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Reconstructing Oral Health in Pre-Hispanic Peru: Antemortem Tooth Loss and Caries as Possible Evidence of Dental Care in Túcume, Peru

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RECONSTRUCTING ORAL HEALTH IN PRE-HISPANIC PERU: ANTEMORTEM TOOTH LOSS AND CARIES AS POSSIBLE EVIDENCE OF DENTAL CARE IN TÚCUME, PERU

By

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ABSTRACT

Evidence of dental manipulation dates back several centuries and is identifiable through modification of human skeletal remains and the remnants of ancient tools. The act of caring for dental patients, on the other hand, is much more abstract and not as explicitly documented throughout history. Through the analysis of skeletal dentition of individuals from Pre-Hispanic Peru, this research aims to understand possible early forms of dental care practices. Specifically, by calculating the frequency of common dental pathology, I evaluated the possible presence of dental care in Túcume, Peru, during the Late Intermediate Period (1000 to 1500 AD) and what this could mean for those who once lived there. For this investigation, I used observations of the presence of antemortem tooth loss and caries to score the dentition of 57 skeletonized adult individuals. Descriptive and analytical statistics were performed based on the scores to determine the frequency of pathology and the patterns associated with age, sex, and burial context variables. Research on dental paleopathology has been done before; however, it is rarely interpreted using the bioarchaeology of care model. This research could elicit conversation and further investigation into how past civilizations may have cared for individuals in the form of tooth ablation. Additionally, it could demonstrate how current dental care has changed over time and how care is still an important aspect of humanity.

DEDICATION

To Mom, my favorite dentist.

To Dad, who never fails to remind me of the importance of education.

ACKNOWLEDGEMENTS

This research would not have been possible had it not been for Dr. J. Marla Toyne, my thesis chair, whose work has inspired me to chase the unknown. What started as an interest in immunology has evolved into a newly found appreciation of anthropology. Thank you for your continued support, patience, and access to your research and mind. Thank you, Dr. Donavan Adams, the other half of my thesis committee for your guidance. Most importantly, thank you to my family for the constant reassurance and for being the foundation of my life.

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CHAPTER 1: INTRODUCTION

Whether attending to unwell individuals has always been instinctive or simply considered an evolutionary advantage, caring for the ill can be traced back to ancient societies through evidence of healthcare practices in human remains (Powell et al., 2017; Tilley, 2015; Tilley & Schrenk, 2017; Shaw & Sykes, 2018). One way to investigate these past practices is through bioarchaeology (Powell et al., 2017; Tilley, 2015; Tilley & Schrenk, 2017; Shaw & Sykes, 2018), a discipline that studies skeletal remains. Because the human skeleton is susceptible to functional changes in response to natural and cultural influences, it may serve as a "reflection of a lifetime of interaction with the world" (Buzon, 2011, p. 60). With the use of this multidisciplinary science, this thesis investigates how the individuals of Túcume, Perú during the Late Intermediate Period (LIP) may contribute to our understanding of the development of one of the oldest medical professions: dentistry (Ergünol et al., 2022).

Research Overview

The purpose of this research is to conceptualize possible dental practices in Túcume. Specifically, this research uses antemortem tooth loss (AMTL) and dental caries as possible indicators of early forms of dental care. The legal practice of preserving oral health, or *dentistry*, refers to "the art of preserving the dental organs in a sound and healthy condition" (Miles, 1877). This branch of medicine includes a wide variety of careers: dental hygienists (who perform teeth cleanings), general practitioners (who have general knowledge on in all of the specialties and whose everyday routine may include performing extractions, restorations, fillings, and examinations), and specialists (who have received advanced education in their area) (Kendall, 2001). In modern dentistry, oral and maxillofacial surgeons specialize in tooth extractions, the treatment of injuries, and the removal of tumors (Kendall, 2001). This thesis focuses on tooth extractions, which are generally performed by general dentists or oral and maxillofacial surgeons in modern society.

For this research, a sample of individuals and a prepared spreadsheet provided by Dr. J. Marla Toyne was used to score teeth and determine the frequency of pathology in the well-preserved skeletal remains from the archaeological site of Túcume, Peru. Investigating based on the assumption that AMTL serves as an intentional practice to remove teeth, any evidence of AMTL may suggest that dental care was practiced during the LIP. A high frequency of AMTL could provide insight as to which individuals experienced more frequent care. Similarly, a pattern in the location caries serves as an indicator of the prevalence of oral pathology that could have led to AMTL and the importance of oral health during this time.

Importance

Few tooth-related bioarchaeological research focus on dental care (Gagnon, 2020). Rather, oral paleopathological research is often used to reconstruct diet or used to determine frequency of pathology in a region (Gagnon, 2020). This research, instead, uses the bioarchaeology of care approach to study oral pathology (Tilley, 2015). This approach attempts to reconstruct dental practices and the demographic that was may have been more inclined to receive dental care. This research could elicit conversation and further investigation on how past civilizations may have cared for individuals in the form of tooth ablation. If we can assume that carious lesions may have led to intentional intervention via tooth removal, then AMTL could reflect a dental healthcare practice or dentistry in Túcume. Modern dentistry has evolved exponentially since its estimated origination, ancient Egypt around 2660 BC (Vieira & Caramelli, 2009; Forshaw, 2009). With this being said, it could be beneficial to look backwards in history as we keep moving forwards to gain insight on distinct cultures, human interactions, and healthcare practices.

Research Questions

The following research questions guide the investigation of bioarchaeology of dental care at Túcume:

- How many adult individuals present AMTL?
- How many adult individuals present caries?
- Is there a pattern of tooth types with AMTL?
- Is there a pattern of tooth types with caries?
- Does a certain demographic within the sample have more AMTL?
- Does a certain demographic within the sample have more caries?
- Is it possible to suggest that the location of caries could predict subsequent AMTL?

Hypothesis

In an effort to answer the previous research questions, I propose the following hypotheses:

I. No individuals in the study set will present AMTL or caries. If this is false, then evidence suggests that only certain individuals in Túcume had AMTL that may be evidence of special dental care.

II. Sex estimate, age estimate, and burial context will not correlate with the frequency of AMTL or caries in Túcume. If this is false, then evidence may suggest that one sex, age, or burial group has more evidence of dental pathology than another.

III. This study set will not show preferential loss of one tooth type within the oral cavity. If this is false, then evidence could suggest that there is a pattern of tooth ablation.

Research Outline

This thesis will begin with a literature review, discussing background research on bioarchaeology, dental health, and the archaeological site of Túcume. The research materials, methodology, and analyses that were conducted will then be explained. The results and the interpretation of these results will follow. Finally, this thesis will end with a conclusion summarizing the outcome and importance of this research.

CHAPTER 2: BACKGROUND

Introduction

To investigate possible signs of early dentistry in Túcume, it is necessary to understand the use of bioarchaeology, dental functions, the causes of antemortem tooth loss (AMTL), and the defining culture of pre-Hispanic Peru. The purpose of this chapter is to provide historical and scientific context and explain how bioarchaeology is essential for such investigation, taking into consideration previous research. This chapter describes dental health and pathology, Dr. Lorna Tilley's bioarchaeology of care, and the Túcume archaeological complex**.**

Dental Health and Pathology

Tooth Anatomy

A comparison between healthy dentition and abnormal tooth conditions allows for a better understanding of how poor oral health that may result in AMTL. Thus, it is useful to note how a tooth should appear in the mouth under normal conditions. Three sections form the external anatomy of a tooth: the crown, the root, and the cementoenamel junction. Covering the crown is the enamel. The enamel is mainly comprised of inorganic materials—making it the most durable substance of the body (Kinaston et al., 2019). Due to its high mineral content, the enamel cannot be naturally restored once cracked or damaged, and enamel-impacting diseases will leave evidence of destruction (Lynnerup & Klaus, 2019). Each tooth root is contained within the alveolar sockets (alveoli) of the mandible and maxilla. Surrounding the root is a mineralized tissue, cementum, which provides support. The periodontal ligament (a type of connective tissue that connects bone to bone) connects cementum to the alveolar process to keep the tooth within the socket (Saffar et al., 1997). It should be noted that the periodontal ligament can adapt to resist stress to the tooth root and prevent tooth loss if healthy (Yamamoto et al., 2016). The final feature of the tooth, the cementoenamel junction, creates an anatomical border between the cementum and the enamel.

Directly under the enamel, dentin is the supporting tissue that contains the pulp chamber. Its lower mineral content makes the underlying tissue only slightly softer than enamel yet harder than bone (Morris & Tadi, 2022). Its phosphate composition allows it to flex, absorb force, and serve as a substructure for the enamel (Morris & Tadi, 2022). Unlike enamel, dentin can be remodeled and repaired on its own with limited capacity (Huang, 2011). Such an ability to regenerate could help the tooth protect itself from caries destruction, but ultimately enough pathological progress can lead to tooth destruction (Huang, 2011).

Tooth Development

Contrary to tooth anatomy, tooth development and eruption is less understood in its entirety (Jain & Rathee, 2023). Humans form two sets of teeth: deciduous and permanent. For this investigation, only permanent dentition will be taken into consideration to ensure consistency. Permanent dentition eruption varies between individuals and usually begins around the age of six years (Jain & Rathee, 2023). Normally, the first teeth to emerge are the maxillary and mandibular first molars, followed by the mandibular central incisors, then the maxillary central incisors, and finally the premolars (Jain & Rathee, 2023). Third molars are the last to appear if they are not impacted, which is most commonly the case in modern times (Jain & Rathee, 2023). An impacted tooth is one is "prevented from erupting by some physical barrier in their path" (Suri et al., 2004, p. 432). Figure 1 is an atlas summarizing the process of tooth formation in single rooted teeth, initiated by "interactions between the oral epithelium and underlying neural crest-derived mesenchymal cells" (Hildebrand et al., 1995, p. 170). Tooth development is divided into two main stages: crown shaping and root formation. Substages include the bud, cap, bell, root and cap formation, and eruption stages (Yu & Klein, 2020). Eruption requires the removal of "bone and primary roots" followed by a force that "propels the tooth toward the occlusal surface, directing it along an established eruption pathway" (Jain & Rathee, 2023, para. 5). Multirooted teeth follow a similar path until the Hertwig's epithelial root sheath initiates furcation of the roots (Li et al., 2017).

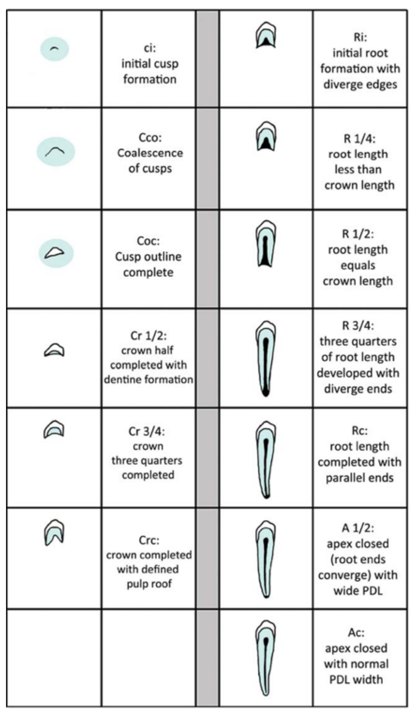


Figure 1. Atlas of tooth development and eruption of single rooted teeth (AlQahtani et al., 2010:483, Figure 1).

Several abnormalities can occur during this process: ectopic eruption, delayed eruption, impacted teeth, embedded teeth, submerged teeth, etc. (Jain & Rathee, 202). The eruption phase varies by individual with numerous factors such as genetics, race, sex, nutrition, etc. playing key roles in the eruption time (Kutesa et al., 2013). Additionally, it may be possible that an individual's tooth does not develop. This abnormality is referred to as tooth agenesis or hypodontia (Shimizu & Maeda, 2009), and such cases are taken into consideration in this investigation. It must be emphasized that tooth agenesis is not synonymous with AMTL because, in such cases, a tooth was never formed to begin with.

Antemortem Tooth Loss

Tooth maintenance can be even more problematic than tooth development as tooth health depends on numerous factors throughout the remainder of one's life. Luckily for researchers, the advantage of using teeth as the basis of investigation stems from dentition being the only component of the skeletal system that is accessible to the external environment (Lynnerup & Klause, 2019). A commonly studied tooth pathology in bioarchaeology is AMTL, contributing significantly to the analysis of influencing factors and behavioral patterns in ancient societies (Cucina & Tiesler, 2003; Lukacs, 2007; Smith & Betsinger, 2021). *Antemortem tooth loss* is defined as "permanent teeth lost prematurely through trauma, chronic pathology, or intentional ablation" (Kinaston et al, 2019, p. 770).

It must be emphasized that despite this research associating AMTL with intentional ablation practices, it does recognize the other possible explanations for AMTL: trauma and chronic pathology. Being aware of the characteristics associated with trauma-induced AMTL and pathology-induced AMTL could help determine if intentional ablation is the most probable explanation for the missing teeth discovered in the dentition of these individuals.

Trauma Causing Antemortem Tooth Loss

Trauma-induced AMTL is characterized by irregular fractures (such as broken alveolar walls) with signs of alveolar bone remodeling (Lukacs, 2007). The greatest difference between postmortem trauma-associated tooth loss and antemortem trauma-associated tooth loss is the smoothing of fractured areas; however, microscopic examination is often required to differentiate the two (Wedel & Galloway, 2014). Antemortem traumatic fractures tend to originate externally and can affect both the mandible and maxilla (Wedel & Galloway, 2014). Due to the protrusion and lack of protection, the maxillary central incisors are most vulnerable to dental trauma (Kinaston et al, 2019). Other research notes the premolars as the second most commonly affected teeth, with the canines and molar teeth seemingly unaffected (Lukacs, 2007).

Dental trauma typically results in enamel damage, but on more serious occasions, the pulp chamber can become exposed (Brüllmann et al., 2010). An exposed root usually requires a root canal to treat the infection or nerve damage and a fractured crown with pulp exposure could require vital pulp therapy to prevent necrosis of the pulp (Brüllmann et al., 2010). If left untreated, pulp chamber exposure increases the mouth's susceptibility to infection, which could induce alveolar lesions. If the alveolar socket is compromised, then the tooth loses that which holds it in place, and the tooth could fall out or be easily removed (Cucina & Tiesler, 2003). Similarly, trauma to the alveolar process can cause bone damage that leads to tooth loss (Wedel & Galloway, 2014).

Trauma-induced AMTL has been explored in archaeological literature (Lukacs, 2007; Gibbon & Grimoud, 2014; Lukacs & Hemphill, 1990). It is important to note that the frequency of tooth loss attributed to trauma is significant but not very high. One study reported 11 out of 36

(30.6%) skulls with evidence of trauma-induced AMTL (Lukacs, 2007), while another reported 104 out of 482 (21.5%) with evidence of pathology *or* trauma. Based on this evidence, tooth trauma can most likely not be used to explain the majority of AMTL found in dentition.

Pathology Causing Antemortem Tooth Loss

Certain pathological conditions can also lead to AMTL: periodontal disease and caries. *Periodontal disease* is a condition related to bacterial-derived plaque signaled by inflamed soft tissue (gingivitis) and alveolar bone loss (periodontitis), resulting in a decrease of the effectiveness of supporting structures (Gosman, 2011). Specifically, mechanical and chemical dental wear and the replacement of microbiota with harmful pathogens result in a porotic, ragged alveolar bone. In the case of periodontitis, due to the "compromised bony and ligamentous tooth support" (Gosman, 2011, p. 87), the tooth can become loose and in the most severe cases, the tooth may fall out of the socket by itself.

In modern dentistry, a patient can be referred to a periodontist for the evaluation of the severity of periodontal disease (Moreira et al., 2007). Treatment to prevent the further advancement of this disease can be set in place to prevent tooth loss (Moreira et al., 2007). However, "tooth mobility, severity of attachment loss and radiographic bone loss greater than 50%" often result in the extraction of the tooth (Moreira et al., 2007, p. 439). It is important to understand that bone loss caused by periodontal disease reduces the alveolar bone height (Boehm & Chui, 2020). For a tooth to fall out on its own, bone recession would have to reach below the gum line to expose the ligaments (Boehm & Chui, 2020). These cases would be noted in skeletal remains as the alveolus would not be able to regenerate completely, resulting in healed bone that is “smooth and depressed relative to the height of the alveolar crests of healthy sockets” (Gilmore & Weaver, 2016).

Periodontal disease has been extensively studied in archaeological research (Gagnon et al., 2013; Al-Mutairi et al., 2022; Raitapuro-Murray, et al., 2014). Prevalence of periodontal disease can vary greatly depending on the sample and time period that a researcher chooses to investigate (Al-Mutairi et al., 2022, Raitapuro-Murray, et al., 2014; Bertl et al., 2020). Although it is possible for AMTL to be caused by periodontal disease, extraction is usually still necessary for the tooth to be lost to prevent the infection from spreading or worsening (Passarelli et al., 2020). Such extraction would still be considered intentional ablation and a form of dental care.

While some cases with periodontal disease show a strong correlation with caries (Yu, et al, 2021), others show little to none (Balachandran & Gurucharan, 2020). Nonetheless, *caries* is a complex sugar-related disease resulting in erosive lesions and necrosis of the tooth (Hillson, 2018). The consumption of carbohydrates (sugary and starchy foods) leads to a decrease in oral saliva pH and the presence of organic acids. In this environment, the enamel, cementum, and dentin become progressively demineralized due to the increased activity of localized bacteria (Hillson, 2018). Similar to periodontal disease, the tooth can be lost through unhealthy gingiva and alveolar resorption. Additionally, carious lesions can lead to significant destruction and damage to the tooth nerve if the erosion reaches the pulp chamber. With an exposed pulp, bacteria are transmitted to the root, through the apical foramen, and can lead to destruction of the periapical alveolar bone (Hillson, 2018). Once dental pulp is infected due to caries, trauma, or periodontal disease, the abnormality manifests as alveolar lesions. Damage to the nerve could secondarily cause localized pain symptoms. In such cases, the tooth can also be lost due to caries through deliberate manipulation to alleviate the individual's pain. Hillson (2018) proposes that molars are most commonly the tooth type to be affected by this extraction. To emphasize, a distinction between periodontal disease and caries is that the former consists of a cellular response to bacteria, while the latter consists of an acellular response to bacteria (Loesche, 2007).

Another leading cause of AMTL, tooth ablation, refers to the intentional removal of a tooth. In ancient Hawaii, bioarchaeologists have hypothesized that the removal method involved striking a rock to one end of a stick while the other end was positioned onto the targeted tooth (Pietrusewsky & Douglas, 1993). In this case, tooth ablation was said to be done as a ritualistic practice to demonstrate pain tolerance, and as a result, anterior teeth were commonly removed as a rite of passage (Pietrusewsky & Douglas, 1993).

Evidence of tooth ablation and manipulation for pain alleviation has also been recorded by bioarchaeologists. For example, reports in Cusco, Peru examined two cases in which individuals' mouths displayed signs of artificial drilling due to seemingly deliberate holes at the center of the dental crowns based on their depth and symmetry (Ortiz et al., 2016). In Pakistan, a bow drill tipped with a flint head used for decayed tissue removal was investigated based on the presence of drilled molar crowns in the dentition of nine Neolithic skeletons dated to be from 7,500 to 9,000 years ago (Coppa, et al, 2006). Furthermore, intentional removal of dental decay was investigated in an individual of the Late Upper Paleolithic era in Italy based on striations in inaccessible areas of their oral cavity and surrounding demineralized tissue (Oxilia, et al, 2015). Despite ongoing research, evidence of surgical, dental manipulation for therapeutic reasons remains limited.

It must also be mentioned that tooth loss can also occur after an individual's death (postmortem) due to a variety of biological and physical factors (Manoilescu et al., 2015). To not confuse the two forms of tooth loss, it is essential to distinguish that postmortem tooth loss "is characterized by the presence of alveoli with no evidence of remodeling" (Kinaston et al., 2019, p. 770). As AMTL occurs while the body can still regenerate tissue, AMTL will display resorption and remodeling of the alveolar corpus (Smith & Betsinger, 2021). Such cases of AMTL provide insight on past oral health and possible cultural healthcare practices.

The Correlation Between Oral and General Health

An increasing amount of research has suggested a strong correlation between oral health and an individual's overall health. For this reason, it is not uncommon for a primary care physician to examine a patient's oral cavity as an indicator of good overall health. According to the World Health Organization (WHO) Constitution, "overall health" refers to the "complete state of physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO, 1976). Examples of these connections include the linkages between oral health and rheumatoid arthritis (Chalmers et al., 2017), periodontal disease and cardiovascular disease, stroke, diabetes, dementia (Sabbah et al., 2019), and significant tooth loss and mortality (Kim et al., 2013). Despite evidence of a strong correlation, further research must be done to prove causation of secondary systemic diseases. All things considered, it is crucial to maintain good oral health through diet, hygiene, and dental checkups.

<u>Bioarchaeology of Care (and Dental Care)</u>

Bioarchaeology

Bioarchaeology can often serve as a link between the past and present by generating discussions that help conceptualize ancient lifestyles. Specifically, bioarchaeology is a subdiscipline of anthropology that studies skeletal remains, taking biological and cultural factors into consideration to reconstruct once-living societies (Cheverko et al., 2020). This field of study can and has been utilized in various disciplines to understand many aspects of past lives (Briggs, et al., 2006; Robson, 2020; Tilley, 2015). An example of a pioneering development in the field of archaeology is Dr. Lorna Tilley's bioarchaeology of care method, which uses skeletal remains to infer aspects of earlier or ancient forms of healthcare (2015).

Tilley's Bioarchaeology of Care

Specifically, Tilley's bioarchaeology of care refers to the examination of physical evidence through archaeological findings to infer details regarding past caregiving practices (Tilley, 2015, p. 1). According to Tilley, in order to use this approach, the chosen skeletal remains must reveal evidence of survival or rehabilitation from a debilitating illness attributed to external aid.

Archaeological healthcare remains an underdeveloped topic, as many archaeologists focus on the evolution and frequency of pathology rather than the evolution of treatment (Tilley, 2015). In her book *Theory and Practice in the Bioarchaeology of Care*, Dr. Lorna Tilley explains that the main objection to this type of investigation is that "retrospective analysis of such complex behaviour (sic) will invariably result in the researcher ascribing modern (western) understandings of disability and modern (western) values and motivations to the actors and actions of the past" (2015, p. 8). For this reason, many believe it is impractical to reach an indeterminate conclusion based solely on skeletal remains and cultural evidence. Despite not being able to confirm our interpretations, it would be unstimulating not to attempt to understand what could give us more insight into past cultural values, skills, social classes, etc. With this being said, if a researcher chooses to investigate this topic further, it is vital that the researcher is transparent with their methodology and justifies their reasoning to the best of their ability.

After seeing the lack of research concerning care provision in bioarchaeological remains, Dr. Lorna Tilley proposed the bioarchaeology of care approach with the intent of making investigation into the topic more structured. The methodology consists of four stages:

1. Record and diagnosis.
2. Assessment of pathology to determine if care is needed.
3. Identification remedies and care.
4. Interpretation of past customs, social classes, and beliefs.

Stage one consists of documenting every aspect of the individual's remains, the diagnosis, and the environment. Stage two uses modern clinical knowledge and the information from Stage one to consider if the disability would require modern care and if the disability impeded the individual's daily functions resulting in accommodation. Stage three identifies possible treatments based on cultural context. A basic model of care is created during this step. Step four construes information from steps one through three to suggest new information on contemporary social interaction and care-recipient identity. This approach serves as the most conclusive way to reconstruct patient care in a civilization.

Application of Bioarchaeology of Care

Various applications of Tilley's model have emerged since its publication. In an investigation conducted on a disabled elderly female skeleton from the archaeological site of Pachacamac, Peru, archaeologists Martha R. Palma Málaga and Krzysztof Makowski (2019) were able to propose a diagnosis and a potential method of care based on the individual's pathology-induced lesions. The elderly female, with the assigned name "H3-CF3" was thought to belong to an early Ychsma (AD 900 – 1100) *ayllu* based on pottery associated with the burial. Málaga and Makowski used a modified version of Tilley's methodology by discussing disease diagnoses and proposed care provisions (stages one through three) in one section instead of in individual stages. Based on the presence of the cervical ribs and lesions in the right shoulder joint, the researchers concluded that the individual most likely suffered from Thoracic Outlet Syndrome (TOS). Málaga and Makowski used modern clinical literature (Roos, 1996; Davidovic et al., 2003; Kirgis & Reed, 1948; Molina and D'Cuhna, 2008) to support their conclusion: "1 in 10 people who have cervical ribs develop TOS" (p. 146). Due to the pain, loss of sensation, and secondary pathology often associated with this compression on the thoracic outlet (the lower neck and/or upper chest area), the researchers suggested that the functionality in the individual's right arm and/or shoulder might have been impacted. With this being said, the researchers did recognize that 50-70% of individuals with this syndrome remain asymptomatic (Roos, 1996).

The researchers also made note of arthritic changes on the surface of the right humeral head, glenoid cavity, and acromion. The researchers recognized the several factors that may have contributed to the observed osteoarthritis (age, genetics, sex, obesity, trauma, etc.), and concluded that the overuse of the joint was most likely the cause. They eliminated the other factors by considering the absence of fractures and pathology on other parts of the body. The researchers ended their discussion by making note of the simple, yet specific burial treatment that further supported that the individual did receive special care to treat her ailments while she was alive.

Past Healthcare Practices

In general, there exists limited knowledge of past healthcare practices in the archaeological record. Additionally, evidence for existing remedies is different based on culture and location, varying from animal and plant-based medicine to magic to innovative surgery. Within a tribe of hunter-gatherers in South Africa, it had been documented that they used granulated ostrich shells to treat fever, diarrhea, and stomach pain (Low, 2011). In Maglemose and Ertebølle sites in Germany, eroded animal bone remains suggested that fine bone powder had also been used for medicinal purposes (Lage, 2009). In ancient Peru, evidence suggests that they may have used hallucinogenic herbs as a form of medicine (Merlin, 2003). Another study used the bioarchaeology of care model to suggest the unsuccessful application of a postcranial surgical treatment for curative purposes (Toyne, 2015). With this being said, it is worth noting the abundance of research that investigates successful trepanation in the Andes (Verano, 2003; Weiss, 1953; Weiss, 1961). Such evidence suggests that Andean practitioners had a considerable understanding of healing, medicine, and physiology in order to consistently perform successful trepanations. Lastly, objects left in burial grounds from 11th to 15th century Britain reflect the strategic use of folk magic to "heal or reconstitute the corpse" (Gilchrist, 2008).

Past Oral Health Practices

To provide a more detailed definition, *dentistry* refers to the, "art of (a) preventing, curing or alleviating conditions of disease, and of repairing defects of teeth, jaws or closely adjacent oral tissues, by hygienic, surgical, medicinal or mechanical treatment or procedure; and by similar means of (b) preventing, removing or diminishing the consequences of deformity, derangement or abnormal relationship of teeth, jaws or closely adjacent oral tissues; and of, (c) obtaining impressions and models for artificial restorations or mechanical modification of dental or oral parts that have been rendered deficient, or which have been removed, by disease, accident, violence or surgical intervention, including the functional and esthetic placement of the appliances or substituted" (Miner, 1995, p. 6).

The first evidence of a "dentist" was found in the hieroglyphic inscriptions of ancient Egyptian tombs: Hesyre, who lived around 2660 BC. (Forshaw, 2009). Evidence of dental interventions is scarce within ancient Egyptian human remains. In some instances, researchers have suggested possible extractions and prosthetic work. However, these claims have been readily countered. For example, a study of an ancient Egyptian mandible from around 2,500 BC showed two holes "penetrating the outer cortical plate above the mental foramen," most likely resulting from artificial drillings (formed by a bow drill) to "drain the pus from the nearby apical abscess" (Forshaw, 2009, p. 482). Arguments against this proposed that a hole of that angle could only be drilled with technology that was not yet available. An example of prosthetic manipulation documented from ancient Egypt consisted of "a mandibular second molar connected by gold wire to a worn third molar" found in Cairo, dating to approximately 2,500 BC (Forshaw, 2009, p. 483). Researchers concluded that it was most likely placed to stabilize a tooth that had become mobile due to pathology. Others disputed this stance by mentioning how it could not be confirmed that the teeth came from the same individual due to excessive tooth wear.

Within the medical papyri, there exists no evidence of manual manipulation; instead, prescriptions and therapeutic remedies are mentioned. Evidence for later-dated treatments consists of herbs for pain relief, drilling for caries removal, rudimentary forms of toothpicks for ordinary oral hygiene, and beeswax as dental fillings (Oxilia et al., 2015). Despite earlier evidence of dental care in locations outside of the Central Andes, evidence of dental care in Peru could serve as more relevant references for this research. But first, general oral health in the region must be considered.

Oral Health in Peru

In general, the bioarchaeology of oral health has been extensively investigated in the Central Andes, the location of interest for this research. In the study "Interpreting Oral Pathology at Machu Picchu, Peru," Turner (2015) examines the relationship between caries prevalence and diet through the analysis of oral pathology in individuals from the Late Horizon (1400-1535 AD) Inca estate of Machu Picchu. Turner (2015) chose a study sample based on the presence of permanent molars for isotopic analysis and bone collagen isotopic values set by Burger et al. (2003). The bioarchaeologist used a fluorescent magnifier light (and a dental probe when necessary) and scored the teeth per the criteria in Buikstra and Ubelaker (1994) to identify tooth caries, abscesses, and antemortem tooth loss (AMTL). She concluded that the corrected caries prevalence (CCP) for her subpopulation was 21% (with a comparable observed prevalence of 16% by individuals), higher than reports in the Peruvian coast. Turner also noted the higher prevalence of caries in older females compared to younger females, suggesting that the diet in later years influenced caries formation more than in earlier years. According to Turner (2015), this finding can be attributed to the heavier consumption of high-protein grains and plants.

In the study "The usefulness of caries frequency, depth, and location in determining carcinogenicity and past subsistence: A test on early and later agriculturalists from the Peruvian coast," Pezo-Lanfranco and Eggers (2010) describe oral pathology patterns among four pre-Hispanic samples (three belonging to certain phases of the Formative Period and the fourth belonging to the LIP) from two sites in the Peruvian Coast to determine if the development of agriculture impacted oral health. Pezo-Lanfranco and Eggers (2010) collected data on 5,662 teeth and 7,551 alveoli (from 263 individuals) by recording the total number of teeth, carious teeth, AMTL, and caries depth with the use of a dental probe. The researchers found an insufficient frequency of carious lesions, preventing them from analyzing carious patterns between the two periods. However, the researchers did notice an increase within two phases of the Formative Period, followed by a decrease in the LIP. In terms of caries depth, the researchers found that a trackable enamel caries pattern was not observed, the frequency of dentine caries increased with time, and the frequency of pulper caries decreased with time. Pezo-Lanfranco and Eggers (2010) concluded that "simple frequencies of carious lesions and AMTL are insufficient in reflecting known differences in agricultural development" (p. 89) and that many factors must be considered for such investigation.

In the study "Oral pathology patterns in late farmers of the Central Andes: A comparative perspective between coastal and highland populations," Pezo-Lanfranco et al., (2017) describe oral pathology patterns among four burial sites (three of them corresponding to the LIP and one of them corresponding to the Inca Period) to reconstruct the oral health of late agriculturalists and determine differences in oral health in coastal and highland populations. The researchers analyzed the skeletonized and mummified human remains of 303 individuals (7933 alveoli and 5593 teeth), ensuring that each individual had no less than 50% of alveoli and teeth present. To describe oral health in this investigation, the researchers used 14 oral pathology markers (caries and AMTL frequency, prevalence of periodontal disease, dental wear index, etc.). Through their investigation, the researchers defined the oral pathology patterns of the late Andean farmers as “(a) a high proportion of extra-occlusal caries (above 60%); (b) the predominance of large proportions of cervical caries (above 30%) in the posterior sector of maxilla and mandible, and (c) high rates of gross-gross caries (more common in the posterior sector of maxilla) associated with large amounts of periapical lesions and AMTL (more common in posterior sector)” (p. 357). The researchers concluded that due to the more abrasive and carcinogenic diet, the caries frequency in the coastal populations was more intense compared to the frequency in the highland population.

Past Oral Health Practices in Peru

It is also crucial to acknowledge the first signs of dentistry (dental treatment to preserve oral heath) around the South American region. Reports of dental implants comprised of metals and animal bones, complete tooth extractions (Ortiz et al., 2016), and medicinal plants for pain alleviation from oral diseases (Cobo, 1964) reflect the skill for initial developments of dentistry in Peru. With this being said, most of the archaeological evidence of intentional dental modifications found from pre-Colombian Peru is believed to be associated with ritualistic, decorative, or disciplinary purposes rather than therapeutic reasons.

In the study “First evidence of pre-Hispanic dentistry in South America – Insights from Cusco, Peru,” Ortiz et al., (2016) present strong evidence for what they claim is the first evidence of prehistoric dentistry in pre-hispanic America. This investigation is based on the skeletal remains of two individuals dating from the Late Horizon Period from Cusco, Peru. Due to the “central location of the perforations on the incisal surface, the internal grooves and deep marks along the walls of the perforations, and the morphology of the pulp chambers” (p. 103), Ortiz et al. (2016) have concluded that these abnormalities were the product of intentional dental manipulation. Despite the lack of written accounts of remedial oral treatments in ancient Peru, evidence of dentistry in this region implies that dental care was provided for those in need of it.

Andean Context and the Túcume Archaeological Site

Geographical Context

Túcume, the location of interest is found along the northern coast of Peru (located in a region most known as the "Central Andes") (Heyerdahl et al., 1995). With the Pacific Ocean to the west of this desert and the Central Andes to the east, this 2,000-km long coast is characterized by "a narrow belt of sand, open beaches, and rocky cliffs (Heyerdahl et al., 1995, p. 9). The geographic location of Túcume relative to the Central Andes can be observed in Figure 2. Túcume is located roughly 28 km north of the modern center of the Lambayeque Valley (Chiclayo) and remains a well-preserved archaeological site (Heyerdahl et al., 1995). This location differs from the rest of the foothills of the Andes as its coastal plain increases in width and valley size rather than narrowing down until it reaches the shore (Heyerdahl et al., 1995).

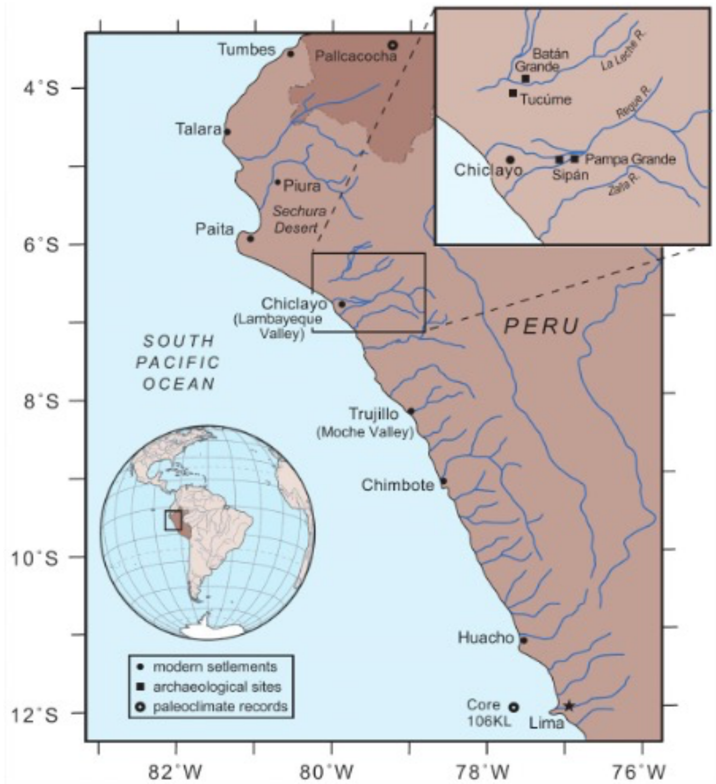


Figure 2. Location of Túcume on map of Peru (Sandweiss & Maasch, 2022, Figure 1 p. 3).

Historical Context

The individuals analyzed in this thesis belonged to the Late Intermediate Period (LIP). The LIP dates from AD 1000 to 1450, following the collapse of the Tiahuanaco and Wari empires, until the rise of the Inca empire (Heyerdahl et al., 1995). This era is known for its radical changes in the Lambayeque area regarding pottery, settlement pattern, and the representation of the previously idolized Sicán Lord (Heyerdahl et al., 1995). AD 1350 marks the Lambayeque region's conquest of the Chimú Empire of the Moche Valley, adding Chimú-inspired pottery (without replacing traditional pottery) and ruling through local lords (Heyerdahl et al., 1995). Following the Chimú rule, the Inca armies conquered this area (Heyerdahl et al., 1995). Later, the Spanish took rule and eventually Túcume was burned down (Heyerdahl et al., 1995).

Túcume Site

Túcume is a rather large site, estimated to cover 540 acres and is known for its man-made pyramids (Heyerdahl et al., 1995). Many of these pyramids are now eroded, leaving only remnants of these once colossal buildings (Heyerdahl et al., 1995). Today, this “naked wilderness” is referred to as *El Purgatorio* (Heyerdahl et al., 1995).

A distinct feature of Túcume is the 26 platform mounds encircling a hill known today as *Cerro La Raya* (Heyerdahl et al., 1995). Through excavation, archaeologists have revealed that these mounds served as the location of residence and ceremonial activities, suggesting a form of a local authority and social hierarchy (Heyerdahl et al., 1995).

Social Organization at Túcume

Understanding the social organization at Túcume can help with the interpretation of social interactions. Under the Spanish rule, the basic unit of Andean social organization was the *ayllu* (Heyerdahl et al., 1995). The investigation of open tombs has allowed researchers to isolate the origin and track the spread of *ayllu* organization (Shimada 2000). In other words, burial content may provide insight on social structure at Túcume (Heyerdahl et al., 1995). These investigations have shown that high-status individuals did exist, as evidenced by their elite burial traditions (Heyerdahl et al., 1995).

If burial contents reflected the wealth of an individual while they were alive, burial sites could serve as indicators for social status (Shimada et al. 2004), which would allow for the investigation of pathology among individuals of difference social classes. However, this investigation does not consider social class as a variable and, therefore, social class will not be explored.

Diet and Agriculture at Túcume

To evaluate the need for oral care at Túcume, diet should be considered since it plays a significant role in oral health. Many polities in the northern coast of Peru took advantage of their proximity to the ocean (Covey, 2008). Their geology allowed coastal settlements to depend on valley-bottom agriculture and marine resource exploitation, preserving a hydraulic agriculture system from earlier societies (Covey, 2008).

Investigation into Sector V at Túcume provided specific information regarding their potential food sources (Heyerdahl et al., 1995). Faunal and palaeobotanical remains such as squash, avocados, peanuts, sapote, maize, dogs, camelids, duck, deer, clams, crustaceans, and conches were just some of the most frequently recovered remains at the site. Such evidence should be taken into consideration as diet could correlate with patterns of oral health in Túcume. Additional research found that the individuals buried at Huaca Las Abejas "consumed a high percentage of C4 plants," the most abundant plant source being maize (Smith, 2021, p. 114).

Burial Sites at Túcume

Each one of Túcume's burial sites provides an opportunity to learn more about their society. The burial sites explored in this thesis include Cementerio Sur/Los Gavilanes (Cem Sur/LG), Huaca 1/Huaca Larga (H 1/HL), and Huaca Abejas/Las Balsas (HA/LB). Figure 3 shows a general map of Túcume with labels to indicate the locations of Huaca Larga and Huaca 1 (and Temple of Sacred Stone). Huaca Larga is a "700-m long raised platform" with ramps and a number of subdivisions (Heyerdahl et al., 1995, p. 79). Ramps were common in the old north coast (Heyerdahl et al., 1995). Huaca 1 "is the tallest of the man-made Túcume pyramids, measuring over 30 m above current ground level" and characterized by its L-shaped lower platform (Heyerdahl et al., 1995).

As previously mentioned, the burial contents at Túcume do show evidence of differences in social status (Heyerdahl et al., 1995). It should be emphasized, however, that the burial contexts analyzed in this thesis were grouped together based on proximity as cemetery units, not specific social status groups.

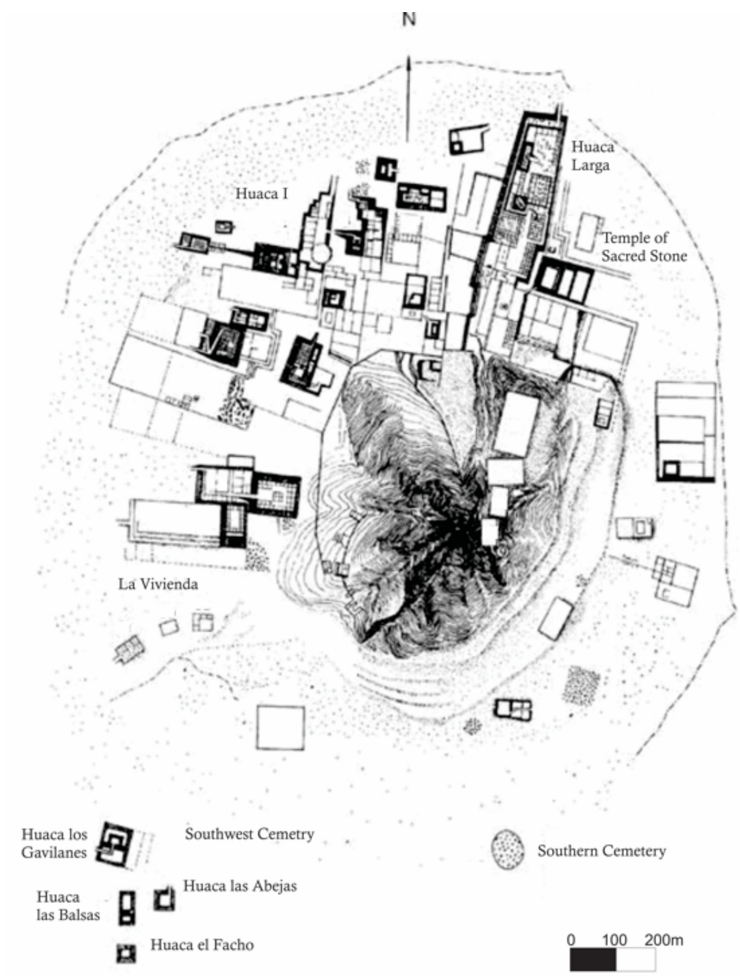


Figure 3. General map of Túcume with the location of Huaca 1, Huaca Larga, and the Temple of Sacred Stone labeled (modified from Heyerdahl et al., 1995, Figure 33, p. 78).

Bioarchaeological Research at Túcume

As previously mentioned, remains at Túcume are generally well-preserved, which has allowed for a great deal of research to be conducted at this archaeological site. Ritual violence (Toyne, 2015), migration (Hewitt, 2013), diet (Smith, 2021), etc. has been researched in Túcume, providing strong foundational knowledge of what life could have been like at Túcume.

Summary

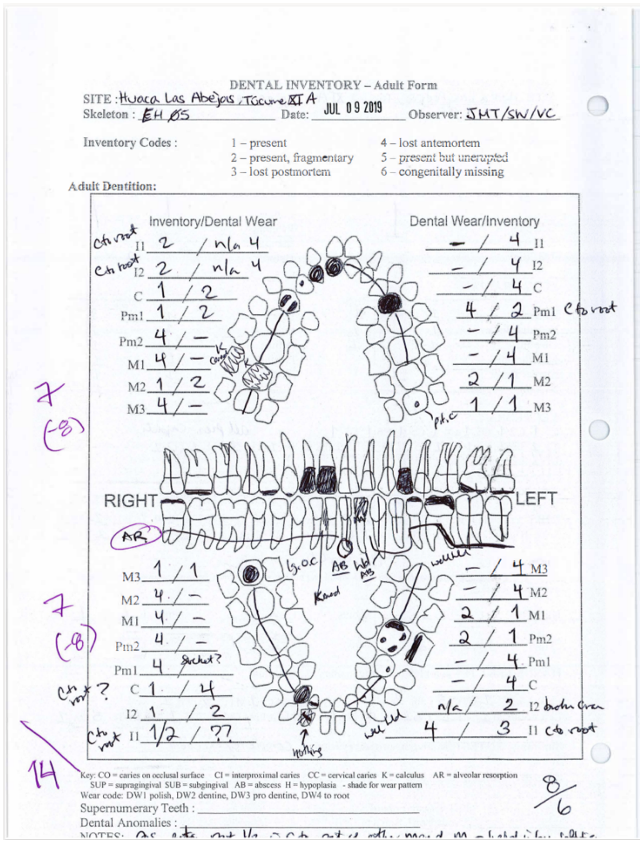
By observing evidence of ailment in human skeletons, we can use the bioarchaeology of care approach to make a possible diagnosis and theorize the care that might have been provided to these individuals. Teeth are especially ideal for bioarchaeological inquisition due to their high degree of archaeological preservation, attributed to their mineralization composition. This research utilizes teeth from the archaeological site of Túcume. Understanding the historical and social context of Túcume can is necessary for this analysis of early possible dentistry in Pre-Hispanic Peru.

CHAPTER 3: METHODOLOGY

The purpose of this research is to use the presence of antemortem tooth loss (AMTL) and caries as a possible indication of early dentistry in Pre-Hispanic Peru. To do so, this investigation utilized a quantitative approach through the scoring of individual teeth within skeletal remains, followed by a correlational study through statistical analysis. This chapter establishes the specific materials, data collection, and data analysis guiding the process.

Materials

This research used a subsample of data (dental observations) of skeletal remains from Túcume, Peru, provided by Dr. J. Marla Toyne. The original number of excavated human skeletal remains (n = 507) was narrowed down to only include adult individuals with complete dentition (n = 57). Adults were selected for this sample due to the consistency of their dentition. It must be emphasized that this research did not involve direct contact with human remains; instead, it analyzed prepared datasheets created by Dr. Toyne that provide AMTL and caries observations (along with dental wear) per individual. Dr. Toyne also made note of the state of skeletal preservation and any important observations made on the cranium and teeth. Photos of individual dentition were used as a supplement to identify and describe dental pathology more accurately. Dr. Toyne's datasheet was further quantified and catalogued to better suit the testable research questions. Figure 4 shows an example of a prepared datasheets that was used to score the individual T-SO HAb XIa EH05. Figure 5 shows one of photos taken of the skeletal remains of individual T-SO HAb XIa EH05 that were used as a supplement for scoring.



DENTAL INVENTORY – Adult Form

SITE : Huaca Las Abejas, Tácume XI A
Skeleton : EH 05 Date: JUL 09 2019 Observer: JMT/SW/VC

Inventory Codes : 1 – present; 2 – present, fragmentary; 3 – lost postmortem; 4 – lost antemortem; 5 – present but unerupted; 6 – congenitally missing

Adult Dentition:

Inventory/Dental Wear		Dental Wear/Inventory	
I1	2 / n/a 4	– / 4	I1
I2	2 / n/a 4	– / 4	I2
C	1 / 2	– / 4	C
Pm1	1 / 2	4 / 2	Pm1
Pm2	4 / –	– / 4	Pm2
M1	4 / –	– / 4	M1
M2	1 / 2	2 / 1	M2
M3	4 / –	1 / 1	M3

7 (-8)

RIGHT LEFT

AR

M3	1 / 1	– / 4	M3
M2	4 / –	– / 4	M2
M1	4 / –	2 / 1	M1
Pm2	4 / –	2 / 1	Pm2
Pm1	4 Socket?	– / 4	Pm1
C	1 / 4	– / 4	C
I2	1 / 2	n/a / 2	I2
I1	1/2 / ??	4 / 3	I1

7 (-8)

14

Key: CO = caries on occlusal surface CI = interproximal caries CC = cervical caries K = calculus AR = alveolar resorption SUP = supragingival SUB = subgingival AB = abscess H = hypoplasia - shade for wear pattern
Wear code: DW1 polish, DW2 dentine, DW3 pro dentine, DW4 to root
Supernumerary Teeth :
Dental Anomalies :

8/6

Figure 4. Example of a prepared datasheets of individual T-SO HAb XIa EH05 (from Dr. Toyne, recorded in 2019).

Figure 5. Photo of the skeletal remains of individual T-SO HAb XIa EH05 (from Dr. Toyne, recorded in 2019).

Methodology

Research of AMTL and caries at Túcume requires the data to be divided into two parts: the analysis per individual and the analysis for each tooth type. Both analyses require the count of AMTL and caries in each dentition. It should be restated that the presence of dental caries is considered in the investigation as it may have served as the precursor condition to tooth ablation. As Hillson (2008) notes, populations with higher occurrences of caries are more likely to suggest that the extractions of heavily affected teeth.

To begin, the sample was categorized into groups depending on sex estimate category, age estimate category, and burial context. Sex was estimated to be female (F), male (M), or indeterminate (IND). Age category includes young adult (20 – 35 years) denoted as YA, middle-aged adult (35 – 50 years) denoted as MA, and old adult (over 50 years) denoted as OA (Buikstra and Ubelaker, 1994). Burial context is divided based on location of the site (Huaca Abejas and Huaca Las Balsas), (Huaca Larga and Huaca I), and (Cementerio Sur and Cementerio Los Gavilanes). Tables 1, 2, and 3 show the distribution between the different variables.

Table 1. Sample distribution based on sex and age.

Sex/age	F	M	IND	Total
YA	14	13	0	27
MA	11	15	1	27
OA	3	0	0	3
Total	28	28	1	57
Mean age of death	35.82	34.86	37	34.72

Table 2. Sample distribution based on burial and age.

Burial/age	YA	MA	OA	Total
Cem Sur/Los Gavilanes	2	4	0	6
H 1/H Larga	14	7	0	21
H Abejas/Las Balsas	11	16	3	30
Total	27	27	3	57

Table 3. Sample distribution based on burial and sex.

Sex/burial	F	M	IND	Total
Cem Sur/Los Gavilanes	2	4	0	6
H 1/H Larga	13	7	1	21
H Abejas/Las Balsas	13	17	0	30
Total	28	28	1	57

Next, a table was created to record dental variation for each individual. Each row includes their estimated sex, age category, burial context, and the AMTL and caries score for each tooth. An inventory code accounts for the range of a tooth's condition: 1 (present), 2 (fragmented), 3 (postmortem tooth loss), 4 (antemortem tooth loss), 5 (unerupted), and 6 (congenitally absent). Meanwhile, the caries code uses 0 for the absence of caries and 1 for the presence of caries. If the tooth was missing (recorded as a score of 3, 4, 5, or 6), "N/A" as not available would take the place of a 0 or a 1. Table 4 is an example of the master Excel® worksheet that was used to input the data of all individuals. In this table, the teeth are abbreviated based on the location of the mouth and tooth type and further separated by AMTL and caries. The tooth type is abbreviated in accordance with the Anthropological System of classifying teeth where incisors are denoted as I, canines a C, premolars as P, and molars as M (Gellis et al., 2021). For example, RU3MI is an abbreviation for right upper third molar inventory for the AMTL score, and RU3MC is an abbreviation for right upper third molar caries for the caries score.

Table 4. Example of data recording spreadsheet.

				Inventory	Caries	Inventory	Caries	Inventory	Caries
Individual ID	**Context**	**Sex**	**Age Category**	**RU3MI**	**RU3MC**	**RU2MI**	**RU2MC**	**RU1MI**	**RU1MC**
T CS IA E3	Cem Sur	M	YA						
Tuc-H1 IVi c6 Ent4	H 1	M	MA						
Tuc-H1 IVi c6 Ent5	H 1	IND	MA						

Descriptive Analysis

The first descriptive analysis examines the mean, median, and mode of AMTL and caries for the entire sample, all categories of each variable, and the tooth type. This is done by isolating the count of AMTL and caries for each individual and inserting these values into an Excel spreadsheet with the corresponding functions. This descriptive analysis could be done manually, but Excel® is used to ensure accuracy.

The second descriptive analysis examines the frequency of pathology of dentition per individual/group. For antemortem tooth loss, this requires the summation of all the "4" scores found under the "Inventory" column; for caries, this requires the summation of all the "1" scores found under the "Caries" column. To calculate the frequency of AMTL for each individual, the number of AMTL observed is divided by 32 (the maximum number of teeth possible). To calculate the frequency of caries for each individual, the number of caries observed is divided by the total number of teeth observed for that individual.

The frequency of AMTL per sex, age estimate, and burial context variable was calculated by dividing the total AMTL observed by the maximum number of teeth the variable could have

(32 times number of individuals). The frequency of caries per variable was calculated by dividing the total caries observed throughout a variable by the total teeth observed for that variable.

The third descriptive analysis focuses on the frequency of AMTL and caries for each tooth. The frequency of pathology in each alveolar (maxilla and mandible) and grouped by tooth type (incisors, canines, premolars, and molars) was also taken into consideration.

The frequency of AMTL for each tooth type was calculated by dividing the total AMTL observed by the maximum number of each tooth type (57, equivalent to the number of individuals). The frequency of caries per variable was calculated by dividing the total caries observed by the total teeth present for each tooth type.

It must be emphasized that this research focuses on the frequency of AMTL and caries rather than the severity. Table 5 provides an example of the table that includes mean, median, and mode for the sample, Table 6 displays these descriptive analyses for each variable, and Table 7 displays them for a given tooth. Tables 8, 9, 10 provide an example of the frequency statistics table for each variable. For clarification, N is the total number of possible pathological teeth. Specifically, N for AMTL was calculated by multiplying 32 (number of teeth in typical dentition) by 57 (number of individuals). N for caries was calculating by adding the total number of teeth present (the total number of “1” or “present" for that variable).

Table 5. Empty table of summary statistic of descriptive analysis for sample.

		Mean	**Median**	**Mode**
Sample	AMTL			
	Caries			

Table 6. Empty table of descriptive statistics for all categories for each variable.

			Mean	Median	Mode
Sex	M	AMTL			
		Caries			
	F	AMTL			
		Caries			
	IND	AMTL			
		Caries			
Age	YA	AMTL			
		Caries			
	MA	AMTL			
		Caries			
	OA	AMTL			
		Caries			
Burial Context	Cem Sur/Los Gavilanes	AMTL			
		Caries			
	H 1/Huaca Larga	AMTL			
		Caries			
	H Abejas/Las Balsas	AMTL			
		Caries			

Table 7. Empty table of descriptive statics based on a given tooth.

		Mean	Median	Mode
Tooth type	AMTL			
	Caries			

Table 8. Empty table of frequency statistics by sex.

	Males			**Females**			**IND**			**Total**		
	N	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**
AMTL												
Caries												

Table 9. Empty table of frequency statistics by age group.

	YA			MA			OA			Total		
	N	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**
AMTL												
Caries												

Table 10. Empty table of frequency statistics by burial context.

	Cem Sur/Los Gavilanes			H 1/H Larga			H Abejas/Las Balsas			Total		
	N	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**
AMTL												
Caries												

Statistical Analysis

To perform the statistical analyses, the R statistical program (R Core Team, 2023) was utilized. Specifically, the base, datasets, graphics, grDevices, methods, stats, and utils packages were used.

The first statistical analysis (Fisher's exact test) compares experimental data to a null hypothesis and calculates the p-value to failt to reject or reject the null hypothesis (Otárola-Castillo & Torquato, 2018). A p-value of 0.05 or greater will be deemed insignificant and will result in the rejection of the null hypothesis. These p-values should be adjusted to account for the increased risk of making a Type I error (a false positive) from multiple testing. Adjustments were conducted using the Hochberg procedure. The second statistical analysis (Cramer's Vtest) shows the strength of association between two variables. The final statistical analysis (Pairwise Fisher's Exact test) helps estimate which specific pairs of proportions (associations) are significant (Taeger & Kuhnt, 2014). These statistical analyses allow for the comparison of observed data versus expected data due to chance and aid with the comprehensive investigation of AMTL and caries found at Túcume.

Summary

To investigate presence of dental care at Túcume, I completed two sets of descriptive statistics and one set of analytical statistics for the different variables connected to my primary hypotheses. The descriptive statistics consisted of calculating the frequency of pathology per individual and tooth type (which was used to create a summary statistic). The analytical statistics required R programming to determine chi-square and comparative significance.

CHAPTER 4: RESULTS

This chapter presents the results of the descriptive and analytical analyses exploring the frequency and correlation between dental pathology and sex, age, and burial context at Túcume.

Descriptive Analysis

Sample-wide Counts

An individual with an inventory score of 4 indicated the presence of AMTL in their dentition, while a caries score of a 1 indicated the presence of caries. Both scores indicate the presence of dental pathology. The AMTL and caries scoring for each individual's teeth can be found in Appendix A. This extensive table also includes the sex, age, and burial context. The counts of AMTL and caries for each individual can be found in Appendix B, where the AMTL count varied from 0 to 32 and the caries count varied from 0 to 9. Out of 57 individuals, 37 of them had at least one tooth lost antemortem (64.9% of the sample experienced AMTL), while 55 of them had at least one caries within their dentition (96.5% of the sample). Table 11 summarizes the total count of each tooth status with its corresponding inventory code, indicating that 416 teeth out of the entire sample were lost antemortem. Table 12 summarizes the total count of each caries status with its corresponding caries code, indicating that 140 teeth out of the entire sample displayed carious lesions. Based on the total counts of pathology for each individual, Table 13 presents the mean, median, and mode (descriptive analysis) of pathology for the entire sample, showing that each individual had an average of 7.30 teeth lost antemortem and an average of 2.46 teeth with evidence of carious lesions.

Table 11. Total count of AMTL status for sample.

Pres	Frag'd	PMTL	AMTL	Unerupt	Congen
1	2	3	4	5	6
1075	84	214	416	3	32

Table 12. Total count of caries status for sample.

Absent	Present	n/a
0	1	n/a
1019	140	665

Table 13. Summary statistic of descriptive analysis for sample.

		Mean	Median	Mode
Sample	AMTL	7.30	3.00	0.00
	Caries	2.46	1.00	0.00

The frequency of pathology (AMTL and caries) for each individual can be found in Appendix C. The frequency of AMTL ranged from zero percent (no evidence of AMTL) to one hundred percent (an edentulous individual), with approximately thirty percent (17/57) of individuals with an AMTL frequency of 25.00% or greater and thirty-five percent (20/57) of individuals with an AMTL frequency of 0.00%. The frequency of caries ranged from zero percent (no evidence of caries) to fifty-seven point fourteen percent (over half of the teeth with evidence of caries), with nineteen point three percent (11/57) of individuals with a caries frequency of 25% or greater and 38.60% (22/57) of individuals with a caries frequency of 0%.

Tooth Type Counts

The frequency of pathology for types of teeth was also analyzed to determine which tooth type experienced the most pathology. Table 14 displays the pathology counts and frequencies of each tooth type of the maxilla (both left and right antimeres are counted together). In the maxilla, first molars were shown to have the highest frequency of AMTL (30.70%) and caries (19.44%). Canines had that lowest frequency of AMTL (16.67%), and second premolars had the lowest frequency of caries (7.35%). Table 15 displays the pathology counts and frequencies of each tooth type of the mandible (both left and right antimeres are counted together). In the mandible, third molars were shown to have the highest frequency of AMTL (38.60%) and caries (29.17%). Canines had the lowest frequency of AMTL (10.53%), and central incisors had the lowest frequency of caries (4.29%). Pathology of the mandible and maxilla were considered separately to identify patterns between the upper and lower teeth. Table 16 displays the pathology counts and frequencies of each tooth type for all four quadrants: all third molars (3M), second molars (2M), first molars (1M), second premolars (2PM), first premolars (1PM), caries (C), lateral incisors (LI), and central incisors (CI). Out the entire dentition, third molars had the highest frequency of AMTL (33.77%) and caries (22.45%). Canines had the lowest frequency of AMTL (13.60%), and central incisors had the lowest frequency of caries (6.57%). Table 17 presents the mean, median, and mode (descriptive analysis) of pathology among tooth type, showing that a given tooth had an average of 13 individuals that lost it antemortem and 4.38 individuals showing evidence of carious lesions.

Table 14. Table of pathology count and frequency of tooth type in maxilla.

	U3M		U2M		U1M		U2PM		U1PM		UC		ULI		UCI	
	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries
Total Count	33	8	33	12	35	14	32	5	25	11	19	12	21	9	25	6
Total Possible	114	50	114	73	114	72	114	68	114	75	114	78	114	67	114	67
%	28.95	16.00	28.95	16.44	30.70	19.44	28.07	7.35	21.93	14.67	16.67	15.38	18.42	13.43	21.93	8.96

Table 15. Table of pathology count and frequency tooth type in mandible.

	L3M		L2M		L1M		L2PM		L1PM		LC		LLI		LCI	
	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries
Total Count	44	14	39	10	34	9	17	13	13	6	12	6	14	2	20	3
Total Possible	114	48	114	67	114	74	114	87	114	89	114	88	114	86	114	70
%	38.60	29.17	34.21	14.93	29.82	12.16	14.91	14.94	11.40	6.74	10.53	6.82	12.28	2.33	17.54	4.29

Table 16. Table of pathology count and frequency of tooth type in the mouth.

	3M		2M		1M		2PM		1PM		C		LI		CI	
	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries	AMTL	Caries
Total Count	77	22	72	22	69	23	49	18	38	17	31	18	35	11	45	9
Total Possible	228	98	228	140	228	146	228	155	228	164	228	166	228	153	228	137
%	33.77	22.45	31.58	15.71	30.26	15.75	21.49	11.61	16.67	10.37	13.60	10.84	15.35	7.19	19.74	6.57

Table 17. Summary statistic of descriptive analysis for tooth type.

		Mean	**Median**	**Mode**
Tooth type	AMTL	13.00	12.50	17.00
	Caries	4.38	4.00	5.00

Variable-specific Counts

The pathology count was also broken down by variables (sex, age, and burial context). Table 18 displays the total count and frequency of AMTL and caries based on sex. It was discovered that males had the highest frequency of AMTL (25.00%), while IND had the lowest (9.38%). IND had the highest frequency of caries (25.00%), while females had the lowest

(7.91%). Table 19 displays counts based on age. Older adults had the highest frequency of AMTL (81.25%), while young adults had the lowest (6.37%). Middle-aged adults had the highest frequency of caries (19.75%), while older adults had the lowest (0.00%). Table 20 displays counts based on burial context. Huaca Abejas/Las Balsas had the highest frequency of AMTL (34.06%) and caries (18.62%). Meanwhile, Huaca 1/Huaca Larga had the lowest frequency of AMTL (6.85%), and Cementerio Sur/Los Gavilanes had the lowest frequency of caries (3.26%). Table 21 presents the mean, median, and mode (descriptive analysis) of pathology throughout all variables. For the sex variable, males had the highest average of AMTL (8.00) and caries (3.29), while IND had the lowest average of AMTL (3.00) and caries (1.00). For the age variable, middle-aged adults had the highest average of AMTL (10.48) and caries (3.48). Young adults had the lowest average of AMTL (2.04), and older adults had the lowest average of caries (0.00). For the burial context variable, Huaca Abejas/Las Balsas had the highest average of AMTL (10.90) and caries (3.50). Huaca 1/Huaca Larga had the lowest average of AMTL (2.19), while Cementerio Sur/Los Gavilanes had the lowest average of caries (0.50).

Table 18. Table of pathology count and frequency based on sex.

	Males			**Females**			**IND**			**Total**		
	N	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**
AMTL	896	224	25.00	896	189	21.09	32	3	9.38	1824	416	22.81
Caries	561	92	16.40	594	47	7.91	4	1	25.00	1159	140	12.08

Table 19. Table of pathology count and frequency based on age.

	YA			MA			OA			Total		
	N	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**
AMTL	864	55	6.37	864	283	32.75	96	78	81.25	1824	416	22.81
Caries	666	46	6.91	476	94	19.75	17	0	0.00	1159	140	12.08

Table 20. Table of pathology count and frequency based on burial context.

	Cem Sur/Los Gavilanes			H 1/H Larga			H Abejas/Las Balsas			Total		
	N	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**	**N**	**n**	**%**
AMTL	192	43	22.40	672	46	6.85	960	327	34.06	1824	416	22.81
Caries	92	3	3.26	503	32	6.36	564	105	18.62	1159	140	12.08

Table 21. Summary statistic of descriptive analysis among all variables.

			Mean	**Median**	**Mode**
Sex	M	AMTL	8.00	4.50	0.00
		Caries	3.29	2.50	0.00
	F	AMTL	6.75	1.50	0.00
		Caries	1.68	0.50	0.00
	IND	AMTL	3.00	3.00	N/A
		Caries	1.00	1.00	N/A
Age	YA	AMTL	2.04	0.00	0.00
		Caries	1.70	1.00	0.00
	MA	AMTL	10.48	7.00	1.00
		Caries	3.48	2.00	0.00
	OA	AMTL	4.14	28.00	N/A
		Caries	0.00	0.00	0.00
Burial Context	Cem Sur/Los Gavilanes	AMTL	7.17	2.50	0.00
		Caries	0.50	0.00	0.00
	H 1/Huaca Larga	AMTL	2.19	0.00	0.00
		Caries	1.52	1.00	0.00
	H Abejas/Las Balsas	AMTL	10.90	7.50	0.00
		Caries	3.50	3.00	0.00

Statistical Analysis

Several tests were used for the statistical analyses of this investigation, all which help determine the correlation between pathology and the three variables of sex, age, and burial context. Table 22 presents the results of the Fisher and Cramer's V tests, including the adjusted p-values for ensured accuracy. The text displayed in red under the "Adjusted P-Value" column highlights the p-values that are considered significant. According to these data, all associations, excluding sex and AMTL, can be considered significant. Cramér's V demonstrates how significant two associations are (Kim, 2017). A chart indicating the strength of an effect size based on degrees of freedom was used to determine which associations had a strong correlation (Kim, 2017). The text displayed in red under the "CramerV" column highlights these values. Based on this chart, the only associations with a strong correlation were age and AMTL.

Table 22. Table summary of the Fisher and Cramér's V tests.

	P-Value	Adjusted P-Value	CramerV
Sex & AMTL	0.05	0.05	N/A
Sex & Caries	<0.01	<0.01	0.13
Age & AMTL	<0.01	<0.01	0.46
Age & Caries	<0.01	<0.01	0.20
Context & AMTL	<0.01	<0.01	0.29
Context & Caries	<0.01	<0.01	0.20

A Pairwise Fisher's Exact test was also performed to evalaute which associations within a variable were responsible for the significant p-values found in the Fisher test (Kim, 2017). Associations with values below 0.05 are to be considered significant (Nordstokke & Stelnicki, 2014). Table 23 displays the results of the Pairwise test that analyzed the associations between sex and caries. As the table indicates, only males and females had a strong difference between their data. Table 24 displays the results of the Pairwise test that analyzed the associations between age and AMTL It was found that there were strong differences between young adult and middle-aged adults, young adults and older adults, and middle-aged adults and older adults. Table 25 displays the results of the Pairwise test that analyzed the associations between age and caries. It was found that there was a strong difference between young adults and older adults. Table 26 displays the results of the Pairwise test that analyzed the associations between burial context and AMTL. It was found that there was a strong difference between Cementerio Sur/Los Gavilanes and Huaca 1/Huaca Larga. There was also a strong correlation between Huaca 1/Huaca Larga and Huaca Abejas/Las Balsas. Table 27 displays the results of the Pairwise test that analyzed the associations between burial context and caries. It was found that there was a strong association between Cementerio Sur/Los Gavilanes and Huaca Abejas/Las Balsas. There was also a strong association between Huaca 1/Huaca Larga and Huaca Abejas/Las Balsas.

Table 23. Table of Pairwise test results that analyzed the relationship between sex and caries.

Sex Categories	M	F
F	3.60E-05	
IND	0.22	0.02

Table 24. Table of Pairwise test results that analyzed the relationship between age and AMTL.

Age Categories	YA	MA
MA	2.00E-16	
OA	2.00E-16	2.00E-16

Table 25. Table of Pairwise test results that analyzed the relationship between age and caries.

Age Categories	YA	MA
MA	0.62	
OA	2.80E-10	0.11

Table 26. Pairwise test results that analyzed the relationship between burial context and AMTL.

Burial Context	Cem Sur/LG	H 1/HL
H 1/HL	2.30E-09	
HA/LB	1.10E-01	2.00E-16

Table 27. Pairwise test results that analyzed the relationship between burial context and caries.

Burial Context	Cem Sur/LG	H 1/HL
H 1/HL	0.33	
HA/LB	6.80E-05	2.20E-09

Summary

In this chapter, the results of the descriptive and statistical analyses were presented. Total counts and frequency were used for the descriptive analysis, and the statistical significance based on chi-squared was used for the statistical analysis.

CHAPTER 5: DISCUSSION

Bioarchaeology stimulates discussion about the interactions, health, and way of life of ancient cultures (Cheverko et al., 2020). It does so by analyzing the remains recovered from archaeological contexts (Cheverko et al., 2020). Specifically, teeth can provide evidence of early forms of oral care and suggest how dental pathology differs among categories of individuals (Turner, 2015). This research tests the hypothesis that there is a similar frequency of AMTL and caries regardless of differences in sex, age, and burial contexts (the first hypothesis mentioned in Chapter 1) by using the bioarchaeology of care method. If AMTL is the result of intentional ablation for pain alleviation, these data could allow for further interpretation of oral care prevalence among the sample. This chapter interprets the results of descriptive and statistical tooth analyses discussed in Chapter 4 and uses the bioarchaeology of care model to make inferences about healthcare practices in Túcume.

Descriptive Analysis Results

Pathology Among the Sample

The results in Chapter 4 can be used to answer the research questioned outlined in Chapter 1 (How many adult individuals present AMTL? How many adult individuals present caries?). Of the 57 adult individuals, 37 presented at least one tooth lost antemortem (64.9%). 32 of these 37 individuals presented more than one tooth lost antemortem (86.5%). Additionally, of the 57 individuals, 55 presented at least one tooth with a carious lesion (96.5%). Of these 55 individuals, 26 presented more than one tooth with carious lesions (47.3%). Since caries is caused by the fermentation of carbohydrates (Hillson, 2018) and carbohydrates are an essential dietary requirement (WHO, 2017), any evidence of caries could indicate the habitual use of teeth (Molnar, 2008). This idea is supported by the possible food sources at Túcume mentioned in Chapter 2. It has been investigated that Túcume's diet included starchy crops (Heyerdahl et al., 1995), which could have contributed to the bacterial buildup. Furthermore, since the presence of caries is often characterized by toothache (Hillson, 2018), a high frequency of caries could suggest the need for individuals to seek out healthcare in order to alleviate their pain (Renton, 2011). In cases where the tooth is not able to be saved, extraction is the only solution (Renton, 2011).

The sample having 96.5% of individuals with at least one caries implies that dental decay was a common occurrence. As previously alluded to, this could be attributed to the high prevalence of carbohydrates in their diet (Heyerdahl et al., 1995). Another possible explanation for this high frequency of caries is limited oral hygiene as it plays a significant role in the development of caries (Renton, 2011). Regular dental cleanings could have been limited or nonexistent.

The higher average of AMTL than caries per individual (as displayed in Table 13) could suggest that intentional ablation may have been a common solution to alleviate the pain caused by advanced dentals caries. However, this can only be said if the tooth type with the highest frequency of caries was also the tooth type with the highest frequency of AMTL, which will be reviewed in a further section. If this is the case, these results could indicate that individuals may have been more likely to have their teeth extracted than live with cavities. Dental extraction in response to caries can be further supported by individuals with a high frequency of AMTL and a low frequency of caries. As shown in Appendix C, 8 of the 10 individuals with an AMTL frequency of 50% or greater had a caries frequency of less than 25%. This makes caries-induced extraction a possibility among this sample.

Compared to other bioarchaeological studies, the sample studied in this thesis displayed a relatively similar prevalence of pathology. In a study describing oral pathology patterns among Peruvian coastal and highland populations (Pezo-Lanfranco et al., 2017), researchers found that the prevalence of AMTL during the Late Intermediate Period was 60.9%, while the prevalence of caries was 90%. The findings from Pezo-Lanfranco et al.'s study align almost perfectly with the findings from this investigation. In a study analyzing oral health in the Moche Valley of Peru among four different samples (Gagnon & Wieson, 2013) during the Early Intermediate Period, the prevalence of AMTL ranged 54.5% to 72.7% and the prevalence of caries ranged from 34.1% to 72.7%. The findings in this thesis are considerably higher than the findings from Gagnon and Wieson's findings. The difference could be attributed to the difference in time periods (Early vs. Late Intermediate Period). This could suggest, at least, slight differences in diet, lifestyle, or resources among the various archaeological sites along the northern coast of Peru during different periods.

Frequency of Pathology Based on Tooth Type

The second hypothesis states that each type of tooth (molar, pre-molar, canine, and incisors) would present an equal frequency of AMTL and dental caries. Based on Table 16, the third molars had the highest frequency of pathology (33.77% AMTL and 22.45% caries) when analyzing the mouth as a whole. Meanwhile, canines had the lowest frequency of AMTL, and the central incisors had the lowest frequency of caries. The results do coincide with previous research, supporting the idea that the permanent molar is the tooth type most likely to display abnormalities in adults, while the incisors are the least likely (Almasri, 2019; Elzay et al., 1977).

As mentioned in the previous section, the tooth type with the highest frequency of caries also having the highest frequency of AMTL may suggest that caries led to the AMTL for pain alleviation. In the case of the maxilla, it was the first molars (Table 14). In the case of the mandible, it was the third molars (Table 15). Considering both the mandible and maxilla, the third molars displayed the highest frequency of pathology (Table 16). It is interesting to note that third molars having the highest frequency of AMTL may implicate dental manipulation from an outside source (a caregiver) due to the great dexterity required to reach the back of one's own mouth to perform tooth ablation.

Molars having the highest frequency of caries is a well-studied idea (Agrawal et al., 2023; Leroy et al., 2009; Jafari et al., 2021). This is due to molars being the primary teeth for mastication (Nutr, 2014), their morphology (their ridges increase the chance of food accumulation), their location in the mouth (closest teeth to the saliva glands and difficult to reach for extractions), and their time of emergence (usually the first set of teeth to erupt) (Agrawal et al., 2023). With this being said, it is interesting to isolate the finding that the third molar (often referred to as the "wisdom teeth") did not have the highest AMTL frequency in the maxilla. In modern dentistry, third molars are often the target of preventative extractions because the alveolar portion has decreased in size and length throughout human biological evolution, leading to dental crowding and maloclusion (Zou et al., 2010). The maxillary third molar not being the most commonly extracted tooth could indicate that it caused less discomfort, which suggests their maxillary alveolar processes may have been able to accommodate all erupting teeth. At the same time, third molars (along with second molars) are more commonly congenitally absent (Rakhshan, 2015). These teeth were indicated with a score of "6." There are many reasons why a tooth is congenitally missing, one of them being space limitation (Nuvvula et al., 2010).

Frequency of Pathology Among the Sample Population

This thesis also aims to answer which demographic group in this sample is most likely to display dental pathology, if any. Each variable (sex, age, and burial context) was divided into three categories. If dental pathology is more prominent in one category than another within the same variable, further discussion is needed to interpret the possible reasons for the pattern.

Sex

Based on Tables 18 and 21, males had a higher frequency and average of pathology than females. As already suggested, this could be due to diet or poor hygiene. Males may have had more access to more starchy foods and/or were less likely to properly care for their teeth. It should be mentioned, however, that the indetermined sex had the highest frequency of caries. As there was only one individual (with four teeth) investigated for caries, even one tooth with evidence of caries would have caused a major increase in frequency.

These results contradict some previously done research that suggests that women are more likely to demonstrate caries due to hormone changes, diets, and social roles (Ferraro & Vieira, 2010). Túcume could have had societal differences that contribute to this particular result. These societal differences may include household or work obligations that provided one sex more access to starchy foods than the other or simply differences in diet based on societal expectations. Oral paleopathology research conducted in the Andes that test sex as a variable are also variable. With some research displaying similar pathological prevalence in males (Pezo-

Lanfranco & Eggers, 2010) and others finding the opposite result (Klaus & Tam, 2010; Gagnon & Wiesen, 2013; Williams & Murphy, 2013), it cannot be said that one sex was more likely to suffer from dental pathology than the other in the Central Andes. Again, this could suggest differences in diet, lifestyle, or resources throughout the northern coast of Peru.

Age

Based on Table 19, young adults had the lowest percentage of AMTL, while older adults had a significantly larger percentage. Meanwhile, the frequency of caries increases from young adult to middle-aged adult. However, this increasing trend does not continue as older adults had no evidence of caries.

The increasing trend of AMTL in increasing age could help support claims of dental care at Túcume. A possible increased exposure to bacteria with increasing age could have allowed more caries to develop. Enough progressive tooth decay could have resulted in the damage of the tooth, which necessitated help (in this case, in the form of tooth extraction), thus manifesting as AMTL. The older individuals in this sample may not have displayed evidence of caries because the infected teeth had already been removed or "lost". If caries was the cause of AMTL, then this intentional removal of the tooth could indicate that older adults would have rather lived without a tooth than with dental decay.

Burial Context

Based on Table 20, Huaca Abejas/Las Balsas was the burial site with the most cases of AMTL and caries. If burial context is used as a model for social status, this burial site was believed to have been allotted to elite, higher social class individuals. If we assume that AMTL could be the result of intentional extraction for pain alleviation, then this group has more evidence of oral care. This could mean that dental care could have been considered a "luxury" that was not available to all. The high frequency of caries could also indicate that these individuals consumed a more carbohydrate-based diet compared to the other burial sites. The elites were most likely able to afford or had more access to starchy foods. As mentioned in a research article using dental caries and AMTL to analyze social status differences in the Classic Maya, ritual feasting (a common activity among high social class individuals) could contribute to this caries prone diet despite evidence that suggests that elite individuals would have had a more balanced diet than those of lower social status (Cucina & Tiesler, 2003).

Statistical Analysis Results

Statistical analyses were needed to explore the data from the descriptive analyses. Table 22 displays the results of the Fisher test computed by R statistical programming (R Core Team, 2023). A p-value less than 0.05 (which is considered statistically significant) allows for the rejection of the null hypothesis. As the results show (Table 22), the data for sex and AMTL is considered "not statistically significant." This could be due to a Type II error (a false negative) (Visentin et al., 2020). Type II errors can occur because of a small effect size, large variation in the groups, or a small sample size (Visentin et al., 2020). For this reason, there is not enough evidence to reject the second hypothesis. Although sex was not the only variable analyzed, the lack of significance between sex and AMTL must be noted. Although it can be stated that there were certain demographics that experienced more caries than others (males, middle adults, and those buried in the Huaca Abejas/Las Balsas site), the results from the sex and AMTL analysis could have been due to chance.

Based on the results of the Cramér's V tests (Table 22), only age and AMTL had a strong association, suggesting a meaningful relationship between these two variables. Additionally, based on the results of the Pairwise tests (Tables 23, 24, 25, 26, and 27), there were significant differences between certain categories, allowing for, at least, the partial rejection of hypothesis II.

Bioarchaeology of Care

Tilley's Bioarchaeology of Care can play a key role in reconstructing Túcume's dental care. Although the application of stage was not specifically highlighted, the method served as a model for interpretation and was applied throughout. To reiterate Tilley's approach, stages one through three create an argument for the need of care through observations and the analysis of evidence (Tilley, 2015). The pathology that these individuals presented was caries, which would have made it difficult for these individuals to "manage successfully in a modern medical environment" (Tilley, 2015, p. 191). Caries is progressive and, in modern society, usually treated in a dental visit to prevent further pain or spread of infection (Passarelli et al., 2020). In other words, the individuals presented in this sample would have needed to seek care. In modern dentistry, pain alleviation and caries remedy can include a reduction of an acidic diet, root canal treatment, and in worse cases, an extraction (Renton, 2011). AMTL was also observed among these individuals. Although pain alleviation is not the only possible explanation for the AMTL, this thesis aimed to explore the possibility of such dental care. Certain results of the descriptive and statistical analyses allowed for the argument of possible intentional tooth ablation for caries-associated pain alleviation to be made. These results include a tooth type having the highest frequency of AMTL also having the highest frequency of caries and AMTL prevalence increasing with age. This foundation allows for interpretation in stage four.

Stage four examines “what a single case of caregiving may reveal about both the community in which it occurred and the individual who was its focus” (Tilley, 2015, p. 177). Although much was speculated about Túcume based on the results, nothing mentioned is definite. For example, it is impossible to say if individuals did not manual remove teeth themselves, or if there was a specialized person responsible for provide this service. However, if the AMTL observed in this investigation was a result of pain alleviation caused by dental decay, it suggests that Túcume had performed an early form of dentistry and used it to provide care. Tilley’s approach served as a stimulating method to investigate possible dental care at Túcume during the LIP.

Summary

Based on the results of the analyses, it is possible to reject all hypotheses presented in the first chapter as there is evidence of variation and patterns in dental pathology at the site. At Túcume, there is an unequal frequency of pathology among males, females, and indetermined sex; young adults, middle-aged adults, and older adults; Cementerio Sur/Los Gavilanes, Huaca 1/Huaca Larga, and Huaca Abejas/Las Balsas. Statistical analysis showed the positive correlation between dental pathology and the different social variables.

CHAPTER 6: CONCLUSION

This research used patterns of AMTL and caries to investigate possible ancient dental intervention. The purpose of this research was to explore the possibility that individuals at Túcume may have practiced an early form of dental care through the analysis of their pathology. This research utilized a subsample from Túcume provided by Dr. J. Marla Toyne, Tilly's bioarchaeology of care (2014), and the various descriptive and statistical computations to analyze the frequency of pathology. The frequency of pathology per individual, tooth type, sex, age, and burial context was examined.

Based on the data from the sample and the results from the analyses, the null hypotheses can be rejected: individuals did present AMTL and caries; certain demographics among the sex, age, and burial variables had a higher frequency of pathology than the rest; one tooth type was more pathology-prone than the others. This evidence suggests that the individuals of Túcume may have practiced a form of oral health care in which teeth were extracted.

A pattern of pathology was observed in this sample: males were more likely to have both forms of dental pathology, older adults had the highest frequency of AMTL, middle-aged adults had the highest frequency of caries, and individuals from Huaca 1/Huaca Larga had the highest frequency of both forms of pathology. Additionally, the third molars were the most frequently affected teeth out of all tooth types. If the AMTL observed in this sample was the result of intentional ablation for pain alleviation, this research could serve as evidence of early forms of healthcare in Túcume. Additionally, the patterns of pathology indicate that a certain demographic was more likely to seek dental care compared to the rest of the individuals. By bridging the gap between bioarchaeology and health care, this research aimed to acquire a deeper understanding of the Túcume region and, ultimately, discover similarities between past and present caregiving practices.

Limitations

This research recognizes the possibilities for improvement. For example, a larger sample size could have provided a more accurate analysis of oral pathology at Túcume. Incorporating individuals with partially completed dentition could have also provided more inclusive results.

Additionally, the lack of comparative studies prevented more accurate interpretations of the results. More teeth-related research at Túcume would have been useful for a more comprehensive idea of oral health in this region.

Time also posed a limitation. With more time, more analyses could have been run to analyze caries location and severity, as well as the correlation across AMTL and caries by tooth type, which require more complex statistical analysis of the data.

Future Research

Regarding future paleopathological investigation, it is interesting to note Gagnon's "Exploring oral paleopathology in the Central Andes: A Review." This article reviews several studies on dental caries, microwear, alveolar abscesses, and AMTL in the region. Gagnon also incorporates suggestions for improving future methodological approaches. These suggestions include "an increased use of multivariate statistical techniques, the addition of calculus content analysis, and the spatial and temporal expansion of Central Andean samples for which oral paleopathological conditions are the central data set" (Gagnon, 2020, p. 32).

This research, specifically, only included individuals with full dentition. For future research, it would be interesting to incorporate the entire population set provided by Dr. Toyne to get a more inclusive idea of dental pathology in Túcume. Additionally, future research should take into consideration the location, orientation, and severity of caries on the tooth, as well as note the location of caries in relation to AMTL. If a caries is adjacent to AMTL or a tooth type consistently precedes AMTL, it would be more accurate to assume that the tooth loss may have been due to decay and not due to aesthetic or ritual purposes.

Despite this, this research proposes that oral health care may had been considered a significant aspect in society at Túcume. Contributions to this topic are scarce but necessary as adequate oral health practice is important for general health (Bhatnagar, 2021), and evidence of it in ancient societies helps us understand human behavior and cultural differences. Ancient societies with evidence of dental care shows the inherent desire to care for their ill, and evolution of this practice demonstrates the continued need for healthy individuals. This research took one step forward to understanding the ancient culture of Túcume, the possible beginnings of dental care in the Andes, and how care may have been provided for one another.

APPENDIX A: COMPLETE SPREADSHEET OF AMTL AND CARIES SCORING FOR EACH INDIVIDUAL'S TEETH

AMTL AND CARIES SCORES FOR EACH INDIVIDUAL'S TEETH

					Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries
	Individual ID	Context	Sex	Age Category	RU3MI	RU3MC	RU2MI	RU2MC	RU1MI	RU1MC	RU2PMI	RU2PMC	RU1PMI	RU1PMC	RUCI	RUCC	RULII	RULIC	RUCII	RUCIC	LUCII	LUCIC	LULII	LULIC	LUCI	LUCC
1	T CS IA E3	Cem Sur	M	YA	6	n/a	1	0	1	P	2	0	1	0	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a
2	Tuc-H1 IVi c6 Ent4	H 1	M	MA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	Tuc-H1 IVi c6 Ent5	H 1	IND	MA	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	1	0	3	n/a	3	n/a	3	n/a	3	n/a
4	Tuc-H1 IVi c6 Ent8	H 1	F	YA	6	n/a	1	0	1	0	1	0	6	n/a	1	0	1	0	3	n/a	1	0	6	n/a	1	0
5	Tuc-H1 IVi c6 Ent15	H 1	F	YA	3	n/a	3	n/a	3	n/a	2	0	2	0	1	0	1	0	1	0	1	0	2	0	1	0
6	Tuc-H1 IVi-IIIi c5 Ent9	H 1	M	YA	6	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
7	Tuc-H1 IVi c6 Ent16	H 1	F	YA	1	0	1	0	1	0	1	0	1	0	1	0	3	n/a	1	0	2	0	1	0	1	0
8	Tuc-H1 IVi c6 Ent26	H 1	F	YA	1	0	1	0	1	0	1	0	1	0	1	0	3	n/a	3	n/a	1	0	1	0	1	0
9	T-H1 Vi ENT7	H 1	F	YA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
10	T-H1 Vi ENT10	H 1	F	YA	6	n/a	1	0	1	0	1	0	1	0	3	n/a	3	n/a	3	n/a	1	0	1	0	1	0
11	T-H1 Vi ENT11	H 1	F	MA	3	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
12	T-H1 Vi ENT9	H 1	F	YA	1	0	1	0	1	0	3	n/a	1	0	1	0	1	0	1	0	3	n/a	1	0	1	0
13	T-H1 VIi ENT17	H 1	M	MA	4	n/a	4	n/a	1	0	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
14	T-H1 VIIi ENT5	H 1	F	YA	3	n/a	1	0	4	n/a	4	n/a	3	n/a	3	n/a	3	n/a	4	n/a	4	n/a	3	n/a	3	n/a
15	TUC-H1 VIIi EH6	H 1	F	MA	1	0	1	P	1	0	1	P	1	0	1	P	1	P	1	0	1	0	3	n/a	1	0
16	T-H1 IC -Vk Ent6	H 1	F	MA	1	0	1	P	1	0	1	0	1	0	1	0	1	0	1	0	3	n/a	1	0	1	0
17	T CS IA T14b	Cem Sur	F	MA	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
18	T-SO HAb Xz EH1	H Abejas	F	YA	6	n/a	1	0	1	0	1	P	1	P	1	0	1	0	3	n/a	1	0	3	n/a	1	0
19	Tuc-HL R1 Ent2	H Larga	M	YA	1	P	1	P	1	0	1	0	1	0	1	0	1	0	1	0	3	n/a	1	0	1	0
20	Tuc-HL R1 Ent3	H Larga	M	YA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
21	Tuc-HL R1 Ent4	H Larga	M	YA	1	0	1	0	1	P	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
22	Tuc-TPS F70 Ent53a	H Larga	M	YA	1	0	1	0	1	0	2	0	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	2	0
23	Tuc-TPS F70 Ent53b	H Larga	F	MA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
24	Tuc-HL -IB Ent4	H Larga	F	YA	1	0	1	0	1	0	1	0	1	0	1	0	3	n/a	3	n/a	3	n/a	3	n/a	2	0
25	T-SO HAb Xa EH1	H Abejas	M	MA	3	n/a	4	n/a	2	0	1	0	2	0	1	P	1	0	1	0	1	0	1	P	1	0
26	T-SO HAb Xa EH2	H Abejas	F	MA	1	0	4	n/a	4	n/a	4	n/a	4	n/a	1	0	1	0	1	0	4	n/a	4	n/a	3	n/a
27	T-SO HAb Xa EH3	H Abejas	F	MA	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
28	T-SO HAb Xa EH5	H Abejas	M	YA	4	n/a	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	3	n/a	3	n/a
29	T-SO HAb Xa EH7	H Abejas	F	MA	1	0	1	0	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
30	T-SO HAb Xa EH10	H Abejas	M	YA	1	P	1	P	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
31	T-SO HAb Xa EH11	H Abejas	M	MA	4	n/a	1	P	4	n/a	4	n/a	1	P	1	P	1	0	1	P	1	P	1	P	1	P
32	T-SO HAb Xa EH12	H Abejas	M	MA	1	0	1	P	1	P	1	0	1	P	1	P	1	0	4	n/a	4	n/a	1	0	1	P
33	T-Bal IB ENT1	Las Balsas	F	YA	1	0	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
34	T-Bal IB ENT3	Las Balsas	F	YA	6	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
35	T-Bal IB ENT4	Las Balsas	M	YA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	P	1	0
36	T-Bal IB ENT5	Las Balsas	F	MA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
37	T-Bal IB ENT7	Las Balsas	M	YA	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	1	0	3	n/a	3	n/a
38	Tuc-SO CemO IXs Ent2	Los Gavilanes	M	MA	4	n/a	1	0	3	n/a	4	n/a	3	n/a	1	0	3	n/a	1	0	1	0	1	0	1	0
39	Tuc-SO CemO IXs Ent4	Los Gavilanes	F	YA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
40	T-SO C.Gav VIIIr EH06	Los Gavilanes	M	MA	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a
41	T-SO HAb Xa EH18	H Abejas	M	MA	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	P	1	0	1	0	4	n/a	1	0	1	0
42	T-SO HAb XIa EH01	H Abejas	F	YA	3	n/a	1	0	1	0	3	n/a	1	0	3	n/a	1	0	1	0	1	0	3	n/a	1	0
43	T-SO HAb XIa EH02	H Abejas	M	MA	4	n/a	4	n/a	2	0	1	0	1	P	1	P	1	0	1	P	1	P	3	n/a	4	n/a
44	T-SO HAb XIa EH03	H Abejas	F	MA	1	P	1	P	2	0	1	P	2	0	1	0	2	0	2	0	2	0	4	n/a	2	0
45	T-SO HAb XIa EH05	H Abejas	M	MA	4	n/a	1	0	4	n/a	4	n/a	1	0	1	0	2	P	2	P	4	n/a	4	n/a	4	n/a
46	T-SO Gav IXq CamFun Eh03	Los Gavilanes	M	MA	4	n/a	3	n/a	1	0	3	n/a	1	0	1	0	3	n/a	1	0	3	n/a	3	n/a	2	0
47	T-SO HAb Xa EH21	H Abejas	F	MA	6	n/a	4	n/a	2	0	3	n/a	4	n/a	3	n/a	2	0	3	n/a	3	n/a	2	0	2	P
48	T-SO HAb Xa EH23	H Abejas	F	OA	4	n/a	4	n/a	1	0	4	n/a	1	0	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
49	T-SO HAb Xa EH14	H Abejas	M	MA	1	P	4	n/a	1	P	1	0	1	P	1	0	1	P	1	0	1	0	1	P	1	P
50	T-SO HAb XIa EH04	H Abejas	M	YA	1	P	1	P	1	P	1	0	1	0	1	0	1	0	1	0	1	0	3	n/a	1	0
51	T-SO HAb XIa EH9	H Abejas	F	OA	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
52	T-SO HAb XIa EH12	H Abejas	M	MA	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
53	T-SO HAb XIa EH13	H Abejas	M	MA	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
54	T-SO HAb XIa EH14	H Abejas	M	YA	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
55	T-SO HAb XIa EH15	H Abejas	M	MA	4	n/a	4	n/a	4	n/a	1	P	4	n/a	2	P	2	P	3	n/a	2	P	1	P	2	P
56	T-SO HAb XIa EH16	H Abejas	F	OA	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	3	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
57	T-SO HAb XIa EH17	H Abejas	M	YA	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a

		Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory
	Individual ID	LU1PMI	LU1PMC	LU2PMI	LU2PMC	LU1MI	LU1MC	LU2MI	LU2MC	LU3MI	LU3MC	LL3MI	LL3MC	LL2MI	LL2MC	LL1MI	LL1MC	LL2PMI	LL2PMC	LL1PMI	LL1PMC	LLCI	LLCC	LLLII	LLLIC	LLCII
1	T CS IA E3	3	n/a	3	n/a	1	P	1	0	6	n/a	6	n/a	1	0	1	0	1	0	1	0	1	0	1	0	2
2	Tuc-H1 IVi c6 Ent4	1	0	1	0	1	0	1	0	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
3	Tuc-H1 IVi c6 Ent5	3	n/a	3	n/a	1	0	1	0	3	n/a	1	P	4	n/a	4	n/a	4	n/a	3	n/a	3	n/a	3	n/a	3
4	Tuc-H1 IVi c6 Ent8	6	n/a	1	0	1	0	1	0	6	n/a	6	n/a	2	0	2	0	1	0	1	0	1	0	1	0	3
5	Tuc-H1 IVi c6 Ent15	1	0	1	0	2	0	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	1	0	1
6	Tuc-H1 IVi-IIIi c5 Ent9	1	0	1	0	1	0	1	0	6	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
7	Tuc-H1 IVi c6 Ent16	1	0	1	0	1	P	1	0	1	0	1	P	1	0	1	P	2	0	2	0	2	0	2	0	2
8	Tuc-H1 IVi c6 Ent26	3	n/a	3	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	2
9	T-H1 Vi ENT7	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
10	T-H1 Vi ENT10	1	0	1	0	1	0	1	0	6	n/a	6	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1
11	T-H1 Vi ENT11	1	0	1	0	4	n/a	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	4
12	T-H1 Vi ENT9	1	0	1	0	1	0	1	0	1	0	1	0	1	P	1	0	1	P	1	0	1	0	1	0	3
13	T-H1 VIi ENT17	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	0	1	P	4	n/a	4
14	T-H1 VIIi ENT5	1	0	3	n/a	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
15	TUC-H1 VIIi EH6	1	0	1	P	1	P	1	0	1	0	1	0	4	n/a	4	n/a	1	P	1	0	1	0	1	0	3
16	T-H1 IC -Vk Ent6	1	0	1	0	1	0	4	n/a	3	n/a	1	P	1	0	1	0	1	0	1	0	1	0	1	0	1
17	T CS IA T14b	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4
18	T-SO HAb Xz EH1	1	0	4	n/a	1	0	2	0	6	n/a	6	n/a	1	0	1	0	1	0	1	0	1	0	3	n/a	3
19	Tuc-HL R1 Ent2	1	0	1	0	1	0	1	P	6	n/a	1	P	1	0	1	0	1	0	1	0	1	0	1	0	1
20	Tuc-HL R1 Ent3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
21	Tuc-HL R1 Ent4	1	0	1	0	1	P	1	0	1	0	1	0	1	0	1	0	1	0	1	P	1	0	1	0	1
22	Tuc-TPS F70 Ent53a	2	0	2	0	1	0	1	0	1	0	2	0	2	0	2	0	2	0	2	0	3	n/a	2	0	2
23	Tuc-TPS F70 Ent53b	1	0	1	0	1	P	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
24	Tuc-HL -IB Ent4	2	0	1	0	2	0	2	0	3	n/a	5	n/a	3	n/a	1	0	3	n/a	1	0	3	n/a	3	n/a	3
25	T-SO HAb Xa EH1	1	0	2	0	2	P	1	0	1	0	4	n/a	4	n/a	1	0	1	0	1	0	1	0	1	0	1
26	T-SO HAb Xa EH2	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	0	4	n/a	4	n/a	4	n/a	1	0	1	0	1	0	1
27	T-SO HAb Xa EH3	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	0	1
28	T-SO HAb Xa EH5	1	0	1	0	1	P	1	P	1	P	4	n/a	1	0	2	0	4	n/a	1	0	4	n/a	1	0	1
29	T-SO HAb Xa EH7	1	0	1	0	1	0	1	0	1	0	1	P	4	n/a	1	P	1	0	1	0	1	0	3	n/a	1
30	T-SO HAb Xa EH10	1	0	1	0	1	0	1	0	1	0	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1
31	T-SO HAb Xa EH11	4	n/a	1	0	1	0	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	0	1	0	3	n/a	1	0	3
32	T-SO HAb Xa EH12	1	P	4	n/a	4	n/a	1	0	1	0	4	n/a	4	n/a	1	0	1	0	1	0	1	0	1	0	1
33	T-Bal IB ENT1	1	0	4	n/a	4	n/a	4	n/a	1	0	1	P	1	0	1	0	1	0	1	0	1	0	1	0	1
34	T-Bal IB ENT3	1	0	1	0	1	0	1	0	6	n/a	6	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1
35	T-Bal IB ENT4	1	P	4	n/a	1	P	1	0	1	0	1	P	1	P	1	0	1	0	1	0	1	0	1	0	1
36	T-Bal IB ENT5	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
37	T-Bal IB ENT7	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
38	Tuc-SO CemO IXs Ent2	1	0	2	0	2	0	2	P	4	n/a	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1
39	Tuc-SO CemO IXs Ent4	1	0	1	0	1	0	1	0	3	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	3
40	T-SO C.Gav VIIIr EH06	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1
41	T-SO HAb Xa EH18	3	n/a	4	n/a	4	n/a	1	0	4	n/a	4	n/a	3	n/a	2	0	1	0	1	0	1	0	1	0	6
42	T-SO HAb XIa EH01	1	0	1	0	1	0	1	0	1	0	4	n/a	1	0	4	n/a	1	0	1	0	1	0	1	0	1
43	T-SO HAb XIa EH02	4	n/a	1	0	4	n/a	1	P	4	n/a	4	n/a	4	n/a	4	n/a	1	0	1	0	1	0	1	0	4
44	T-SO HAb XIa EH03	1	P	2	0	4	n/a	1	0	1	0	4	n/a	4	n/a	1	P	1	0	1	0	1	0	1	0	1
45	T-SO HAb XIa EH05	2	P	4	n/a	4	n/a	1	0	1	P	4	n/a	4	n/a	1	0	1	0	4	n/a	4	n/a	2	P	3
46	T-SO Gav IXq CamFun Eh03	1	0	1	0	4	n/a	1	0	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3
47	T-SO HAb Xa EH21	2	P	1	0	4	n/a	4	n/a	6	n/a	4	n/a	1	P	2	P	2	P	1	0	1	0	3	n/a	4
48	T-SO HAb Xa EH23	4	n/a	4	n/a	1	0	1	0	1	0	4	n/a	4	n/a	4	n/a	4	n/a	1	0	1	0	1	0	1
49	T-SO HAb Xa EH14	1	P	1	0	4	n/a	1	0	4	n/a	4	n/a	1	0	4	n/a	1	0	1	0	1	0	1	0	1
50	T-SO HAb XIa EH04	1	0	1	0	1	P	1	0	1	P	1	P	1	0	1	0	1	P	1	0	1	0	1	0	1
51	T-SO HAb XIa EH9	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	0	4	n/a	1	0	4	n/a	4	n/a	4	n/a	4
52	T-SO HAb XIa EH12	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	0	1	0	1	0	4	n/a	4
53	T-SO HAb XIa EH13	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	3	n/a	3	n/a	3	n/a	4	n/a	4
54	T-SO HAb XIa EH14	1	0	6	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
55	T-SO HAb XIa EH15	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	0	1	P	2	0	1	0	1
56	T-SO HAb XIa EH16	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4
57	T-SO HAb XIa EH17	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4

		Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries	Inventory	Caries
	Individual ID	LLCIC	RLCII	RLCIC	RLLII	RLLIC	RLCI	RLCC	RL1PMI	RL1PMC	RL2PMI	RL2PMC	RL1MI	RL1MC	RL2MI	RL2MC	RL3MI	RL3MC
1	T CS IA E3	0	1	0	1	0	1	0	3	n/a	2	0	1	0	1	0	6	n/a
2	Tuc-H1 IVi c6 Ent4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	P	1	0
3	Tuc-H1 IVi c6 Ent5	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a
4	Tuc-H1 IVi c6 Ent8	n/a	3	n/a	3	n/a	1	0	1	0	2	0	2	0	1	0	6	n/a
5	Tuc-H1 IVi c6 Ent15	0	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a
6	Tuc-H1 IVi-IIIi c5 Ent9	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	6	n/a
7	Tuc-H1 IVi c6 Ent16	0	2	0	2	0	1	0	1	0	1	0	2	0	1	0	1	0
8	Tuc-H1 IVi c6 Ent26	0	3	n/a	3	n/a	1	0	1	0	1	0	1	0	1	0	1	0
9	T-H1 Vi ENT7	0	1	0	1	0	1	0	1	0	1	0	1	0	1	P	1	0
10	T-H1 Vi ENT10	0	3	n/a	1	0	1	0	1	0	1	0	1	0	1	0	6	n/a
11	T-H1 Vi ENT11	n/a	4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	3	n/a
12	T-H1 Vi ENT9	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	P	1	0
13	T-H1 VIi ENT17	n/a	4	n/a	4	n/a	1	0	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
14	T-H1 VIIi ENT5	0	3	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0
15	TUC-H1 VIIi EH6	n/a	3	n/a	1	0	1	0	1	0	1	P	1	P	1	0	4	n/a
16	T-H1 IC -Vk Ent6	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
17	T CS IA T14b	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
18	T-SO HAb Xz EH1	n/a	2	0	2	0	1	0	1	0	1	0	1	0	1	0	6	n/a
19	Tuc-HL R1 Ent2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	P
20	Tuc-HL R1 Ent3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	P
21	Tuc-HL R1 Ent4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	5	n/a
22	Tuc-TPS F70 Ent53a	0	2	0	3	n/a	3	n/a	1	0	1	0	1	0	1	0	3	n/a
23	Tuc-TPS F70 Ent53b	0	1	0	1	0	1	0	3	n/a	3	n/a	4	n/a	1	P	1	0
24	Tuc-HL -IB Ent4	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	1	0	1	0	5	n/a
25	T-SO HAb Xa EH1	0	1	0	1	0	1	P	1	P	4	n/a	1	0	4	n/a	1	P
26	T-SO HAb Xa EH2	0	1	0	1	0	1	0	1	0	1	P	1	P	1	P	4	n/a
27	T-SO HAb Xa EH3	0	1	0	1	0	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	1	0
28	T-SO HAb Xa EH5	0	1	0	1	0	1	0	1	0	1	P	4	n/a	4	n/a	4	n/a
29	T-SO HAb Xa EH7	0	1	0	1	0	1	0	1	0	1	0	1	P	1	0	1	0
30	T-SO HAb Xa EH10	0	1	0	1	0	1	0	1	0	1	0	1	0	1	P	6	n/a
31	T-SO HAb Xa EH11	n/a	1	0	1	0	1	P	1	P	1	0	4	n/a	4	n/a	4	n/a
32	T-SO HAb Xa EH12	0	1	0	1	0	1	0	4	n/a	1	P	1	0	4	n/a	4	n/a
33	T-Bal IB ENT1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
34	T-Bal IB ENT3	0	1	0	1	0	1	0	1	0	1	P	1	0	1	0	6	n/a
35	T-Bal IB ENT4	0	1	0	1	0	1	0	1	0	4	n/a	4	n/a	4	n/a	1	P
36	T-Bal IB ENT5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
37	T-Bal IB ENT7	0	3	n/a	3	n/a	1	0	1	0	1	0	1	0	3	n/a	1	0
38	Tuc-SO CemO IXs Ent2	0	1	0	1	0	3	n/a	1	0	1	0	1	0	4	n/a	4	n/a
39	Tuc-SO CemO IXs Ent4	n/a	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
40	T-SO C.Gav VIIIr EH06	0	4	n/a	1	0	1	0	1	0	1	0	4	n/a	2	0	1	0
41	T-SO HAb Xa EH18	n/a	3	n/a	1	0	1	0	1	P	1	P	1	0	4	n/a	4	n/a
42	T-SO HAb XIa EH01	0	1	0	1	0	1	0	1	0	1	0	1	P	1	P	1	0
43	T-SO HAb XIa EH02	n/a	4	n/a	1	0	1	P	1	P	1	0	4	n/a	2	0	4	n/a
44	T-SO HAb XIa EH03	P	3	n/a	2	P	2	P	2	0	2	0	4	n/a	4	n/a	4	n/a
45	T-SO HAb XIa EH05	n/a	2	P	1	0	1	P	4	n/a	4	n/a	4	n/a	4	n/a	1	P
46	T-SO Gav IXq CamFun Eh03	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a	3	n/a
47	T-SO HAb Xa EH21	n/a	3	n/a	2	0	1	0	3	n/a	2	P	1	P	1	0	4	n/a
48	T-SO HAb Xa EH23	0	1	0	1	0	1	0	1	0	4	n/a	4	n/a	4	n/a	4	n/a
49	T-SO HAb Xa EH14	0	1	0	1	0	1	0	1	0	1	0	1	0	4	n/a	4	n/a
50	T-SO HAb XIa EH04	0	1	0	1	0	1	0	1	0	1	P	1	0	1	0	1	P
51	T-SO HAb XIa EH9	n/a	4	n/a	4	n/a	4	n/a	1	0	1	0	4	n/a	4	n/a	4	n/a
52	T-SO HAb XIa EH12	n/a	4	n/a	4	n/a	1	0	1	0	1	P	4	n/a	4	n/a	4	n/a
53	T-SO HAb XIa EH13	n/a	4	n/a	4	n/a	3	n/a	4	n/a	1	0	3	n/a	4	n/a	4	n/a
54	T-SO HAb XIa EH14	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
55	T-SO HAb XIa EH15	P	1	0	1	0	2	0	3	n/a	3	n/a	4	n/a	4	n/a	4	n/a
56	T-SO HAb XIa EH16	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a	4	n/a
57	T-SO HAb XIa EH17	n/a	4	n/a	4	n/a	4	n/a	1	0	1	0	4	n/a	4	n/a	4	n/a

APPENDIX B: AMTL AND CARIES COUNT FOR EACH INDIVIDUAL

AMTL AND CARIES TOTAL COUNT FOR EACH INDIVIDUAL'S DENTITION

Individual ID	AMTL Count	Caries Count
T CS IA E3	0	2
Tuc-H1 IVi c6 Ent4	1	1
Tuc-H1 IVi c6 Ent5	3	1
Tuc-H1 IVi c6 Ent8	0	0
Tuc-H1 IVi c6 Ent15	0	0
Tuc-H1 IVi-IIIi c5 Ent9	0	0
Tuc-H1 IVi c6 Ent16	0	3
Tuc-H1 IVi c6 Ent26	0	0
T-H1 Vi ENT7	0	1
T-H1 Vi ENT10	0	0
T-H1 Vi ENT11	4	0
T-H1 Vi ENT9	0	3
T-H1 VIi ENT17	28	1
T-H1 VIIi ENT5	5	0
TUC-H1 VIIi EH6	3	9
T-H1 IC -Vk Ent6	1	2
T CS IA T14b	32	0
T-SO HAb Xz EH1	1	2
Tuc-HL R1 Ent2	0	5
Tuc-HL R1 Ent3	0	1
Tuc-HL R1 Ent4	0	3
Tuc-TPS F70 Ent53a	0	0
Tuc-TPS F70 Ent53b	1	2
Tuc-HL -IB Ent4	0	0
T-SO HAb Xa EH1	5	6
T-SO HAb Xa EH2	15	3
T-SO HAb Xa EH3	27	0
T-SO HAb Xa EH5	8	4
T-SO HAb Xa EH7	2	3
T-SO HAb Xa EH10	1	3
T-SO HAb Xa EH11	12	9
T-SO HAb Xa EH12	9	7

Individual ID	AMTL Count	Caries Count
T-Bal IB ENT1	4	1
T-Bal IB ENT3	0	1
T-Bal IB ENT4	4	6
T-Bal IB ENT5	0	0
T-Bal IB ENT7	0	0
Tuc-SO CemO IXs Ent2	6	1
Tuc-SO CemO IXs Ent4	0	0
T-SO C.Gav VIIIr EH06	3	0
T-SO HAb Xa EH18	12	3
T-SO HAb XIa EH01	2	2
T-SO HAb XIa EH02	13	7
T-SO HAb XIa EH03	7	8
T-SO HAb XIa EH05	16	8
T-SO Gav IXq CamFun Eh03	2	0
T-SO HAb Xa EH21	7	7
T-SO HAb Xa EH23	19	0
T-SO HAb Xa EH14	7	7
T-SO HAb XIa EH04	0	9
T-SO HAb XIa EH9	28	0
T-SO HAb XIa EH12	26	1
T-SO HAb XIa EH13	26	0
T-SO HAb XIa EH14	0	0
T-SO HAb XIa EH15	15	8
T-SO HAb XIa EH16	31	0
T-SO HAb XIa EH17	30	0

APPENDIX C: FREQUENCY OF AMTL AND CARIES PER INDIVIDUAL

AMTL AND CARIES TOTAL FREQUENCY FOR EACH INDIVIDUAL'S DENTITION

Individual ID	Frequency of AMTL	Frequency of Caries
T CS IA E3	0	10.53
Tuc-H1 IVi c6 Ent4	3.13	3.23
Tuc-H1 IVi c6 Ent5	9.38	25
Tuc-H1 IVi c6 Ent8	0	0
Tuc-H1 IVi c6 Ent15	0	0
Tuc-H1 IVi-IIIi c5 Ent9	0	0
Tuc-H1 IVi c6 Ent16	0	9.68
Tuc-H1 IVi c6 Ent26	0	0
T-H1 Vi ENT7	0	3.13
T-H1 Vi ENT10	0	0
T-H1 Vi ENT11	12.50	0
T-H1 Vi ENT9	0	10.34
T-H1 VIi ENT17	87.50	25
T-H1 VIIi ENT5	15.63	0
TUC-H1 VIIi EH6	9.38	34.62
T-H1 IC -Vk Ent6	3.13	6.90
T CS IA T14b	100	0
T-SO HAb Xz EH1	3.13	8.70
Tuc-HL R1 Ent2	0	16.67
Tuc-HL R1 Ent3	0	3.13
Tuc-HL R1 Ent4	0	9.68
Tuc-TPS F70 Ent53a	0	0
Tuc-TPS F70 Ent53b	3.13	6.90
Tuc-HL -IB Ent4	0	0
T-SO HAb Xa EH1	15.63	23.08
T-SO HAb Xa EH2	46.88	18.75
T-SO HAb Xa EH3	84.38	0
T-SO HAb Xa EH5	25	18.18
T-SO HAb Xa EH7	6.25	10.34
T-SO HAb Xa EH10	3.13	10
T-SO HAb Xa EH11	37.5	50
T-SO HAb Xa EH12	28.13	30.43

Individual ID	Frequency of AMTL	Frequency of Caries
T-Bal IB ENT1	12.50	3.57
T-Bal IB ENT3	0	3.57
T-Bal IB ENT4	12.5	21.43
T-Bal IB ENT5	0	0
T-Bal IB ENT7	0	0
Tuc-SO CemO IXs Ent2	18.75	4.55
Tuc-SO CemO IXs Ent4	0	0
T-SO C.Gav VIIIr EH06	9.38	0
T-SO HAb Xa EH18	37.50	18.75
T-SO HAb XIa EH01	6.25	7.69
T-SO HAb XIa EH02	40.63	38.89
T-SO HAb XIa EH03	21.88	33.33
T-SO HAb XIa EH05	50	53.33
T-SO Gav IXq CamFun Eh03	6.25	0
T-SO HAb Xa EH21	21.88	43.75
T-SO HAb Xa EH23	59.38	0
T-SO HAb Xa EH14	21.88	28
T-SO HAb XIa EH04	0	29.03
T-SO HAb XIa EH9	87.50	0
T-SO HAb XIa EH12	81.25	16.67
T-SO HAb XIa EH13	81.25	0
T-SO HAb XIa EH14	0	0
T-SO HAb XIa EH15	46.88	57.14
T-SO HAb XIa EH16	96.88	0
T-SO HAb XIa EH17	93.75	0

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