Cau, and Chavez 2006, 133-145).

The Oratorio de Sta. Ana is a Medieval Christian church built on top of a cemetery. The individuals from the cemetery were recovered in 2013, and have been dated to the 12th/13th century directly before the Catalan conquest of the Balearics. The church itself was thought to have been built soon after the use of the cemetery stopped. When I refer to the Oratorio de Sta. Ana, I refer to the cemetery underneath the church.

Ca'n Fanals is another cemetery toward the southern limit of Pollentia (Ranieri et al. 2016). The cemetery was originally excavated in the 1930's and was subsequently covered to make space for an olive orchard (Ranieri et al. 2016; Orfila, Cau, and Chavez 2006, 133-145). Ca'n Fanals is currently known to be composed of a long row of 70 tombs with 8 cremations, a religious building, a wall, and a limestone quarry (Orfila, Cau, and Chavez 2006, 133-145). The site is thought to be from the 1st or 2nd century A.D. during the Early Imperial Period; after the invasion of the island and before the fire that destroyed the city (Orfila, Cau, and Chavez 2006, 133-145). The inhabitants of this area are thought to be early Christians based on how they were buried and the presence of church building close by.

The Forum encompasses residences, a portico street, a marketplace (macellum), temples, and tombs (Fig. 4) (Cau Ontiveros et al. 2015). The Forum went through several periods of construction, destruction, and rebuilding and therefore the chronology of the Forum is difficult to decipher, but the major periods of construction took place between the 1st century B.C.-3rd century A.D. and in the Byzantine period (Cau Ontiveros et al. 2015). Overlaying the older southeastern sections of the forum, the older sections, is an expansive necropolis (Cau Ontiveros et al. 2015). Since I am studying human remains, when I refer to the Forum, I refer to the necropolis overlaying the Forum. The location of the tombs suggest that they were created while the Tuscan temple was still in use as none overlay the remaining structures of that temple (Cau Ontiveros et al. 2015). Although the stratigraphy of the necropolis is unclear, individuals excavated from the necropolis have recently been dated with radiocarbon dating to the 9th and 12th century, during the Muslim occupation of the city. (Cau Ontiveros et al. 2015). However, due to the positioning of the bodies inside of the grave and the orientation of the tombs, it was the concluded that their burials are consistent with non-Muslim burials and are speculated, instead, to be Christian burials (Cau Ontiveros et al. 2015). In the current research, the presence of these Christians during the Islamic occupation is very interesting, and researchers are attempting to understand their involvement in the Muslim community (Cau Ontiveros et al. 2015).

Figure 4. Map of the Forum.

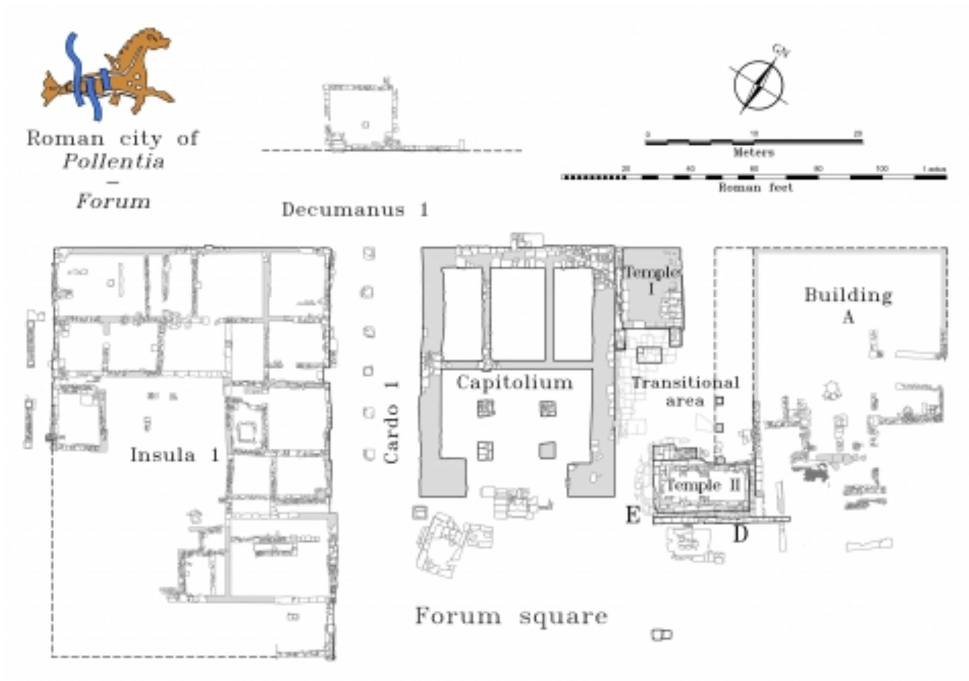

Figure 4. Labeled map of the Forum of Pollentia (Image from Márquez, Ontiveros, and Pons 2016).

Pollentia now exists as an active archaeological site. Excavations have taken place since the early 20th century and have continued, interrupted, until present day (Ranieri et al. 2016). Unfortunately, the work done during the excavations of the early 20th century had to covered up (Ranieri et al. 2016). Therefore most of the work in the modern excavations so far seeks to recover what was excavated in the early 20th century. The present excavations are conducted through the Bryant Foundation under the leadership of Dr. Miguel Angel Cau Ontiveros and Dr. Esther Alvarez Chavez.

1.2 *Dental Anatomy and Function*

Before further discussion of the archaeology of Pollentia, and how this project contributes to the understanding of Roman Christian populations, it is important first to discuss dental anatomy and tooth function.

The anatomy of a human tooth is shown in Figure 5. The human tooth is composed of two basic materials: dentin, which is living tissue, and enamel and cementum, both hard non-living bone-like materials deposited to enclose the living tissue (White and Folkens 2005). The exposed portion of the tooth is called the crown and the portion that is anchored in the bone of the maxilla and mandible (the alveolar bone), is called the root (Wheeler 1969; White and Folkens 2005).

The dentin of the tooth is cellular, but avascular (White and Folkens 2005). Covering the dentin of the crown is the enamel and covering the root is the cementum (White and Folkens 2005). Separating the enamel and the cementum as well as delineating where the root's insertion into the alveolar bone ends, is the cervicoenamel line (Wheeler 1969; White and Folkens 2005). The cementum itself is bone-like tissue, whereas the enamel is made up of 97% mineralized material that is not living and never was (White and Folkens 2005). It is the enamel that is exposed to the outside environment and carries the evidence of interaction with food, tools, and other teeth (Buikstra and Haas 1994).

Figure 5. Anatomy of the Human Tooth.

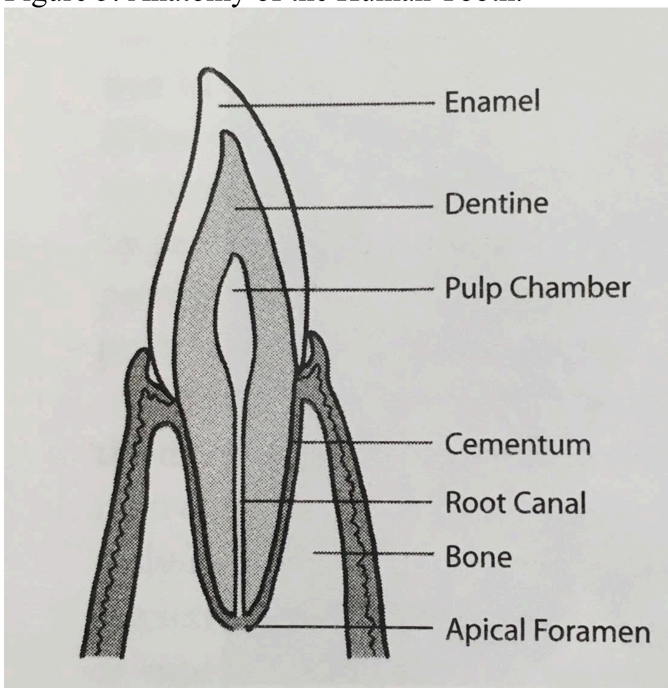

Figure 4. The anatomy of the human tooth with elements labeled (Image from White and Folkens 2005).

Humans have two sets of permanent16 teeth, one set per maxilla and mandible, and 32 teeth in total (Wheeler 1969). Due to their generalized diet, within these 32 teeth, humans have four general types of teeth, each with their own specific function (DiGangi and Moore 2013). These are the incisors, canines, premolars, and molars (Fig. 6) (White and Folkens 2005; DiGangi and Moore 2013). Incisors slice, canines tear, and premolars and molars crush and grind (White and Folkens 2005).

Figure 6. Categories of Human Teeth.

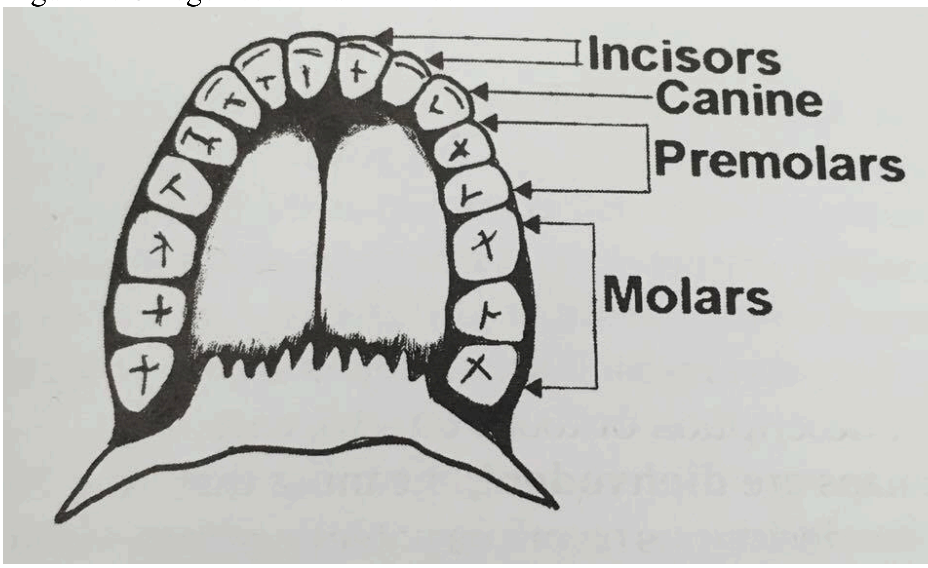

Figure 5. The four categories of human teeth labeled on a drawing of the maxilla (Image from DiGangi and Moore 2013).

The crown of the incisor is flat and broad, and comes to a blade-like edge (White and Folkens 2005). The crown of a canine almost comes to a pointed edge and is generally shaped like a cone (White and Folkens 2005). The crown of the premolar has two cusps instead of one, one taller than the other (White and Folkens 2005). Molars are the largest of the 4 types of teeth can have three to five cusps depending on it is an upper or lower molar and have multiple roots (White and Folkens 2005). The morphology of the human teeth serve the purpose of chewing food, but can also allow for the use of teeth as tools (DiGangi and Moore 2013).

Identification of human teeth is understood within four quadrants that are set up along the median line (Wheeler 1969). The quadrants are the upper left and upper right of the maxilla, and the lower left and lower right of the mandible (White and Folkens 2005). Each quadrant contains, from front to back: 2 incisors, 1 canine, 2 premolars and 3 molars (White and Folkens 2005). The terminology to describe the position of a tooth in the dental arcade is organized so that RC^1 describes the upper right canine of the maxilla (White and Folkens 2005).

There is additional language to describe the surfaces of the enamel of a tooth (Fig. 6). The surface at the top edge of the tooth that comes into contact with other teeth is called the occlusal surface (White and Folkens 2005). The surface of the incisors and canines that touches the lips is called the labial surface and the surface of the premolars and molars that touches the cheeks is called the buccal surface (White and Folkens 2005). The surface that touches the tongue is called the labial surface (White and Folkens 2005). The surfaces in between the teeth are called the interproximal surfaces; the surface towards the front of the mouth is called the mesial surface and the surface towards the back of the mouth is called the distal surface (White and Folkens 2005).

Figure 7. Surface of the Human Tooth.

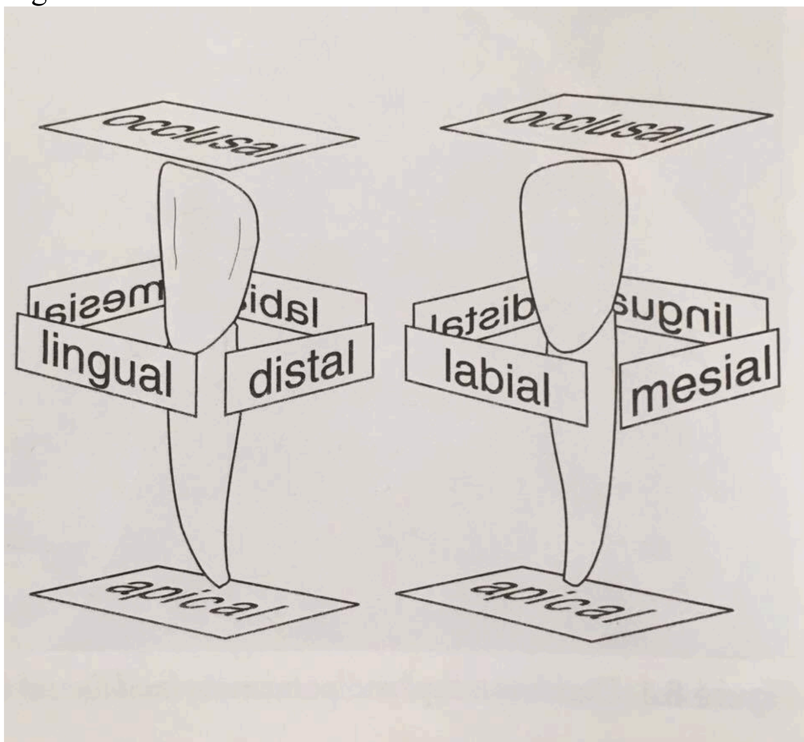

Figure 6. The labeled surfaces of the human tooth (Image from White and Folkens 2005).

1.3 *Dental Archaeology*

Dental archaeology is the examination of the indicators left on the teeth during the life of the individuals of a population (DiGangi and Moore 2013). As teeth are uniquely in contact with the outside world of an individual and, uniquely, survive better than other skeletal remains, dental remains prove important to the interpretation of age, diet, health, disease, and genetics of an ancient human population (Buikstra and Haas 1994). For these reasons, dental remains have been used in many studies of prehistoric and archaeological populations as reliable sources of information (Buikstra and Haas 1994).

The premise of dental archaeology is that during the life of an individual, interactions with the physical quality of food, other teeth, disease, nutrition, and genetics leave identifiable markers on the dental remains of that individual (Buikstra and Haas 1994). From those markers, archaeologists are then able to gain an understanding about the quality of the food, nutrition, and surrounding environment of that individual or population (Buikstra and Haas 1994).

While the evidence that a tooth provides about the diet and health of an individual can stem from the isotopic composition of material in that tooth, most of the best understood indicators of diet and stress are at the level of both the enamel of the tooth and the surrounding bone (Irish and Scott 2016). Therefore, the definition of dental remains encompasses not only the crown and the root of the tooth, but also the alveolar bone.

A great deal of stress occurs at the level of the enamel and the alveolar bone and that stress can take many forms and have varied causes. Ultimately, the categorization of indicator boils down to dental pathology and dental wear (Irish and Scott 2016; DiGangi and Moore 2013). For the purposes of this study, the indicators are termed pathologies and modifications. Aside from observational methods of dental archaeology is chemical analysis (DiGangi and Moore 2013).

Dental pathologies result from the nutrition and health of the individual whereas dental wear results from the interaction of the tooth with food, objects, and other teeth (White and Folkens 2005). Discussed below are the more commonly studied pathologies and modifications including caries, dental hypoplasia, dental calculus, periodontal disease, attrition, abrasion, and microwear patterns. Less common, but present in the sample at Pollentia, were agenesis and deformed teeth. The focus of the discussion below is the six dental pathologies and modifications that were observed in Pollentia.

Enamel hypoplasia is a product of the development of the enamel of the tooth (Irish and Scott 2016). Enamel hypoplasia is part of a class of enamel defects that also includes opacities and discolorations (Irish and Scott 2016). Hypoplasia is the reduction of the surface enamel and presents itself as horizontal grooves on the enamel of the tooth, typically on the labial or buccal surface (Fig. 8) (Irish and Scott 2016). Reduction of the enamel in this specific pattern is caused by a disruption in the development of the enamel at the level of the ameloblasts, the cells that secrete the mineralized enamel (Irish and Scott 2016; DiGangi and Moore 2013).

The causes of the disruption are generally attributed to punctuated malnutrition during childhood, when the enamel develops (DiGangi and Moore 2013). Hypoplasia is so true to timeline that it is possible to tell when a person experienced malnutrition based on the positioning of the grooves (Forshaw 2014, 529-535). Additional causes of hypoplasia include infectious disease, genetic mutation, and environmental stress (Irish and Scott 2016). Overwhelmingly, the consensus is that hypoplasia is the result of periods of malnutrition during childhood in conjunction with one or more additional factors, such as unreliable food supply and poor health (Forshaw 2014, 529-535).

Figure 8. Example of Enamel Hypoplasia.

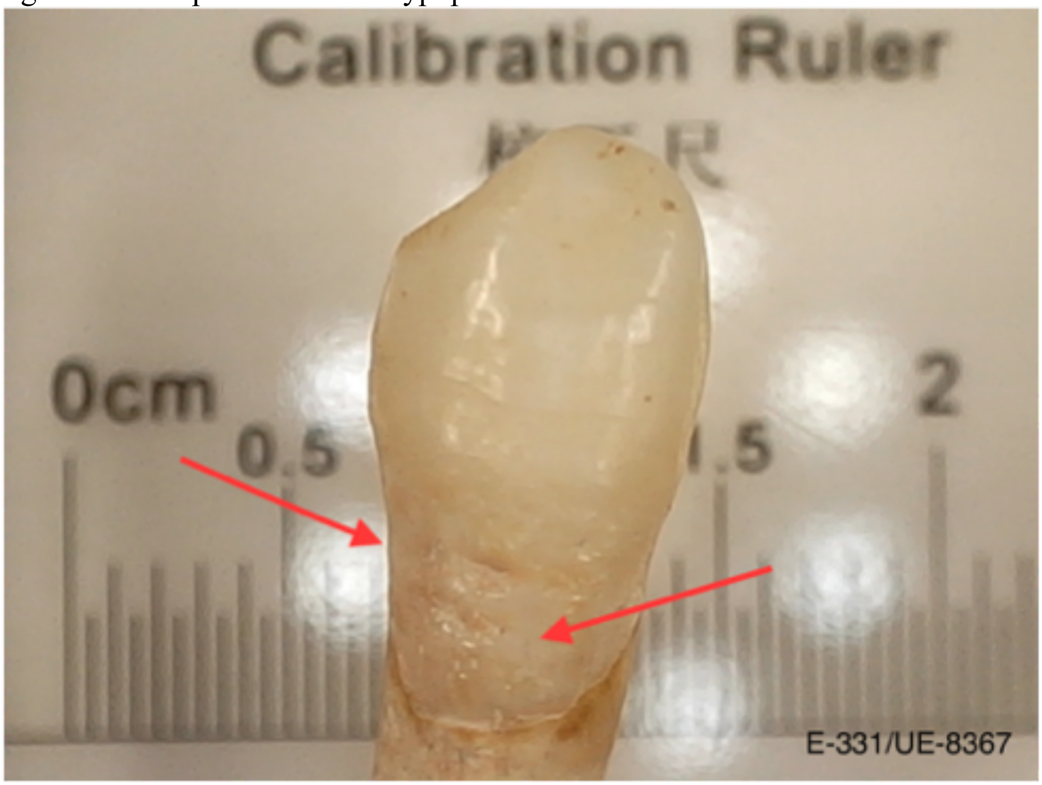

Figure 8. An example of the grooving due to enamel hypoplasia present on individual, E-331/UE-8367, from Pollentia. This micrograph was taken in July 2016.

Dental calculus is a brittle mineralized plaque that forms on the surface of all teeth and is generally the precursor to dental caries (Fig. 9) (White and Folkens 2005). Unlike the mineralized enamel, the mineralized plaque of calculus is not deposited by the body, but by a chemical reaction between the contents of saliva that takes place in the mouth (Forshaw 2014, 529-535). The plaque is formed in a matrix on the surface of a tooth so food particles get trapped in that matrix and survive to become part of the archaeological record (White and Folkens 2005).

The likelihood of formation of dental calculus depends on details of diet (Forshaw 2014, 529-535). Diets that increase the alkalinity of the mouth environment increase the ability of minerals to be deposited on the teeth and, therefore, contribute to the formation of calculus (Forshaw 2014, 529-535). Therefore, the information that calculus can reveal about dietary reconstruction is limited to indicating the chemical content of food and drinking water (Forshaw 2014, 529-535). Generally, calculus is an indicator of food that is high in protein and alkalinity (Forshaw 2014, 529-535).

Figure 9. Two Examples of Dental Calculus.

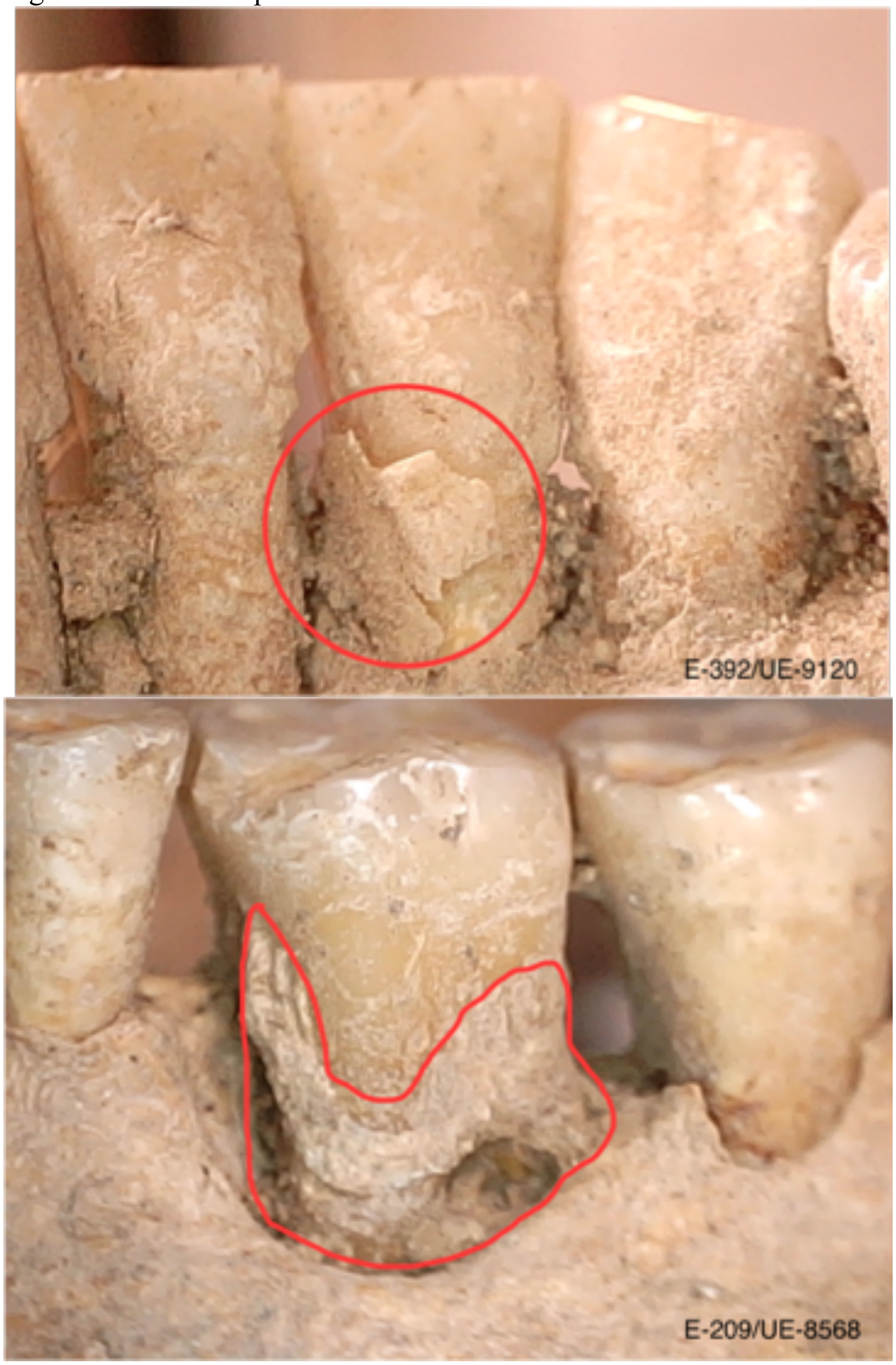

Figure 9. Two examples of dental calculus. The mandibular central incisor (top) demonstrates a brittle mineralized sheet of plaque on the labial surface (E-392/UE-9120). The 1st left mandibular molar (bottom) demonstrate a compacted deposit of plaque (E-209/UE-8568). This micrograph was taken in July 2016.

Dental caries, or cavities, are disease-related lesions that present on teeth as decalcified pits (Fig. 10), discolored enamel, or total destruction of the crown of the tooth (Fig. 10) (Irish and Scott 2016; Forshaw 2014, 529-535). Caries are the result of the formation of dental calculus or plaque (White and Folkens 2005). Bacteria are captured by dental calculus and an acid produced by the bacteria causes the demineralization of the enamel and dentin of a tooth (DiGangi and Moore 2013). There are several standardized methods of quantifying and comparing caries based on the advancement, the size, and location of the lesion (Irish and Scott 2016). These methods produce a score that can be used to compare large samples (Buikstra and Haas 1994).

While there are several hypothesized dietary causes for the presence of the bacteria that cause caries, the most well-understood cause is the inclusion of fermentable carbohydrates in the diet (Forshaw 2014, 529-535). The evidence for the link between carbohydrates and carious lesions is the link between the increase in farmed carbohydrates and caries present in the archaeological record at the time of the advent of agriculture (Forshaw 2014, 529-535).

Figure 10. Two Examples of Dental Caries.

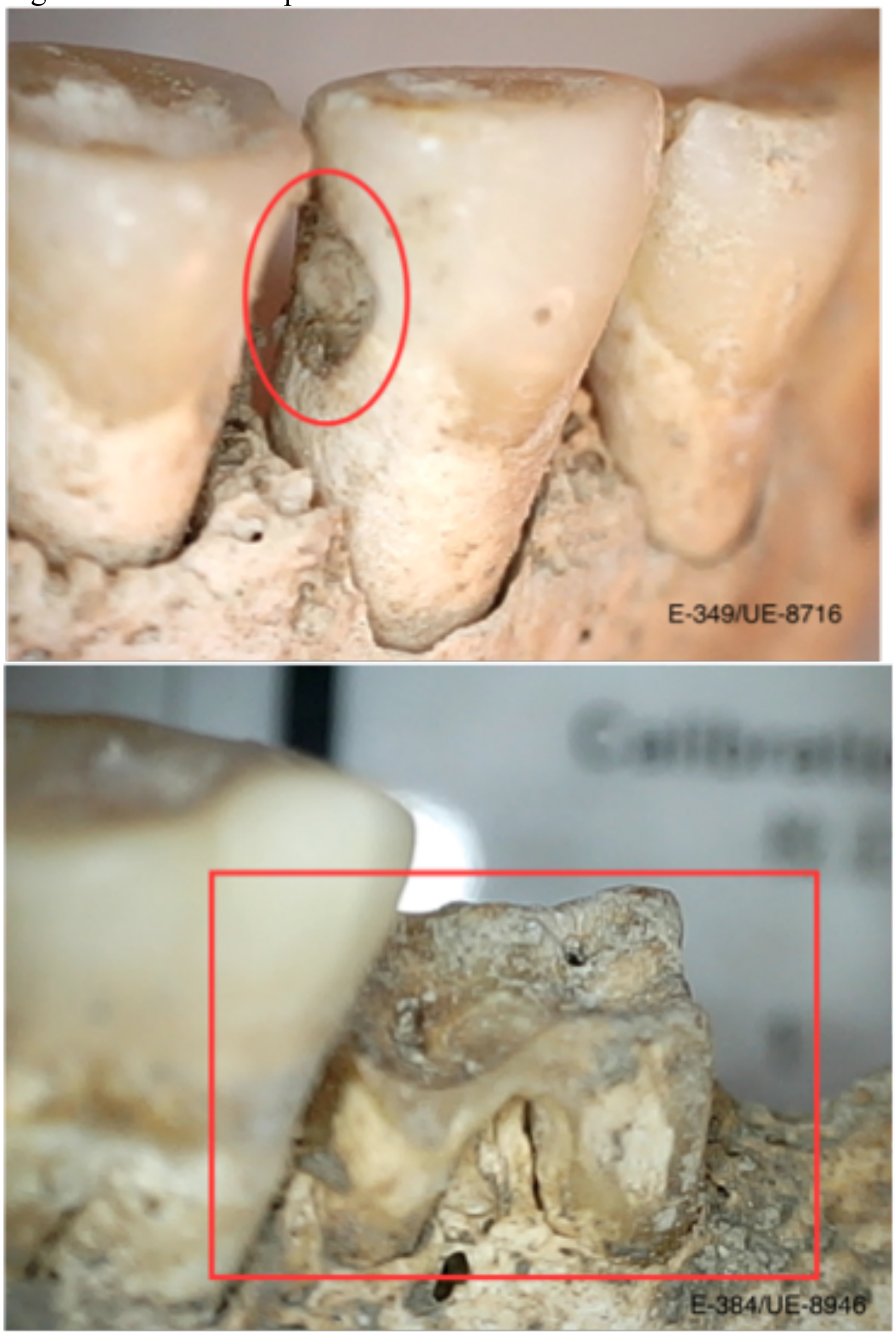

Figure 10. Two examples of dental caries from the observed sample from Pollentia. The above is an example of a decalcified pit in the interproximal distal surface of a LC^1 (E-349/UE-8716) and the below is an example of destruction of enamel and dentin on LM_1 (E-384/UE-8946). This micrograph was taken in July 2016.

Periodontal disease, or periodontitis, is another disease that leaves identifiable marks on dental remains (White and Folkens 2005). Periodontitis is a disease of the living tissue that surrounds the tooth, but the inflammation of the tissues cause the horizontal resorption of or large abscesses in the surrounding alveolar bone (Fig. 11) (White and Folkens 2005). Like dental caries, the infection causing periodontitis is provoked by the bacteria trapped by dental calculus (Irish and Scott 2016). As for caries, there is a scale of measurement for the severity of periodontal disease, the Ogden four-grade system (Irish and Scott 2016).

As previously mentioned, periodontal disease is the result of bacteria; therefore any diet with food that supports bacterial growth is likely to be the cause of periodontal disease (DiGangi and Moore 2013). Vitamin B deficiency, stress, smoking, and scurvy have also been identified as causes of periodontal disease (Forshaw 2014, 529-535). Additionally, because of its association with several modern day diseases, cardiovascular disease, diabetes, and cancer, periodontal disease can be used as a measure of overall health in addition to dental health (Irish and Scott 2016).

Figure 11. Example of Periodontal Disease.

Figure 11. An example of the horizontal resorption due to periodontal disease on the buccal surface of LM_1 (E-322/UE-8525). This micrograph was taken in July 2016.

The genetics of an individual are the main factor in the presence of agenesis (Irish and Scott 2016). Agenesis occurs when there is a failure of one or more teeth to germinate, grow, or erupt (Irish and Scott 2016) Classifications of agenesis as anadontia, oligodontia, and hypodontia, etc., are based on the number of teeth that are missing (Irish and Scott 2016).

Figure 12. Example of Agenesis.

Figure 12. An example of agenesis on the maxilla of an individual from Pollentia (E-384/UE-8946). This individual is missing four (LM^1, LM^2, LM^3, RM^1, RM^2) maxillary teeth. This micrograph was taken in July 2016.

In the literature, the most commonly employed indicators of dental stress and health are isotope analysis and microwear analysis (Irish and Scott 2016). However, the limits of this study were such that did not allow for either type of analysis, but for analysis on a more macro-scale instead.

Dental wear, as a category of wear patterns, provides the most direct evidence for diet reconstruction (Irish and Scott 2016). The presence of pathologies like hypoplasia and caries have immediate interpretations, but dental wear occurs in degrees and measurements of those degrees determine how the wear is interpreted (Irish and Scott 2016). Dental wear is defined as the degradation of enamel and dentin of teeth and usually occurs on several teeth, rather than on a single tooth (Forshaw 2014, 529-535). Dental wear has been more commonly examined on permanent teeth, but can also be recorded on deciduous teeth (baby teeth) (Dawson and Brown 2013, 433-441). There are three general categories of dental wear: attrition, abrasion, and corrosion (Irish and Scott 2016). Outside of these categories is dental mutilation (Beck and Blakely 1984, 269-284). Dental mutilation is distinct from dental wear because dental mutilation is the intentional alteration of the tooth that is meant to be seen and understood as culturally significant (Beck and Blakely 1984, 269-284).

Attrition and abrasion are often confused, but are fairly different; together they create a profile of the masticatory behaviors of an individual (Forshaw 2014, 529-535). Attrition describes wear patterns that result from occlusion, or the grinding together of teeth (Irish and Scott 2016). Corrosion describes the result of acidic corrosion of the enamel (Irish and Scott 2016). Abrasion describes the wear patterns that are a result of the interaction between the teeth and an introduced object, such as food or a tool (Irish and Scott 2016).

Abrasion produces a superficial polish over the entire exposed surface of the tooth (Irish and Scott 2016). These types of wear produce a specific pattern identifiable to the object that was used in the mouth cavity (Irish and Scott 2016).

Attrition consistently results in a flattened plane of wear as the enamel and dentin are worn away on both the occlusal surface and the interproximal surfaces (Fig. 13) (Irish and Scott 2016). This is the type of dental wear that was observed at Pollentia and is, from this point on, referred to as occlusal wear. Depending on the method of mastication necessary to grind up a specific food type, the patterns of wear differ in angle (Smith 1984, 39-56). For example, the masticatory patterns for tough fibrous food result in a completely flat wear plane in the molars, whereas the patterns for grains and food cooked in water result in the same amount of wear, but in a slanted wear pattern in the molars (Smith 1984, 39-56). Therefore, the type of wear pattern left on the tooth can help in the determination of what generalized type of food an individual was eating (Forshaw 2014, 529-535). In fact, there exist several scale systems for the grading of wear patterns that match those grades with food type (Irish and Scott 2016).

Figure 13. Two Examples of Occlusal Wear.

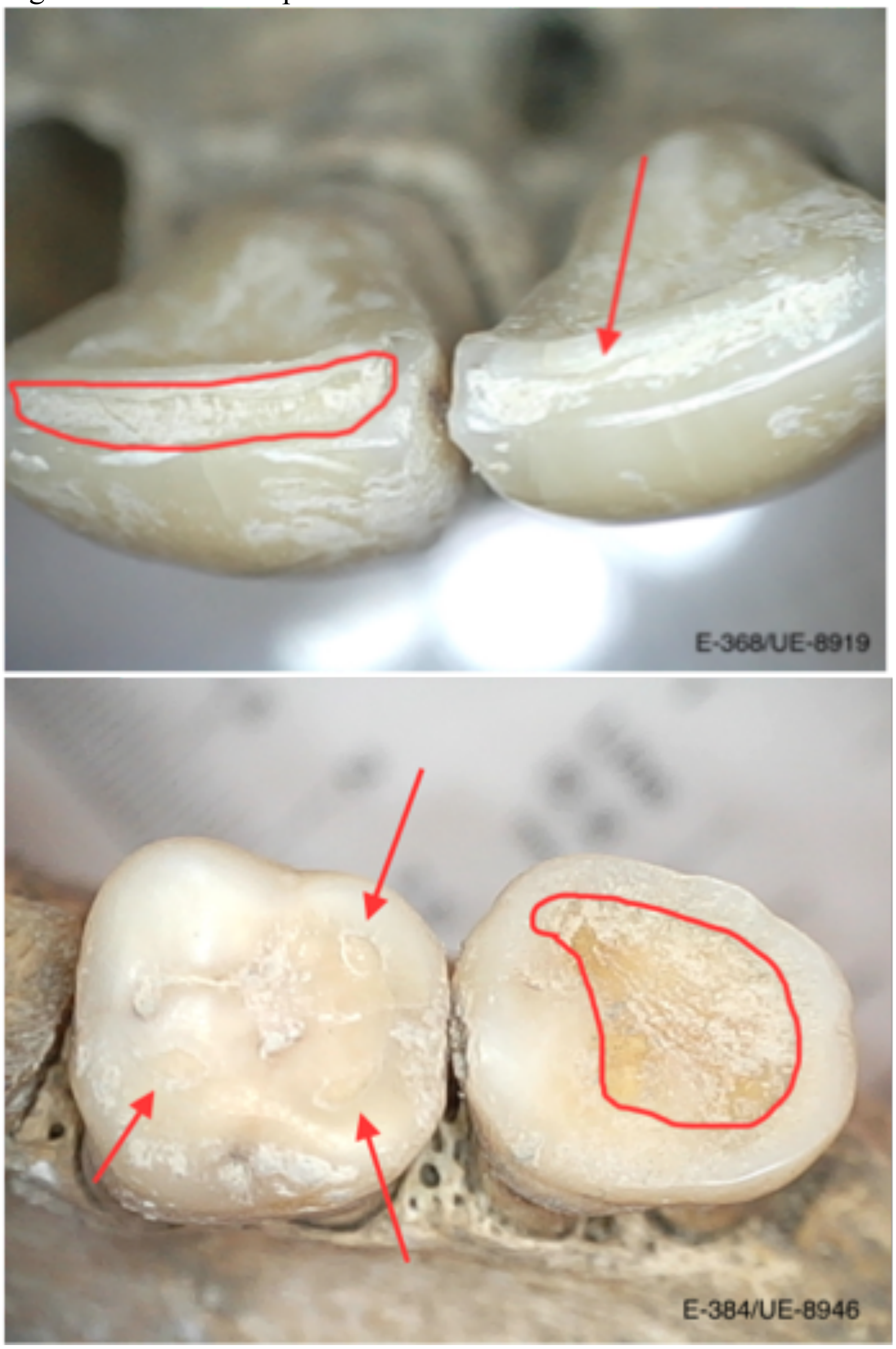

Figure 13. Two examples of occlusal wear observed on individuals from Pollentia. The above is an example of attrition on the incisors (LI^1 and RI^1) where the enamel has worn down slightly and the dentin is clearly visible (E-368/UE-8919). The below is an example of attrition on the molars, where the left molar (LM_2) exhibits smoothed facets with minimal exposed dentine and the right molar (LM_3) has a large portion of visible dentin (E-384/UE-8946). This micrograph was taken in July 2016.

1.4 *Goal of the Present Study*

The following examination the dental archaeology of Pollentians attempts to elucidate the role of the non-Muslims buried in the Forum, who were probably Christians, living in Pollentia during the Islamic period. The following study is my contribution to the ongoing investigations. The main goal of this study is to understand the role of the Forum Christians of the Islamic Period of Pollentia through dental archaeology.

As previously mentioned, this study focuses on three subsites within the greater city of Pollentia: the necropolis overlaying the Forum, the cemetery underneath the Oratorio de Sta. Ana, and Ca'n Fanals. My focus was to examine the occurrence of six different dental pathologies and modifications: enamel hypoplasia, dental calculus, dental caries, occlusal wear, periodontal disease, and agenesis in individuals from the three subsites. The quantifiable data of the occurrence of each pathology and modification were put in the context of a population of Christians from three different subsites and time periods.

The following is a populational study. The focus is not on the individuals examined in the course of data collection, but instead on one of three populations of Christians to which they belong. The specific pathologies and modifications are studied at an individual level, but to grasp their greater meaning, it should be expanded into a populational context (White and Folkens 2005; Cobb 2002).

from each location to be generalized and averaged in a way that allows for statistical testing (White and Folkens 2005;). Additionally, as there were not sufficient data to allow for a more in-depth study of the diet of these Pollentians, diet reconstruction was not possible.

As previously mentioned, the dental pathologies and modifications examined in this study are general indicators of health, diet, and genetics when studied at the level of a population (Irish and Scott 2016). Ultimately, the comparison the quantified occurrence of the six specified dental pathologies and modifications becomes a comparison of health and diet. Therefore, the end result is a comparison of the health, diet, genetics, and lifestyle of the Christians of the 1st/2nd centuries of Ca'n Fanals, the Christians of the Islamic period of the Forum, and the Christians of Sta Ana from the 12th/13th centuries, after the end of the Muslim occupation. By comparing the dental archaeology of the Christians of the Forum, the Christians of Sta. Ana, and the Christians of Ca'n Fanals, the health, diet, and lifestyle of the Christians in the Islamic Period can be better understood. The differences and similarities of the Christians of the Forum to the Christians of the other two locations revealed by this comparison will isolate the characteristics of the health, diet, and lifestyle of the Forum Christians and will help further the understanding of their presence in the Islamic Period.

2. METHODS AND MATERIALS

2.1 *Experimental Design*

The data gathering portion of my research was conducted in July of 2016 as part of the excavation of the Roman city, Pollentia, near the modern city of Alcúdia on the island of Mallorca. I traveled there with researchers from the University of Portland to participate in the University of Portland Pollentia Undergraduate Research Expedition, a program that partners with the University of Barcelona and the Bryant Foundation to conduct student-professor led archaeological research projects in a wide range of disciplines. I worked under the mentorship of Dr. Paqui Cardona, Dr. Miguel Angel Cau Ontiveros, and Fr. Richard Rutherford. I also worked in collaboration with two other student researchers, Margaret Murdock, Mount Holyoke College, and Taylor Hudson, Lewis and Clark College, who studied osteopathologies and sex and age, respectively. During my time in Pollentia, I participated in the archaeological dig at the cemetery of the city, Ca'n Fanals, and conducted an independent research project on the dental remains of the individuals recovered from graves sites within the city.

While conducting my preliminary research before arriving in Pollentia, I intended to study specific dental modifications that are characterized by abrasion patterns associated with cultural or medicinal practices within the population in Pollentia. My initial goal was to search the collection of dental remains for these patterns of wear to recreate certain cultural and medicinal practices. As I developed my research methodology, I came to the realization that these types of modifications are rare, difficult to identify, and hard to distinguish from food-related wear patterns. Additionally, these modifications are generally only present in populations from earlier time periods and are usually affected by sex and age. It became clear to me that if I decided to focus on these patterns of wear, I would have little data, if any at all.

Overall, I realized that I could not go into this project with an expectation of what I would find without knowing anything about the sample beforehand. Instead, I decided to look for the dental modifications and pathologies that were present in the population rather than look for specific and rare modifications. Thus, my goal when I arrived in Pollentia was to record all of the modifications and pathologies that I could identify and create a catalog of what I found. From this catalog, I would be able to characterize the population as a whole and make conclusions about their dietary and nutritional lives.

Once I arrived to Pollentia and work began, it was clear that my project needed further development. In the first week, I had begun my work examining all of the available teeth regardless of location or age of the specimen for any and all modification and pathology I could find. I was hopeful that I would be able to examine dental remains that had been excavated from the site I was working in, Ca'n Fanals, the very same day. However, sitting in the courtyard of the excavation house with a wooden stick and toothbrush in my hands, looking down at the first tooth that I had cleaned, I realized that the data from this tooth and others like it would not be amenable to meaningful statistical analysis that, in turn, would lead to reliable or interesting conclusions. If I had continued with this methodology, I would have been left with a mountain of data that would have been possible to analyze, but those results would not say anything important about diet, lifestyle, or population as they are not specific to individual or time period. I realized that I had to restrict my data collection to specific individuals and modify my data collection process.

Although there were many human teeth recovered from all of the subsites within the entire city over the years, I decided to restrict my data collection to the adult teeth and dental remains of complete or almost complete skeletons that had been radiocarbon dated. From these individuals with complete or almost complete skeletons, I was able to study the available adult teeth, defined as any fragment with a cusp, and the maxillary and mandibular bone, if present, for known pathologies and wear patterns.

This decision allowed me to collect data from which I would be able to draw interesting and meaningful conclusions as each set of dental remains was not only associated with a specific individual whose skeletal remains were largely intact, but also was associated with a time period and specific location. With this additional information, the data I collected could reveal similarities and differences between time periods, locations, and individuals. I would even be able to build a profile of a location at a certain time period based on the dental remains of individuals found in necropolises in that location. Rather than digging around in a bag of loose bones for teeth that could not be identified with an individual, location, and time period and creating a catalog of every pathology or modification that I could find, I was now able to create a project that could lead to relevant conclusions. This decision opened up a wide range of possibilities for my data collection and for my potential contribution to the project at Pollentia as a whole.

Once we expressed our interest in studying individuals rather than loose bones, Maggie, Taylor, and I were handed a list of 34 individuals with almost complete sets of skeletal remains that had been radiocarbon dated. Taylor had done extensive work to determine the sex and age of the individuals and Maggie had done work to examine osteopathologies on the long bones of those same individuals. Each of these individuals had been excavated in the summers of 2014 and 2015 from a necropolis or cemetery located in one of three sites within the city of Pollentia. The city of Pollentia is separated into several subsites that are separated based on the organization of the city itself. These subsites often represent the different periods of history of the city. The remains that I studied came from the subsites called Ca'n Fanals, Santa Anna, and The Forum. Ca'n

Fanals is a cemetery on the outskirts of the main part of the city and is thought to be a part of the later Christian occupation. Santa Anna is another cemetery on top of which now stands a church which is thought to be a part of the medieval Christian period of the city. Lastly, The Forum is located at the heart of the city and encompasses homes, temples, churches, and a marketplace with a necropolis overlaying these structures thought to be from a Muslim occupation (Cau Ontiveros et al. 2015). All of these sites are thought to be representative of different periods of religious occupation of the city. The skeletal remains and artifacts from each site are generally from the same time period. Therefore the remains excavated from these locations can be positively separated across specific location, population, religion, and time period.

From a cursory examination of the list of 34 individuals, only 22 had teeth that were recovered and connected to that individual. From that collection, I was only able to collect data on 14 set of remains. Of the eight individuals that I could not study, some of them only had deciduous teeth, some had a mixture of deciduous and permanent teeth, one simply had too many teeth, and one too many maxillae for one individual. I excluded the individual with too many adult teeth and maxillae because there was no way to tell which set of bones belonged to the rest of the skeleton. Then I excluded the individuals with deciduous teeth, but included the 2 individuals with deciduous and adult teeth, only studying their adult teeth. The deciduous teeth carry very few markers and those that they do, are difficult to identify.

Again, I restricted my sample in the data collection by exclusively including individuals with fully formed and erupted adult teeth in my study. I did this to create a consistent and meaningful basis by which I could compare the dental remains of individuals within and across a population. Several of the individuals were likely toddlers at time of death with a full set of deciduous teeth and a number of still-forming adult teeth. I did not include these still-forming adult teeth as they would not have interacted with the world yet and would not be able to represent the data I was interested in. Although hypoplasia could present itself on still-forming adult teeth, I excluded these teeth to maintain a consistent comparison across all the individuals studied. Some of these individuals were infants and their teeth were so underdeveloped that their teeth would not have erupted or would just have erupted at the time of death. Additionally, individuals with only permanent teeth have survived past puberty and can be considered adults whereas individuals with deciduous teeth are usually infants and young children (White and Folkens 2005).

Not restricting the sample to only one age range and type of teeth allows for variation in the data that is not caused by the conditions, but caused by variation in the sample material. By confining my sample material to one type of teeth, I isolated the source of variation in my analysis. If I had included infants and adults in the same study, the data would not have made as much sense as if I had just included infants, or just included adults. As I had access to more adult remains, and more modifications and pathologies show up on adult teeth than deciduous teeth, I decided only to include adult teeth (White and Folkens 2005). By only exclusively including adults in my study, I created a consistent basis for comparison between individuals and locations.

The rest of the individuals that I included in my study had either a complete or incomplete set of adult teeth. Most had at least partial maxillary and/or mandibular bone attached or associated with the teeth, but several others only had a bag of loose teeth. A few still had teeth that were floating around in the bin with the individual, but in bags with leg or arm bones. I had to search for all the teeth available per individual.

Of these 14 individuals that I was able to include in my study, eight were found in the Church of Sta. Ana, five were found in the necropolis overlaying the Forum, and one was found in the cemetery of Ca'n Fanals. Of these individuals excavated from Sta. Ana, one was dated to the 16th century and is an outlier as she was from a vastly different time period than the others of Sta. Ana. The individual is from the 16th century (E-331/UE-8367) must be excluded from further analysis.

With my sample finally narrowed down, I was able to start my data collection, and at this point my project design underwent its final transformation.

After a full day of data collection, I realized that the data was not very concise nor did it seem easily understandable or significant. I had spent the day identifying the modifications and pathologies that I observed and taking pictures of examples of these occurrences with the goal of reporting all the different modifications and pathologies I could find. It was then that I made the decision to shift my focus from identifying the modifications or pathologies to quantifying the occurrence of the modifications and pathologies that were in my sample per individual. My previous data consisted of pictures of descriptions. The data that I ended up collecting and that I discuss in this paper is the number of times each modification or pathology, from a list determined by which modifications and pathologies I encountered, occurred in each individual.

2.2 *Data Collection*

At this point of my investigation, I finally had a specified sample and a concise standard for data collection. This procedure allowed me to analyze each set of teeth with consistency and in a way that provided me with quantitative data.

The tools that I had at my disposal were a Global USB digital microscope (item code: UM012C) with a compatible laptop, MicroCapture Pro Software Package, two magnifying glasses (3x, 15x, and 45x), and a trusty lab notebook. With the magnifying glasses, I examined the sample and with the digital microscope, I took pictures of the examples of modifications and pathologies that I found.

Across my entire sample, I identified seven modifications and pathologies: enamel hypoplasia, caries, dental calculus, occlusal wear, periodontitis, agenesis, and deformed teeth. The presence, absence, and occurrence of every one of these modifications and pathologies can reveal important information about the dietary and nutritional profile of a population. Therefore, after having observed that these were the most popular dental modifications and pathologies in my sample, these seven became the scale by which I measured each individual. Each set of dental remains was examined for each of these seven traits. These traits became the basis of comparison between individuals and populations within location.

My data collection was conducted as follows. First, I would take out a bone box containing all of the recovered skeletal remains from one individual from the bone room located in the excavation house. Remains were labeled by stratum number and by tomb number as several individuals may have been buried in the same tomb. Then, I would search all of the bags in the box for all of the mandibular and maxillary bone and all the of available teeth. From that selection, I identified the teeth and separated them into the categories of mandibular and maxillary. I would then record the numerical label for the individual, the number of available teeth and bone and specify which teeth were recovered. After having taken down general observations on the available teeth and bone, I examined the teeth and bone with two types of magnifying glasses. I then recorded the number modifications and pathologies, within the categories previously defined, present in each one individual. To finish my data collection on the individual, I took pictures of the available teeth and exceptional cases of modifications and pathologies with the digital microscope. Afterwards, I packed up the bones and placed them back in the bone room.

2.3 *Data Analysis*

After my data collection was complete, I was left with pictures and micrographs of my sample and a spreadsheet of quantitative data detailing the location, age, and sex of each individual, and the number of modifications and pathologies observed per individual. In order to complete the goal of comparing the data between the subsites within Pollentia to reveal similarities and differences, I employed several statistical methods of analysis.

It is important to recognize that there is bias in my sample that cannot be eliminated. The origin of this bias is the fact that I had only access to a portion of the remains that were located in the subsites. From those skeletal remains to which I had access, only a portion had teeth that I was able to examine. Instead of selecting the sample with a chance device, my sample was determined by the survival of the dental remains and the availability of the remains. Therefore, my sample is not random, but is large enough to be considered representative.

Additionally, as each subsite has a different number of representatives, my design is also not balanced. The results of this project cannot be considered conclusive or definitive, but must be examined with the full understanding that this sample may not reliably represent the population.

With this in mind, my goal was to organize and analyze my data in meaningful ways. To organize my data, I first considered how to represent my data as numerical or categorical values. Almost every individual in the sample had an occurrence of hypoplasia, calculus, and occlusal wear. The number of affected teeth per individual and within subsite was very high for each of these three traits. Therefore, I chose to represent the data for hypoplasia, calculus, and occlusal wear as a ratio in terms of the percent of affected teeth per individual. This ratio was calculated by taking the number of affected teeth and dividing it by the number of available teeth per individual. This ratio was calculated in terms of per individual as not every individual had a full set of teeth. The percent affected per individual then provides an estimate of how many total teeth would have been affected if the individual had complete dentition. This method of calculation allowed for a consistent basis for comparison between individuals regardless of how many teeth were available for each individual. Unlike the occurrence for these three traits, the occurrence for the traits of caries, periodontal disease, agenesis, and deformed teeth, was not as high. The occurrence of these three traits amongst subsites was so low that I decided to organize them on the ordinal scale of presence/absence. As they rely on the presence of mandibular and maxillary bone, the presence/absence of periodontal disease and agenesis could not be determined for some individuals and are labeled as N/A. These individuals must be excluded from any analysis of these traits.

With the data organized as such, it is then easy to pick out and use the appropriate statistical test. Two threads of statistical analysis was done on the data. The first was to compare the occurrence of dental wear patterns and disease between the subsites and the second was to test the significance of the occurrence of a trait within a subsite. The program IMB SPSS Statistics was used in both cases to carry out the analysis.

In addition to comparing the occurrence of dental modifications and pathologies, a comparison across sex and age of individuals would also be interesting. Unfortunately, information on the sex and age of the individuals was not complete or definite. Some individuals have an age range while others are characterized by a ordinal term and others were unidentifiable. The case for the same for data on sex. The data was so limited and varied so much, that statistical analysis is not appropriate.

In all statistical analyses, I was also forced to exclude E-331, the modern individual, the trait of deformed teeth, and the subsite of Ca'n Fanals. I excluded E-331 as it was not consistent with the rest of the sample from Sta. Ana. I excluded the trait of deformed teeth as only two individuals out of the 14 presented this trait reliably. Unfortunately, Ca'n Fanals was also excluded from this study it is represented by a single individual. One set of values for a single subsite is not sufficient for a comparison.

In order to evaluate the significance of the occurrence of each modification and pathology within a subsite, I calculated the number of individuals affected out of the total number of observed individuals within a subsite and turned that into a percent. Therefore, I ended up with the percent chance that an individual within a subsite would experience a pathology of modification. This was done so that I would be able to build a profile of each site. The results of these tests allow the subsite to be characterized by a set of traits.

While comparing the occurrence of traits across subsites, I used both a presence/absence test and a one-way basic factorial design to conduct the analysis of variance across subsites. When considering dental caries, periodontal disease, and agenesis, I used Fisher’s Exact Test to compare the variation between groups. For tests on periodontal disease and agenesis, I had to exclude the individuals E-344 and E-328 as there was no data for those individuals. I used this style of test as the data was organized ordinally with yes/no. When considering hypoplasia, calculus, and occlusal wear, I employed a One-Way ANOVA to test if the variation between groups is larger than the variation within groups. The spread on the hypoplasia ANOVA was too great and the ratio of the standard deviations was almost equal to two, so it was necessary to transform the data. Because several data points were zero, I had to add +1 to each value and transform the data onto a log scale in order to conduct ANOVA.

3. RESULTS

As previously mentioned, the data that I collected in July of 2016 were in the form of micrographs of interesting modifications and pathologies and spreadsheet with the number of occurrences of different pathologies and dental modifications. The preliminary quantitative data are presented below with biographical information for the individuals who were examined. Also below are the results of the statistical tests that compare the occurrence of pathologies and modifications across the subsites of Sta. Ana and the Forum. Lastly, presented below are the data related to each subsite that will be expanded to create a dental health profile of each population.

The three subsites are fairly close together and are within a five-minute walk from each other. The surrounding environment was hot and humid with sparsely distributed vegetation. The vegetation consisted mostly of large olive trees and low grasses. The area received very little precipitation while I was present.

Both Ca'n Fanals and the Forum are active archaeological sites. While the Forum is largely excavated and is quite large, excavation at Ca'n Fanals began in 2013 and the site is still quite small. The Forum is a city center with the exposed remains of buildings, houses, tombs, and a marketplace. Ca'n Fanals is largely composed of tombs, but includes a quarry and a wall.

Sta. Ana was excavated in 2014 and is no longer an active site. It is covered by a medieval church and the cemetery lies underneath the church. The construction of the church caused damage to several of the recovered individuals, as their tombs and skeletons were cut in half by the church walls. Sta. Ana is the farthest away from the other two subsites.

3.1 *Preliminary Data*

The initial raw data collected in July 2016 in Pollentia are presented in Tables 1-9. There are 14 described individuals from the three subsites of Oratorio de Sta. Ana, the Forum macellum, and Ca'n Fanals. Eight individuals were excavated from Sta. Ana, five from the Forum, and one from Ca'n Fanals.

Before the preliminary data are discussed, it is important to note that individual E-331/UE- 8367 and the occurrence of deformed teeth, though included in the presentation of the raw data, were not included in the analysis of the data. Similarly, the data collected from Ca'n Fanals were not included in the statistical analysis, nor were the data included in the overall analysis of Pollentia as a whole.

Table 1. Location, Age, Sex, and Time Period of Observed Individuals.

INDIVIDUAL	LOCATION	LOCATION CODE	AGE RANGE	SEX	TIME PERIOD (AD)
E-368/UE-8919	Oratorio de Sta. Ana	1	39-50	Male	1142 ± 59
E-384/UE-8946	Oratorio de Sta. Ana	1	Adult	Male	-
E-372/UE-8902	Oratorio de Sta. Ana	1	18-22	Female	1197 ± 31
E-344/UE-8671	Oratorio de Sta. Ana	1	Adult/Mature	Male (?)	1060 ± 51
E-342/UE-8651	Oratorio de Sta. Ana	1	Juvenile	Male	1140 ± 60
E-380/UE-8936	Oratorio de Sta. Ana	1	25-34	Female	1220 ± 26
E-349/UE-8716	Oratorio de Sta. Ana	1	Mature	Female	1181 ± 28
E-331/UE-8367	Oratorio de Sta. Ana	1	~16	Male (?)	1540 ± 64
E-316/UE-8506	Forum macellum	2	6-15	Male	9th/12th century
E-209/UE-8568 (B-17)	Forum macellum	2	Mature	Male	9th/12th century
E-339/UE-8595	Forum macellum	2	<18	Male	9th/12th century
E-328/UE-8545	Forum macellum	2	10-16	Female	9th/12th century
E-322/UE-8525	Forum macellum	2	-	N/A	9th/12th century
E-392/UE-9120	Ca'n Fanals	3	30-38	Male	1st/2nd century

Table 1. Observed individuals listed with the location, location code, the sex, age at death, and age of the specimen (AD). A dash indicates information was not sufficient to make a conclusion. A question mark indicates that the conclusion was not certain. The location code will identify the location for preceding tables. (1 = Oratorio de Sta. Ana, 2 = Forum macellum, 3 = Ca'n Fanals)

Nine of the individuals were identified as male, four were identified as female, and one was could not be sexed by experts on site due to the lack of skeletal remains. Six individuals were under 20 years old, four were adults under

40, three were mature adults over 40, and one could not be aged by the experts on site due to the lack of skeletal remains. The youngest was estimated to have been under 15 years old, and the oldest was estimated to be around 50 years old.

Seven individuals, all from the Oratorio de Sta. Ana, had a reported radiocarbon date. Of those seven, four were dated to the 12th century, one was dated to the 11th century, one was dated to the 13th century and the last was dated to the 16th century. The individual recovered from Ca'n Fanals is estimated to date to the 1st or 2nd century. The individuals recovered from the Forum are estimated to date from the 9th and 12th century and were recovered from a section of the necropolis overlaying Building A, located in the marketplace.

Table 2. Location, Number of Available Teeth, and Dentition of Observed Individuals.

INDIVIDUAL	LOCATION	LOCATION CODE	# OF AVAILABLE TEETH	COMPLETE DENTITION
E-368/UE-8919	Oratorio de Sta. Ana	1	32	Y
E-384/UE-8946	Oratorio de Sta. Ana	1	18	N
E-372/UE-8902	Oratorio de Sta. Ana	1	31	N
E-344/UE-8671	Oratorio de Sta. Ana	1	6	N
E-342/UE-8651	Oratorio de Sta. Ana	1	32	Y
E-380/UE-8936	Oratorio de Sta. Ana	1	32	Y
E-349/UE-8716	Oratorio de Sta. Ana	1	24	N
E-331/UE-8367	Oratorio de Sta. Ana	1	21	N
E-316/UE-8506	Forum macellum	2	15	N
E-209/UE-8568 (B-17)	Forum macellum	2	23	N
E-339/UE-8595	Forum macellum	2	30	Y
E-328/UE-8545	Forum macellum	2	30	N
E-322/UE-8525	Forum macellum	2	18	N
E-392/UE-9120	Ca'n Fanals	3	20	N

Table 2. Observed individuals listed with the location, location code, the number of teeth identified with that individual, and whether or not the available teeth constituted a complete dentition for the age of that individual.

Not all the individuals had been recovered with a complete set of dentition. Four individuals were excavated with a complete set of dentition, and ten had incomplete dentition. One of the four was excavated with a complete set of dentition, but their 3rd molars had not yet come in, so only 30 teeth were accessible as the other 2 were still embedded in the alveolar bone. Three individuals had a complete set of dentition, one was too young for their third molars to come in but otherwise had complete dentition, 8 individuals did not have complete dentition, and two were only missing one tooth.

Table 3. Number of Teeth Affected by and Percent Occurrence of Hypoplasia in Observed Individuals by Location.

INDIVIDUAL	LOCATION CODE	Number of Teeth Affected by Hypoplasia	% Occurrence of Hypoplasia per Individual
E-368/UE-8919	1	11	34.38
E-384/UE-8946	1	7	38.89
E-372/UE-8902	1	16	51.61
E-344/UE-8671	1	0	0
E-342/UE-8651	1	0	0
E-380/UE-8936	1	8	25.00
E-349/UE-8716	1	5	20.83
E-331/UE-8367	1	11	52.38
E-316/UE-8506	2	11	73.33
E-209/UE-8568 (B-17)	2	0	0
E-339/UE-8595	2	30	100
E-328/UE-8545	2	7	23.33
E-322/UE-8525	2	8	44.44
E-392/UE-9120	3	10	50.00

Table 3. The number of teeth affected by hypoplasia out of the available teeth per individual organized by location code. Also presented is the percentage of affected teeth out of the total number of teeth available per individual.

Among the 14 individuals examined, hypoplasia was present in 11 individuals. Among the eight from Sta. Ana, hypoplasia was present in six individuals. Among the five from the Forum, hypoplasia was present in four individuals. And of the single individual from Ca'n Fanals, hypoplasia was present. Overall, hypoplasia was largely present in the larger sample from Pollentia and in the smaller samples from each of the subsites. The percent value included in Table 3 represents the percent chance that an individual's tooth will experience hypoplasia. This value was used in the analysis of variance.

Hypoplasia was present reliably in almost all of the observed individuals. The intensity of the horizontal grooving indicative of hypoplasia tended to be consistent within an individual. When the grooves were deep and very noticeable they were so for every affected tooth. When present, there were multiple grooves on each affected tooth.

Table 4. Number of Teeth Affected by and Percent Occurrence of Calculus in Observed Individuals by Location.

INDIVIDUAL	LOCATION CODE	Number of Teeth Affected by Calculus	% Occurrence of Calculus per Individual
E-368/UE-8919	1	20	62.50
E-384/UE-8946	1	7	38.89
E-372/UE-8902	1	8	25.81
E-344/UE-8671	1	1	16.67
E-342/UE-8651	1	17	53.13
E-380/UE-8936	1	5	15.63
E-349/UE-8716	1	8	33.33
E-331/UE-8367	1	0	0
E-316/UE-8506	2	1	6.67
E-209/UE-8568 (B-17)	2	11	47.83
E-339/UE-8595	2	7	23.33
E-328/UE-8545	2	4	13.33
E-322/UE-8525	2	10	55.56
E-392/UE-9120	3	1	5.00

Table 4. The number of teeth affected by calculus out of the available teeth per individual organized by location code. Also presented is the percentage of affected teeth out of the total number of teeth available per individual.

Of the 14 individuals examined, calculus was present in 13 individuals. Of the eight from Sta. Ana, calculus was present in seven individuals. Of the five from the Forum, calculus was present in all individuals. And of the single individual from Ca'n Fanals, calculus was present. Overall, calculus was largely present in the larger sample from Pollentia and in the smaller samples from each of the subsites. The percent value included in Table 3 represents the percent chance that an individual's tooth will experience calculus. This value was used in the analysis of variance.

In my observations, there is a wide range for the physical manifestation of calculus, when present. The calculus was obvious and large on the remains of some individuals, and on others, the calculus was hardly identifiable. Most often, the calculus would be found on the lingual surface of the incisors and canines. The second most frequent location of calculus was the lingual surface of the third molars, which would have occurred later in life.

Table 5. Number of Teeth Affected by and Percent Occurrence of Occlusal Wear in Observed Individuals by Location.

INDIVIDUAL	LOCATION CODE	Number of Teeth Affected by Occlusal Wear	% Occurrence of Occlusal Wear per Individual
E-368/UE-8919	1	32	100
E-384/UE-8946	1	18	100
E-372/UE-8902	1	22	70.97
E-344/UE-8671	1	2	33.33
E-342/UE-8651	1	16	50.00
E-380/UE-8936	1	18	56.25
E-349/UE-8716	1	24	100
E-331/UE-8367	1	8	38.10
E-316/UE-8506	2	3	20.00
E-209/UE-8568 (B-17)	2	23	100
E-339/UE-8595	2	15	50.00
E-328/UE-8545	2	3	10.00
E-322/UE-8525	2	18	100
E-392/UE-9120	3	17	85.00

Table 5. The number of teeth affected by occlusal wear out of the available teeth per individual organized by location code. Also presented is the percentage of affected teeth out of the total number of teeth available per individual.

Evidence of occlusal wear was present in all of the individuals from all three subsites and locations. However, the degree of occlusal wear did vary from individual to individual. The percent value included in Table 3 represents the percent chance that any of the individual's teeth will experience occlusal wear. This value was used in the analysis of variance.

The occlusal wear observed in the examined sample was very interesting and varied. In all cases, the individual would have smooth occlusal surfaces with at least minimal exposed dentine. For some individuals, the exposed dentine would only occur in the occlusal surfaces of their incisors, but for others still, every tooth would have flat smooth surfaces with exposed dentine. In this way, there were degrees of occlusal wear that were not quantified. For some the occlusal surfaces of their teeth were completely flat, but for others, their occlusal surfaces were slanted inward towards the tongue. Frequently, I observed an interesting shovelling pattern on the lingual surface of the upper incisors.

Table 6. Number of Teeth Affected by and Presence/Absence of Caries in Observed Individuals by Location.

INDIVIDUAL	LOCATION CODE	Presence/Absence of Caries	Number of Teeth Affected by Caries
E-368/UE-8919	1	N	0
E-384/UE-8946	1	Y	8
E-372/UE-8902	1	N	0
E-344/UE-8671	1	N	0
E-342/UE-8651	1	Y	8
E-380/UE-8936	1	N	0
E-349/UE-8716	1	Y	3
E-331/UE-8367	1	Y	2
E-316/UE-8506	2	N	0
E-209/UE-8568 (B-17)	2	N	0
E-339/UE-8595	2	N	0
E-328/UE-8545	2	Y	4
E-322/UE-8525	2	Y	10
E-392/UE-9120	3	N	0

Table 6. The presence or absence of the caries in the available teeth per individual. The number of affected teeth is also presented. The difference in the occurrence of caries between sites will be measured by a Fisher's Exact Test.

Of the 14 individuals examined, caries were present in 6 individuals. Among the eight from Sta. Ana, caries were present in four individuals. Among the five from the Forum, caries were present in two individuals. And of the single individual from Ca'n Fanals, caries were not present. Overall, caries were not largely present in the larger sample from Pollentia and in the smaller samples from each of the subsites. In the following statistical analysis, the presence or absence of caries were used rather than the number of teeth affected.

Though not overwhelmingly present in the Pollentia population as a whole, there were some very interesting cases of caries in the sample. Caries were never observed as a single occurrence. Most often, the caries I observed manifested themselves as dark pits or grooves on any surface of the teeth, especially between two teeth. In a few cases, the caries were so severe that almost the entire tooth was rotted away. In the case of E-384/UE-8946, one tooth was left as a root, the entire rest of the tooth had rotted away.

Table 7. Number of Teeth Affected by and Presence/Absence of Periodontal Disease in Observed Individuals by Location.

INDIVIDUAL	LOCATION CODE	Presence/Absence of Periodontal Disease	Number of Teeth Affected by Periodontal Disease
E-368/UE-8919	1	Y	13
E-384/UE-8946	1	Y	15
E-372/UE-8902	1	N	0
E-344/UE-8671	1	N/A	N/A
E-342/UE-8651	1	N	0
E-380/UE-8936	1	N	0
E-349/UE-8716	1	Y	1
E-331/UE-8367	1	N	0
E-316/UE-8506	2	N	0
E-209/UE-8568 (B-17)	2	Y	1
E-339/UE-8595	2	N	0
E-328/UE-8545	2	N/A	N/A
E-322/UE-8525	2	Y	13
E-392/UE-9120	3	N	0

Table 7. The presence or absence of the periodontal disease in the available teeth per individual; the number of affected teeth is also presented. N/A denotes a situation in which the individual's alveolar bone was not preserved, so it was not possible to determine the presence of absence of periodontal disease. The difference in the occurrence of periodontal disease between sites will be measured by a Fisher's Exact Test.

Among the 12 individuals examined for periodontal disease, evidence of the disease was found in five individuals. Among the seven from Sta. Ana, periodontal disease was present in three individuals. Among the four from the Forum, periodontal disease was present in two individuals. And of the single individual from Ca'n Fanals, periodontal disease was not present. Overall, periodontal disease was not largely present in the larger sample from Pollentia or in the smaller samples from each of the subsites. In the following statistical analysis, the presence or absence of periodontal disease were used rather than the number of teeth affected.

Periodontal disease was identified when the alveolar bone surrounding the teeth was lower than usual or the bone was noticeably porous. The teeth in the area affected by periodontal disease were counted and used as the measurement. In all cases, there were multiple teeth affected by one occurrence of periodontal disease. As with the other pathologies and modifications, there were degrees of severity of the observed periodontal disease. In some cases, it was hardly noticeable and in other cases the disease was obvious and severe, accompanied by an abscess. Additionally, where there were multiple occurrences of periodontal disease in one individual, they were of similar severity.

Table 8. Number of Teeth Affected by and Presence/Absence of Deformed Teeth in Observed Individuals by Location.

INDIVIDUAL	LOCATION CODE	Presence/Absence of Deformed Teeth	Number of Teeth Affected by Deformed Teeth
E-368/UE-8919	1	N	0
E-384/UE-8946	1	Y	1
E-372/UE-8902	1	N	0
E-344/UE-8671	1	N	0
E-342/UE-8651	1	N	0
E-380/UE-8936	1	N	0
E-349/UE-8716	1	N	0
E-331/UE-8367	1	N	0
E-316/UE-8506	2	N	0
E-209/UE-8568 (B-17)	2	Y	1
E-339/UE-8595	2	N	0
E-328/UE-8545	2	N	0
E-322/UE-8525	2	N	0
E-392/UE-9120	3	N	0

Table 8. The presence or absence of the deformed teeth in the available teeth per individual. The number of affected teeth is also presented.

Among the 14 individuals examined, two of those individuals had deformed teeth. Among the eight from Sta. Ana, one individual had deformed teeth. Among the five from the Forum, one individual had deformed teeth. And the single individual from Ca'n Fanals did not have deformed teeth. Overall, deformed teeth were not common in the larger sample from Pollentia and in the smaller samples from each of the subsites. The difference in occurrence of deformed teeth between locations will not be analyzed as there are so few (2) positive samples. Deformed teeth were rarely observed in the sample and could have been conflated with the after effects of caries.

Table 9. Number of Teeth Affected by and Presence/Absence of Agenesis in Observed Individuals by Location.

INDIVIDUAL	LOCATION CODE	Presence/Absence of Agenesis	Number of Teeth Affected by Agenesis
E-368/UE-8919	1	N	0
E-384/UE-8946	1	Y	8
E-372/UE-8902	1	N	0
E-344/UE-8671	1	N/A	N/A
E-342/UE-8651	1	N	0
E-380/UE-8936	1	N	0
E-349/UE-8716	1	Y	7
E-331/UE-8367	1	N	0
E-316/UE-8506	2	N	0
E-209/UE-8568 (B-17)	2	Y	3
E-339/UE-8595	2	Y	2
E-328/UE-8545	2	N/A	N/A
E-322/UE-8525	2	Y	0
E-392/UE-9120	3	N	0

Table 9. The presence or absence of the periodontal disease in the available teeth per individual; the number of affected teeth is also presented. N/A denotes a situation in which the individual's alveolar bone was not preserved, so it was not possible to determine the presence of absence of periodontal disease. The difference in the occurrence of periodontal disease between sites will be measured by a Fisher's Exact Test.

Among the 12 individuals examined for agenesis, evidence of agenesis was found in five individuals. Among the seven from Sta. Ana, agenesis was present in two individuals. Among the four from the Forum, agenesis was present in three individuals. And agenesis was not present in the single individual from

Ca'n Fanals. Overall, agenesis was rarely encountered in the larger sample from Pollentia or in the smaller samples from each of the subsites. In the following statistical analysis, the presence or absence of agenesis were used rather than the number of teeth affected.

Agenesis was observed as an obvious failure of a tooth to erupt where all of the surrounding and corresponding teeth had erupted. Agenesis of a tooth was often accompanied by many other pathologies and modifications indicating a possible genetic factor.

Table 10. Percent Occurrence of Each Modification and Pathology per Subsite.

	Sta. Ana	**Forum**	**Ca'n Fanals**
Hypoplasia	71%	80%	100%
Calculus	100%	100%	100%
Occlusal Wear	100%	100%	100%
Caries	42%	40%	0%
Periodontitis	42%	40%	0%
Agenesis	28%	60%	0%

Table 10. Percent occurrence of each pathology and modification per subsite. The likelihood an individual within a location will have each pathology and modification.

Table 10 presents occurrence of dental alterations by subsite. This value was calculated by taking the number of individuals within each subsite affected divided by the total number of individuals within that subsite. This value does not take into account the number of teeth affected out of all the available teeth per individual, only the presence or absence of the modification or pathology per individual. This calculation reflects the exclusion of the 16th century individual and deformed teeth. Within Sta. Ana, individuals experienced hypoplasia, calculus, and occlusal wear over 50% of the time, caries and periodontitis over 30% of the time, and agenesis and deformed teeth under 30% of the time. Within the Forum, individuals experienced hypoplasia, calculus, occlusal wear, and agenesis over 50% of the time, caries and periodontitis 40% of the time, and deformed teeth under 15% of the time. Within Ca'n Fanals, individuals would have experienced hypoplasia, calculus, and occlusal wear, but not agenesis, deformed teeth, caries, or periodontitis.

3.2 *Statistical Comparison of Subsites with ANOVA*

The analysis of calculus, hypoplasia, and occlusal wear as variables was conducted as a comparison between the subsites of Sta. Ana and the Forum to determine if there was a significant difference in the occurrence of these variables between the two subsites. Because the variables were quantifiable and only concerned a single factor of interest, the analysis completed was a One-Way ANOVA, which assesses the variability between the two groups as compared to the difference within the two groups.

3.2.1 Calculus

The parallel dot plot (Fig. 14) displays the relationship of the occurrence of calculus between individuals excavated in Sta. Ana (1) and the Forum (2). The two groups are fairly similar. The Sta. Ana group contains individuals with values that are only slightly lower than the Forum and the Forum contains individuals with values only slightly higher than the Sta. Ana group. The spreads are fairly even and there are no outliers in this sample. Therefore there was no need to transform the data according to the GOST method. However, the similarity between the groups in this preview suggests that the variance between the groups may not be significantly different.

Figure 14. Parallel Dot Plot of the Occurrence of Calculus in Sta. Ana and the Forum.

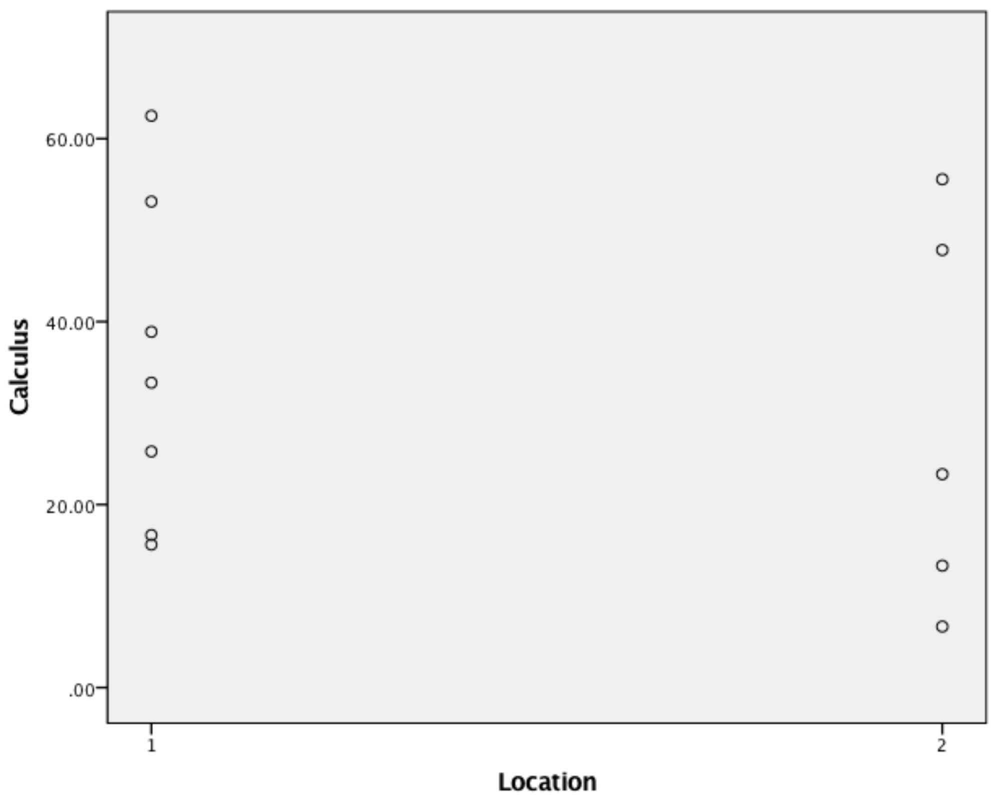

Figure 14. Graph of the percent occurrence of calculus between the two locations of Sta. Ana and the Forum amongst the sample size of 12 individuals (7 from Sta. Ana and 5 from the Forum). The numerical values of 1 and 2 are assigned to Sta. Ana and the Forum, respectively.

The ANOVA confirms the suggestion of the parallel dot plot. In terms of the effect of the location, as the $F_{1,10} < F_{crit}$ ($F_{1.10}$= 0.262, F_{crit}= 4.9646, Table 11), the variance between the locations is not larger than the variance within the locations. The variance between the locations is not significant (p>0.05). Therefore, the occurrence of calculus in the Forum is not significantly different from the occurrence of calculus in Sta. Ana. Individuals in Sta. Ana and the Forum have the same likelihood to experience calculus. Therefore, I fail to reject the null hypothesis.

Table 11. ANOVA Table for the Occurrence of Calculus.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	97.885	1	97.885	.262	.620
Within Groups	3734.116	10	373.412		
Total	3832.000	11			

Table 11. The results of a One-Way ANOVA run on the percent occurrence of calculus between two locations. The critical F-value for these degrees of freedom is 4.9646. The actual F-value is 0.262 and as 0.262 < 4.9646, the variability between locations is not larger than the variability within the locations (p>0.05).

3.2.2 Occlusal Wear

As it did for the occurrence of calculus, the parallel dot plot above (Fig. 15) displays the relationship of the occurrence of occlusal wear between individuals excavated in Sta. Ana (1) and the Forum (2). Between the two groups there is a great amount of overlap. The Sta. Ana group contains individuals with lower values than the Forum group. Both groups have the same upper limit. The spreads are fairly even, with some inconsistencies, and there are no outliers in this sample, therefore there was no need to transform the data. However, that the groups are so similar in this preview suggests that the variance between the groups may not be significantly different.

Figure 15. Parallel Dot Plot of the Occurrence of Occlusal Wear in Sta. Ana and the Forum.

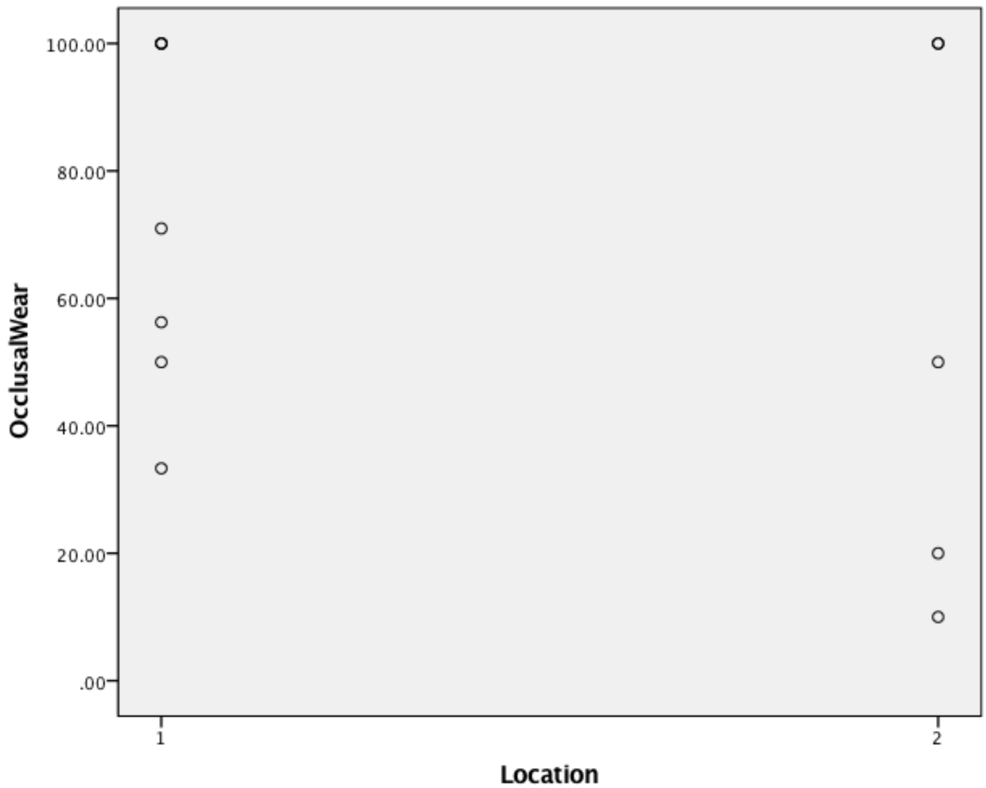

Figure 15. Graph of the percent occurrence of occlusal wear between the two locations of Sta. Ana and the Forum amongst the sample size of 12 individuals (7 from Sta. Ana and 5 from the Forum). The numerical values of 1 and 2 are assigned to Sta. Ana and the Forum, respectively.

The ANOVA confirms the suggestion of the parallel dot plot. In terms of the effect of the location, as the $F_{1,10} < F_{crit}$ ($F_{1.10} = 0.703$, $F_{crit} = 4.9646$, Table 12), the variance between the locations is not larger than the variance within the locations.

The variance between the locations is not significant (p>0.05). Therefore, the occurrence of occlusal wear in the Forum is not significantly different from the occurrence of calculus in Sta. Ana. Individuals in Sta. Ana and the Forum have the same likelihood to experience occlusal wear. Therefore, I fail to reject the null hypothesis.

Table 12. ANOVA Table for the Occurrence of Occlusal Wear

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	836.554	1	836.554	.703	.421
Within Groups	11894.363	10	1189.436		
Total	12730.917	11			

Table 12. The results of a One-Way ANOVA run on the percent occurrence of occlusal wear between two locations. The critical F-value for these degrees of freedom is 4.9646. The actual F-vlaue is 0.703 and as 0.703 < 4.9646, the variability between locations is not larger than the variability within the locations (p>0.05).

3.2.3 Hypoplasia

As it did for the occurrence of calculus and occlusal wear, the parallel dot plot above (Fig. 16) displays the relationship of the occurrence of hypoplasia between individuals excavated in Sta. Ana (1) and the Forum (2). With the original non-transformed data, there was a large standard deviation between the two sites resulting in a large difference in spreads necessitating a transformation onto a log scale. On the log scale, the two groups are roughly the same. The spreads are fairly even and there are two individuals that are potential outliers, but it is hard to tell with such a small sample size. Therefore there was no further need to transform the data. However, that the groups are so similar in this preview suggests that the variance between the groups may not be significantly different.

Figure 16. Parallel Dot Plot of the Occurrence of log(Hypoplasia) in Sta. Ana and the Forum.

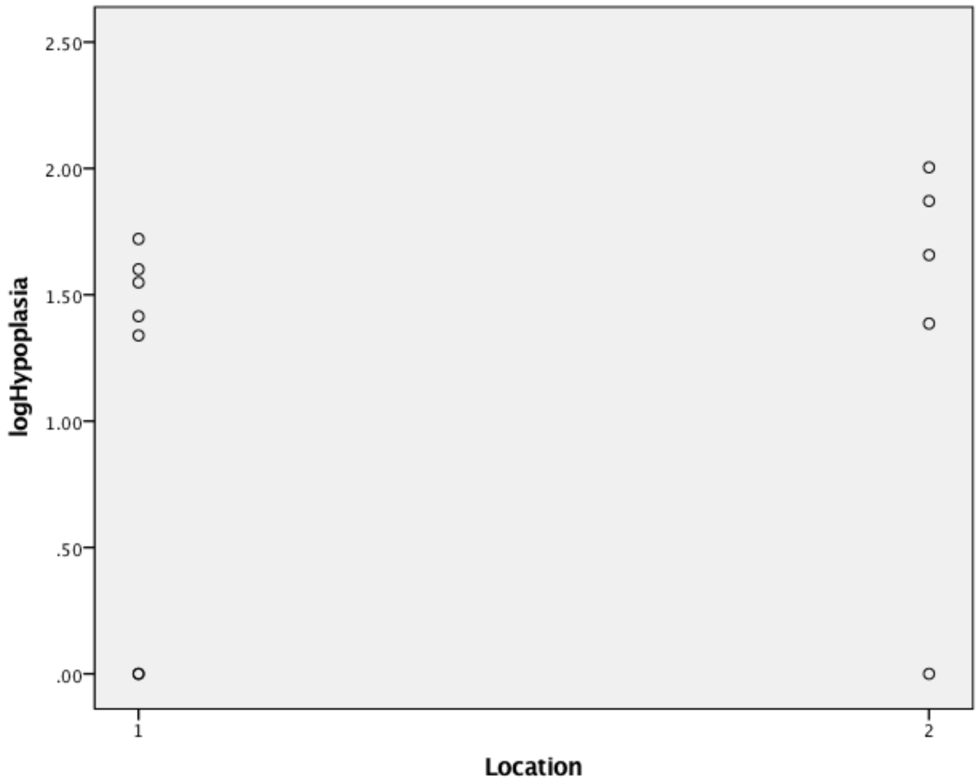

Figure 16. Graph of the percent occurrence of hypoplasia between the two locations of Sta. Ana and the Forum amongst the sample size of 12 individuals (7 from Sta. Ana and 5 from the Forum). The numerical values of 1 and 2 are assigned to Sta. Ana and the Forum, respectively.

The ANOVA confirms the suggestion of the parallel dot plot. In terms of the effect of the location, as the $F_{1,10} < F_{crit}$ ($F_{1.10} = 0.420$, $F_{crit} = 4.9646$, Table 13), the variance between the locations is not larger than the variance within the locations. The variance between the locations is not significant ($p>0.05$). Therefore, the occurrence of hypoplasia in the Forum is not different from the occurrence of calculus in Sta. Ana. Individuals in Sta. Ana and the Forum have the same likelihood to experience hypoplasia. Therefore, I must fail to reject the null hypothesis.

Table 13. ANOVA Table for the Occurrence of Hypoplasia

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.253	1	.253	.420	.532
Within Groups	6.026	10	.603		
Total	6.279	11			

Table 13. The results of a One-Way ANOVA run on the log transformed percent occurrence of hypoplasia between two locations with a sample size of 12 individuals. The critical F-value for these degrees of freedom is 4.9646. The actual F-vlaue is 0.420 and as $0.420 < 4.9646$, the variability between locations is not larger than the variability within the locations ($p>0.05$).

The overwhelming result of the One-Way ANOVA conducted on the variables of hypoplasia, calculus, and occlusal wear is that the variance in the occurrence of each individual modification and pathology between the two locations is not bigger than the variance within the two locations. In other words, the difference in means between these two locations is not significant. As the variance between the locations is not greater that the variability within groups, there is no significant difference between the occurrence of hypoplasia, calculus, and occlusal wear between Sta. Ana and the Forum. The variance within the locations is the same as the variance between the locations. The occurrences of these modifications and pathologies are equal in each group. The occurrence of these modifications is not affected by location, and the time period/religious occupation that is associated. The results of the Fisher's Exact Test conducted on the variables of caries, periodontitis, and agenesis will further elucidate these findings and expand on their meaning.

3.3 *Statistical Comparison of Subsites with Two-Tailed Test*

As previously mentioned, the analysis of the occurrence of caries, periodontitis, and agenesis was conducted with the Fisher's Exact Test, a two-tailed test as the data collected on these variables is best analyzed as nominal. A Fisher's Exact Test was conducted because the sample size is so small. As did the One-Way ANOVA, the Fisher's Exact Test will determine if the difference in the occurrence of periodontitis, agenesis, and caries is significant between the two locations of Sta. Ana and the Forum based on the presence or absence of each variable. Below are the tables used to run the test and a table of results from the results of the test (Table 14).

Table 14. Table of Results of the Fisher's Exact Test on Caries, Periodontitis, and Agenesis.

	p-value	**Significance**
Caries	1.0000	$p > 0.05$
Periodontitis	1.0000	$p > 0.05$
Agenesis	0.5238	$p > 0.05$

Table 17. Results of the comparison of the occurrence of caries, periodontitis, and agenesis across Sta. Ana and the Forum using the Fisher's Exact Test. For caries $p=1.0000$, for periodontitis $p=1.0000$, and for agenesis, $p=0.5238$. As $p>0.05$ for all three tests, the difference between the subsites is not significant.

3.3.1 Caries

Of the seven total individuals from Sta. Ana, caries were present in three and absent in four and of the five total individuals from the Forum, caries were present in two and absent in three (Table 15). The results of the Fisher's Exact Test reveal that the p-value was calculated to be 1.000 signifying that the difference in presence or absence between the two groups is not significant ($p>0.05$, Table 14). Caries are no more likely to be present in Sta. Ana than they are to be present in the Forum.

Table 15. Contingency Table for Caries.

	Presence	Absence
Oratorio de Sta. Ana	3	4
Forum	2	3

Table 14. The presence/absence table used to conduct Fisher's Exact Test on the occurrence of caries between Sta. Ana and the Forum. Seven individuals from Sta. Ana and five individuals from the Forum were available for this analysis.

3.3.2 Periodontitis

When considering the presence and absence of periodontitis and agenesis, one individual from both Sta. Ana and the Forum could not be qualified as they did not have associated alveolar bone and the presence or absence of either could not be confirmed. Therefore, among the available six individuals from Sta. Ana, periodontitis was present in three and absent in three. Among the available four from the Forum, periodontitis was present in two and absent in two (Table 16). The results of the Fisher's Exact Test reveal that the p-value was calculated to be 1.000 signifying that the difference in presence or absence between the two groups is not significant (p>0.05, Table 14). Periodontitis is no more likely to be present in Sta. Ana than in the Forum.

Table 16. Contingency Table for Periodontitis.

	Presence	Absence
Oratorio de Sta. Ana	3	3
Forum	2	2

Table 15. The presence/absence table used to conduct Fisher's Exact Test on the occurrence of periodontitis between Sta. Ana and the Forum. Six individuals from Sta. Ana and four individuals from the Forum were available for this analysis.

3.3.3 Agenesis

Among the available six individuals from Sta. Ana, agenesis was present in two and absent in four. Among the available four from the Forum, agenesis was present in three and absent in one (Table 17). The results of the Fisher's Exact Test reveal that the p-value was calculated to be 1.000 signifying that the difference in presence or absence between the two groups is not significant (p>0.05, Table 14). Agenesis is no more likely to be present in Sta. Ana than it is to be present in the Forum.

Table 17. Contingency Table for Agenesis.

	Presence	Absence
Oratorio de Sta. Ana	2	4
Forum	3	1

Table 16. The presence/absence table used to conduct Fisher's Exact Test on the occurrence of agenesis between Sta. Ana and the Forum. Six individuals from Sta. Ana and four individuals from the Forum were available for this analysis.

As promised, the results of the Fisher's Exact Test elucidate the results of the One-Way ANOVA: there is no significant difference in the occurrence and presence of any of the examined variables between the two subsites of Sta. Ana and the Forum. This data suggests that it is possible that the occurrence of all of these modifications and pathologies was not affected by diet related to difference in location, or population, or by health.

4. DISCUSSION

Before discussion of analysis, it is necessary to address the assumptions made below. Firstly, it is assumed that the individuals of each of the populations of Christians lived where they died. In other words, in the following analysis, I assume that the individuals that were buried at Ca'n Fanals, Sta. Ana, and the Forum also lived there. This assumption mirrors that of the study of the Forum that introduced the problem of the non-Muslims in the Islamic Period (Cau Ontiveros et al. 2015). This assumption allows me to speak about the populations as a singular entity equally affected by the surrounding environment and by population genetics. This would be in contrast to treating the populations as a compilation of different individuals from different locations and backgrounds.

Another assumption, again following the example of the previous study, is that the occupants buried in the necropolis overlaying the Forum were Christians (Cau Ontiveros et al. 2015). The evidence discussed in the Ontiveros study supports the conclusion that the individuals buried in the Forum were non-Muslims (Cau Ontiveros et al. 2015). However, it was the interpretation of Ontiveros that, because the history of the city was Christian, that those non-Muslims inhabitants were Christians (Cau Ontiveros et al. 2015). And thus, this assumption carries over to the present study.

With these assumptions acknowledged, it is important to state that the model of analysis is a populational comparative analysis. Although the data were collected by individual, the results are understood as a population. Therefore, the conclusions that I make below are about three populations of Christians rather than a single group of Christians from Pollentia. Populational analysis gets rid of the invisible outliers and unexpected variation that occur amongst individuals of a larger group. This model allows me to understand the health and diet of a group of people. This method of determining changes in environment and society through the examination of dental remains has already been explored in the literature and has yielded promising results (Whiting, Hillson, and Antoine 2016, 333). This model is also how biological anthropology is conducted as agreed upon in the early stages of the field's conception (Binford 1983). This study is also done in the style of a comparison. Therefore, the conclusions I make below are limited to how each population compares to the others. Specifically, they are limited to how the Forum population compares to the population at Sta. Ana.

It is important to acknowledge the limits of the statistical analysis. The overwhelming limit of the following analysis is the small and unbalanced sample size. This means that the results of the statistical analysis cannot be understood as representative of the entire population. Overall, it is impossible to make conclusions about a whole population of individuals with as few as 14 individuals for the whole site and an average of 6 individuals per subpopulation.

Specifically, the usefulness of Fisher's Exact Test decreases when the sample size is as small as it was for the analyses conducted above. Similarly, the ANOVA conducted on hypoplasia, calculus, and occlusal wear is not to be understood as representative of the entire population of the Forum and Sta. Ana.

The patterns observed may not actually be representative of what actually happened at Pollentia. Therefore, from the statistical analysis presented above, I cannot make conclusions about the populations that I studied. The best that I can do is to use those results to speculate about possible conclusions. This is why there are several ideas presented below.

However, because my interest is to compare the dental health and dietary patterns of the populations within subsites, I will treat my analysis as viable. I will do this with the understanding that what conclusions I make are possible explanations for the patterns observed and that there are many more.

Lastly, because the datum from Ca'n Fanals was deleted, the only successful comparison that came out of the statistical analysis was the comparison between Sta. Ana and the Forum. Therefore, all possible conclusions must be understood as how the Christians of the Forum compare to the Christians of Sta. Ana.

4.1 *Preliminary Conclusions*

Without the statistical analysis, I can make a few preliminary conclusions based on the general observations of the sample. There were six dental pathologies and modifications commonly seen throughout the entire sample. Generally, the presence of these pathologies and modifications means that the diet and health of the individuals of the entire sample provide for simple presence of caries, enamel hypoplasia, dental calculus, occlusal wear, agenesis, and periodontal disease. These six conditions indicate that the sample as a population of individuals from several different time periods experienced malnutrition as children, were grinding their food, had diets high in protein and fermentable carbohydrates, had poor oral health, and had genes that produced agenesis.

As for specific populations, the presence of each pathology and modification was calculated in terms of the percentage of individuals within a population experience hypoplasia, dental caries, calculus, periodontal disease, agenesis, and occlusal wear (Table 10). The percent value also represents the percent chance that an individual living within a subsite may experience each pathology and modification.

According to this calculation, 71% of individuals in Sta. Ana experienced enamel hypoplasia. This means that 71% of individuals living in Sta. Ana during the 12th/13th century went through malnutrition as a child. All of the individuals in Sta. Ana had occlusal wear and experienced dental calculus.

This means that all of the individuals of Sta. Ana were grinding their food and those foods were high in protein and alkaline metals. Additionally, 42% of Sta. Ana Pollentians had caries, meaning that 42% of Sta. Ana Pollentians had dental calculus and a diet high in fermentable carbohydrates. Another 42% of the individuals living in Sta. Ana had periodontal disease, indicating that 42% of the population had poor oral health. Finally, 28% of Sta. Ana residents had genes that produced agenesis.

In terms of the individuals who lived around and were buried at Ca'n Fanals during the 1st/2nd century, it is important to remember that this population is represented by one individual. It was calculated that 100% were likely to have experienced occlusal wear, calculus, and hypoplasia. Like the population at Sta. Ana, 100% of the individuals buried in the area of Ca'n Fanals had a diet high in proteins and alkaline metals and were grinding those foods well. Unlike the population at Sta. Ana, all of the individuals of Ca'n Fanals had been malnourished at some point in their childhood. And according to the calculations, none of the individuals at Ca'n Fanals experienced periodontal disease, agenesis, or dental caries. None of the individuals at Ca'n Fanals had a diet of fermentable carbohydrates and all had perfect oral health and dental genes.

As for the individuals living in the Forum during the Islamic period, and like the population at Sta. Ana, 100% of Forum Christians experienced both occlusal wear and calculus. Therefore, I conclude all the individuals living in the

Forum during the Islamic period had a diet high in proteins and alkaline metals and were grinding those foods well. 80% of the individuals of the Forum had hypoplasia and were malnourished during childhood. 40% of the Forum Christians had caries and a diet high in carbohydrates. Another 40% of the individuals had periodontal disease and poor oral hygiene. Lastly, 60% of the individuals at the Forum had genes that produced agenesis.

4.2 *Comparison of Sta. Ana and the Forum*

The results of the three ANOVA that were run on the occurrence of hypoplasia, calculus, and occlusal wear demonstrated that the variability of the occurrence of pathology between populations was not greater than the variability within the populations. In other words, the variability of the occurrence of pathologies was essentially the same for both of the subsites. Further still, the test affirmed that the variability between groups is not greater that the variability within groups, so there is no significant difference between the occurrence of hypoplasia, calculus, and occlusal wear between Sta. Anna and the Forum. The occurrence of these pathologies and modifications was not affected by location nor the time period to which they are associated.

The results of the Fisher's Exact Test expand on the results of the One-Way ANOVA: there is no significant difference in the presence and absence of caries, periodontal disease, and agenesis between the two subsites. The same number of cases of caries were observed in Sta. Ana as in the Forum. The same is true of periodontal disease and agenesis. The presence of these pathologies and modifications were not affected by the location or time period of the populations in question.

The overwhelming result of the statistical analysis is that there is no significant difference in the occurrence of all of the studied dental pathologies and modifications between the two subsites of Sta. Ana and the necropolis overlaying the Forum. There is no significant difference in the percent occurrence of hypoplasia, calculus, and occlusal wear nor is there a significant difference in the presence/absence of agenesis, periodontal disease, and caries between the individuals of the two locations. There was no significant difference in the likelihood of an individual of either population of Christians to experience any of the studied conditions. The populations experienced the same dental pathologies and modifications at the same percent occurrence.

According to this assertion, as dental pathologies and modifications are indicators of health, diet, and genetics, I can conclude that there is no significant difference in the oral health, diet, and dental genetics of the Christian population of Sta. Ana and the Christian population of the necropolis overlaying the Forum. Further still, as oral health and diet are influenced by the food quality and nutrition, I can also conclude, according the results of the statistical tests, that there was no significant difference in the nutrition and food quality of the Christians of Sta. Ana and the Forum.

Therefore the Christians of the Forum and of Sta. Ana had similar diets, oral health, and their diets were composed of comparable nutrition and physical food quality. In other words, the two populations had access to a similar diet and quality of food that resulted in the oral health of the Christians of the Forum to be very similar. Regardless of the fact that the Christians of the Forum lived during the Islamic Period, they had access to the same nutrition and oral health that did the Christians of Sta. Ana who lived after the Islamic Period in a Christian society.

This overwhelming similarity raises yet another interesting question about the population buried in the necropolis overlaying the Forum: what does it mean for the Christians in the Islamic Period (9th-12th centuries) if their diet and nutrition were not significantly different from those of Christians living in a Christian community (12th/13th century)?

There are many possible explanations for why these similarities exist and, likewise, there are many possible interpretations of the role of Christians of the Forum. Again, following the example of the previous study by Ontiveros, all of these interpretations have to do with the status of the Forum Christians as conferred by the quality of food they had access to and their overall oral health (Cau Ontiveros et al. 2015).

As the Christians of Sta. Ana were living in a medieval Christian city, it is assumed that they were the primary members of the community and had elevated (or equal) status. There is also the fact that they were not cremated, but were buried in a religious area suggesting elevated status. This means that they had access to the best food with the highest nutritional value that was available to Pollentia at that time. It is also assumed that the primary members of a community have access to the high quality foods. The similarity of dental pathology and modification means that the Christians of the Forum were probably eating the same high quality food. The fact that the Forum Christians had access to the same diet that was of high quality for the Sta. Ana Christians suggests that the Christians of the Forum were of equal or lower status of the Muslims of the Islamic Period.

If the analysis operates under the assumption that the Christians of the Forum were of lower status to the Muslims of the community, there are several explanations as to why they had access to a nutritional diet and had good oral health. The first explanation is that the Christians of the Forum were the servants or slaves of the Muslims in the larger community and were treated very well. The Muslims of the Forum gave their Christian servants the highest quality food of the area.

It is also possible that the Christians of the Forum were treated poorly by the Muslims of the community and were given low quality food. The reason that there is a similarity between Sta. Ana and the Forum Christians could be that the diet of the Sta. Ana Christians was poor due to crop and trade failure. While possible, this is not likely as the individuals from the Forum and from Sta. Ana are only separated by roughly a century are span at least two centuries within a single population. That is not enough time for a drastic change in agriculture and commerce. It is more likely that the agricultural and commercial aspect of the city remained relatively constant over these two time periods. Another explanation could be that the Christians of Sta. Ana were not the primary members of their community, but were also treated poorly and given a poor diet.

On the other hand, it is also possible that if the Forum Christians had access to high quality food, it follows that the Forum Christians probably did not have low status within the Muslim community. This assertion negates the hypothesis that the Christians of the Forum were the servants or slaves of the Muslims. Instead, it would meant that their status probably equaled that of the Muslims, the primary members of the community. In this case, the Christians and Muslims would have lived together peacefully in Pollentia.

However, that the individuals were of equal status to the Muslims at Pollentia could also mean that the individuals buried in the necropolis overlaying the Forum did not live where they died. Still assuming they had good access to high quality nutrition, it is possible that these individuals were of high status where they lived and came to Pollentia only to be killed or to die shortly after their arrival.

Lastly, it is possible that the Christians of the Forum had access to good food in the Islamic Period because they were not Christians at all. Despite the fact that they were buried in a way that is not traditional of Muslim burials, these individuals could have been Muslim members of the community. They could have also been representatives of another religion altogether that played an entirely different role in the Muslim community than Christians would.

There are a lot of possible explanations for this new question and all of them depend on different assumptions. However, as previously mentioned any conclusion made from this study must be treated as an assertion rather than a definite explanation. And because there are so many possible explanations for the observed similarity between the diet and health of the Christians of the Forum and the Christians of Sta. Ana, any further study should be aimed at answering this new question by isolating the true assumptions of the populations.

5. CONCLUSION

5.1 *Sources of Error*

It is important to acknowledge the sources of systematic and random errors of this project. All of the errors discussed below have or could have skewed the results of the analysis and therefore the conclusions of this study. I must acknowledge the limits of this study: the assertions of this study cannot be deemed as definitive conclusions.

The most glaring source of error that contributes to this problem is the small sample size. I was only able to collect data on 14 individuals total. Eight of these individuals were excavated from the Oratorio de Sta. Ana, five from the Forum, and one from Ca'n Fanals. To begin with, 14 individuals make for a very small sample size, but for a statistical analysis between these subsites, the population sizes end up being below, at most, eight individuals, which is almost impossible to deal with (Cobb 2002). Eight individuals cannot be representative of a population and assertions about a population from a single individual certainly cannot be considered representative patterns.

Expanding the problem is the exclusion of Ca'n Fanals from the statistical analysis. The third population of Christians had to excluded because one observation is not enough to compare. Therefore, the study was, from the beginning, limited to two bases for comparison instead of the potential of three.

Additionally, the method by which these individuals were chosen was not randomized and, instead, was highly biased. A biased study is one in which the method of choosing subjects is influenced by confounding factors (Cobb 2002). In this case, the method of choosing individuals to study was heavily influenced by several factors. These factors include which individuals were buried as skeletons and not cremated, individuals that survived in the archaeological record, skeletal remains that included dental remains, and dental remains that were identifiable. Age of the individual was used as a purposeful selection factor as individuals with exclusively deciduous teeth were excluded and, therefore, does not contribute to the biased nature of the design. Individuals were not selected by a randomization device, but they were chosen because they were the only ones available.

Lastly, as there is a different number of observed individuals per subsite both the One-Way ANOVA and the Fisher's Exact Test are unbalanced designs. It is possible to analyze an unbalanced design, but the results are less likely to be reliable. All three of the above sources of error complicate the trustworthiness of the results of the statistical analysis (Cobb 2002).

In addition to the sources of error that directly impact the statistical analysis, there were several sources of error that impacted the data collection and therefore the reliability of the data. These sources of error have to do with the nature of biological anthropology and also the fact that at the time of data collection, I, as a researcher, was not as knowledgeable about dental pathologies and modifications as I am now.

First and foremost, I learned how to identify dental pathologies and modifications in the field while I was conducting my data collection. So, inherently, it is possible that at the beginning of my data collection, I may have misidentified or missed dental pathologies. Seeing as calculus, hypoplasia, and periodontal disease are especially difficult to identify, that there could have been more cases that I was able to identify in the first individuals I examined. By itself, periodontal disease is difficult to identify and if a researcher is not careful, they could easily misidentify periodontal disease (Forshaw 2014, 529-535). And, being new to dental pathology identification, I was not careful, especially at the beginning of my data collection. I tried to minimize these potential errors by going back and reexamining the first individuals, but it is possible that I missed occurrences.

Additionally, the skeletal remains that were available for study were not always reliably complete. Several of the individuals I studied did not have alveolar bone associated with the teeth and just had a bag of loose teeth. The incompleteness of these skeletal remains is due to the nature of how skeletal remains survive in the archaeological record, not always very well, and also to how the remains were excavated. It is not always possible for the excavator to preserve all of the skeletal remains or excavate all of the skeletal remains. But this lack of alveolar bone meant that for the disease whose identification relies on alveolar bone (periodontal disease and agenesis), their occurrence cannot be taken as completely reliable even for this small sample. In fact, during the statistical analysis of those pathologies, I was forced to exclude the individuals without alveolar bone. This also meant that there was a lack of complete dentition for nine individuals. Without the complete dentition, the data that I collected are not representative of the whole individual and, by extension, the whole population.

Lastly, the data that I was able to collect are not useful for diet reconstruction. At the time of data collection, I was not aware of the scale systems that exist to classify and interpret dental wear and pathologies and therefore only sought to create a catalog of pathologies and modifications. This specific instance is not a source of error, but I believe that was erroneous in not collecting data that would have been useful for diet reconstruction. It would have been a useful tactic as diet reconstruction is how dental archaeology is commonly understood in the biological anthropological literature (Irish and Scott 2016).

5.2 *Further Studies*

The results of this project are preliminary and largely incomplete due to the limitations and sources of error of the data collection and the statistical analysis. In other words, there are many opportunities to expand on the results of this present study and put them into a larger context.

Several of the above mentioned sources of error cannot be eliminated due to the nature of archaeological excavation, but several can be minimized in the future. Additionally, some of the future directions discussed below would certainly expand on the present study, but would not be feasible for an undergraduate researcher. Yet they are worth discussing.

As mentioned in the introduction, there exist scales of graded measurement for several of the pathologies and modifications discussed: caries, occlusal wear, and periodontal disease specifically. Those grades specify the interpretation of the pathologies and modifications applicable, and make diet reconstruction possible for a sample. The data that I collected on the dental remains of Pollentians focused on the occurrence of the six pathologies and modifications, not the specific qualities and classification of these pathologies and modifications. However, I suggest that additional study of individuals from the same subsites, with the scales of classification in use and the appropriate measurements, would increase the understanding of the diet of all three populations of Pollentian Christians, and more interestingly, the Forum Christians.

The diet reconstruction of these locations and populations would offer more specific information about the health, food type, and lifestyle of Pollentian Christians as a whole. This reconstruction effort would also provide a profile of the diet of the Forum Christians that will make the results of the previously executed comparison more interesting and meaningful. An understanding of what type of food and the exact profile of health for these Forum Christians would expand the base of knowledge and help to answer the general question of what these Christians of the Islamic period were doing.

Additionally, with more specific information on the diets and health of all the populations, a comparison of the three would becomes more interesting. At that point, the comparison would be between health status and food type instead of simple occurrence of dental pathology and modification. Because the occurrence of pathologies and modification is blind to exact food types and health, a comparison of complete diet reconstruction may reveal fundamental differences and/or similarities not previously visible. Additionally, the comparison would provide less broad and more specific results unique to food type and health status. For example, it could be determined that the population at Ca'n Fanals experienced occlusal wear that matches a grade associated with farmed grains, whereas individuals of the Forum experienced occlusal wear that is associated with food cooked in water (Smith 1984, 39-56). The results of this type of comparison would not only add to the goal of understanding the role of the Forum Christians, but would also elucidate the general environment of Pollentia.

Along the lines of diet reconstruction, another potential direction for the continuation of this study would be to conduct phytolith analysis. Phytoliths are mineralized negative impressions of plant cells that are identifiable to specific plants and their analysis can reconstruct the vegetative diet of a population (Irish and Scott 2016; Albert, Bamford, and Esteban 2015, 51-66). Phytoliths get trapped in the dental calculus of an individual as they eat vegetation and then survive in the calculus to become part of the archaeological record (Irish and Scott 2016). Phytolith analysis is a method of analysis that is increasingly popular and useful for diet and environment reconstruction (Albert, Bamford, and Esteban 2015, 51-66). In fact, a researcher at Pollentia spent July of 2016 collecting samples of calculus in hopes of encountering phytoliths. The conclusions of the study of phytoliths would expand the understanding of this present study and is an avenue worth investigation.

Though as a researcher I do not have access to the materials necessary, it is interesting to discuss isotope and microwear analysis as possible methods of examination of the dental remains of the sample at Pollentia. Dental microwear describes the pits, striations, and grooves left behind by food and tools, but is much smaller than attrition and abrasion and can only be observed by a microscope (Irish and Scott 2016). Analysis of microwear patterns has been determined to be the most effective in diet reconstruction as food types leave behind characteristic markers on the tooth (Irish and Scott 2016). As the dental microwear analysis functions through comparative analysis of an expanding database on patterns, it would be very interesting to collect micrographs of the microwear patterns at Pollentia and compare them to the database to further identify the food types.

Additionally, it would be interesting to analyze the dental sample at Pollentia with isotope analysis to expand the knowledge of food types. Isotopic analysis would analyze the stable isotopes and trace elements left in the body tissues by food (Forshaw 2014, 529-535). This type of analysis would involve destroying the enamel and dentin of the dental remains to chemically examine the sample (Forshaw 2014, 529-535). However, because this method of analysis is destructive, comprehensive comparative analysis is, unfortunately, impossible (Forshaw 2014, 529-535).

Another area for expansion is the inclusion of deciduous teeth, or baby teeth. I exclusively focused on adult teeth in this present study as it created a level playing field upon which I could make parallel comparisons, but there were many individuals from all three subsites that had deciduous teeth, including deciduous teeth that had not yet erupted. Though deciduous teeth are only in use for a short period of time, those teeth are made in a less careful way, so markers can be left on deciduous teeth and those markers can be useful for diet and health reconstruction. In fact, the study of attrition and abrasion on deciduous incisors has been shown to reveal information about weaning patterns (Mays 2016, 725-731). Therefore, a study of the deciduous teeth of the same populations could add to the analysis of the comparison.

Overall, any further study should be informed by more extensive application of statistical analysis and dental pathologies and modifications. That type of further study would be produce a result with less error and a result that is more in line with the goal of research at Pollentia. Further study would also include a closer examination of studies of Muslim inhabitation of the Balearic Islands and the surrounding area. Additionally, any further study should be designed to answer the interesting question that arose out of this study: what does this mean for the Christians in the Islamic Period if the their diet and food quality was not significantly different from the Christians that were a part of the medieval settlement that was formed right after the Islamic Period?

5.3 *Personal Experience as a Researcher*

The experience of coming up with a project, conducting the research, analyzing the data, making conclusions, and writing it all up has shaped me as a researcher in ways that I did not expect. From the literature that I had read and that classes that I had taken at Mount Holyoke College and the University of Massachusetts Amherst, I went into the project with the conception that the research I was about to do was well-informed and meaningful. I talk about this extensively in the Methods and Conclusion sections, but to sum it up, the reality was that I had no idea what I was doing when I walked on site in July 2016. I knew what dental pathologies were and what information they could convey, but I had no idea how to measure them or make sense of them. The bulk of the design phase of my research took place in conversations with Dr. Miguel Angel Cau Ontiveros and Dr. Francisca Cardona about the context of Pollentia and what information they had already discovered. Their combined experience and know-how boldly reshaped how I thought about my role on site and the research I wanted to conduct there. So I ended up with this incredible haphazard experience of learning how to do independent research under the guidance of real archaeologists. I learned how to form my research from how they spoke about archaeology and the questions that they had about Pollentia.

Though I had already learned the basics from textbooks, the experience taught me how to live out my research. I learned that the context of the site is essential to forming research questions. I had gone to Pollentia without understanding the context and with the intention of cataloging dental pathologies and modifications. Within one week of being there, my research suddenly had a larger purpose; the purpose of deepening the understanding of what was happening in Pollentia during the Islamic period.

And when I came back to Mount Holyoke, my data in hand, my understanding deepened even further. In conversations with Professor Gifford, I learned that my data is nothing without statistics. And in class with Professor Rachootin, I learned about what context my research had. With calm and a deeper understanding of my data and what other researchers had done, I began to understand the limits of my own research and how to make my analysis a contribution instead of a simple answer. I learned what I can do and as my thesis ends, I am filled with anticipation for the future.

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