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Prevalence of Dental Pathology in a Juvenile Population from the Ancient Maya site of Altun Ha

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PREVALENCE OF DENTAL PATHOLOGY IN A JUVENILE POPULATION FROM THE ANCIENT MAYA SITE OF ALTUN HA

By

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ABSTRACT

The present research seeks to assesses the presence and prevalence of two distinct dental pathologies: linear enamel hypoplasia and caries in an ancient Maya juvenile subsample from Altun Ha, Belize spanning the Preclassic (ca. 600 B.C.) through the Terminal Classic (ca. 900 A.D.) periods. Teeth offer a remarkable wealth of information about the human experience in the past. Developmental and post-eruption pathology can provide insight into cultural and evolutionary processes by illuminating social and biological factors such as diet, weaning, illness, and overall health that manifest in observable changes to the composition of teeth. In addition, growth and developmental stages of juveniles provide an ideal framework in which to qualify paleopathological research. From a biological standpoint, high ante-mortem resistance to physiological stress and post-mortem preservation make teeth ideal for analyses of pathology in archaeological contexts. For the analysis of the Altun Ha juvenile subsample, a cohort approach is used in the presentation and discussion of results. Discrete pathologies are analyzed based on age cohorts, individual, tooth type, tooth surface location, and archaeological time period. The results indicate an increase in prevalence of pathology concurrent with increasing dental age as well as a predisposition to pathology among specific tooth types and locations on the crown surface and within the dental arcade as well as temporal shifts in pathology prevalence. These analyses demonstrate the importance of assessing juveniles within the archaeological record with emphasis on the transitory developmental stages experienced by children.

For the good of all children: past, present, and future

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CHAPTER ONE: INTRODUCTION

Children occupy a special role in society during life and in the archaeological record in death. Their existence in archaeological contexts speak volumes simply by their presence. Juvenile age-at-death indicates mortality from causes including but not limited to illness, famine, warfare, neglect, accident, or murder (Lewis, 2007:1). The systematic analysis of juvenile remains can thus provide insight into the lifecourse of individuals at a population-level (Mays et al, 2017; Lewis, 2007). Juvenile dental remains offer a wealth of information about individual life experiences through their developmental stage at time-of-death and their manifestation of pathology, or lack thereof. The present research seeks to assess the presence of two common dental pathologies (caries and linear enamel hypoplasia) among the juvenile population at Altun Ha from the Preclassic through the Terminal Classic periods.

Dental pathology manifests in a complex framework which is more than a binary status of present or not present. Thus, the causal processes of pathology must be understood in order to gain a complete picture of the biological and cultural factors acting upon the individual. Carious dental lesions are the most commonly observed defect of the teeth (Hillson, 2001). The Center for Disease Control defines dental caries as "a breakdown of the tooth enamel [as] the result of bacteria on teeth". Microorganisms destroy the enamel of the tooth, causing exposure of dentin, resulting in infection and alteration of the tooth surface (Slootweg 2007:55). Carious lesion prevalence correlates to high dietary carbohydrate intake and poor oral hygiene at both the individual and societal levels (Cucina, 2003). Additionally, presence of caries among juveniles can be indicative of food consumption patterns and weaning practices within the societies to which they belong (Williams, 2005).

Linear Enamel Hypoplasia (LEH) is an alteration of the tooth surface resulting from a temporary disruption in enamel secretion during dental development (Al-Shoreman 2014:204). LEH develops when maternal distress, malnutrition, trauma, or disease episodes occur during the time of dental formation interrupting the secretion of the enamel matrix (HIllson, 2014). The disruption to enamel secretion affects the resulting pattern of perikymata and alters the appearance and morphology of the crown surface (Hillson 2014:162). Furthermore, LEH can predispose individuals to caries due to the defective tooth structure (Brown 1981 cited in Whittington 152). Although most thoroughly observed through microscopic analysis, LEH produces distinctive horizontal bands on the tooth surface that can be observed macroscopically (Hassett, 2012, 2014; Hilson, 2014).

In an effort to contribute to the understanding of the relationship between juveniles and dental pathology, the following chapters offer an overview of pertinent background information in bioarchaeology and dental pathology, methods of age and pathology assessment, and results of the dental pathology analyses of juveniles at Altun Ha. First, a literature review in the areas of dental form and function, dental anatomy and development, dental pathology, dental anthropology in bioarchaeology, and children in bioarchaeology is presented. Next, the Altun Ha environmental setting, site setting, and skeletal sample are discussed. Then, methods of data collection for juvenile dental aging and pathology assessment are discussed. Finally, results and discussion are presented using an age cohort approach in the areas of tooth type, tooth surface location, and archaeological time period. The use of cohorts facilitates the analysis of developmental trends in pathology prevalence and emphasizes the ephemerality of the transitional stages of childhood.

Research Questions

The following research questions are addressed in this study:

1. What is the prevalence of carious lesions and linear enamel hypoplasia within the Altun Ha juvenile subsample?
2. Is there correlation between age-at-death and frequency of dental pathology?
3. Are specific tooth types and tooth surface locations more frequently affected by dental pathology manifestation?
4. Are there temporal trends of dental pathology throughout the defined archaeological time periods?

CHAPTER TWO: LITERATURE REVIEW

The study of human remains in the archaeological record is primarily achieved through the analysis of bone and teeth. Bone is constituted by organic (35% collagen) and inorganic (65% mineral) material and is subject to remodeling throughout life (Olsen, 2006:8). Conversely, teeth are composed of a dense enamel exterior (97% bioapatite) and a less-dense dentin core. Teeth develop at a known rate and, unlike bone, do not remodel (Simpson, 1999:241). Thus, human dentition in particular offers a significant source of information regarding pathology for bioarchaeologists and forensic anthropologists (Lewis, 2009; Harris, 2016). Assessment of juveniles provides a model for the population because they are in the process of development and thus metabolic stress is recorded on their bones and teeth. Consequently, it is important to understand the development and composition of teeth to inform proper analysis, such as age or pathology assessment. Additionally, it is important to understand the ways in which the role of dental anthropology in archaeological research has progressed over time and the changing approaches to the study of children in past. This chapter includes five sections in the areas of: dental form and function; dental anatomy and development; dental pathology under observation in this research; dental anthropology in bioarchaeology and implications in the present; and, finally, juveniles in bioarcheology research and the archaeological record.

Human Dental Form and Function

Humans, like most mammals, are diphyodonts (Kent, 2001). During the life course, they have two successive sets of teeth, deciduous (primary) and permanent (secondary). The primary set begins to develop *in utero* and will ultimately consist of 20 specialized teeth. In modern populations, initialization of crown formation begins in the 4th fetal month (American Academy of Pediatric Dentistry; Kronfeld, 1933). While exact formation timing is impacted by biological and epigenetic factors, mineralization generally follows a predictable timeline (Harris, 2016). Deciduous eruption occurs in a sequence beginning with the mandibular central incisors around 5-8 months postnatal and ending with the eruption of the second deciduous molars around 20-30 months postnatal (American Academy of Pediatric Dentistry; Kronfeld, 1933). Permanent dentition consists of 28-32 specialized teeth. The secondary set begins to mineralize around the time of birth, beginning with the permanent first molars (American Academy of Pediatric Dentistry; Kronfeld, 1933). Eruption of the permanent teeth begins with the mandibular central incisors around 6 years old and completes with the eruption of the second molars around 14 years old. Third molars will erupt much later (between 17-30 years old). However, due to a natural condition known as third molar agenesis, not all individuals have any and/or all of their third molars. Also, individuals with third molars may never experience eruption.

The human dentition is heterodontic, having 4 classes of specialized tooth types. The anterior-most, spatula-shaped teeth, incisors, are responsible for cutting (White et al., 2011). Distal to the incisors, the canines are sharp, cone-shaped teeth used for ripping and tearing. Premolars are the mesial teeth in the buccal region which assist the final tooth type, molars, in crushing and grinding (White et al., 2011). Premolars may also be referred to as 'bicuspid' due to their morphological trait of having two defined crests, one lingual and one buccal. In contrast,

molars may have 4 to 5 well-defined cusps, dependent on tooth location (maxillary/mandibular) (White et al, 2011). The specialization of human dentition is an evolutionary response to an increasingly generalized diet (Larsen, 2014).

As mentioned, variability in mineralization and eruption must be considered when assessing dentition. In addition to the influences of biological and population-specific factors, the timeline of eruption of permanent dentition differs among sexes with females having slightly advanced eruption times when compared with males (Smith, 1991; Moorees, 1963). However, the dimorphic discrepancy results in a difference of only months between sexes (Smith, 1991). Hillson (2014) indicates four key developmental events in tooth formation: crown initiation, crown completion, eruption, and apex closure. Each stage is tooth-specific and subject to variation creating complexities which can be useful when analyzing dentition for age and pathology. In an effort to gain the most accurate assessment of dental development and eruption across populations, recent research seeks to quantitatively address the disparity between the timeline and the individual (Halcrow, 2007; Holman and Jones, 1998; Lewis, 2007; Liversidge et al., 2003; King and Ulijaszek, 2000). Development of the individual tooth structure is discussed in more detail below.

Human Dental Anatomy and Development

All human teeth are comprised of two main surface structures: the crown and the root (figure 2.1). The crown is made up of a superficial layer of avascular, acellular enamel which is composed mostly of hydroxyapatite (White et al, 2011). Deep to the enamel at the dentinoenamel junction (DEJ), a layer of soft, vascular dentin extends from the crown to the root

(White et al., 2011). The dentin encapsulates the deepest layer of the tooth structure, the pulp wherein is contained the associated dental nerves and blood vessels within the pulp chamber.

Externally, the crown and root meet at a cervix near the gingival line. The cementoenamel junction (CEJ) further delineates the cervix as the point where the enamel terminates, and the cementum begins. The cementum is a hardened structure which covers tooth roots within the alveolar socket (White et al, 2011). The individual teeth are secured into the alveolar matrix by periodontal ligaments which extend from the cementum. And finally, the tooth root terminates at the apical foramen through which the nerves and blood vessels enter the tooth structure to provide blood supply and innervation.

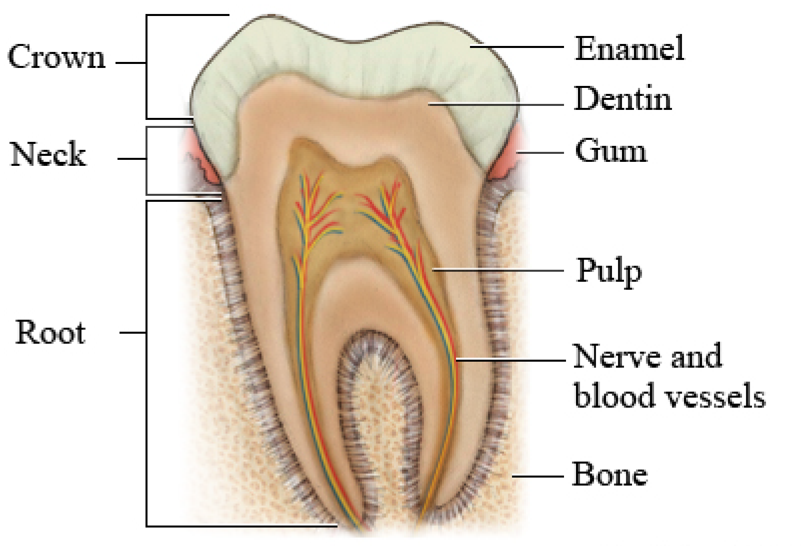

Figure 1 Anatomy of a Tooth (photo credit: Healthwise, Inc.)

Teeth are thought to have developed evolutionarily from the placoid scales of archaic fishes (White et al., 2011). In modern humans, teeth develop *in utero* from differentiated mesenchyme and are described in stages (figure 2.2). First, linear arrangements of dental

papillae will each initiate the formation of a single tooth from the ectodermal dental lamina (Kent, 1992). As deciduous precursors, tooth germs will then form along the local regions which will become the alveolar sites of fully-formed teeth (Hillson, 2014). Next, the bud stage occurs which is characterized by swelling of the lamina (Hillson, 2014). The bud stage is followed by the cap stage during which morphogenesis continues in the development of an indentation in the tooth germ (Hillson, 2014). In the bell stage, amelogenesis and dentinogenesis at the local tooth sites are responsible for the formation of enamel and dentin respectively. In the next stage, apposition, layers of enamel are secreted in a non-calcified matrix along with cementum and dentin (Slootweg, 2007). In the final phase, maturation occurs in the form of full mineralization. It is important to note that teeth erupt before the roots are fully formed (Moorees et al, 1963; Smith, 1991). Therefore, the apposition and maturation phases are ongoing even after gingival eruption, until apical completion is achieved.

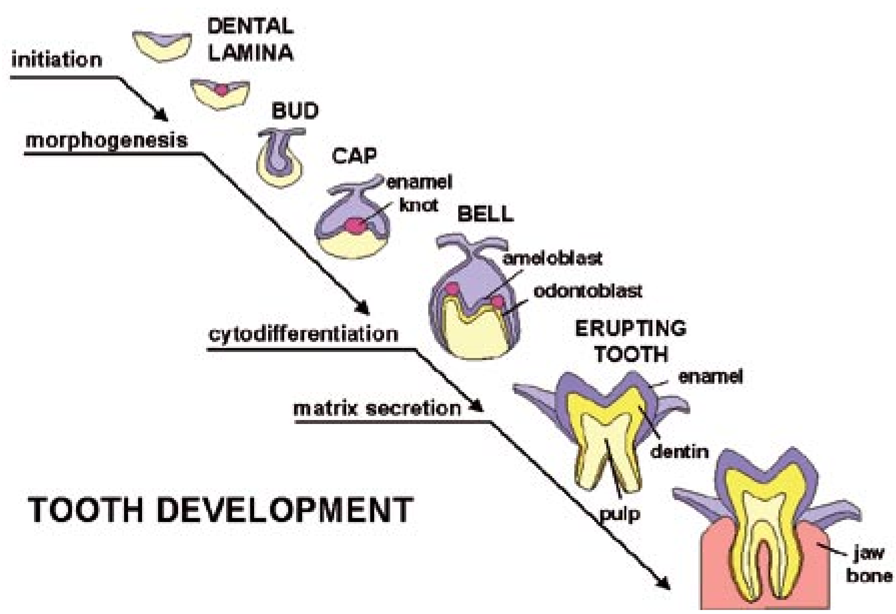

Figure 2 Stages of Dental Development (photo credit: Thesleff, 2004)

Dental Pathology

The purpose of this section is to provide a brief introduction to dental pathology and its application in bioarchaeology. Individual pathologies and mechanisms are described in further detail in the discussion section (chapter 5). Dental development has been shown to be less affected by metabolic stress episodes than bone in terms of observable pathology (Acheson, 1959 cited in Lewis, 2007). However, pathologies manifested in the teeth are optimal for observation because, unlike bone, teeth do not remodel and thus provide a record of stress episodes. Teeth can exhibit external and internal features which indicate disease and malnutrition (Hillson, 2014). Factors such as trauma, rickets, vitamin D deficiency, syphilis, weaning, and dietary and cultural practices can all impact the integrity of the tooth structure in the form of hypoplastic defects during development (Lewis, 2007:105). After teeth have erupted, they are then exposed to degradational agents, such as carbohydrates and bacteria, which may contribute to the initiation of carious lesions (Hillson, 2008:111). Therefore, the archaeological study of dental pathology provides insight into health and diet of past populations by indicating disease, diet, and cultural patterns which manifest in the dentition.

There are two dental pathologies assessed in this research: linear enamel hypoplasias and caries. Hypoplastic defects must occur during the time of enamel formation (Reid and Dean,2006). Therefore, dietary and cultural practices which produce developmental defects act on the tooth both indirectly and directly through maternal health in the former and individual health in the latter. Conversely, caries are typically associated with post-eruption factors such as diet and hygiene (Hillson, 2001; Whittington, 1999). Many factors can influence the formation of dental caries, however there is a high correlation between dietary carbohydrate intake and the formation of lesions (Hillson, 2001; Larsen, 2015; Whittington, 1999). In addition, there is an

interplay between enamel hypoplasia and caries in that the defective tooth structure can lead to a higher susceptibility to develop diet-related carious lesions. Thus, nutrition-infection interactions can result in comorbidities of both hypoplasia and caries (King and Ulijaszek, 2000).

Dental pathologies are observed most frequently according to specific tooth type and region. Linear enamel hypoplasia is most common on the labial and lingual aspects of the incisors, canines, and premolars (Hillson, 2014:164). The canines exhibit the longest duration of enamel formation and thus have the largest window during which a defect may occur. Conversely, caries are most common in the maxillary premolars and molars (Whittington, 1999). The location of these teeth in the dental arcade decreases the interaction with saliva, increasing plaque, which can predispose the teeth to carious lesions (Whittington, 1999). Labial caries of the anterior teeth are also observed with regularity and, in juveniles, indicate a classification of severe early childhood caries (sECC) (Drury, 1999). The tooth types and locations mentioned above represent only the most common associated with each pathology, however, each pathology can be observed on any tooth (deciduous/permanent; incisor/canine/premolar/molar). Caries may be observed on any surface: labial, lingual, buccal, interproximal, or occlusal (White et al., 2011). However, linear enamel hypoplasias will always be observed on the crown surface (labial/lingual) as they are a product of interrupted enamel secretion during the formation of the tooth (Hillson, 2014).

Dental Anthropology in Bioarchaeology

Today, the study of dentition in bioarchaeology can contribute to dietary reconstruction and analysis of childhood disease and stress patterns (Buikstra and Beck, 2006). However, the

objective study of human teeth began in England with observation of dental anomalies and a simple question: “Why are diseases of the teeth more common now in civilized life [than] they formerly were?” (Mummery, 1870:73 as cited in Buikstra and Beck, 2006). Building on observations made by Mummery that there was an inverse relationship between cultural civilization and tooth quality, Miller (1883a) suggested that the carious lesions present on teeth may be caused by the interaction of dietary carbohydrates with the tooth’s enamel. These early observations, though oversimplifying the complex interaction between environment, diet, individual, and pathology, paved the way for the development of dental anthropology into the specialty it is today.

In its early stages in America, dental anthropology followed closely the theoretical trend of the time, with focus on classification and description, but little to no interpretive analysis (Buikstra and Beck, 2006). In the early 1900s, however, skeletal samples began being used in comparison with modern human populations in an attempt to analyze the apparent widespread decline of dental health. It was at this time that the focus on agricultural origins intensified (Buikstra and Beck, 2006). In the mid-1900s, there was vast development in clinical dentistry, though the advancements were not applied to dental anthropology until a decade later, and a new focus on anthropometry and dental wear analysis (Buikstra and Beck, 2006:335). Then, in the 1960s, there were prolific advancements in dental anthropology as a specialized field of study (Scott, 2016:9). The publication of *Dental Anthropology* (Brothwell, 1963a) was the first of its kind to address the archaeological study of dentition and generated interest in the academic community. Also, during this period, several methods of tooth mineralization and eruption were published, including some still in standard use today (Chagula, 1960; Nolla, 1960; Moorees et al., 1963a; Fanning and Moorees, 1969; Demirjian et al., 1973; Demirjian and Goldstein, 1976

cited in Lewis, 2007). This new methodological approach allowed for interpretation of past populations within a quantitative manner and brought paleopathology to the forefront of archaeological research.

Prior to the 1990s, dental anthropology research was largely undertaken by dentists and biologists. However, in the 1990s, anthropologists began to shift focus toward the discipline (Scott, 2016:11). During this period, several landmark publications emerged which have become integral to the advancement of methods and analysis in dental research (Buikstra and Ubelaker, 1994; Kelley and Larsen, 1991; Smith, 1991). Despite ever-increasing accuracy in methodological approaches, there remains a need for more population-specific research focuses, especially in the area of dental formation and eruption timelines (King and Ulijaszek, 2000). However, much research has been conducted toward the goal of understanding cross-population and temporal variation in dental development (Lewis, 2007).

Children in Bioarchaeology

The study of children in the archaeological record is confounded by several confounding factors. In a biological sense, their small, unfused skeletal remains create challenges in location and recovery (Lewis, 2007:26). In addition, their status as juveniles make them prone to marginalization for their "invisible" role in societies past and present (Crawford, 2009:6). However, in the past 25 years, an intensive focus on the inclusion of juveniles in bioarchaeology has seen a cross-disciplinary effort to reconcile the child's undeniable importance in the study of the past (Lillehammer, 2015).

Once thought to be inconsequential to bioarchaeological analysis, children have come to be recognized as social entities having individual agency within the cultural processes of the societies to which they belong as well as an impact on the behavior of their adult counterparts (Halcrow and Tayles, 2008). In addition, childhood is not a static category, but is instead a transitional stage through which we all pass (Crawford, 2009:6). Therefore, it is important to analyze juvenile remains in addition to and independent of adults as it gives a complete picture of the life course of a population (Mays et al. 2017).

Even after the shift toward the inclusion of juveniles within bioarchaeology, there remained a science/social theory divide in which the biological body was analyzed discrete from social and cultural processes (Mays et al., 2017:41). In an effort to address this gap, a social bioarchaeology approach emerged which contextualized the human body as a dynamic vessel impacted by the environment and by cultural practices and influences. The analysis of juvenile remains within a biocultural approach considers these natural and cultural processes which exist in a feedback loop that both influence and are influenced by our behaviors and biology (Mays et al, 2017). Integral to this theoretical position is the idea that social age and biological age are distinct from chronological age (Halcrow and Tayles, 2008). Growth, development, and physiology are intertwined with the external factors acting upon overall fitness and are thus largely dependent on cultural and environmental conditions. In the last decade, trends of child bioarchaeology research have expanded into categories such as: bone chemistry, paleodemography, normal skeletal variation, and paleopathology (Mays, 2017:39). In addition, many notable publications have emerged emphasizing juveniles in bioarchaeology (Baker et al., 2005; Mays, 2017; Lewis, 2007; Scheuer and Black, 2000). In accordance with this trend, the

present research will constitute an analysis of the juvenile mixed dentition at Altun Ha for the prevalence of dental pathology in this population.

CHAPTER THREE: MATERIALS AND METHODS

When assessing skeletal remains in an archaeological context, it is important to consider environment and ecology: landscape, climate, flora and fauna. Factors of the immediate surroundings, such as exposure to pathogens and access to water and food sources significantly impacts human health and development (Tetlow, 2010). These factors in turn influence epigenetic expression by impacting diet, pathology, and overall wellness. In addition to the influence of the external environment on the human body during life, climate and burial conditions can affect preservation of buried remains (Dupras et al., 2012:90). It is important to understand the environment, both past and present, from which the remains were recovered as taphonomic processes can affect the appearance and preservation of bone and teeth and must be considered when assessing pathology.

To explore the research questions stated in chapter 1, the isolated dental remains of a subsample of juveniles from the Altun Ha skeletal sample were examined for the presence and prevalence of dental pathology. This chapter provides details about the natural environment of the Maya lowlands region, the site of Altun Ha and the Altun Ha skeletal sample. Finally, methods of tooth identification, age assessment, and scoring of dental pathology are discussed.

Altun Ha

Environmental Setting

Altun Ha is a coastal Maya site located in the north-central Lowlands region of Belize (Figure 3.1). The region is classified as subtropical, receiving moderate annual rainfall (<80in.)

(Sharer and Traxler, 2006:46). The area is characterized by a dry season (January to May) and a wet season (June to December), but receives less rainfall than the tropical region to the north (Olsen, 2006). The decreased rainfall corresponds with a diminishing rainforest. Thus, the Altun Ha settlement is surrounded by dense, yet comparatively short vegetation as the landscape nears the sea. Mangrove swamps border the site to the north and east (Olsen, 2006:25). In addition, there are many tributaries, swamps, and lagoons surrounding the site. The site is bordered to the east by the Caribbean Sea and to the west and southwest by granite outcrops (Wright et al. 1959 cited in Olsen, 2006:25). The ground consists of sandy loam and sandy clay loam (Song, 1997:7). Cenozoic limestone belies much of the region increasing rainwater loss due to ground porosity and contributing to an extensive underground cave landscape (Sharer and Traxler, 2006:51).

The lowlands region hosts diverse flora and fauna. The region supports tropical plant life such as palmetto, agave, and cacti (Sharer and Traxler, 2006:42). In addition, there is a forest landscape composed of subtropical tree species such as mahogany, sapote, breadnut, and cohune (Sharer and Traxler:42). Though vegetation is plentiful and diverse, only a third of the plant species are edible, having implications for the dietary ecology at Altun Ha (Song, 1996:13). There exists a wide variety of fauna in the lowlands region, but Altun Ha is most notable for its access to marine sources. The inland water sources contain mostly fish, crayfish, and edible snails (Sharer and Traxler, 2006). Additionally, the Caribbean Sea to the east hosts many types of marine mammals, fish, shellfish, and sea turtles. It is suggested that the availability of marine food sources may have influenced settlement at Altun Ha (Pendergast, 1979 cited in Olsen, 2006:25). In the next section, the site and settlement pattern will be discussed in more detail.

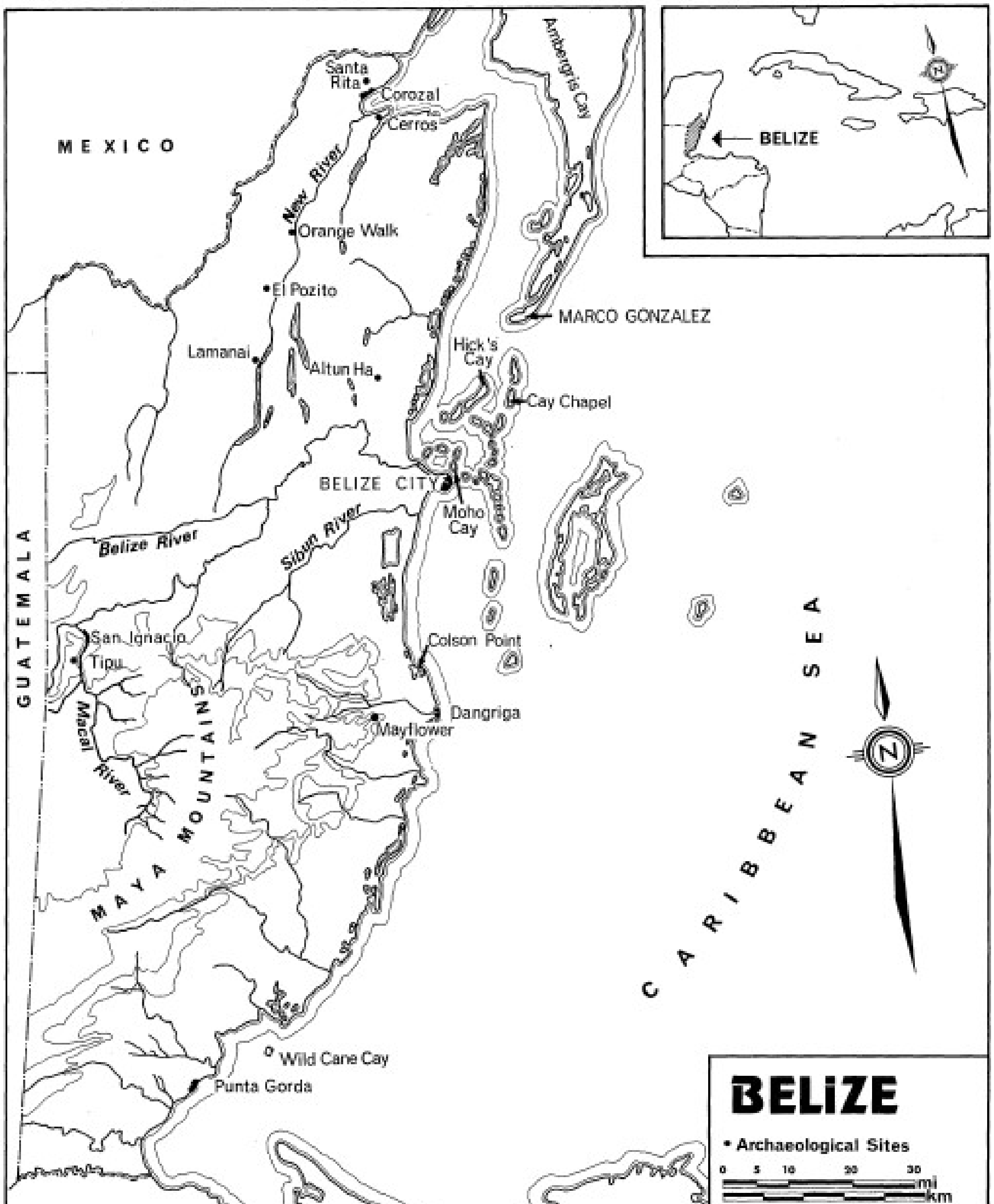

Figure 3 Map of Belize with Altun Ha and other Maya sites (Graham and Pendergast, 1989)

Site Setting

The site of Altun Ha spans roughly 2.33 km^2 and is located a little over seven miles from the sea at an elevation of 5 to 15 meters above sea level (Pendergast, 1979 cited in Olsen, 2006:25). The range in elevation represents a landscape with a slight gradient. It is one of the eastern-most Maya sites, perhaps indicating an attempt by initial settlers to exploit the coastal resources. Proximity to the Caribbean Sea and natural local fresh-water supply may have played a role in both settlement and longevity at Altun Ha. Though no direct routes to the sea have been discovered, faunal evidence at the site suggests that inhabitants exploited the rich marine resources to the east (Pendergast, 1979). This is corroborated by isotopic analysis of bone and teeth which indicate a diet high in marine-source protein (White et al., 2001). Additionally, Altun Ha is situated around a natural spring-fed pond. There is evidence of landscape modification which would have increased pond capacity and prevented excess rain runoff (Song, 1997:19). As previously stated, though Altun Ha was situated near fresh and marine water sources, the ground composition retained very little rainwater. Modifications to the pond could have helped to mediate agricultural cultivation at the site as well as provided a source of fresh water for direct consumption. However, the availability of water sources central and proximal to Altun Ha likely had a significant impact on dietary patterns of its inhabitants in contrast to other more agriculturally-intensive Maya sites (White et al., 2001).

In addition to the dietary implications, the swampy, flood-prone landscape impacted land availability for construction. Therefore, building structures are clustered into areas of suitable occupation (Pendergast, 1979) (figure 3.2). Groups A and B form the core of the site surrounded by Group C and J to the west, Group D to the east, Groups E-H to the south and Group K to the northeast. Of the 516 identified structures at Altun Ha, 56 were excavated during fieldwork from

Zones A, B, C, D, E, F, H, J, and K (Pendergast, 1979 cited in Song, 1997:16). The site was continually occupied from the Preclassic through the Postclassic, with peak activity in the Late Classic and Terminal Classic periods (Pendergast, 1979) (table 3.1). The continual occupation make Altun Ha ideal for the analysis of temporal shifts in dietary and pathology-related frequencies.

Table 1 Altun Ha Occupation Periods (Song, 1997; Pendergast, 1979)

Time Period	Altun Ha Phase	Dates
PRECLASSIC	Xul	600 B.C. – 100 B.C.
	Yaxkin	100 B.C. – A.D. 170
PROTOCLASSIC	Mol	A.D. 170 – 280
EARLY CLASSIC	Ch'en	A.D. 280 – 400
	Yax	A.D. 400 – 500
LATE CLASSIC	Ceh	A.D. 500 – 580
	Mac	A.D. 580 – 650
	Kankin	A.D. 650 – 750
	Muan	A.D. 750 – 830
TERMINAL CLASSIC	Pax	A.D. 830 – 900
EARLY POSTCLASSIC	Kayab	A.D. 900 – 1000
	Partial abandonment	A.D. 1000 – 1230
LATE POSTCLASSIC	Uayeb	A.D. 1230 – 1500

Mortuary Contexts

Mortuary contexts at Altun Ha were intertwined with the built landscape. As is often seen in Maya settlements, burials were incorporated into the building structures through time (Olsen, 2006). Pendergast (1979) recognized three distinct types of burials at Altun Ha: primary, secondary, and dedicatory (Olsen, 2006). Primary burials refer to those which were placed within a structure and then sealed. Secondary burials are those which contained incomplete

skeletal remains, indicating relocation. Finally, dedicatory burials are those which are associated with new construction or expansion of an existing structure. Additionally, in the mortuary contexts at Altun Ha, a high level of multiple interments are observed (Song, 1997:62). Thus, comingling within burial contexts create challenges when assessing individual skeletal remains.

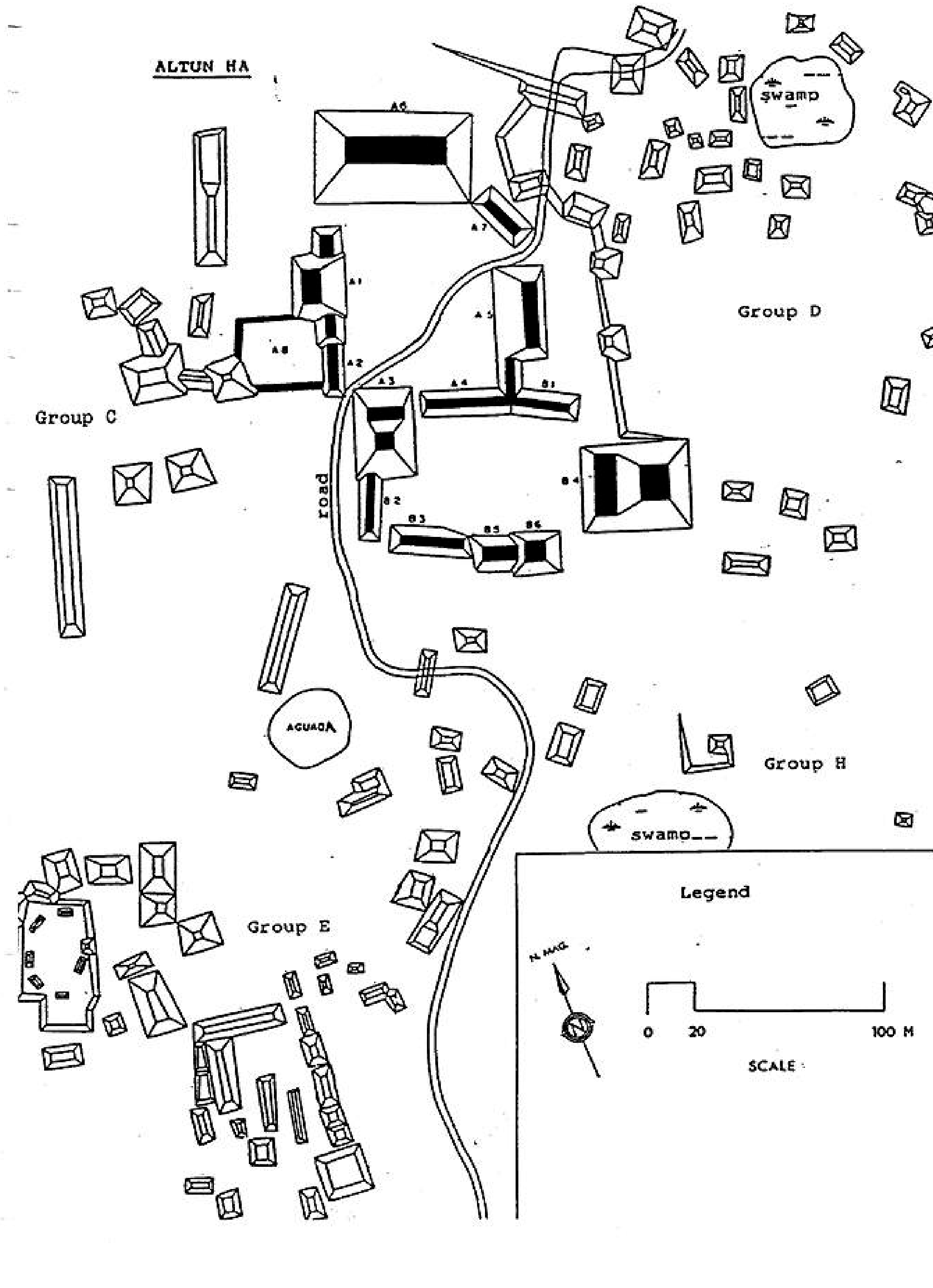

Figure 4 Site map of Altun Ha (Pendergast, 1979)

Materials

The Altun Ha Skeletal Sample

During the combined field seasons, approximately 509 individuals were recovered from 406 burials excavated at Altun Ha between 1964-1970 (Pendergast, 1979). The full sample of individuals in the Altun Ha skeletal collection contained adults, juveniles, and infants (table 3.2). For the present research, a subsample of n=27 subadult individuals, hereafter referred to as the Altun Ha juvenile subsample, was selected and analyzed for dental pathology. The Altun Ha juvenile subsample consisted of n=345 teeth (tables 3.5 and 3.6). The individuals in the subsample were recovered from five of nine total zones (A, C, E, H, and K). The continuous occupation at Altun Ha yields individuals which span from the Preclassic to Post-Abandonment periods with a majority of remains dating to the Late Classic and Terminal Classic (Song, 1997). The sample distribution by archaeological time period is discussed in the next section.

The Altun Ha juvenile subsample consists of the mixed dentition of juveniles aged newborn to 12 years. In most cases, the teeth are loose, without the associated alveolar bone (maxilla/mandible). However, for some individuals, jaw segments are present both with and without associated dentition. The dentition includes deciduous and permanent teeth in various stages of development (mineralization: initiated/complete; teeth: erupted/unerupted). The skeletal collection is currently housed in the National Center for Forensic Science Anthropology Lab at the University of Central Florida under the stewardship of Drs. Lana Williams and Sandra Wheeler.

Table 2 Altun Ha Total Number of Individuals

Time Period	Male	Female	Unknown	Subadult	?	Total
Xul (Preclassic)	9	10	20	15	2	56
Yax/Ceh (Early Classic)	21	6	31	21	0	79
Mac/Kankin/Muan (Late)	51	43	45	81	2	222
Pax/Kayab (Terminal)	24	25	11	50	0	110
Post-abandonment	9	6	8	11	0	34
Unknown	2	4	0	2	0	8
TOTAL	**116**	**94**	**115**	**180**	**4**	**509**

(table adapted from Song 1992; Pendergast 1979, 1982, 1990)

Methods

Identification

First, teeth were sorted and identified according to developmental advancement (deciduous and permanent) and tooth type and location (incisors, canines, premolars and molars; maxillary/mandibular) (Baker et al, 2005). Teeth were arranged according to location in the dental arcade, photographed, and annotated in printed data sheets formatted from Smith, 1991. Individual tooth notes were recorded using the following dental code suggested in White (2012): side was indicated by L or R (left/right); tooth type was indicated by the first letter of the designation using lower case for deciduous and uppercase for permanent (i/I; c/C; PM; m/M);

and location (maxillary/mandibular) was indicated using superscript and subscript numbers (1; 2). For example, a right deciduous maxillary central incisor would have the formula: rm^1. Additionally, all teeth were compared with Nissen educational dental models (both juvenile and adult models).

Age-at-Death Assessment

After identification and sorting, individuals were assessed for dental age based on crown and root formation (Smith, 1991) and eruption (Ubelaker, 1989). For continuity, Smith (1991) was used for final age assignment. Ubelaker (1989) was used in instances where developmental stage or degree of preservation prevented the use of Smith (1991). Individuals were then assigned into four age cohorts based on dental age assessment: newborn; 0-1 years; 2-6 years; 7-12 years based on Baker et al. (2005) (table 3.3). The individuals were also assigned to an archaeological time period using combined data (Pendergast, 1979; Song, 1997; White, 2001) (table 3.4). Total number of deciduous and permanent teeth by type and cohort is shown in table 3.5 and table 3.6, respectively.

Table 3 Cohort Distribution of Altun Ha Juvenile Subsample

Age Cohort	Individuals (n=)	Sample Frequency
1-Newborn	1	4%
2-Infant (0-1)	7	26%
3-Young child (2-6)	13	48%
4-Older Child (7-12)	6	22%
Total	27	100%

Table 4 Distribution of Altun Ha Juvenile Subsample by Archaeological Time Period

Time Period	Individuals (n=)	Sample frequency
Preclassic	2	7%
Early Classic	3	11%
Late Classic	9	34%
Terminal Classic	11	41%
Unknown	2	7%
Total	27	100%

Table 5 Number of Deciduous Teeth by Type and Cohort

Tooth Type	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Total
Central Incisors	0	7	15	0	22
Lateral incisors	0	8	14	0	22
Canines	2	8	16	6	32
First Molars	1	12	25	8	46
Second Molars	1	13	27	17	58
Total	4	48	97	31	180

Table 6 Number of Permanent Teeth by Type and Cohort

Tooth Type	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Total
Central Incisors	0	0	13	10	23
Lateral Incisors	0	0	12	8	20
Canines	0	0	10	11	21
1st Premolars	0	0	8	13	21
2nd Premolars	0	0	8	7	15
1st Molars	0	1	22	21	44
2nd Molars	0	0	8	13	21
3rd Molars	0	0	0	0	0
Total	0	1	81	83	165

Dental Pathology Assessment

Next, individual teeth were observed macroscopically under incandescent lighting and with a Stalwart 6 LED 4x handheld magnifying glass. A wooden dowel was used to clear any loose material from tooth and root surfaces where needed. Each tooth was assessed for the presence of caries and/or linear enamel hypoplasias. Caries were recorded based on presence or absence, location on tooth surface, and size/severity following Hillson (2001). Linear enamel hypoplasia was recorded as present or absent based on a tactile assessment using a wooden dowel on the crown surface to detect surface anomaly. Linear enamel hypoplasia location within the enamel matrix was recorded and compared to Reid and Dean (2006) to establish timing of pathology manifestation. Tooth types were recorded separately to facilitate subsequent analysis.

CHAPTER FOUR: RESULTS

Introduction

The prevalence of dental caries and linear enamel hypoplasias are presented below. Results are presented by cohort, individual, and tooth type for each pathology separately. Caries data for location of lesion is also presented. Categorization of data in this way allows for analysis of the overlapping factors affecting oral pathology: age, developmental stage, and tooth type and location. Additionally, discrete pathology prevalence by archaeological time period is presented. It is important to include the component of time when analyzing pathology prevalence as this can illuminate temporal changes in overall health.

Caries

Juveniles in the Altun Ha subsample exhibited caries ranging in severity from mild to acute. Caries were observed representing both smooth surface and pit and fissure form types. However, for the present research, caries were scored in binary as present or not present. Caries were said to be present when the lesion penetrated the enamel surface. Additionally, locations of caries were recorded (occlusal, interproximal, lingual, and labial). This section will include data for caries by cohort, individual, tooth type, location, and archaeological time period. Deciduous and permanent data are presented separately.

Caries by Cohort

Caries were present in deciduous teeth in Cohorts 3 (*2 – 6 years old*) and 4 (*7 – 12 years old*). The total prevalence of individuals with carious deciduous teeth was 29.6% (n=8). The total prevalence range by cohort of caries in deciduous teeth was 38.4% (n=5) in Cohort 3 to 50% (n=3) in Cohort 4 (figure 4.1). The highest concentration of caries was in the fourth cohort. Thus, caries prevalence in deciduous teeth increased with age. The absence of caries in Cohorts 1 (*newborn*) and 2 (*0 -1 years old*) is interpreted to represent the relatively short span of time that the erupted teeth were exposed in the gingiva.

Caries were present in permanent teeth only in Cohort 3 (*2 – 6 years old*). The sample total prevalence of caries in permanent teeth was 3.7%, representing only one individual with this pathology. The total cohort prevalence of caries in permanent teeth was 7.7% (n=1) in Cohort 3 (Figure 4.2). The absence of caries in Cohort 1 (*newborn*) is signified by the absence of permanent teeth in newborns. The absence of caries in permanent teeth in Cohorts 2 (*0 -1 years old*) and 4 (*7 – 12 years old*) may be a result of the fragmentary nature of the remains.

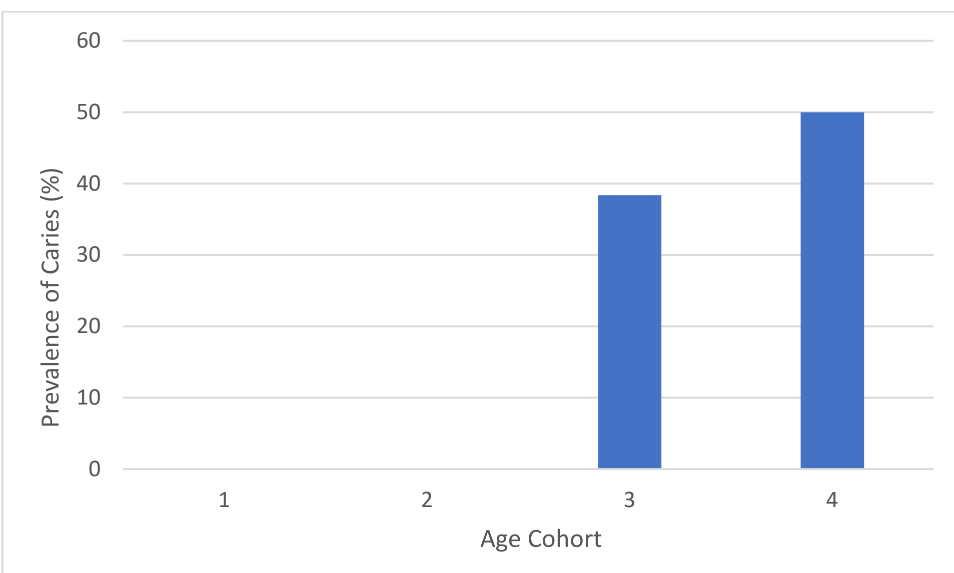

Figure 5 Age distribution of deciduous teeth with caries

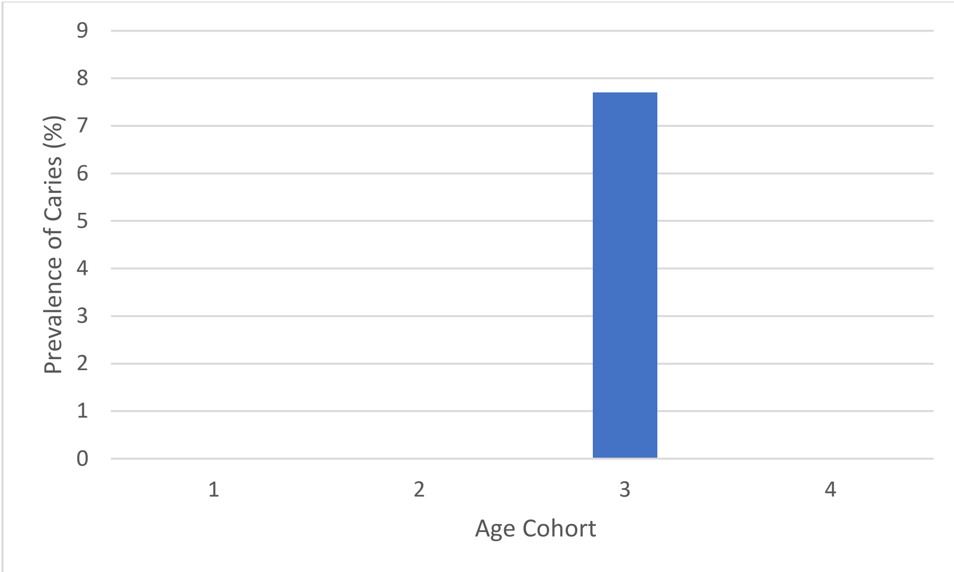

Figure 6 Age distribution of permanent teeth with caries

Caries by Individual

Individuals with caries present exhibited lesions on one or more deciduous teeth. As previously stated, caries were only present in Cohorts 3 (*2 – 6 years old*) and 4 (*7 – 12 years old*). Of the individuals with deciduous carious lesions in cohort 3, 20% (n=1) exhibited pathology on only one tooth while 80% (n=4) exhibited caries on more than one tooth (Figures 4.3 and Figure 4.4). In Cohort 4, caries were only present on deciduous teeth with none observed on the permanent dentition. A figure representing age distribution of individuals with one or more carious permanent teeth is not presented as only one individual in the total sample exhibited a carious lesion in permanent dentition.

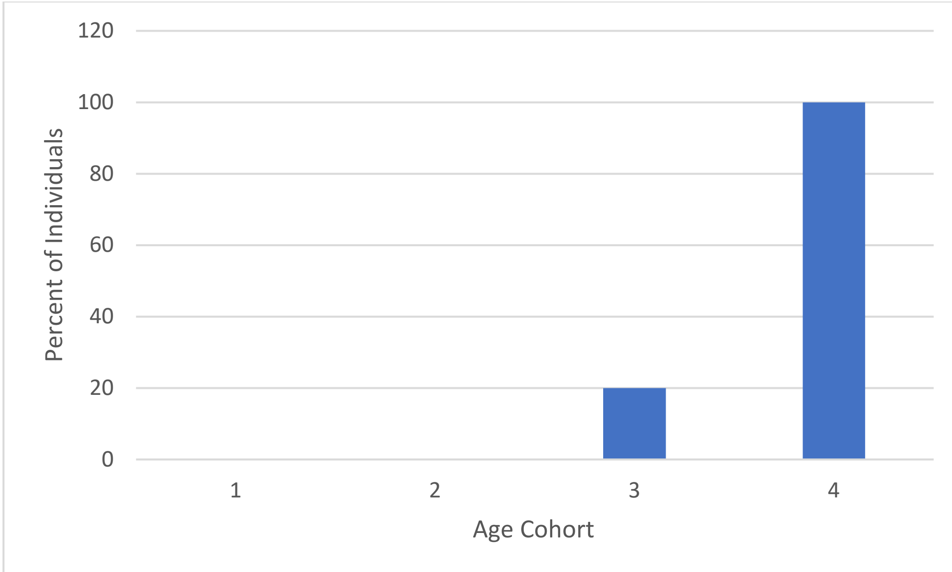

Figure 7 Age distribution of individuals with one carious deciduous tooth

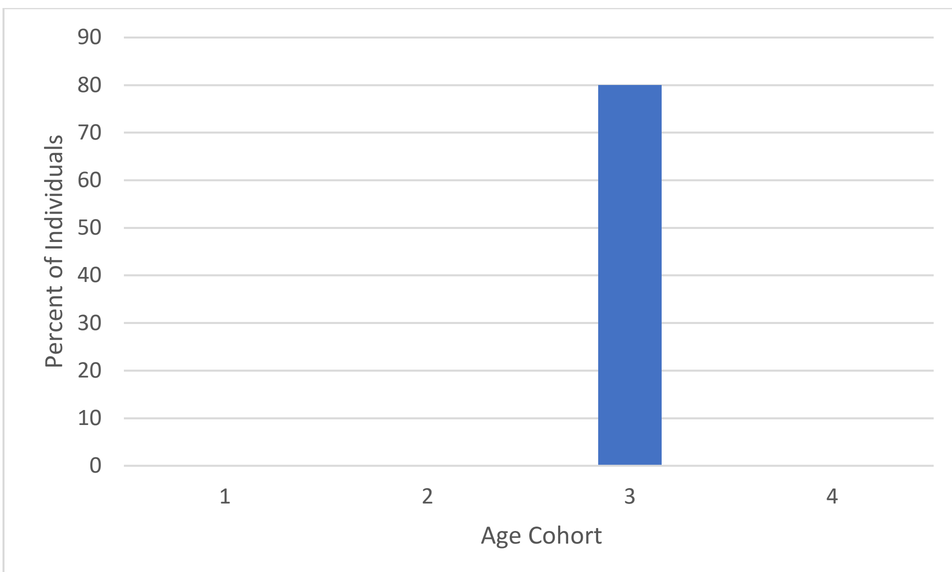

Figure 8 Age distribution of individuals with more than one carious deciduous tooth

Caries by Tooth Type

The prevalence of caries in deciduous teeth by tooth type is presented in Figure 4.5. The total number of caries in the subsample of deciduous teeth is n=15 (8.3%). Deciduous first

molars exhibited the highest prevalence of caries (n=6), followed by deciduous second molars (n=5) and deciduous central incisors (n=4). The highest rate of caries by number of teeth was observed in Cohort 3 (*2 – 6 years old*). As stated in the previous section, the paucity of caries in Cohort 4 (*7 – 12 years old*) is explained by the fragmentary nature of the remains. There were no caries observed in deciduous lateral incisors or deciduous canines. The results likely reflect the fact that first and second deciduous molars are the last teeth to shed during development and thus have prolonged exposure to lesion-causing agents. In addition, the deciduous central incisors are the first to erupt, but also first to shed, creating early exposure to lesion-causing agents.

The prevalence of caries in permanent teeth by tooth type is presented in Figure 4.6. The total number of caries in the subsample of permanent teeth is n=1. The single instance of caries in permanent teeth was observed on a permanent first molar of an individual in cohort 3 (*2 – 6 years old*). The permanent first molar is one of the first permanent teeth to erupt (6-7 years) and thus is exposed to lesion-causing agents very early when compared with corresponding permanent dentition. The presence of caries on a newly erupted molar represents an oral environment with extreme susceptibility to carious lesion formation and will be discussed in more detail in chapter 5.

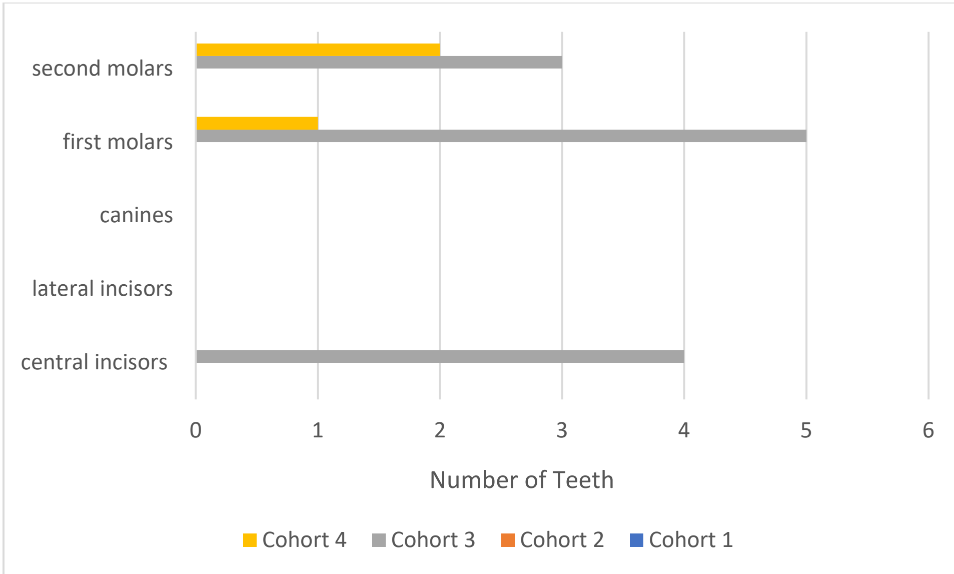

Figure 9 Age distribution of caries by deciduous tooth type

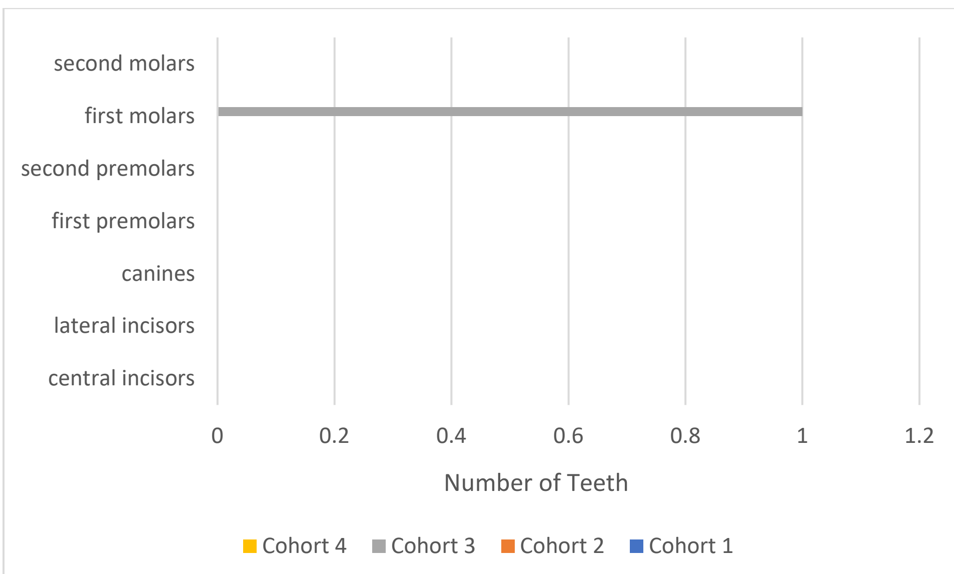

Figure 10 Age distribution of caries by permanent tooth type

Figure 11 Individual AH E-7/11b (2-3 years age-at-death). Occlusal caries on left deciduous mandibular first molar.

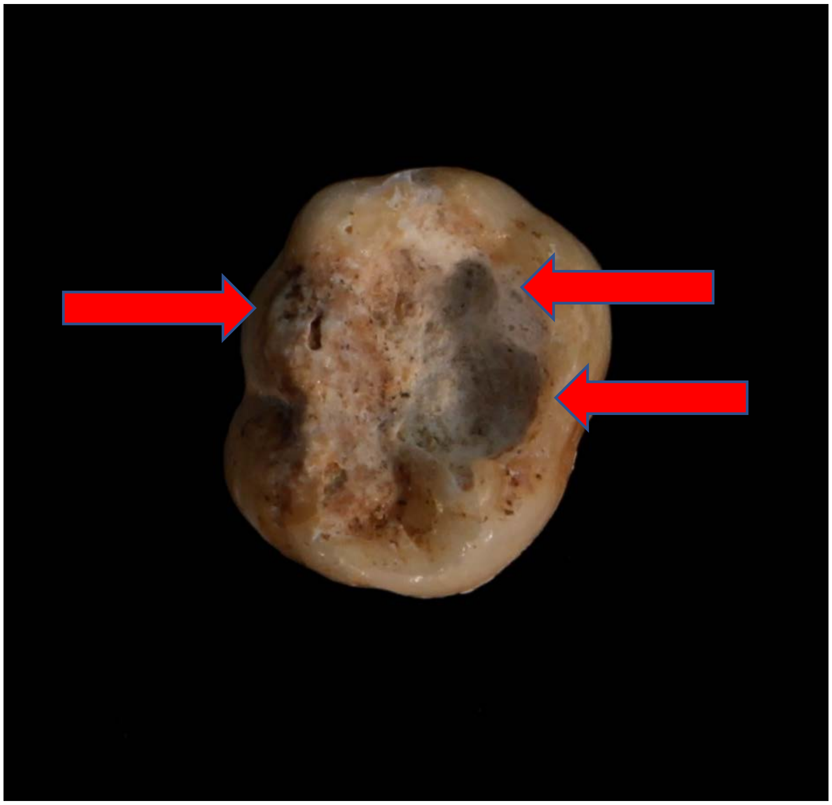

Figure 12 Individual AH E-7/20 (4-5 years age-at-death). Occlusal caries on right deciduous mandibular second molar

Figure 13 Individual AH K-29/3 (2-3 years age-at-death). Labial caries on right deciduous maxillary central incisor

Caries by Location

The prevalence of caries in deciduous teeth by location on tooth surface is presented in Figure 4.10. In molars (deciduous and permanent) the occlusal surface was the most frequent location of caries and was observed in Cohorts 3 (*2 – 6 years)* and 4 (*7 – 12 years).* In deciduous incisors, the labial surface was most frequently affected followed by the lingual surface. Labial and lingual caries on deciduous teeth were observed in Cohort 3 only. There was no instance of interproximal caries in deciduous dentition. The singular instance of caries in the permanent

molar discussed previously was observed on the occlusal surface from an individual in Cohort 3 (Figure 4.11).

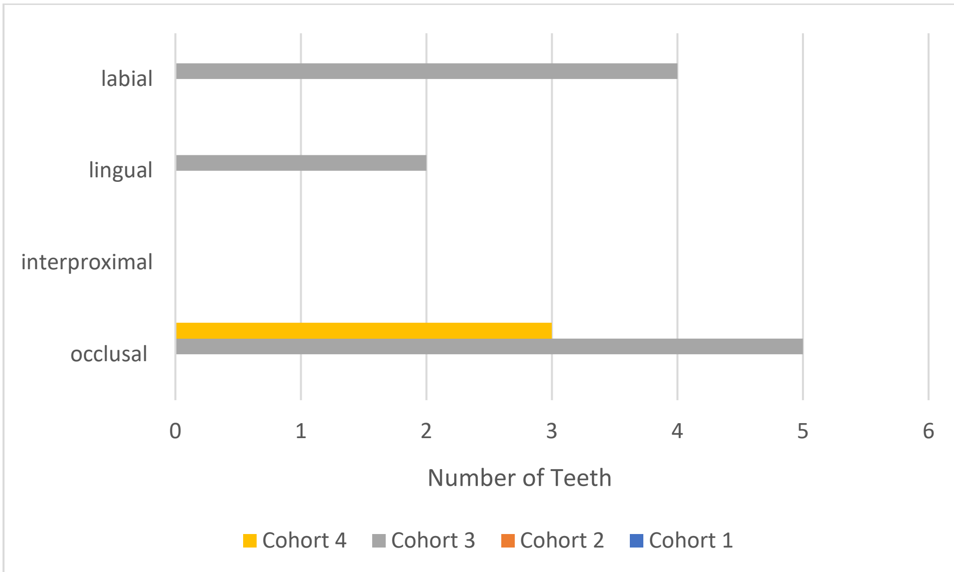

Figure 14 Age distribution of carious lesions by site on deciduous teeth

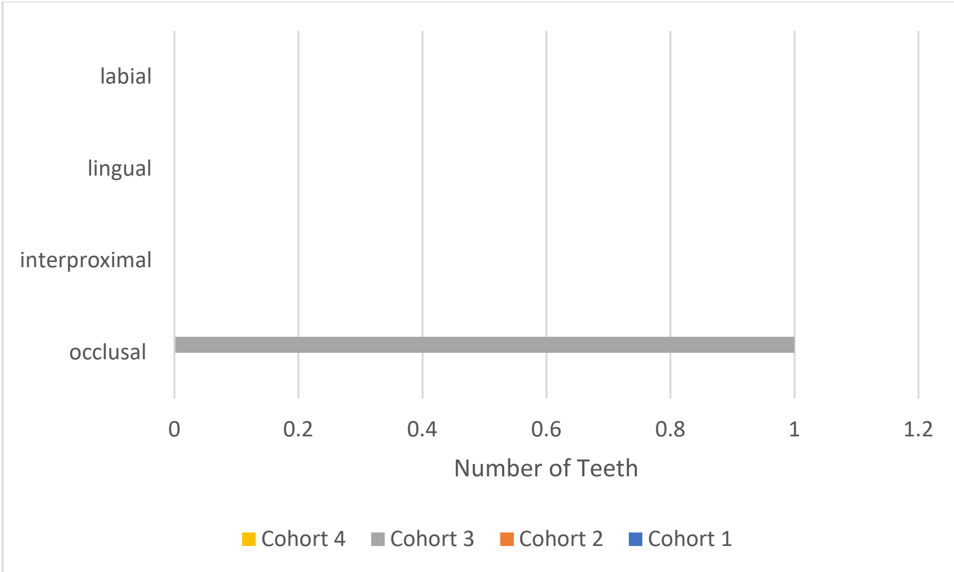

Figure 15 Age distribution of carious lesions by site on permanent teeth

Figure 16 Individual AH E-7/20 (4-5 years age-at-death). Occlusal caries on the left deciduous maxillary second molar

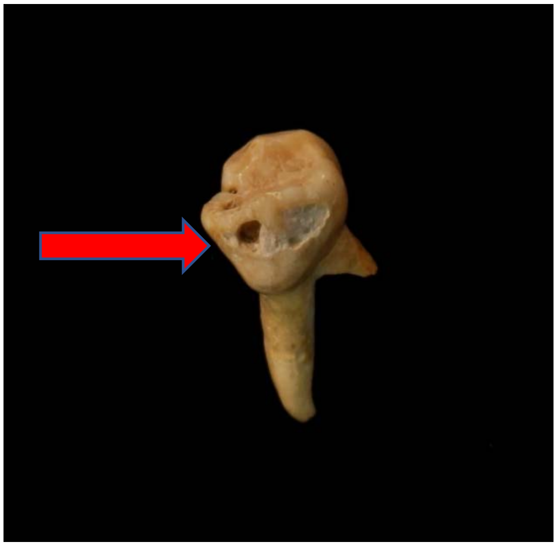

Figure 17 Individual AH E-7/11b (2-3 years age-at-death). Buccal caries on deciduous right maxillary first molar.

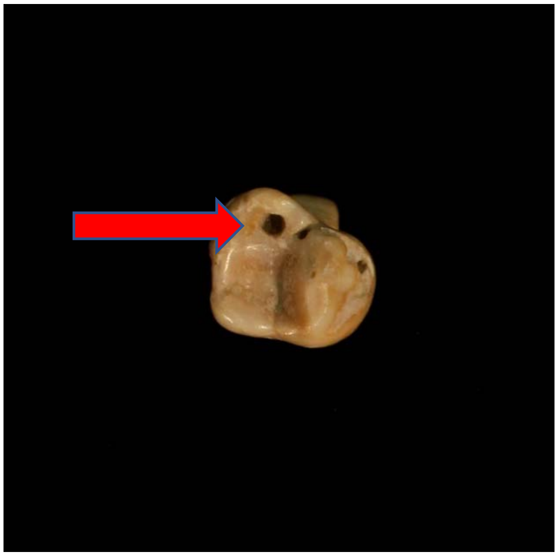

Figure 18 Individual AH E-7/11b (2-3 years age-at-death). Occlusal caries on deciduous right maxillary first molar.

Figure 19 Individual AH E-7/17 (1-2 years age-at-death). Labial caries on the left deciduous maxillary central incisor.

Caries by Archaeological Time Period

The prevalence of caries by time period is presented in Figure 4.16 and Table 4.1. The greatest prevalence of caries was observed in the Terminal Classic subsample, followed by the Late Classic and the Preclassic. There were no caries observed in the Early Classic subsample. Cohort 3 (*2 – 6 years)* contained the highest number of individuals (n=5) with caries across all periods with a frequency of 38.5%. However, the greatest prevalence of caries, 50%, was observed in Cohort 4 (*7 – 12 years)*.

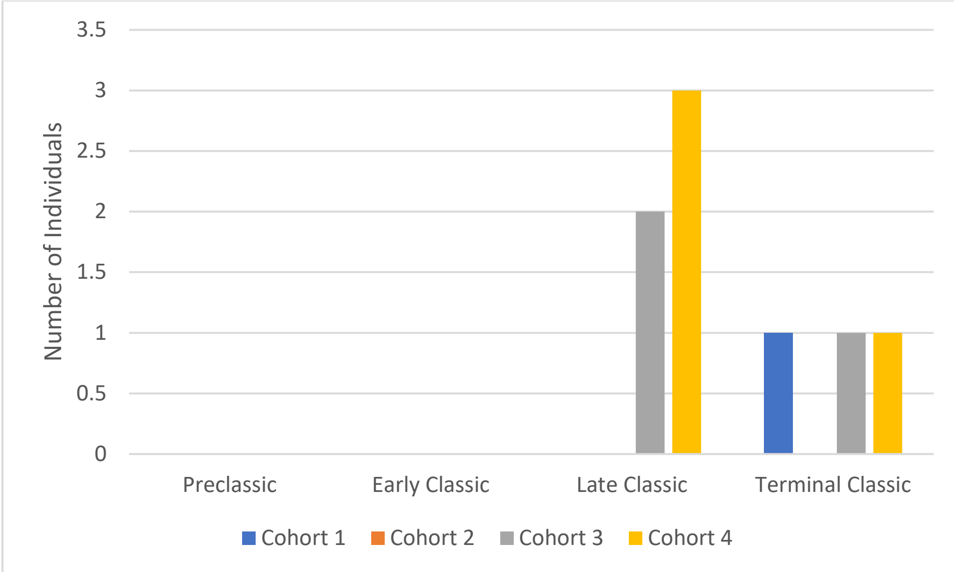

Figure 20 Age distribution of carious lesion prevalence by archaeological time period (includes deciduous and permanent teeth)

Table 7 Age distribution of carious lesion prevalence by time period (includes deciduous and permanent teeth)

Time Period	1	2	3	4
Preclassic	0	0	0	1
Early Classic	0	0	0	0
Late Classic	0	0	2	1
Terminal Classic	0	0	3	1
Total	0	0	5	3

Linear Enamel Hypoplasia

Linear Enamel Hypoplasia (LEH) was scored as present or not present. LEH was determined to be present when interruption in the enamel matrix produced a palpable indentation in the tooth surface indicating a furrow-form defect. LEH was present predominantly in the permanent dentition, though two individuals exhibited manifestations in the deciduous dentition.

Hypoplastic defects such as pit-form, plane-form and hypocalcification were excluded for the scope of this research. LEH was more prevalent in the Altun Ha sample than were caries.

LEH by Cohort

Linear Enamel Hypoplasia was present in deciduous teeth in Cohorts 2 *(0 – 1 years old)* and 3 (*2 – 6 years old*). The total prevalence of LEH in deciduous teeth was 15.4%. The total prevalence range of LEH by cohort in deciduous teeth was 7.7% to 14.3% (Figure 4.17). The greatest prevalence of LEH in deciduous teeth was in the second cohort. The absence of LEH in Cohort 4 (*7 – 12 years* old) can be attributed to the shedding of deciduous dentition most commonly exhibiting the pathology at the time that this age range is achieved.

Linear Enamel Hypoplasia was present in the permanent teeth in Cohorts 3 (*2 – 6 years old*) and 4 (*7 – 12 years old)*. The sample total prevalence of LEH in permanent teeth was 40.7%. The total cohort prevalence of LEH in permanent teeth was 46.2% in Cohort 3 and 83.3% in Cohort 4 (Figure 4.18). The absence of LEH in Cohort 1 is signified by the absence of permanent teeth in newborns.

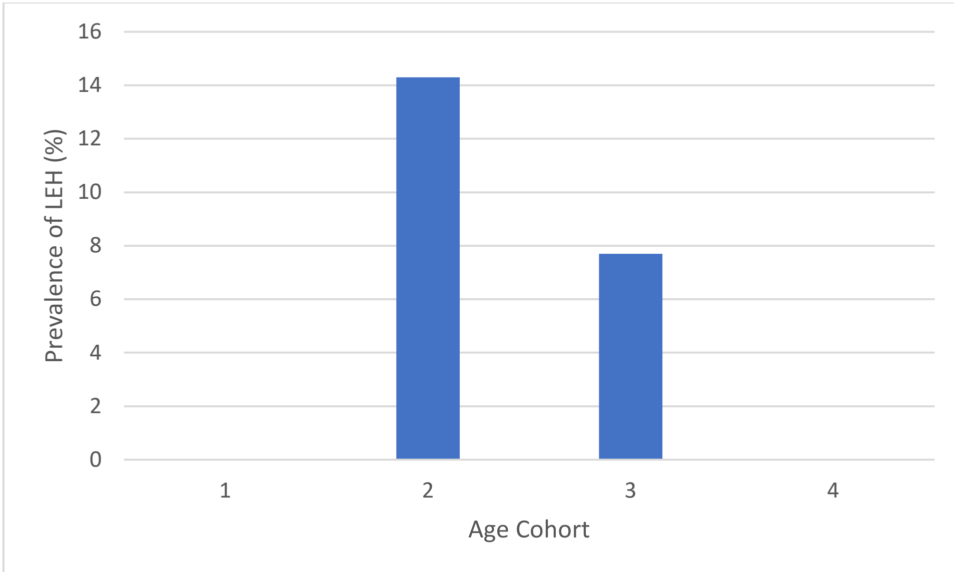

Figure 21 Age distribution of deciduous teeth with linear enamel hypoplasia

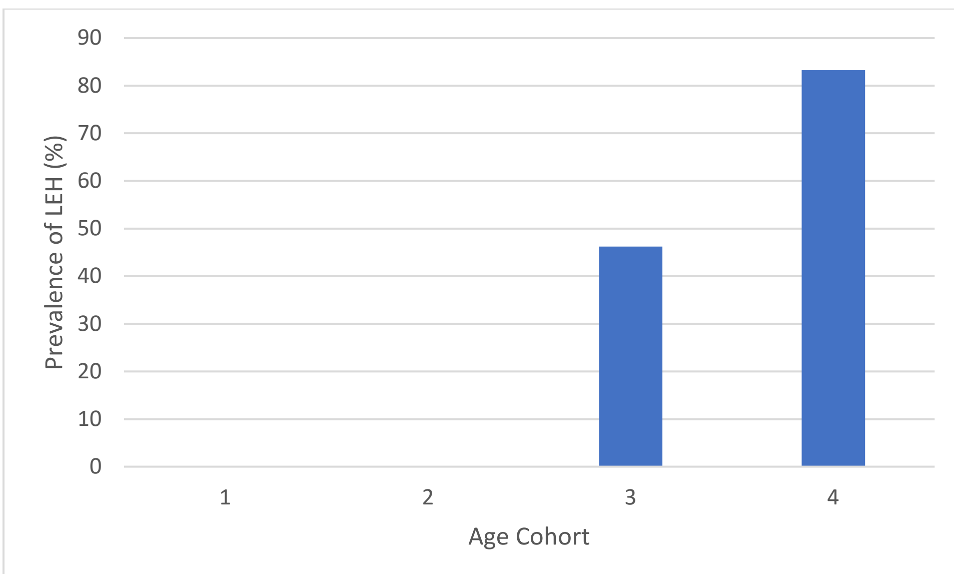

Figure 22 Age distribution of permanent teeth with linear enamel hypoplasia

LEH by Individual

All individuals except one exhibited LEH on more than one tooth from an individual in Cohort 3 (*2 – 6 years old*) (Figure 4.19). By definition, LEH must be present on multiple teeth to

be considered such (HIllson, 2014:167). Typically, presence of enamel defects on only one tooth could be indicative of trauma rather than developmental defect. However, the singular individual presenting localized enamel hypoplasia in this instance is treated as presence of LEH due to the general appearance and the absence of antimeres for comparison. LEH was present in multiple teeth per individual in Cohorts 2, 3, and 4 (Figure 4.20).

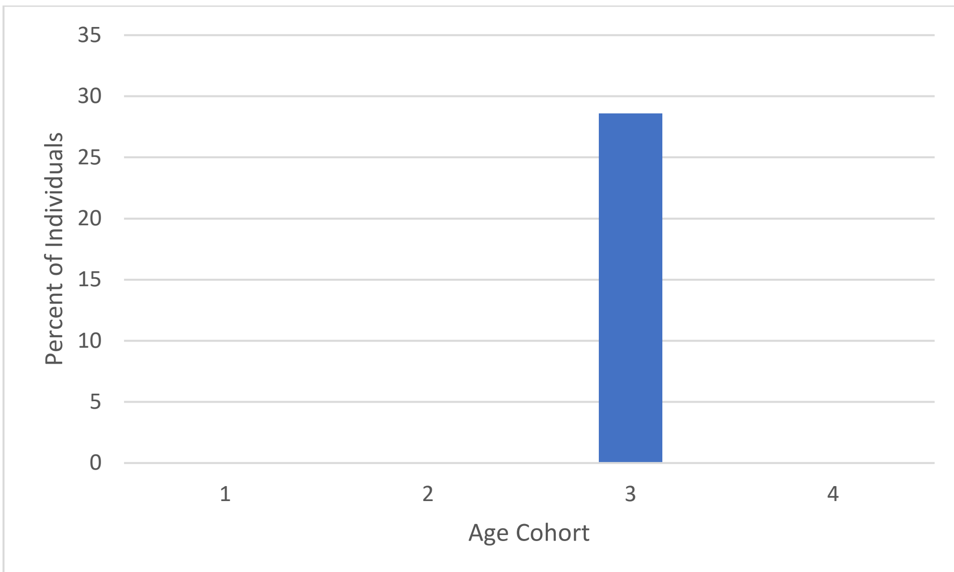

Figure 23 Age distribution of individuals with LEH on one tooth

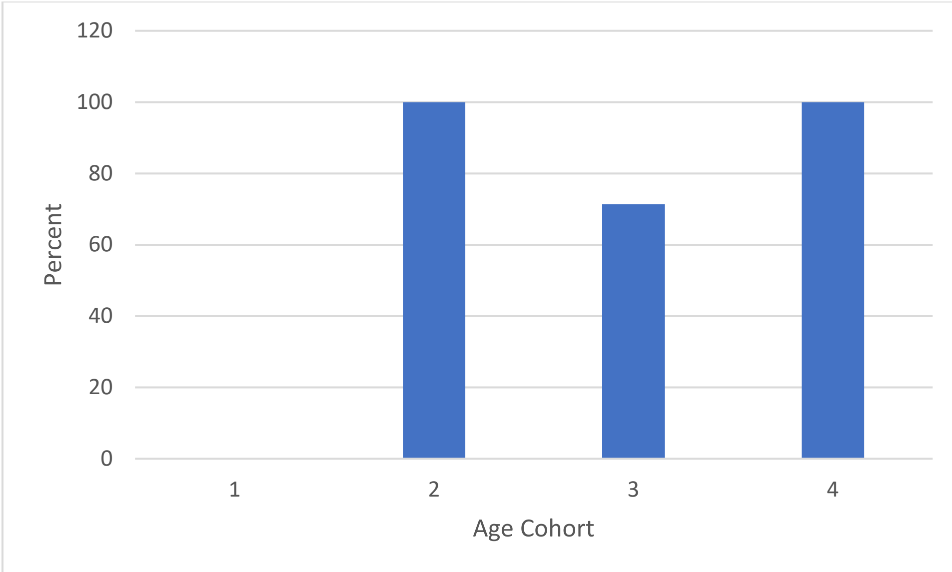

Figure 24 Age distribution of individuals with LEH on more than one tooth

LEH by Tooth Type

Linear Enamel Hypoplasia prevalence in deciduous dentition was observed on the central and lateral incisors (Figure 4.21). LEH in deciduous dentition suggests maternal distress or infant malnutrition as the timing of enamel deposition for these teeth is perinatal. In permanent teeth, LEH was most commonly observed on the canines, followed by the central incisors (Figure 4.22). The lateral incisors and first premolars exhibited the same rate of LEH, followed by the first molars. Cohort 3 (*2 – 6 years old*) contained the highest number of individual teeth exhibiting LEH, followed by cohort 4 (*7 – 12 years old).*

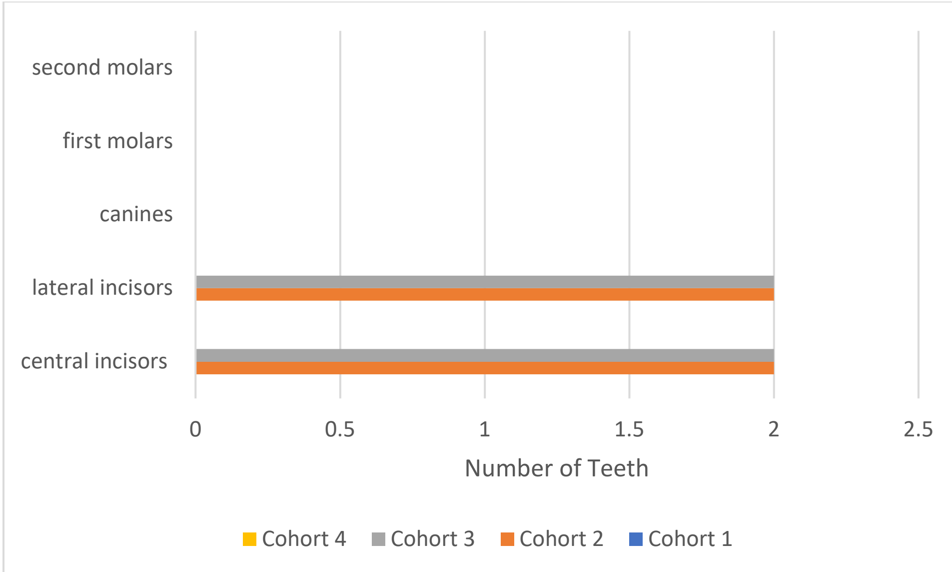

Figure 25 Age distribution of LEH by deciduous tooth type

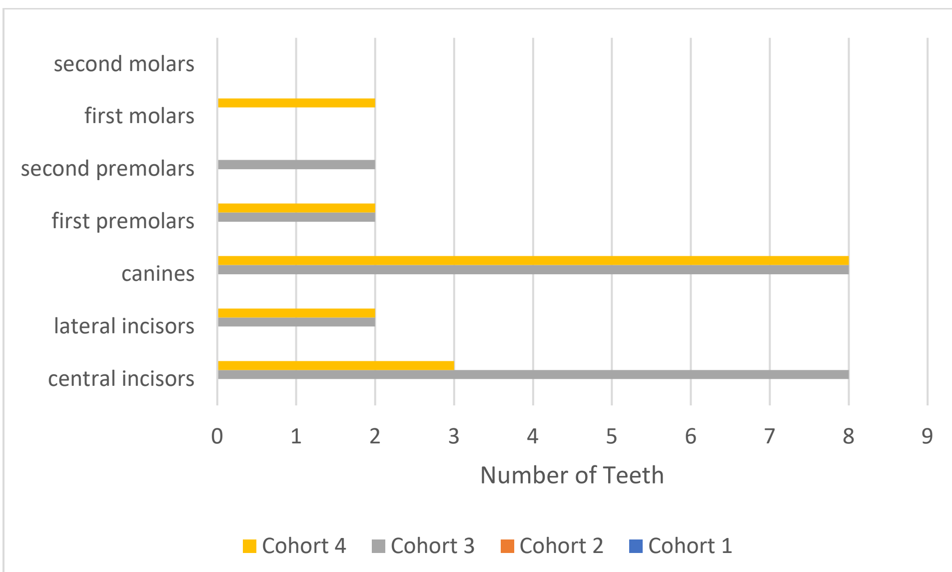

Figure 26 Age distribution of LEH by permanent tooth type

Figure 27 Individual AH C-13/5a (7-8 years age-at-death). LEH of left permanent mandibular canine

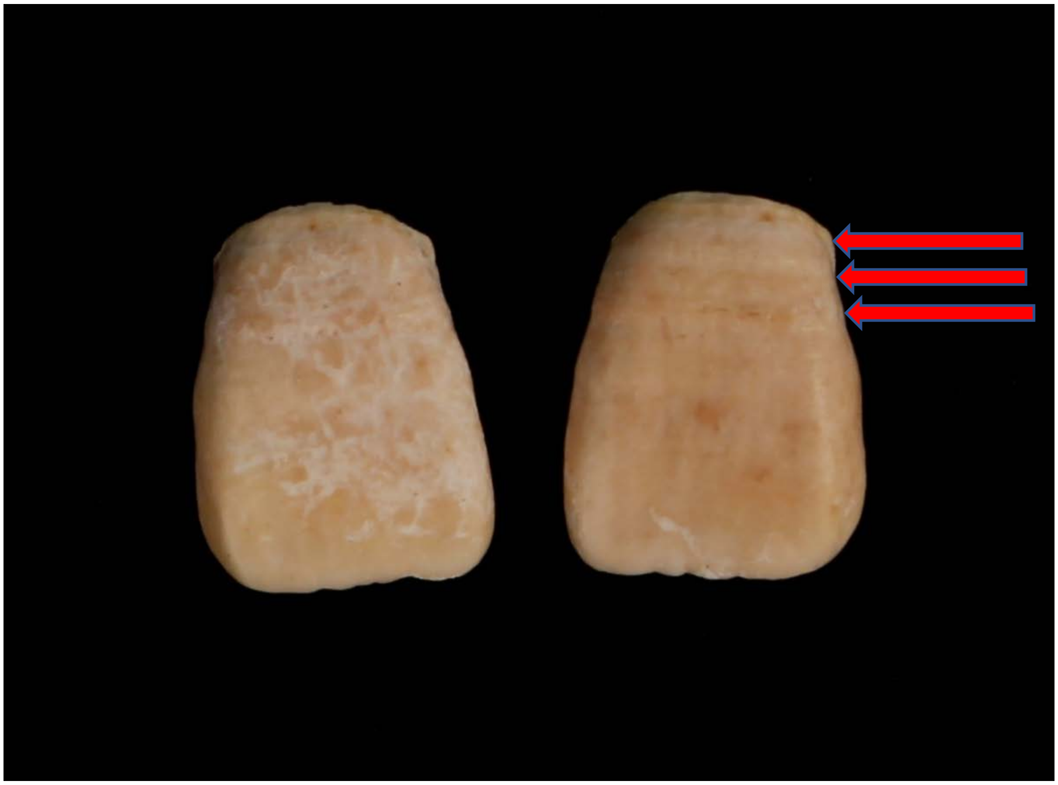

Figure 28 Individual AH C-13/19 (4-6 years age-at-death). LEH on left and right permanent maxillary central incisors

Figure 29 Individual AH E-7/20 (4-5 years age-at-death). LEH on left and right permanent central incisors

Figure 30 Individual AH E-50/16 (8-9 years age-at-death). LEH on left permanent mandibular canine and left permanent mandibular premolar

LEH by Time Period

The prevalence of LEH by time period is presented in Figure 4.27 and Table 4.2. The highest instance of LEH was observed in the Terminal Classic subsample, followed by the Early Classic, the Late Classic and the Preclassic. Cohort 3 contained the highest number of individuals (n=6) with LEH across all periods, followed by cohort 4 and cohort 2. In addition, there is one individual with LEH in cohort 3 (AH E-6/7b) from an unknown time period.

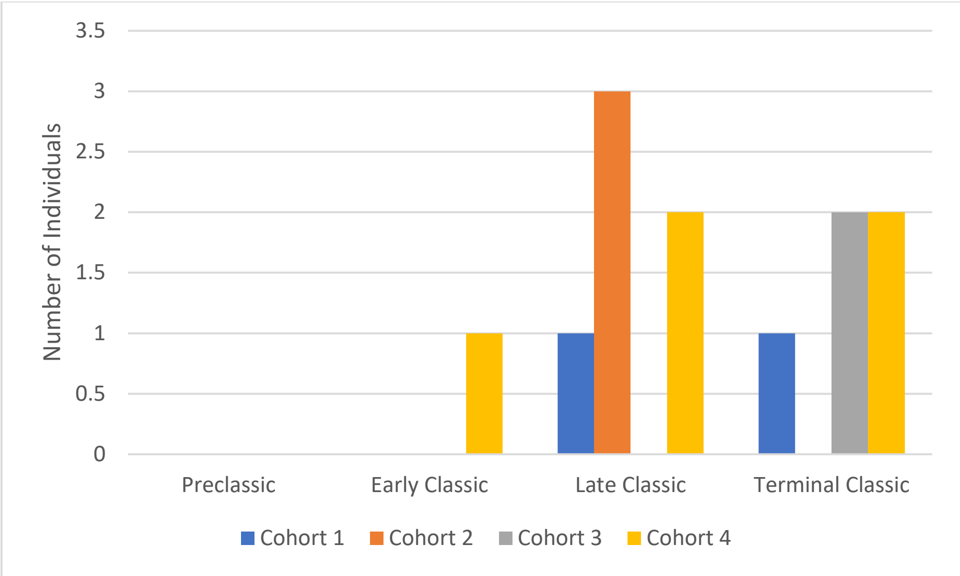

Figure 31 Age distribution of LEH prevalence by archaeological time period (includes deciduous and permanent teeth)

Time Period	1	2	3	4
Preclassic	0	0	1	1
Early Classic	0	0	3	0
Late Classic	0	0	0	2
Terminal Classic	0	1	2	2
Total	0	1	6	5

Table 8 Age distribution of LEH prevalence by time period (includes deciduous and permanent teeth)

CHAPTER FIVE: DISCUSSION, CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

Introduction

Subadults comprise a significant portion of skeletal remains in the archaeological record (Halcrow and Tayles, 2008; Lewis, 2007). However, subadults were largely ignored in archaeological research in the past (Hooten, 1930 cited in Halcrow, 2008). The study of children in the archaeological record has been historically marginalized due to a perceived lack of contribution to cultural constructs (Halcrow and Tayles, 2008:199). However, children have a significant contribution to social processes, and are certainly still affected by them (Crawford and Lewis, 2009; Halcrow and Tayles, 2008; Mays et al., 2017). In recent years, research in the areas of subadult osteology, paleopathology, and paleodiet has burgeoned (Mays et al., 2017). The study of juveniles within the archaeological record offers new insight into the life course of past populations.

In this chapter, the results regarding dental pathology susceptibility will be discussed in terms of age groups, tooth types, tooth surface locations, and archaeological time period. The data is discussed in terms of frequencies within defined age groups: cohort 1 (*newborn*), cohort 2 (*0 – 1 years*), cohort 3 (*2 – 6 years*), and cohort 4 (*7 – 12 years*). The arrangement of the data in this way allows for the analysis of developmental factors contributing to pathology expression within the transitioning landscape of childhood. The present chapter discusses the significance of the results of the previous chapter using both archaeological and modern clinical references.

Discussion

Caries

Overall prevalence of caries in juveniles at Altun Ha was moderate (37%) showing a positive correlation with advanced age. Frequency of caries at Altun Ha differed from that of other Maya sites. In a comprehensive study of skeletal remains at the inland site of Copan in the Southern Maya Region, Maya juveniles exhibited a slightly higher frequency (44%) of caries prevalence than those observed in the Altun Ha juvenile subsample (Whittington, 1999). However, data from two Maya sites in Northern Ambergris Caye (San Juan and Chac Balam) indicated a slightly lower prevalence of caries, 36% (Glassman and Garber, 1999). Skeletal samples from another coastal Maya Lowlands site, Kichpanha, found an even lower instance of caries at 28.5% (Magennis, 1999). There is an observed trend of lower prevalence of caries in individuals from sites with increased proximity to the coast. While commerce made marine resources available to inland sites as well, there is a noticeable dietary impact on coastal sites directly benefiting from these sources. Of significance to the assessment of dental pathology, it has been suggested that marine resource availability may negatively impact caries prevalence as it augments otherwise predominantly carbohydrate-heavy diets (Glassman and Garber, 1999).

In reconstructing the food web at Altun Ha through isotopic analysis of bone carbon and collagen, White et al. (2001) found a stronger marine dietary component than at any other Maya site. Carbon levels from collagen and apatite demonstrated a diet high in reef-source protein in addition to C4 plants such as maize (White et al., 2001:381). The dietary isotopic values at Altun Ha are consistent with individual values from other sites within the Belize Valley region, however a comparison of these values to skeletal samples from the inland sites of Copán and the Petén region indicate a lower consumption of C4 plants at Altun Ha. Maize still constituted a

significant enough portion of the diet at Altun Ha to be considered a staple food. However, it was clearly supplemented by marine-based protein sources (White et al., 2001).

The dietary ecology at Altun Ha was based on analyses of adult and subadult individuals from nine zones including all occupation periods for the population inhabiting the site. Therefore, the baseline can be seen as an overarching pattern of consumption at the site combining all archaeological time periods and developmental ages. It can be inferred that, upon completion of weaning, the juvenile subsample analyzed in this research would have adopted this diet and therefore, eventually acquired dietary protein levels comparable with those in the White et al (2001) study. However, it is unlikely that subadults near weaning age would have had as significant a dietary contribution from marine sources as older children and adults because a majority of their diet would have been comprised of breastmilk supplemented with maize (C4 plant) in the early stages of weaning (Tozzer, 1941 as cited in Williams, 2005:784). Therefore, age is an important consideration in the assessment of consumption related dental pathology.

Breast milk has a unique combination of macronutrients. The composition of breastmilk: carbohydrates (39%), lipids (55%), and proteins (5%) represents the optimal nutrient proportions for the developing infant (Rolfes et. al., 2009:518). As children develop, nutritional needs change necessitating the introduction of macronutrients from solid foods. The carbohydrate content in breastmilk, disaccharide lactose, differs from that of the dietary carbohydrates, such as sucrose, in staple foods (maize). Though both substances are sugars, lactose is not as readily fermentable as sucrose. Sugar fermentation plays a large role in cariogenesis by supporting the proliferation of *mutans streptococci* (Damle et al., 2016; Larsen 2015). For this reason, sucrose is highly correlated with cariogenesis (Anttonen et al., 2012).

Weaning is an important consideration in the analysis of diet-related dental pathology. Based on collagen-apatite spacing, White et al. (2001) found the average age of weaning at Altun Ha to be between 3-4 years of age. Williams et al. (2005) found similar results at two Central Lowlands Maya sites (San Pedro and Marco Gonzales) indicating an average weaning age of 3-4 years of age, but she also found evidence that weaning may have begun as early as 12 months of age. In an analysis of strontium isotopes in juvenile dentition from the Maya Lowlands site of Lamanai, Song (2004) found a sharp increase in dietary carbohydrate intake around age 2, but with indicators of breastmilk consumption until as late as age 5. The commencement timing of weaning is significant as it coincides with the introduction of potentially cariogenic solid foods into the infant's diet. The addition of maize into the diet of weaning-aged juveniles at Altun Ha thus predisposed the oral environment to the potential for the diet-related cariogenesis observed in cohort 3 (2 – 6 years).

Modern clinical studies show a marked paucity of caries in breastfed children when compared with non-breastfed children (Baweja et al., 2017). However, frequent breastfeeding after 12 months as well as the introduction of dietary carbohydrates are associated with development of caries (Baweja et al. 2017; Peres et al. 2017). Additionally, a recent study indicates that certain breastfeeding practices can also contribute to the development of caries (Chaffee et al., 2014). In their longitudinal study of 715 low-income families in Brazil, Chaffee et al. found that deciduous caries increases with duration of breastfeeding with children breastfed two years or more exhibiting the highest rate of cariogenesis. However, they acknowledge the ubiquitous availability of refined sugars in modern diets as a possible contributor to higher instance of caries in this population (Chaffee et al., 2014:453). Erickson et al. (1999) concluded that breastmilk alone did not cause enamel degradation, however, breastmilk augmented with

sucrose caused caries within three weeks of initiation. The Maya weaning practice of maize supplementation thus could have contributed to the pattern of carious lesions found in the Altun Ha juvenile subsample.

In the Altun Ha subsample, the relatively small percentage of juveniles exhibiting caries in cohort 2 (0 - 1 year) and the sharp increase of caries in cohort 3 (2-6 years) coupled with the Altun Ha weaning timeline data observed by White et al.(2001) further supports the previously discussed clinical and archaeological data. The results from this study suggests that the increase in caries among juveniles 2 – 6 years old is at least in part caused by breastfeeding practices, weaning, and the introduction of sucrose-rich maize into the infant diet.

There is also an increase in caries frequency observed between cohorts 3 (2 – 6 years) and 4 (7 – 12 years). While the age-at-death of this cohort exceeds that of the weaning-period, all caries in this cohort were observed on deciduous dentition. It is therefore possible that caries were initiated during the weaning-period and exacerbated in the post-weaning interim.

As previously stated, Altun Ha's unique diet rich in marine-source protein produced low levels of caries when compared with inland, predominantly C4 reliant Maya groups. Indeed, Song (1997) found a lower prevalence of total population caries at Altun Ha than found in this study among the juvenile subsample. The significant differentiating factor here is consideration of deciduous and primary dentition separately. The current study found a comparatively high prevalence of caries in cohort 4 (50%), however, all of the caries observed were on the deciduous dentition. Therefore, it is suggested that the buffering effects of the marine diet which produce comparatively low caries frequencies in coastal Maya sites manifest in the permanent dentition and not the deciduous dentition as a function of dietary and weaning practices.

Next, tooth type is considered in the etiology of caries. Deciduous dentition develops, erupts, and sheds in a regular pattern. The span of time between eruption and shedding is different for each tooth type, according to its position in the dental arcade. Additionally, teeth emerge at different times, including teeth of the same type but differing position in the dental arcade. These cofactors create conditions such that specific tooth types and locations predictably exhibit higher frequencies of dental pathology.

Permanent central incisors, canines, first molars, and second molars are the tooth types most commonly affected by carious lesions (Hilson, 2008:120). A similar pattern of expression in deciduous teeth has been found in other studies (Douglass et al, 2001; Shkrum, 2008). Additionally, maxillary teeth are more susceptible to caries than are mandibular teeth, especially in the anterior dentition, due to the flow of saliva (Hillson, 2001:251). Saliva neutralizes oral pH levels and has antibacterial properties which mediates the proliferation of oral microbes, thereby reducing potential for enamel degradation (Hillson, 2008:115; Larsen, 2015:68; Renke, 2016:65).

The first deciduous teeth to erupt are usually the central mandibular incisors (6 – 10 months), followed by the central maxillary incisors (8 – 12 months) (American Dental Association). Douglass et al. (2001) found carious lesions of the maxillary anterior dentition in individuals as early as 10-12 months, indicating a rapid manifestation of this pathology. There were five instances of deciduous maxillary central incisor caries in the Altun Ha subsample, all on the labial smooth surface or labial CEJ. The significance of location of caries on the individual tooth surface will be discussed in more detail below. There were no caries observed on deciduous mandibular central incisors. All smooth surface caries on the maxillary central incisors were observed on individuals in cohort 3, supporting the weaning/carbohydrate

supplementation hypothesis as well as reinforcing the established caries patterning found in clinical and archaeological data.

Deciduous first molars typically erupt between 14-18 months in the mandible and between 13-19 months in the maxilla (American Dental Association). Deciduous first molar eruption represents an inverse pattern when compared with deciduous incisors because, unlike incisors, the maxillary antimeres are typically first to erupt. The combination of earlier eruption and less advantageous positioning for saliva flow make the maxillary molars of both deciduous and permanent dentition more susceptible to cariogenesis than their mandibular antimeres. The Altun Ha subsample data supports this pattern. Of the 6 instances of deciduous first molar caries, 83.3% (n=5) were observed on the maxillary dentition.

Deciduous second molars generally erupt between 23 – 31 months in the mandible and between 25 – 33 months in the maxilla. Here, there is a return to the pattern observed in the incisors, exhibiting earlier mandibular eruption. The appearance of caries in deciduous second molars (n=5) was slightly lower than in deciduous first molars (n=6). Additionally, there was a narrower ratio of mandibular to maxillary (3:2) caries frequency in deciduous second molars with mandibular caries being slightly more prevalent.

Next, patterns of carious lesions on the individual tooth surfaces are discussed. Hillson (2001:250) recognized two main categories of lesion location: coronal caries (occlusal/pit and fissure, interproximal, and smooth surface) and root surface caries (cemento-enamel junction). Drury et al. (1999) proposed case definitions for caries in childhood with a classification of Early Childhood Caries (ECC) or severe Early Childhood Caries (sECC). ECC is defined as any child between 1 – 71 months showing a DMF (decayed, missing, filled) score of 1 or more. In the more severe form, a child between 1 – 35 months showing a DMF score of 1 or more on a

smooth surface in particular is classified as having sECC. Additionally, a child between 36 – 71 months exhibiting cavitated smooth surface caries on the primary maxillary anterior dentition and/or in excess of 4, 5, or 6 caries throughout total deciduous dentition (dependent upon age group) is classified as having sECC. In the permanent dentition, the most commonly affected areas are the occlusal surfaces of maxillary and mandibular molars as well as interproximal surfaces of the posterior dentition.

Smooth surface caries were observed on the labial surface (n=5 teeth; n=5 individuals) and the lingual surface (n=1) of deciduous central incisors. Occlusal caries were observed on deciduous first molars (n=6 teeth; n=4 individuals) and deciduous second molars (n=5 teeth; n=4 individuals). Four of the 5 individuals having caries on the labial surface of the deciduous central incisors presented on the maxillary dentition and were under the age of 36 months, thus qualifying as having sECC by modern dental standards. While modern standards must be applied to archeological populations with caution, the indication here is sufficient to say that the individuals meeting sECC qualifications were representative of early childhood stress manifested in pathology of the dentition. The locations of caries were otherwise in keeping with expectation, most commonly affecting the occlusal surfaces of the molars. The sole instance of carious lesion on permanent dentition was found on the occlusal/metaconid surface of a maxillary first molar. The paucity of caries in the permanent dentition is interpreted as a function of the fragmentary nature of the remains rather than a general lack indicating low dietary carbohydrate intake. Although, as previously mentioned, Song (1997) found the caries rate among adults at Altun Ha to be low, in keeping with the marine-diet hypothesis. However, without the dentition to examine in the juvenile subsample, it is unclear whether the paucity of

permanent dentition exhibiting caries is due to antemortem dietary factors or postmortem preservation and excavation conditions.

Next, the temporal frequencies of caries prevalence will be discussed. The Altun Ha juvenile subsample shows an increase in instance of caries in cohorts 2 (0 – 1 years), 3 (2 – 6 years), and 4 (7 – 12 years) beginning in the Early Classic and reaching a peak in the Terminal Classic. Agricultural intensification has been shown to correspond with increased caries in the archaeological record (Larsen, 2015). If this is correct, agricultural intensification, particularly of maize, would likely produce an increase in C4 plant levels in bone collagen in correlation with increased subsistence and consumption. However, White et al. (2001) found bone collagen and apatite levels indicating a peak in C4 consumption during the Early Classic, followed by a decrease in C4 consumption during the Late Classic, indicated by comparatively lower levels of C13(apatite) and C13(collagen). Despite this decrease, the N15(collagen) and C13(collagen-apatite spacing) remained unchanged. Therefore, White et al. suggests a potential shift in protein source as the cause of the fluctuating values. The pattern of C4 consumption remained stable from the Late Classic through the Terminal classic (White et al., 2001).

As previously discussed, it is likely that the diet-related high instance of caries among cohort 3 (2 – 6 years) is owed to factors surrounding weaning practices and would be thus unaffected by temporal protein shifts. If maize consumption decreased over time, but there was an inverse increase in caries in the weaning cohort, this suggests that factors other than carbohydrate consumption affected caries prevalence or that weaning-age children were buffered from the factors affecting C4 (maize) resource availability via cultural childcare practices. Cohort 4 (7 – 12 years) more closely reflects the general diet of the Altun Ha population shared by adolescents and adults, as studies have shown weaning in the Maya lowlands ends around age

3-4 years (see above). However, the prevalence of caries was observed in the deciduous dentition. Thus, the caries etiology in this cohort can be interpreted similarly to that of cohort 3 (2 – 6 years).

White et al. (2001) suggests that the drop in C4 consumption at Altun Ha during the Late Classic was a function of cultural processes such as decreased importation or production. Shifts involving food practices can signify technological changes, environmental stress, and/or socioeconomic stress. It is possible that any combination of these factors contributed to the higher prevalence of caries among juveniles at Altun Ha. Factors such as malnutrition, compromised health, and food quality must also be considered. In addition to the external factors discussed above, the developmental structure of the individual teeth plays a significant role in manifestation of dental pathology. Factors of overall individual and maternal health are represented in dental development and, thus, poor health can cause developmental pathologies, such as linear enamel hypoplasia. Hypoplastic defects compromise the tooth structure, potentially predisposing hosts to cariogenesis. In the next section, linear enamel hypoplasia in the Altun Ha juvenile subsample is discussed.

Linear Enamel Hypoplasia

There is a direct relationship between stress and defects of the enamel (Larsen, 2015:44). External stressors cause metabolic disturbances which negatively impact ameliogenesis resulting in changes to the rate of enamel secretion (Larsen, 2015:44; Hillson, 2008). Enamel hypoplasia is characterized by a disruption to the enamel matrix of such severity that it results in a deviation of the normal tooth structure during development. The overall morphology of the tooth crown

develops normally but exhibits macroscopic and/or microscopic pits or lines in the crown surface (Simpson, 1999:242).

Enamel develops in bands of matrix-secreting ameloblasts, each separated by a Striae of Retzius (observed in cross-section) which form successive perikymata on the crown surface (Hillson, 2014:100). The rate of secretion varies by individual, however the span of time for the formation of one complete perikymata is approximately nine days (Hillson, 2014:100). This means that, observation of the location of the hypoplastic defect within the entire tooth crown can indicate age at time of stress episode with a narrow margin of error. Unlike Wilson bands, which indicate acute stress episodes of hours or days, hypoplasias represent an extended period of stress (weeks or months) (Larsen, 2009:49). Average number of perikymata varies by tooth type (300+ on canines, 100 – 250 on incisors, and 70 – 100 on molars) and become more densely packed as they near the cemento-enamel junction (Hillson, 2014:76-85). Deciduous teeth have a smooth surface that does not display perikymata. However, newly-formed permanent teeth in the mixed dentition of a child are optimal for observation of perikymata and associated anomalies (hypoplasias) as they have not long been exposed to normal processes such as attrition and abrasion (Hillson, 2014).

Though hypoplasias can present in a range of forms, only the presence of linear enamel hypoplasias was assessed in the Altun Ha juvenile subsample. LEH defects are transverse, parallel to the gingival line. The individual defects (or lines) each feature an occlusal border, an occlusal wall of perikymata representing the stress episode, a cervical wall of perikymata representing the recovery period, and a cervical border (Larsen, 2015:45). The depth and width of each defect can provide information as to the duration and severity of the stress episode but

also provides an indirect measure of host resistance as an individual with compromised health may have a more severe response to stress and may take longer to recover.

It is important to fully consider the inextricability of time and external influence in the manifestation of dental pathology. Teeth form in the alveolar bone in utero beginning at 4 months gestation (Larsen, 2015:50). At time of birth, all deciduous tooth crowns have been initiated and are in various stages of crown completion (Ubelaker, 1989). Maternal stress, such as poor nutrition, illness, and fever, can cause disturbances to the developing embryo which can result in hypoplastic defects to the deciduous dentition (Shkrum, 2008:118). Permanent dentition begins to form in utero as well, beginning with the first permanent molar. However, this tooth type infrequently manifests hypoplastic defects due to the layering of enamel in the cuspal region (Simpson, 1999:242). Additionally, hypoplasias of the permanent dentition can be more complex to define as they can reflect the overall health and nutrition of the individual and/or the mother as these teeth form in the post-natal interval and are thus affected by cultural influences.

In the post-natal term, the dentition continues to form on a chronological timeline until completion of the permanent second molar at 11-13 years old (American Dental Association). The teeth most frequently effected by LEH (permanent canines, permanent incisors, and permanent premolars) begin to form at different times. The permanent central incisors are first to initiate, beginning around 1 year of age and completing between 3.5 – 5 years depending on the location (maxillary/mandibular) and position (central/lateral) (Reid and Dean, 2006). The canines develop on a longer timeline, initiating around 1.4 years and completing between 5 – 6 years. Finally, the premolars initiate around 2.5 – 3.5 years (dependent on position) and complete between 5.5 – 6.5 years. Any significant stress episode occurring within the formation

window will be recorded in the timeline of the affected tooth and can be attributed to multiple factors acting upon the juvenile during that time.

As discussed above, enamel hypoplasia results from a variety of non-specific extrinsic and intrinsic stressors which arise in the fetal and early childhood term (Irish et al., 2016:457). Linear enamel hypoplasia can be observed on both deciduous and permanent dentition, though is sometimes referred to as circular caries when affecting the deciduous dentition (Shkrum, 2008). There are many factors contributing to the manifestation, including developmental age-specific etiologies (see chart 5.1). Notably, broad agricultural shifts toward subsistence have been shown to be accompanied by increased prevalence of enamel defects (Irish, et al., 2014; Larsen, 2015; Simpson, 1999). More specific nutrition-related factors implicated in expression of enamel defects include maternal calcium deficiency, and individual vitamin A and D deficiency (Shkrum, 2008:118). Though, echoing the etiological background explored in the caries section, perhaps one of the most studied factors in LEH manifestation is weaning. Combined data from many studies spanning regions and archaeological time periods reflect a surge in LEH formation between 2 – 4 year olds across populations (Lewis, 2007). This phenomenon has typically been interpreted to support a weaning-hypothesis which suggested that a shift from breastmilk to less nutrient-rich solid food compromised metabolic processes thereby interrupting enamel deposition. Currently, research suggests that morphology and formation of the tooth itself may be responsible for the disproportionate prevalence of LEH within the 2 – 4 year range as the layering of enamel may obscure earlier (more incisal/occlusal oriented) defects (Lewis, 2007). Despite the many nutrition-related etiologies discussed above, Collí et al. (2009) caution against contextualizing LEH solely within the arena of diet and nutrition. Their research at a coastal Maya site, Xcambó, demonstrates a high frequency of LEH amongst high-status individuals with

a protein-rich diet. They suggest a significant role of water-borne pathogens in the metabolic stress of the well-nourished individuals exhibiting hypoplastic defects. Additionally, studies have linked LEH to factors such as fever, birth trauma, congenital syphilis, and tuberculosis (Lewis, 2007). The findings regarding the myriad causal factors demonstrate the need to consider all potential contributors when attempting to interpret enamel defects in a life course context.

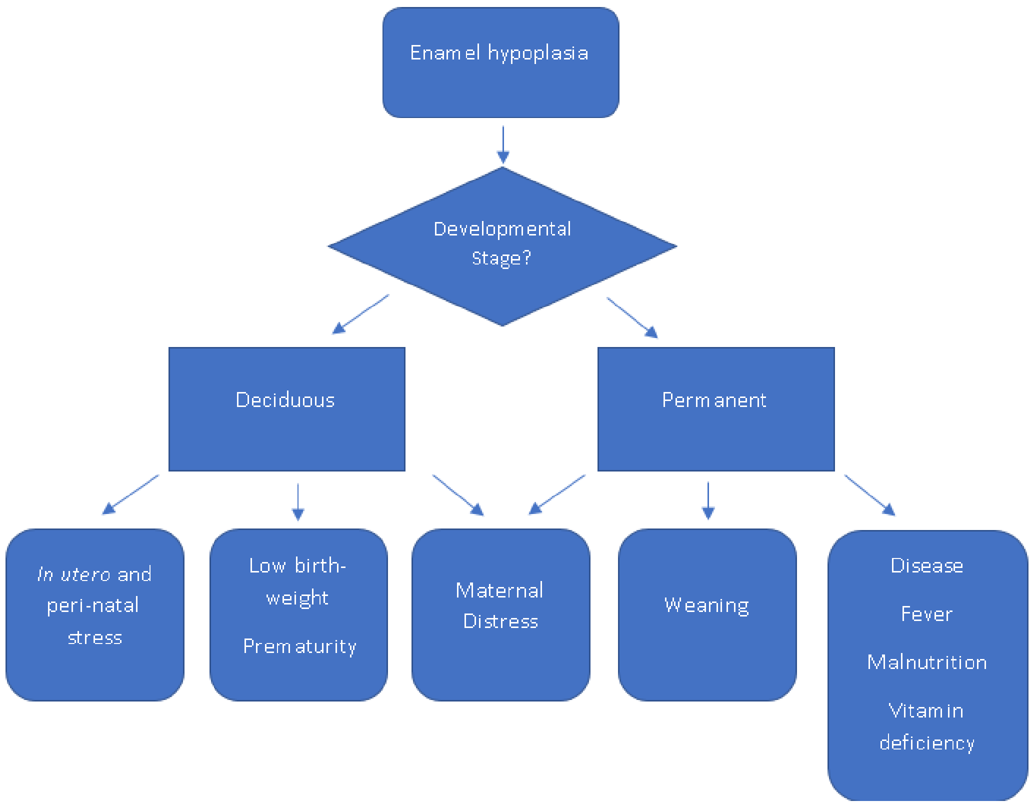

Figure 32 Etiologies of Linear Enamel Hypoplasia by Developmental Stage (adapted from Larsen, 2015, Lewis, 2007; Shkrum, 2008)

The expression of LEHs in the Altun Ha juvenile subsample ranges in severity from mild to moderate. However, in general, the macroscopic lines are relatively few per individual tooth (no more than 2 per tooth) and subtly pronounced (shallow). Each LEH on an individual tooth

surface represents a discrete stress episode. Therefore, it can be concluded that stress episodes were infrequent and/or that the individuals in the subsample were relatively healthy and able to overcome assaults to their metabolic processes before LEHs manifest. It has been suggested that frailty exists in a feedback loop whereas less fit individuals are more prone to negative reactions to stress thereby making them increasingly weaker and further susceptible to those same metabolic insults (Cucina, 2011:110; Wood et al., 1992). In consideration of this phenomenon, the overall expression of LEH in the Altun Ha juvenile subsample would seem to indicate a subadult population of relatively healthy individuals able to overcome stress episodes while subsequently avoiding severe reaction in the future. This interpretation is confounded by the fact that, though the individuals overcame metabolic stress episodes, they still entered the archaeological record as juveniles, seeming to suggest frailty when compared with individuals who survived into adulthood. The non-specific nature of LEH and the inability to examine living individuals within the population further obscure the exact reasons for the low number of LEHs per tooth and their shallow appearance, but their high prevalence among the children of Altun Ha.

Of the 345 individual teeth analyzed from 27 individuals, a total of 45 teeth exhibited LEHs (14.7%). From the perspective of individual teeth, this rate seems to suggest a low prevalence of enamel hypoplasia. However, this distribution represents 48% of the subsample (n=13 individuals). In contrast with the low number of LEHs per affected tooth discussed previously as well as the low total-tooth frequency, the population-level frequency is noticeably high. Two of the 13 individuals (one from cohort 2, one from cohort 3) exhibit LEHs (circular hypoplasia) on the deciduous dentition. The remaining 11 individual (6 from cohort 3, 5 from cohort 4) exhibit LEHs on the permanent dentition. The presence of hypoplasias on the

deciduous dentition in cohort 2 indicates that even pre-weaning age individuals were experiencing stress episodes severe enough to cause metabolic disturbance. This could be a reflection of maternal health, peri-natal stress or could indicate host illness or exposure to pathogens.

In a unique case, one individual (AH E-50/13) in cohort 4 from the Terminal Classic period exhibited a left maxillary permanent canine (antimere not present for observation) with a washboard appearance indicating numerous and frequent stress episodes. This same individual exhibited LEHs on the left mandibular permanent lateral incisor and the left mandibular permanent first premolar. The unique presentation of pathology in the canine of this individual could indicate systemic stress, chronic illness, or compromised immunity. Given the presence of LEH on other dentition and the absence of the right maxillary permanent canine (antimere) for comparison, this case was not treated as trauma. The exact cause is difficult to ascertain without observation of the full skeleton. However, it can be concluded that the individual experienced greater exposure to stress factors and/or possessed less intrinsic ability to recover than other individuals analyzed in the juvenile subsample. The presence of differential response to stress events, as indicated by the variation in severity and manifestation of LEHs, suggests that there may have been differential exposure to stress factors, frailty, or differential treatment of this individual. Status could be a possible explanation of differential overall health within this population. However, status cannot be inferred from a sole individual and is not the focus of the present research.

Limitations and Future Research

There is ongoing debate regarding how much can be ascertained about the overall health status of past populations through analysis of archaeological skeletal remains (Dewitte and Stojanowski, 2015; Wood et al., 1992; Wright et al., 2003). In a landmark publication, Wood et al. (1992) approached the problem of sample bias in bioarchaeology research by suggesting an "osteological paradox" arising from the attempt to infer the experience of a total population via analysis of the potentially least (or most) fit among them: the untimely dead. Caution is urged against "presupposing that…straightforward relationships exist" between individual risk to the living and frequencies of pathology observed among the deceased (Wood et al., 1992:343). It is proposed that demographic nonstationarity, selective mortality and hidden heterogeneity complicate the application of pathology frequencies in intra- and inter-population-level analyses (Dewitte and Stojanowski, 2015; Wood et al., 1992; Wright et al., 2003). Demographic nonstationarity refers to the fluctuation in population size through time and the resulting fluctuation in mortality rates. As a direct consequence, rates obtained by analyzing frequencies of death are indicative of fertility as much as or more than mortality (Wright et al., 2003:45). Selective mortality highlights the fact that the deceased will naturally exhibit a high level of pathology and cannot be used to directly infer rates of pathology among the living, perhaps non-affected individuals within the population. And, finally, the issue of hidden heterogeneity refers to the differential biological makeup of individuals which influences both response to stressors and resulting mortality. Wood et al. (1992) posited that skeletal remains exhibiting non-specific pathology that represents periods of stress and recovery (enamel hypoplasia, bone lesions, porotic hyperostosis) are potentially among the healthier of a population due to the indication of the body's capacity to heal itself. However, Dewitte and Stojanowski (2015) stipulates that this

interpretation was offered as one of many possible explanations not as an absolute solution. Despite its contentious substance, the osteological paradox has served to fortify bioarchaeological theory rather than to discredit it (Wright et. al, 2003:45). Through analysis of aggregate citation data, Dewitte and Stojanowski. (2015:412) suggest that the purpose for mention of the osteological paradox in bioarchaeology literature can be defined into four patterns: incidental reference, study limitation, explanation for data contradiction, and implications in frailty and selectivity. They further assert that the latter pattern is the realm in which the most advancements in reconciliation of the osteological paradox are being made by isolating factors of mortality.

In addition to inherent limitations of generalizing the population based on the individual, there are specific precautions which must be taken when analyzing subadults in isolation. For example, age categories are not standardized within bioarchaeology and social anthropology. Some advocate for the use of developmental processes such as maturation and brain growth in the categorization of age groups (Bogin 2003 cited in Halcrow and Tayles, 2008). While others look to biocultural factors such as breastfeeding and dependence for cohort demarcation (Halcrow and Tayles, 2008). In addition, researchers criticize the use of terminology that favors problematic theoretical foundations such as: oppostional dichotomies (juvenile/adult), reductive, hierarchical labels (subadult), and dualistic "othering" models (non-adult) (Halcrow and Tayles, 2008:193). There is also often a lack of continuity within particular terminology. Individual terms are often used interchangeably without standardization as to the span of time they encompass (Halcrow and Tayles, 2008:196). Clear expression of the methods and ranges employed within research helps to lessen the errors that can arise from attempting cross-

populational studies. However, standardization would be the best remedy in the quest for continuity.

Fragmentary dental remains are another limitation with specific implications in the data observed from the Altun Ha juvenile subsample. Complete dentition was present for only one of the 27 individuals analyzed. The lack of full dentitions poses issues to the exact dental pathology prevalences calculated. However, the general trends observed are supported by the comparison of individual tooth types which are present both with and without pathological indicators.

In future research, it is suggested that the often-singular treatment of the subadult cohort regularly be separated into discreet groups for analysis in keeping with the current trend towards such. Crawford (2018) cautions of the novice's propensity to write as if "they are among the first to investigate their subject". Bearing that caveat in mind, this research strives to incorporate the established with the novel in an attempt to offer a contribution to the modern trend of contextualizing childhood in the past and giving juveniles their proper place in the archaeological record. As demonstrated in this and other research, much variation exists in the susceptibility and manifestation of pathology throughout childhood. Biological and cultural processes acting upon the experience of the child through the rapidly transitioning stages of development necessitate great care when analyzing skeletal remains with the goal of gaining insight into health in the past.

Conclusions

Many factors contribute to the manifestation of dental pathology, not least of which are those explored here: diet, illness, maternal health, individual health, and environmental and social factors. The unique interplay of these and more catalysts for pathology make the analysis of dentition an invaluable method in our efforts to understand health and life experience in the past. The present research has clearly indicated that dental pathology is closely related with age. The rapid changes to the oral environment of children from birth to 12 years necessitates their discreet treatment in bioarchaeological and dental research. The results of this analysis showed an observable increase in prevalence of dental pathology concurrent with increased age. It is evident that the childhood cohort, so often relegated to a single category in the course of research deserves special demarcation to incorporate the transitory nature of juvenile growth in respective developmental stages. In this way, a clearer understanding of the life course of ancient populations may be achieved.

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