ABSTRACT

KIRKLAND, SCOTT. Dental Pathology at Promtin Tai: an Iron Age Site from Central Thailand. (Under the direction of Dr. Scott Fitzpatrick).

The aim of this paper is to further understand the dental health of Thailand and Southeast Asia. An analysis of dental pathology frequencies were conducted using recently excavated remains from the Iron Age site of Promtin Tai in Thailand. Carious lesions, advanced attrition, antemortem tooth loss, and abscessing were scored and the frequencies were then compared to other sites within Thailand. Preliminary work suggests that the overall pathology rate at the Promtin Tai site is lower than other known sites within Thailand. The total caries rate of 0.5 percent at Promtin Tai represents a statistically significant difference in total caries rates between the coastal, central, and Khorat Plateau regions of Thailand. Because this is the first site in the central region to be analyzed for dental pathology, comparisons can only be made to sites of a similar time period from the Khorat Plateau (Eastern Thailand) and coastal Thailand. This new analysis may give insight about how the transition to rice agriculture affects the dentition. It also furthers the knowledge of dental health within Iron Age Thailand and Southeast Asia.

Dental Pathology at Promtin Tai: An Iron Age Cemetery from Central Thailand

by
Scott Kirkland

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Master of Arts

Anthropology

Raleigh, North Carolina

March 29, 2010

APPROVED BY:

Dr. Scott Fitzpatrick Committee Chair	Dr. D. Troy Case
Dr. Ann Ross	Dr. Scott Burnett

DEDICATION

For my parents.

BIOGRAPHY

Scott Kirkland grew up in the unincorporated township of High Forest in southern Minnesota. As a teenager he pack-trained llamas, spent ten years in 4-H, and developed an intense love of learning about bones. After finishing High School, Scott completed his Bachelor of Arts in Anthropology at Hamline University under Dr. Skip Messenger. There he directed his general love of paleontology and anthropology towards the more focused fields of bioarchaeology and skeletal biology. After Hamline, Scott attended North Carolina State University, where he learned the art of digitizing crania and evaluating dental health. He is currently a candidate for the degree of Master's of Arts in Anthropology under the direction of Dr. Scott Fitzpatrick.

ACKNOWLEDGMENTS

I would first like to thank the Department of Sociology and Anthropology, as well as all of the faculty members that make up the Anthropology program. I would like to specifically thank the hard work of Dr. Fitzpatrick who helped shape my thesis into something worth presenting. I would like to also thank Dr. Ross for making the science aspect seem as important as the qualitative observations. A special thanks to Dr. Case for guiding my understanding of anthropology at school and in the field and teaching me the value of regular caffeine intervals. Thank you to Dr. Burnett who taught me more about teeth than I ever thought possible, as well as the proper excavation of human remains. All of you have helped guide my education, and made me even more interested in my field.

I would also like to thank Thanik Lertcharnrit for his hospitality in Thailand and for helping me better understand the Iron Age in Lopburi. My understanding of Thai prehistory would be sorely underdeveloped and I would not have a desire to learn more about the Iron Age in the region. I would also like to thank the 4th Regional Office of the Fine Arts Department in Lopburi for their support of this project.

In addition, I would like to thank my family, especially my parents, for letting me leave the homestead and travel to the opposite ends of the world. Without their love and support, this would not be possible. I would also like to thank Kristin Swanson, for everything. Regardless of her feelings for bones, and anthropology, she has been more supportive than I would have imagined. I would also like to thank my colleague at North Carolina State University Sarah Cunningham, for sticking with me these last two years.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

Southeast Asia has been the focus of recent bioarchaeological work aimed at understanding the association between rice agriculture and rates of dental pathology (Tayles et al. 2000, Oxenham et al. 2006, Douglas 2006, King and Norr 2006). While the analysis of prehistoric health by means of dental pathology has been utilized by bioarchaeologists for decades, the effect on health during the switch to rice-based agriculture is still under scrutiny in Southeast Asia (Larsen 1995, Scott and Turner 1988, Oxenham et al. 2006). Work conducted by Oxenham and colleagues (2006) and by Tayles and colleagues (2000) has suggested that there may be regional differences in dental pathology within Thailand and Southeast Asia.

This study aims to expand the data available on dental health during the Iron Age (after 2400 BP) in Thailand, and to further explore the impact of subsistence strategy on dental health by incorporating information from central Thailand into earlier regional analyses (Higham 2002). Work was conducted at the site of Promtin Tai, near the modern day town of Lopburi in central Thailand during the Summer 2009 field season under the direction of Dr. Thanik Lertcharnrit (formerly Sawang Lertrit), with bioarchaeological co-directors Drs. D. Troy Case of North Carolina State University and Scott Burnett of Eckerd College. Utilizing skeletons excavated during the 2007 field season by Drs. Thanik Lertcharnrit and Nancy Tayles, and one skeleton excavated during the 2009 field season, dental pathology frequencies were calculated and general rates were compared to other sites within Thailand.

The goal of this research is to examine the dental pathology of Promtin Tai and compare the findings to skeletal samples from different regions in Thailand in order to determine whether any similarities or differences exist (see Figure 1 for regional map with primary and comparative archaeological site location). A comparison between Promtin Tai and other contemporary skeletal collections in Thailand was conducted using both raw and published data (See Table 1 for a complete list of all sites, chronology, diet, tooth count, and pathology rates). Results of this comparison will expand the knowledge of Iron Age dental health in the region and help to clarify changes over time.

Because Promtin Tai is in a different region of Thailand than the other sites used in this study, is the only site from the central region of Thailand yet analyzed, and is earlier chronologically than other sites, the combined data provides a new glimpse into the health of prehistoric populations in Southeast Asia. The results suggest further differences in dental pathology amongst different regions within Thailand. The evidence from Promtin Tai shows a drastically lower rate for carious lesions than in any other skeletal collection examined thus far in Thailand.

II. BACKGROUND

Teeth have long been one of the key indicators of population health and are one of the more frequently used elements of the human skeleton for regional comparisons of diet and health (Larsen 1995, Hillson 2001). Because they are more often preserved than other elements and are easily identified even when fragmented, they are often the first indicators in a skeletal sample of the health conditions affecting a population (Hillson 2001).

Dental health is primarily measured by the analysis of carious lesions, attrition, antemortem tooth loss (AMTL), and alveolar resorption (Larsen 1995, Hillson 2001, Turner 1979). While not all of these indicators are solely the result of diet or nutrition, in combination they provide a good picture of the overall health of individuals and a population (Hillson 2001).

a. Indicators of Dental Health

i. Carious Lesions

According to Fejerskov et al. (2008a:pg4) dental caries are the effect "of an imbalance in physiological equilibrium between tooth mineral and biofilm fluid." Recent clinical work has sought to understand the relationship between biofilm, the natural amount of bacteria and saliva that coats the teeth in the mouth, and carious lesion development (Baelum et al. 2008). Changes in bacterial acid production, and the weakening of the biofilm can lead to either carious lesions or the formation of calculus (dental plaque). The reasons have been attributed to minute fluctuations in pH levels (Baelum et al. 2008). One of the causes for fluctuating pH levels is diet, or specifically, the consumption of carbohydrates in the form of sugars, thus dietary change over time could affect caries rates and/or plaque formation (Hillson 2003, Fejerskov et al. 2008b).

At dental eruption, all of the necessary components for the start of carious lesions are present, the enamel is fully formed and the biofilm has the same level of susceptibility to the effects that can break down its barrier between bacteria and teeth (Fejerskov et al. 2008c). Immediately following eruption, there is a brief period of protection from disease, as the levels of fluoride on the surface of the teeth increase, although the reasons for this fluoride increase is unknown (Fejerskov et al. 2008c). In some capacity, the breakdown of bacteria into acid is a constant action in the mouth, and microscopic lesions are forming at a near constant rate on the surface of the teeth and any exposed roots (Fejerskov et al. 2008c). However, due to the minute levels of wear associated with mastication, tooth cleaning, and the movements of the soft tissue of the mouth (including the tongue), these microscopic lesions are effectively transformed from active to inactive before being completely worn away (Fejerskov et al. 2008c). Carious lesions of a larger size occur more often in areas of the teeth that are protected from these actions such as the ridges, grooves, and roots of the teeth (Fejerskov et al. 2008c).

Protection from the wear action is also why there are more carious lesions in the posterior dentition of both the maxilla and mandible, and why there is a slightly higher number of carious lesions on the posterior mandibular dentition, as these areas are more protected from the wear associated with mastication (Fejerskov et al. 2008c, Hillson 2003). A study of caries in medieval Scotland found that root caries were more frequent than other types of lesions (Kerr 1990). Kerr (1990) was able to tie this frequency, in part, to the age of the sample, as less buccal enamel was present for carious lesions to form on. However, this does not explain the overall higher prevalence of carious lesions found on the cemento-enamel junction (the meeting point of the enamel and the root) found by Kerr (1990) in an analysis of other sites.

Lesions are identified either by discoloration of the enamel, mineral loss, or by the destruction of areas of the cusp or root (Fejerskov et al. 2008b, Hillson 2003). Lesions are clinically and archaeologically identified as being active, inactive, or somewhere in between, but the differences may be impossible to distinguish in archaeological material (Fejerskov et al. 2008b, Hillson 2003). Even at the clinical level, the lack of visible carious lesions does not imply that the disease is not present; it just indicates that it is not visible (Fejerskov et al. 2008c). This means that it is impossible to know if caries is active within an individual at any given time, but by the time mineral loss is evident, the disease is already severe (Fejerskov et al. 2008a).

Carious lesions follow known patterns in their development and location within the dentition (Fejerskov et al. 2008c). They are common both on the enamel and on the root (Fejerskov et al. 2008b). Carious lesions are expressed in different ways to a varying degree of severity (Fejerskov et al. 2008b). White spot lesions are typically the first to appear and are only visible by the slight discoloring of the enamel (Fejerskov et al. 2008c). White spot defects are the most difficult to identify archaeologically, and the most likely to be non-active due to the destruction of the lesion site by the regular wear of the tooth through normal processing of food material (Fejerskov et al. 2008c, Hillson 2003). While white spot lesions are the first indicator of caries, they eventually lead to the destruction of the enamel that is visible macroscopically (Hillson 2003). The resulting two types of carious lesions are occlusal caries, located in the grooves and fissures of the cusps of the teeth, and root caries, located either on the root of the tooth or at the junction of the enamel and the root (Fejerskov 2008c). Both of these types of lesions begin as microscopic destruction and gradually advance to larger more destructive lesions without proper treatment (Hillson 2003, Fejerskov et al. 2008c). Root caries are only possible when there is some evidence of periodontal disease, or alveolar resorption, because this part of the tooth is not otherwise exposed (Fejerskov et al. 2008c).

Carious lesions are generally less common in the anterior dentition (incisors, canines, and premolars) than in the molars (Hillson 2003). As Hillson (2003) makes apparent, this is beneficial to the study of carious lesion rates because anterior teeth are more likely to be lost post mortem, and thus the percentages are less likely to change, by individual, with this loss. There is some evidence that moderate rates of attrition are beneficial to the prevention of carious lesions, however this may only affect caries of the cusp as other regions are less affected by the type of wear that would remove surfaces commonly affected by carious lesions (Hillson 2003, Fejerskov et al. 2008c). Such levels of wear are often listed as one of the benefits of hunter/gathering subsistence strategies (Hillson 2003). However, it is more likely that while these teeth were indeed being worn down, lessening the fissures available for carious lesions, the carbohydrate levels of the diet were also significantly lower than those of groups practicing agriculture (Hillson 2003). A comparison of different rates of wear and carious lesions amongst a small sample of Dutch whalers corroborates the association between decreased caries rates with increase wear (Maat and Van der Velde 1987).

Carious lesion rates differ by sex (Hillson 2003, Lukacs 2008, Lukacs and Largaespada 2006). Some of the difference can be explained by the faster rate of dental development in females, allowing for the permanent dentition to be subjected to the processes responsible for dental caries longer (Hillson 2003). Lukacs (2008) and Lukacs and Largaespada (2006) addressed the behavioral reasons behind higher rates in females, such as snacking while foraging and differences in labor. Snaking and differences in labor had been perceived as being the cause of sex differences in caries rates, because the jobs that women often carried out placed them near food, and this would lead to them consuming a higher rate of more cariogenic food (Lukacs 2008, Lukacs and Largaespada 2006).

Lukacs (2006) and Lukacs and Largaespada (2008) dismissed these ideas based on the constant difference between males and females over time, regardless of subsistence, and because of differences in saliva production and pH levels (see below). Overall, Lukacs (2008) found the primary reasons for differences in caries rates between the sexes to be a result of pregnancy and life history differences. Because of shifts in estrogen production and other changes in hormones and fertility rates, such differences in caries rates were natural rather than behavioral (Lukacs 2008). Lukacs (2008) also suggests that increased caries rates in agricultural societies can be traced to increased fertility rates.

Another reason for fluctuation in pH levels has been attributed to differential saliva production and hormone levels between the sexes (Lukacs and Largaespada 2006). Lukacs and Largaespada (2006) examined hormone levels in adolescent males and females, adult males and females, and pregnant females. They found that raw saliva flow rates differed between the sexes, with large differences between pregnant females and adult males (Lukacs and Largaespada 2006). The fluctuations in estrogen production in adolescent females and pregnant females had a strong effect on saliva production and therefore overall rates for the development of carious lesions (Lukacs and Largaespada 2006). These findings support the overall general differences between the rates of carious lesions in males and females (Hillson 2003, Lukacs and Largaespada 2006). Comparisons with archaeological samples found that in general, females had a higher prevalence for carious lesions than males, and the pH and saliva differences may help explain any such difference in the archaeological record (Hillson 2003, Lukacs and Largaespada 2006).

In a recent analysis of the ability of odontologists and osteologists to identify carious lesions in teeth, Liebe-Harkort and colleagues (2009) found that there were differences in the accuracy between both groups depending on the criteria under examination. Odontologists were better at identifying carious teeth, and osteologists were more able to identify healthy teeth (Liebe-Harkort et al. 2009). The finding that has the most troubling results for an archaeological study is the inter-observer agreement between the examinations of archaeological teeth (Liebe-Harkort et al. 2009). Liebe-Harkort et al. (2009) found that the average agreement between osteologists for archaeological teeth was between 0.41 and 0.47 for visual examination, and 0.38 and 0.39 for radiographic examination. The largest factor in the identification of carious lesions was experience (Liebe-Harkort et al. 2009).

ii. Modification and Wear

Two types of action are responsible for the wearing away of the surface of the tooth, attrition and abrasion (Hillson 2003). Attrition is the wear caused by the grinding of teeth together and abrasion is the wear caused by the contact of the teeth and another object or substance (Hillson 2003). The way that teeth are worn is dependent upon the striking of the inferior teeth of the mandible against the superior teeth of the maxilla (Osborn 1982). Attrition decreases over time archaeologically and historically, while abrasion has shown an increase over time, in part due to the coarse grains in toothpaste and the bristles on toothbrushes (Hillson 2003). Attrition decreases over time due to changes in the force necessary in mastication resulting from a decrease in coarse grains and an increase in highly processed and softer foods (Wolpoff 2005, Hillson 2003).

The patterns of attrition in different types of subsistence strategies have been extensively studied (Hillson 2003, Deter 2008, Bonfiglioli et al. 2004, Molnar 1971, Osborn 1982, Hintin 1982, and Molnar et el. 1972). Osborn (1982) noted that because of the timing of the eruption of the molars, dental wear becomes significantly sloped as a result of coarse foods and softer enamel (as found in most mammals). The teeth in Osborn's (1982) study demonstrated different slopes in the mandibular and maxillary molars and premolars, with the maxillary teeth being worn more on the lingual side and mandibular teeth being more worn on the buccal side. While the primary focus of Osborn's (1982) analysis was to determine a difference in the dentition of *Homo sapiens* in comparison to early hominids, it demonstrates a differential wear pattern associated with hunter-gatherer groups in some parts of the world.

The studies on wear patterns between the sexes and between subsistence strategies are not always in agreement (Hillson 2003). Large-scale studies have found that wear is relatively universal across the sexes; however, in the analysis of a hunter/gatherer group in California (2,000 – 3,000 BP), Molnar (1971) found considerable differences between the sexes. While Molnar (1971) was comparing more than one hunter/gatherer group, only the California sample showed such a difference. Molnar (1971) concluded that the differences at this site were probably the result of differences in food production and consumption between the sexes.

A recent analysis of wear differences between subsistence strategies was conducted by Deter (2008). Utilizing a large sample of hunter/gatherers (ca. 3385 BC) and agriculturalists from a modern sample collected at a reservation, Deter (2008) studied the amount of wear on the occlusal surface of the dentition. Deter (2008) found that there was a higher rate of wear associated with the hunter/gatherers than with the agriculturalists. Deter (2008) attributed the differences to be the result of a combination of food production practices and cultural activities. One problem with this study is that food-processing technologies are drastically different between historic reservation sites and prehistoric archaeological sites (Deter 2008, Hillson 2003). Additionally, the higher rate of wear that has been associated with agriculture in older studies was attributed to coarse grains of stone entering the flour in the milling process, while in more modern methods less coarse material enters the food and is less likely to affect the dentition (Deter 2008, Hillson 2003).

Some studies have suggested that there are different angles of wear among hunter/gatherer groups and societies practicing agriculture (Smith 1984). Smith (1984) found that wear associated in hunter/gatherer societies was relatively flat while wear associated with agricultural societies was more angular. Because of the variable ways that wear occurs, such distinctions may not be observable or may not carry over to all areas of the world (Hillson 2003).

Other actions can wear the surface of the teeth including modification, the use of teeth as tools, and other yet unknown factors (Hillson 2003). Chipping and notching are common kinds of wear associated with cultural activities (Bonfiglioli et al. 2004). Chipping is the fracturing of teeth through either the regular use of teeth in mastication or the use of the teeth as tools (Bonfiglioli et al. 2004). The end result of notching is a semi-circular depression or triangular depression in the tooth or teeth that is paired between the mandible and maxilla. In a study of skeletal samples from Morocco, Bonfiglioli et al. (2004) studied the differences in tooth wear between regular tooth wear and non-masticatory wear. Bonfiglioli et al. (2004) found that there was an extremely high rate of chipping with both activities, but that it was more commonly associated with individuals who showed signs of cultural use of their teeth as tools. The two main indicators of the use of teeth as tools were notching, from the repeated movement of an object through the teeth, and interproximal grooving, the result of an object being repeatedly rubbed against a tooth (Bonfiglioli et al. 2004). Bonfiglioli et al. (2004) found, at least in the sample from Morocco, that the grooving was the result of relieving pressure in the gums or soft tissue.

In modern populations, notching is common in occupations that require needles or nails, which are often held in the teeth during a particular activity (Bonfiglioli et al. 2004). In historic English samples, notching has been associated with the processing of sinew in the manufacturing of bows (Cruwys et al. 1992 in Bonfiglioli et al. 2004). Bonfiglioli et al. (2004) found that there was no pattern in the teeth used, and that the location was dependent upon the type of material being worked, though they suggested that it could be the result of tooth cleaning.

Cultural modification of the surfaces of the teeth is sometimes practiced, such as the inlay of objects into the enamel or the sharpening of anterior teeth by the Maya (Hillson 2003, Vukovic et al. 2009). Within the Maya culture there were seven types of artificial modification practiced, with over 62 variations of artificial modification (Williams and White 2006). An analysis of a Mayan site in Belize found that 36% of the adult remains had some form of intentionally modified teeth (Williams and White 2006). Williams and White (2006) found no statistical difference between the frequencies for males or females, but that the modification was more common in adults.

Other types of wear are associated with jewelry, such as labrets, worn in the lips, or the repeated use of pipes as in historic London samples (Hillson 2003). Torres-Rouff (2003) analyzed the effects of labret use in Chile, and found that labret use (in this case dual) resulted in wear and polishing on the teeth that came in contact with the labret, but that there was visible response in the alveolar process near the location of the labret. While these types of activities cause wear on the dentition, they are not common in the archaeological record and are easily identified if present (Hillson 2003).

While significantly more rare than both aesthetic and natural wear and modification, there is evidence that some cultures practiced rudimentary dentistry (White et al. 1997). White et al. (1997) found a canine with evidence of drilling during research in Colorado. Dating to around AD 1025, the drilled canine is the earliest evidence of dentistry recovered (White et al. 1997). Due to the placement of the drilled hole, and the association of an alveolar lesion, White et al. (1997) believe that a carious lesion was present on the tooth, and that the spot was removed through drilling. The placement of the hole in a spot not visible would indicate that this hole was created for reasons other than aesthetics (White et al. 1997). Because of this, and other examples of early dentistry, it is an important consideration when examining factors for the cause of antemortem tooth loss.

iii. Antemortem Tooth Loss (AMTL)

Antemortem tooth loss (AMTL) is the loss of any tooth before death. Because of the exposure of the root and dentine from carious lesions and wear, caries and wear are often seen as the cause of AMTL (Hillson 2003, Lukacs 1995). A method for calculating the number of teeth lost due to advanced carious lesions was first developed by Lukacs (1995), called the *Caries Correction Factor*, which calculates the number of teeth with dentine or pulp exposure due to wear and carious lesions and applies the same percentage to teeth lost antemortem (Lukacs 1995). For example, if 50% of the teeth had pulp exposure due to caries, 50% of the teeth lost antemortem would then be considered lost due to carious lesions (Lukacs 1995). However, due to unknown factors, cultural practices of intentional removal, and differential dental practices in the prehistoric record, the varying ways that a tooth was lost can remain unknown and the practice of applying the *Caries Correction Factor* to archaeological samples is a less common practice in recent literature, and in literature focusing on Southeast Asia (Hillson 2003, Douglas 2006, Oxenham et al. 2006). Due to the fact that an example of early dentistry exists, the removal of teeth to ease pain cannot be entirely dismissed (White et al. 1997).

1. Non-pathological Antemortem Tooth Loss

An issue recently addressed in Southeast Asian dental health, is the intentional removal of anterior teeth (Tayles 1996). Ablation, or intentional removal, is often indistinguishable from other loss of a tooth, but if specific consistent patterns are noticed in the anterior teeth, ablation should remain a possible explanation for such loss. Ethnohistoric data has shown that the removal of anterior teeth is often associated with rites of passage, such as coming of age or marriage (Tayles 1996). Even with the identification of patterns, intentional removal cannot be positively identified as the underlying cause of such patterns (Tayles 1996). In her analysis, Tayles (1996) found that patterns changed over time and varied between sexes. However, the consistent removal of maxillary incisors in the skeletal population of Khok Phanom Di is more suggestive of ablation than other types of loss (Tayles 1996). While this practice is not often identified in an archaeological context, its identification in other regions of Thailand makes it an important aspect to consider when examining antemortem tooth loss.

In an analysis of prehistoric tooth ablation in Japan, Temple et al. (2010) also found that anterior teeth were the most frequently removed. Unlike Tayles (1996) study only two distinct patterns were found in Jomon populations (Temple et al. 2010). The two separate patterns were most likely tied to kin based groups, with the initial removal of the teeth possibly being tied to coming of age ceremonies (Temple et al. 2010).

While a high proportion of anterior teeth lost antemortem has often been tied to ritualistic removal (Tayles 1996, Hillson 2003, Temple et al. 2010), an analysis of anterior tooth loss in Arctic populations suggested loss due to the use of anterior teeth as a tool (Merbs 1968). Originally identified as widespread ablation, the reanalysis demonstrated that observable patterns could be the result of systematic tooth loss in identical areas because of wear (Merbs 1968).

iv. Alveolar Resorption

Bone loss in the alveolar bone surrounding the dentition (alveolar resorption) is often associated with periodontal disease or other inflammations of bone or soft tissue (Hillson 2003). Such reactions in the bone are the result of bacteria passing through the biofilm and triggering immune responses (Hillson 2003). Bone loss can occur in the socket associated with the teeth, in the wall of the alveolar bone, or anywhere on the adjacent surfaces (Hillson 2003). This bone loss can occur in varying degrees, with a slight loss of the alveolar wall surrounding the cemento/enamel junction of the tooth, to the complete destruction of all bone around a tooth (Hillson 2003).

Bone loss related to periodontal disease has been associated with age in modern studies and archaeological samples, suggesting a higher risk of tooth loss due to bone loss as an individual becomes older (Hillson 2003). Extensive loss of teeth due to periodontal disease or other loss can lead to edentulism, or the complete loss of all teeth (Hillson 2003). In clinical samples, men are more often affected by periodontal disease than women, but are virtually identical in the amount of bone loss because of the disease (Hillson 2003). There is some issue with the identification of the root cause of periodontal disease, as the epidemiology is not as well understood as other dental diseases (Hillson 2003). Hillson (2003) states that periodontal disease can be related to "inheritance, environment, diet and hygiene," or to any combination of those factors.

b. Dental Health Studies

One of the first large scale comparisons of dental health and subsistence strategies was conducted by Larsen (1995) as part of a larger review on the effects of the adoption of agriculture on different populations. Utilizing data on carious lesion rates from 64 skeletal collections analyzed and published by Turner (1979), Larsen (1995) combined carious lesion information with published reports of antemortem tooth loss. While not utilizing the full suite of dental pathologies commonly utilized today, Larsen (1995) provided an in depth review of the changes associated with agriculture throughout the world.

The data from Turner (1979) of compiled carious lesion rates is often used as the standard to identify the subsistence strategy for past populations if no other means of analysis, such as plant or faunal remains is present. Turner's (1979) carious lesion rates are converted into percentages by living or skeletal, and by subsistence in Table 2. While these percentages provide a baseline for comparison if no indicators of subsistence strategies are present, one of the problems is that the ranges for each type of subsistence overlap (see Table 1). Because of the overlap, it is possible that populations with low levels of carious lesions may belong to any subsistence type. As such, these numbers should only be used to compare different types of subsistence when no other means of comparison is possible.

While analyses of this scale have not been repeated, they provide a baseline for analysis in modern samples. Much of the difficulty in applying these percentages comes from the understanding of diet and the cultural differences not only in food processing, but also in types of food hunted, gathered, or farmed (Hillson 2003, Hillson 1979, Tayles et al. 2000). With the analysis of diet and dental pathology shifting to areas of the world that had different types of agriculture than those studied by Turner (1975), new baselines need to be developed.

While a majority of studies have found that carious lesion rates increase over time, several studies have found the opposite (Tayles et al. 2000, Hillson 2003, Walker and

Erlandson 1986). In a study of diet change in prehistoric California (4000 – 40 BP), Walker and Erlandson (1986) found that dental pathology, and carious lesions in particular, decreased over time in the Channel Islands. Through an analysis of diet, the authors discovered that earlier people were eating foods heavier in starch and carbohydrates, but switched to a protein rich diet when the populations shifted from higher areas of the islands to coastal sites (Walker and Erlandson 1986). The protein rich seafood that became the majority of the diet has a lower cariogenicity than starchy foods (Walker and Erlandson 1986). The seafood is also naturally high in fluoride, which is known to reduce the risk of carious lesions clinically (Hillson 2003, Walker and Erlandson 1986). While this study is inconsistent with findings of increased carious lesion rates over time, such a drastic switch in subsistence away from agriculture is not common in the archaeological record (Turner 1979, Walker and Erlandson 1986).

In order to examine the effect of different subsistence strategies in a small space, Littleton and Frolich (1993) compared skeletal samples from areas in the Arabian Gulf dominated by fishing (island sites), mixed agriculture (desert oasis sites) and fishing, and primarily agriculture (interior sites). For the sites dependent upon aquatic resources there were low rates for carious lesions and AMTL and high rates of attrition; for sites reliant upon agriculture they found high rates of caries and AMTL and low rates of attrition; for mixed subsistence strategies they found that the rates were less severe than agriculture, but more severe than aquatic resource dependent sites (Littleton and Frolich 1993). One of the more important findings of this study was that the causes of AMTL differed between agriculturalists and people dependent upon seafood (Littleton and Frolich 1993). Since there were large differences between the rates of wear and carious lesions between the two subsistence strategies, they determined that the primary cause of AMTL in agricultural societies was carious lesions, while the primary cause of AMTL in aquatic and hunter/gatherer societies was dental wear (Littleton and Frolich 1993). Because they utilized sites that were consuming the same general array of foods, the pathology rates are dependent upon the quantity of different food types consumed (Littleton and Frolich 1993).

c. Dental Health in Asia

Recent studies have sought to analyze health in different regions of Thailand through the use of dental pathology (Oxenham et al. 2006, Tayles et al. 2000). To this end, individual sites already subject to analysis in the past have been reassessed to provide new information for a more complete picture of the health of populations in prehistoric Thailand (Domett 2001, Douglas 2006, King and Norr 2006). Utilizing all of the available published literature and data collected personally, these authors have created the best available analysis of dental health in the region (Domett 2001, Douglas 2006, King and Norr 2006, Oxenham et al. 2006, and Tayles et al. 2000).

Oxenham et al. (2006) utilized all of the available published dental pathology data for Thailand and Vietnam, and then analyzed the data for any patterns present for sites that are known to have practiced rice agriculture, mixed rice agriculture, or hunting/gathering. For 11 sites the authors calculated the rates for carious lesions, AMTL, and alveolar resorption and compared them statistically for significant differences. Unlike past studies, Oxenham et al. (2006) concluded that the rates for pathology remain relatively static over time, regardless of the type of subsistence strategy employed.

Oxenham et al. (2006) based much of their hypotheses on earlier work by Tayles et al. (2000), who were not only interested in changes in health at the onset of rice agriculture, but also whether pathology increased over time. Utilizing archaeological, historic, and modern samples, they analyzed carious lesion rates to determine if there were any temporal trends in Thailand as a whole (Tayles et al. 2000). In this study, both adults and subadults were used for comparison and they were able to demonstrate that carious lesion rates decreased over time through the prehistoric and historic periods (Tayles et al. 2006). Because the rates for subadult and adult samples are examined separately, the study by Tayles et al. (2006) can be utilized to compare rates over time in relationship with sites that only describe adult samples.

In the modern period, Tayles et al. (2000) found that there was a general increase in carious lesion rates, but the shift toward increased pathology rates was attributed to changes in rice processing methods and the addition of large amounts of sugars and carbohydrates to the diet. Tayles et al. (2000) suggested that some of the higher rates for the early archaeological sites might have been attributed to the use of more starchy foods by hunter/gatherers in Thailand, such as bananas or palm sugar (Tayles et al. 2000). The relatively high cariogenicity of bananas has been reiterated in modern dental literature, as being a possible source of increased caries rates in regions of high consumption, comparable to the relative cariogenicity of soft drinks (Larsen 2008).

Temple and Larsen (2007) analyzed the transition to agriculture of different groups in Japan solely by the frequency of carious lesions. Through a comparison of Yayoi period agriculturalists and Jōmon period hunter/gatherers, Temple and Larsen (2007) compared carious lesion frequencies by sex and region to detect patterns. They found that there were regional similarities in carious lesion rates that persisted regardless of subsistence strategy (Temple and Larsen 2007). Based on previous work, the relationships between Yayoi and Jōmon groups were utilized to show that these groups seemingly passed on dietary habits over large periods of time (Temple and Larsen 2007). A further analysis of previous literature suggested that the Jōmon hunter/gatherers may also have relied on some agricultural products, further blurring the line between the different types of subsistence being practiced over time (Temple and Larsen 2007). Even with similarities over time, there were differences in carious lesion rates within each chronological period, further suggesting regional differences (Temple and Larsen 2007). Using previous stable isotope analysis conducted by other researchers, Temple and Larsen (2007) determined that within the Yayoi groups there was no significant difference in diet, despite differences in carious lesion rates. Because of this, Temple and Larsen (2007) believe that the differences in caries rates were associated with regional variations in food preparation. Such regional variation is consistent with the situation in different areas in Southeast Asia, especially Thailand.

Lukacs (1992) analyzed the dental health of Bronze Age Harappa (2500 – 2000 BC) in present day Pakistan. Lukacs (1992) found that the general world pattern of increased pathology rates with the intensification of agriculture and differences in caries rates between the sexes (38.3% of the males, 61.7% of the females) held true at Harappa. While the non-corrected caries rate was relatively low (6.8%), it was adjusted using his (1995, unpublished at this time, but used in this research by Lukacs) method to account for carious teeth lost antemortem and found a rate of 12.1% for carious lesions (Lukacs 1992). While the adjusted rate is much higher than other sites from the region, it is unclear if all of the sites analyzed use his correction factor.

Under the sites analyzed for prehistoric Pakistan, Lukacs (1995) found an average rate of 5.4 % for the Iron Age, 2.1% (one site) for the Early Historic period, 7% for the Bronze Age, and 0.7% for the Mesolithic and Neolithic ages. The difference between the Iron Age and Bronze Age is most likely the result of the caries rates being uncorrected, having been completed before the development of Lukacs' (1995) method (Lukacs 1992).

d. Cultural History

Hunter-gatherer groups occupied coastal Thailand beginning between 38,000 to 27,000 BP and shifted north into central Thailand by 10,000 BP (Higham 2002). The tradition of hunting and gathering also extended into later, larger sites within Thailand such as Khok Phanom Di (2000 – 1500 BC), which was dependent upon aquatic and terrestrial forms of hunting and gathering (Oxenham et al. 2006, Higham 2002). While it has been shown that some agricultural products were consumed at Khok Phanom Di, it has been largely considered secondary to the other forms of subsistence and the question of whether local populations cultivated plants remains unanswered (Oxenham et al. 2006, Higham 2002).

Because of the long history of hunting and gathering and the relative ambiguity of the introduction of rice agriculture in Thailand, initial periods of agriculture of any type are hard to discern in the archaeological record (Higham 2002). However, work suggests that rice reached the Khorat region of Thailand between 2500 and 2000 BC (Higham 2002). Phytolith analysis has so far been inconclusive due to the similarities between wild strains of rice, cultivated strains of rice, and other wetland grasses (Higham 2002). As a result, any patterns in dental pathology arising from the spread of rice may be hindered by the ambiguity in plant taxa in the archaeological record. Higham (2002) has suggested that it may only be possible to prove that there was the consumption of rice at an archaeological site, but not that it was cultivated. In the Chao Phraya River region near Lopburi, there is evidence of the modification of the river systems, an indication that rice agriculture may have reached the central region of Thailand by 2500 to 2000 BC (Higham 2002).

e. Environmental Background

Much of the paleoecology work in Thailand has focused on the Northwest region and on the shifts in climate associated with the early development of rice agriculture, with some research on climate fluctuations exclusive to mangrove swamps (Higham 2002, King and Nor 2006, Kealhofer 2003). Recent work by Kealhofer (2003) has expanded our understanding of the climate in southern and central Thailand with the analysis of phytolith evidence collected from Lake Thalee Song Hong.

Kealhofer (2003) identified an environmental shift during the early Holocene in forest expansion, with the first evidence of non-rice agricultural plants appearing around 7000 BP. Increased levels of burning accompanied this shift from an environment heavy in grasslands to one consisting of lowland tropical rain forests, identified through charcoal deposits (Kealhofer 2003). Kealhofer (2003) distinguished between natural and man made fires by linking such events to seasonal patterns associated with El Niño and long range patterns of burning that occurred every few hundred years.

Kealhofer (2003) suggests that increased small-scale burning associated with small groups of hunter-gatherers brought about more ecological variation in the habitat. Such increased ecological variation continued through 4000 BP, but mostly consisted of more arboreal resources that were well supported in the new environment (Kealhofer 2003). Overall, Kealhofer (2003) stated that the environment was better suited for the modification and intensification of arboriculture, with the addition of some root crops.

However, Maloney (1992) raised the issue that any data from pollen cores or other indicators of climate change that depended upon the limited data previously collected in Southeast Asia should be further scrutinized. Because pollen sampling and other cores from tropical areas in Southeast Asia have not undergone enough testing for accuracy nor have appropriate comparison samples been collected from the region, such data should be used with caution (Maloney 1992). Other explanations for the increased amounts of charcoal content in the pollen cores, beyond seasonal variation and the El Niño effect, should also be considered. During the Late Holocene in Vietnam, a measurable increase in charcoal levels has been attributed to the expansion of warfare and not shifts in agricultural practices (Li et al. 2009). Such examples demonstrate the relative uncertainty of the interpretation of elevated charcoal levels and that any increases could be multicausal.

f. Promtin Tai

Promtin Tai is a small moated site in central Thailand, with a long history of copper smelting (Lertcharnrit 2006). Excavations began in 1991 with a 3 × 3 meter excavation pit where two skeletons were unearthed from 2 meters below the surface (Lertcharnrit 2006). Four 3 × 3 meter excavation units were opened in 2004 (PTT-S1-4) (Lertcharnrit 2006).

PTT-S2, one of the 3 × 3 meter units opened during 2004 was expanded into a 6 × 3 meter unit upon the discovery of two burials (Lertcharnrit 2006). The expansion resulted in more human burials and evidence of long-term occupation (Lertcharnrit 2006). In 2007, PTT-S2 and PTT-S3 were merged into a 6 × 6 meter excavation unit where the majority of the burials were recovered (Halcrow and Tayles 2008, Lertcharnrit, personal communication 2010). The occupation timeline appears to have begun during the Bronze Age and continued through the Dvaravati period that dates between 1600 and 1400 BP (Lertcharnrit 2006). The site was later reoccupied in the Ayutthaya period (Lertcharnrit 2006).

Promtin Tai is located in an area not only rich in copper, but in terrestrial and aquatic resources (Lertcharnrit 2006). Initial research has shown that Promtin Tai was most likely smelting copper to exchange regionally rather than a site that was producing copper only for local consumption (Lertcharnrit 2006). Such a system of trade could explain the relatively high frequency of burial goods and trade artifacts recovered during excavation. During the 2004 season, a large amount of copper and iron slag was recovered, suggesting that the site was involved with production (Lertcharnrit 2006). The lack of associated copper artifacts, and the presence of non-local beads, suggests that these iron and copper products were meant for exchange (Lertcharnrit 2006). Most of the burials recovered were found with bronze artifacts, beads, and pottery (Lertcharnrit 2006). Initial analysis of these items also suggests that they were not produced locally (Lertcharnrit 2006).

The Promtin Tai archaeological sample consists of 32 known burials (Lertcharnrit 2006, Halcrow and Tayles 2008). Of these, 16 were completely excavated by the end of the 2007 archaeological season (Halcrow and Tayles 2008). The burials recovered in the 2007 season were only subjected to brief analysis. The remaining burials were left *in situ* until Burial 12 was excavated in the 2009 season.

i. Mortuary Patterns and Chronology

The excavations at Promtin Tai have revealed a number of cultural occupation layers, extending from the Late Bronze and Iron Ages (600 BC – AD 500) through the Ayutthaya period (AD 1400 – 1700) (Lertcharnrit 2006). One burial was excavated from the Bronze Age period and tentatively dated to 2430 ± 260 BP (calibrated to 200 BC – AD 70 using OxCal 4.1) (Lertcharnrit 2006). The other burials from the site date to the Iron Age and are characterized by a large number of grave goods, especially beads and iron tools (Lertcharnrit 2006, Lertcharnrit personal communication 2009). One additional burial was dated using radiocarbon through associated charcoal, resulting in an uncalibrated date of 2652 ± 79 BP (calibrated to 1010 – 540 BC using OxCal 4.1) (Lertcharnrit 2009). A complete list of the radiocarbon dates as well as the calibrated dates can be found in Table 3.

All of the burials recovered from Promtin Tai were in the supine position, and all had associated burial goods (Lertcharnrit 2006). Burials ceased at Promtin Tai after the Iron Age, when mortuary practices shifted to cremation during the Dvaravati and Ayutthaya periods (Lertcharnrit 2006, Lertcharnrit, personal communication 2009). Because only the Iron Age remains were available for study, a comparison between the Iron Age skeletal samples and the Bronze Age skeleton was not possible.

ii. Subsistence

While many of the faunal remains recovered during the previous field season are still being studied, some understanding of the subsistence strategies practiced during the Iron Age at Promtin Tai is known (Lertcharnrit 2006). Faunal evidence suggests thus far that the inhabitants at Promtin Tai practiced hunting, gathering, and fishing (Lertcharnrit 2006). A larger variety of species have been identified, including deer, cow, freshwater shellfish, and fish (Lertcharnrit 2006). Because of the close proximity to local aquatic resources and the high amount of shellfish and fish remains recovered, freshwater foods probably made up a large portion of the diet (Lertcharnrit 2006).

Currently there has been no direct evidence of rice agriculture identified from Promtin Tai, but at present the practice cannot be ruled out (Lertcharnrit 2006). Because of the issues discussed above with sampling and identification of rice pollen and phytoliths, it is possible that substantial evidence for rice agriculture is present, but elusive. In an analysis of the diet of Ban Chiang, a site known to have rice agriculture in some capacity, it was shown through the use of stable isotope analysis of the bone, that a large variety of items were consumed with no single item being consumed at a higher rate than another (King and Norr 2006). Even with the addition of rice agriculture, evidence of very diversified diets at other sites is suggestive that rice may not have been a staple crop like maize in the new world, further complicating the issue of not only diet, but the changes in dental pathology (King and Norr 2006, Higham 2002). Analysis of dental pathology in a regional context can help give clues to the type of subsistence strategy practiced at a site (Hillson 2003).

III. MATERIALS AND METHODS

The Promtin Tai skeletal series consists of 32 burials, 16 of which have been completely excavated. Of these 16 individuals, two were subadults and not analyzed for this study because there was not enough time for the remains to be properly cleaned by the close of the 2009 field season. At some point prior to analysis, one posterior tooth was removed from each individual and these were not available for study (Lertcharnrit personal communication 2009). For the purpose of this project, the term “individual” describes a skeleton that consists of at least a single tooth. The excavated sample consists of four males, three females, and seven individuals whose sexes could not be determined. By age, the sample consists of two subadults (not analyzed), two young adults, six adults, three probable adults, and two individuals whose ages were not determined.

Of the individuals excavated, 207 dental alveoli were available for analysis, and 192 teeth were present. See Table 4 for a list of all individuals by age, sex and pathology. See Tables 12 – 19 for a complete dental inventory of all individuals for the presence and absence of the teeth as well as any associated pathology by tooth.

Age and sex estimates were completed as part of the field season activities and confirmed by bioarchaeology co-directors Drs. Scott Burnett and D. Troy Case. Each tooth recovered was analyzed for carious lesions, and attrition. Each tooth socket available for study was examined for signs of antemortem tooth loss (ATML) and alveolar resorption.

a. Age

A further examination of the age range, using dental wear calculations was conducted utilizing the method created by Brothwell (1981). Brothwell (1981) uses the visible observation of wear to divide adult individuals into four age categories; 17 – 25, 25 – 35, 35 – 45, and 45 and older. These categories make it easier to place an individual within a category that most likely encompasses the individual's actual age at death (Hillson 2003). The age ranges calculated from this analysis are located in Table 4. Of the individuals available for analysis, four (28.6%) could not be aged utilizing Brothwell's (1981) method, seven were classified as being 17-25 years of age (50%), and three were classified as being 35-45 years of age (21.4%). The four individuals that were not aged could not be assessed because of a lack of molar teeth.

b. Carious Lesions

Each available tooth was examined for the presence or absence of carious lesions. Carious lesions were scored based on location and severity according to a modified version of Hillson (2001 and 2008). The modified version of Hillson's (2001, 2008) scoring criteria is listed in Table 5. Only the scoring criteria that address visible destruction of the enamel were used to identify carious lesions, thus eliminating the scoring that deals with opaque staining or other criteria that are hard to identify in the field. This modified scale eliminates the recording of phases 1, 2, and 4 of Hillson's (2008) original method, though for ease of comparison with future sites that use this method, the phase numbers in this study will correspond to those of the original recording scheme.

Carious lesions were scored based on tooth number, location on the tooth (occlusal, mesial, distal, buccal, lingual), surface or pit location, and if the lesion is on the root, cusp, or on the cemento-enamel junction. Carious lesions were recorded based on location and severity; however, only severity was used for regional comparisons due to the infrequent or complete absence of the reporting of the location on the tooth of a carious lesion in other studies. Teeth with a carious lesion score of seven and eight were listed as being gross caries; these carious lesions involved the exposure of the dentine or root. Caries rates were recorded based on the number of observed caries over the total teeth examined. Such rates were calculated by sex and by site total.

Lukacs (1995) developed a method for calculating the rate of teeth lost antemortem due to carious lesions. To determine this frequency, the total number of teeth lost antemortem is compared with the number of teeth with carious lesions and attrition that exposes the dentin or root (Lukacs 1995). Lukacs' (1995) method is presented in Table 6. Lukacs' (1995) "caries correction factor" essentially takes the raw percentage of teeth that are listed with gross or "massive" caries and applies that percentage to the number of teeth lost antemortem. In this way, if 20% of the teeth present for analysis suffered from gross or "massive" caries, 20% of the teeth lost antemortem would be attributed as lost due to these types of caries (Lukacs 1995). The corrected caries rate is the combination of the actual caries rate and the number of antemortem teeth discerned to be lost from caries, divided by the total amount of original teeth (both the teeth analyzed and the teeth determined to have been lost antemortem).

An adjustment to this calculation was created by Duyar and Erdal (2003). They adjusted and expanded Lukacs' (1995) method in order to calculate frequencies of corrected caries rates by tooth quadrant and to account for teeth lost post-mortem (Duyar and Erdal 2003). Duyar and Erdal's (2003) method is presented in Table 7. Teeth loss and carious lesions are divided into quadrants; each set of incisors and canines represents a quadrant, as does each set of premolars and molars (Duyar and Erdal 2003). In doing this, they adjust for differences in carious lesion and post/antemortem tooth loss associated with the differential location of the tooth (Duyar and Erdal 2003, Hillson 2003). Such differences can correct for the differential loss of anterior and posterior teeth, as well as the different rates of carious lesions between these two subsets of teeth (Duyar and Erdal 2003, Hillson 2003).

c. Antemortem Tooth Loss (AMTL)

AMTL is identified by the absence of a given tooth and distinguishable from post-mortem tooth loss because of the remodeling of the alveolar bone around the tooth. Every available socket and portion of alveolar bone was analyzed for evidence of AMTL. The calculations of AMTL are completed through division of the number of tooth positions present with alveolar modification compared to the observable number of alveoli. Because of the presence of non-pathological antemortem tooth loss at some sites in Thailand (Tayles 1996), ablation was considered and any patterns arising from the antemortem loss of teeth would have been analyzed.

d. Advanced Attrition

Each available tooth was analyzed for dental wear. Grading of wear was done based on the methods provided in Scott (1979) and Smith (1984) with the utilization of updated illustrations for ease of use in Buikstra and Ubelaker (1994). Incisors, canines, and premolars were graded based on a modified system introduced by Smith (1984). See Table 8 for Smith’s (1984) method for incisors and canines and illustrations for this method from Buikstra and Ubelaker (1994). See Table 9 for Smith’s (1984) method for premolars and illustrations for this method from Buikstra and Ubelaker (1994). Molars were graded based on Scott's (1979) method for wear based on quadrants. See Table 10 for Scott's (1979) method and illustrations for this method from Buikstra and Ubelaker (1994). Wear for incisors, canines, and premolars were analyzed by the qualitative analysis of enamel loss to the cusp (Smith 1984). For molars, each quadrant was scored by qualitative analysis, but the largest amount of wear on a quadrant was used to describe the wear for each tooth (Scott 1979). For each tooth a score was given to the loss of enamel on the occlusal surface. Each score was based on a qualitative assessment to the loss of enamel on that tooth and the presence of any areas of exposure to the dentine or root.

For incisors, canines, and premolars, stages seven and eight of the Smith (1984) method were considered advanced attrition due to the level of exposure from crown loss. For molars, stages nine and ten of enamel loss by quadrants, were considered advanced attrition based on Scott's (1979) method. Only advanced stages of wear were used for site comparison and rates for Promtin Tai due to the frequency of the reporting of advanced stages. Advanced stages of wear are most often reported because of the likelihood that they represent pathological conditions rather than normal wear through mastication (Hillson 2003).

e. Alveolar Resorption

Each available piece of alveolar bone was analyzed for defects or cavities in the alveolar processes. Grading of the defects was modeled after the adaptations to Kerr (1991) outlined in Hillson (2003). Category five of Kerr's grading system identified advanced alveolar resorption and was used for comparisons between sites (Hillson 2003). Category five describes large defects of the alveolar process that are deeper than 3mm and either active or inactive (Kerr 1991 in Hillson 2003). See Table 11 for a reproduction of the modified version of Kerr's (1991) scale in Hillson (2003). Kerr's (1991) system, as modified by Hillson (2003) was utilized because of the integration of the method into the more advanced dental pathology and carious lesion scoring system by Hillson (2006, 2008). Kerr's (1991) scale uses six categories to describe the state of the alveolar bone. Because Kerr's (1991) scale differentiates between active and inactive stages of alveolar resorption, the scale is larger than those used in other studies in Thailand.

While some sites do not use a grading system for analysis, one was utilized in this study for ease of comparison with sites that employ similar methods. Use of an advanced level of wall defect is still comparable to sites that do not employ a grading system because only large defects were utilized between sample comparisons. With the researchers that did use a scale, the simplified 4-point scale used at Ban Chiang and Non Nok Tha is comparable to Kerr's (1991) scale. While alveolar resorption has been seen as a measurement of periodontal disease, the difficulties in identifying the cause of the alveolar resorption make differentiating between types of lesions difficult. Because of this, no attempt to differentiate the cause of the lesions has been made in this paper.

f. Statistics

Because of the larger sample sizes of individuals at the sites used for comparison, the Fisher's Exact statistical tests (FET) were utilized to identify statistically significant differences between pathology rates at Promtin Tai and other sites. Because an alpha level of 0.05 has been used in most other analyses within Thailand, the same method was employed here. This means that in a statistical comparison between two samples a p-value of less than 0.05 is considered to be significant.

Archaeology of skeletal remains within Thailand has been conducted over a large period of time and by many different researchers. As such, the presentation and publication of data has not always been consistent. Oxenham et al. (2005) suggest an adjustment for inter-observer error in their frequency by adjusting the p-value to 0.10 for significant differences. Such inter-observer errors exist because of the many different methods for recording dental pathologies and the varying amount of preparation and differential experience of the observer. A Bonferonni p-value correction is often recommended for multiple statistical tests to maintain an experiment wide p value, however, because the sample for Promtin Tai is relatively small and any comparisons are preliminary, such an adjustment was not employed.

For this study the standard p-value of 0.05 was used, though corrections based on both adjustments should be acknowledged. Post-hoc power and odds ratios were also calculated for all comparisons. Odds ratios report the relative risk of an individual in a population of acquiring the pathology being presented. Odds ratios do not report the actual odds of acquiring a pathology, which is unknown, but reflect the relative change in the odds associated with each pathology between the two groups based on the known ratio between the two outcomes (healthy/unhealthy) of each site. While not typically reported in research such as this, its application is useful in assessing differences between two populations, if differences exist. While p-values associated with a FET test can identify sites that are not significantly different, the odds ratios can show the effect on the odds associated with each pathology.

g. Reanalysis of published data

For between-site comparisons, the original site reports for all comparison sites were used to acquire rates for all dental pathologies. Comparisons by time period were included in the analysis. Because of the high proportion of unsexed individuals in the sample from Promtin Tai, no comparison between the sexes was possible. In all cases, both observed pathology rates and corrected pathology rates such as Lukacs (1995) "Caries Correction Factor" and the revised method by Duyar and Erdal (2003) were considered. Between-site comparisons utilized the FET for statistically significant differences and were conducted using Promtin Tai as the comparison site. Between sites comparisons, excluding Promtin Tai, were completed by Oxenham et al. (2006) and a reanalysis of comparisons without Promtin Tai would be redundant. Sites were then analyzed by location and regional comparisons were conducted. See Table 1 for a complete list of the sites used for comparison and their chronology, pathology rate, and tooth/alveolus count.

For all of the sites analyzed, carious lesions were identified using the macroscopic identification and reporting their presence or absence. The terms "massive" or "gross" were used interchangeably, and generally referred to the destruction of large portions of the crown and/or root that exposed the dentin or root. Antemortem tooth loss was scored visibly for all sites, based on the remodeling of alveolar bone. The majority of the sites used Molnar (1971) to measure wear on all teeth (6/7 sites), the exception being Non Nok Tha, which utilized a system developed by Brothwell (1981). The use of either Molnar (1971) or Brothwell (1981) is comparable to the Smith (1984) and Scott (1979) methods used in this paper. The Scott (1979) method is more complex than Molnar (1971) or Brothwell (1981), but comparison is fairly easy. For all of the sites used in comparisons, alveolar resorption was classified by researchers using a four-point scale, which they occasionally cited as Brothwell (1981). This scale was a four-point scale describing only alveolar resorption as absent, slight, moderate, or acute. These categories are comparable to Kerr (1991) (Table 11).

Two sites were subdivided into early and late periods. For Non Nok Tha, both the early and late period could be compared for all types of pathologies. For Ban Chiang only the data for carious lesions was available for both phases. The rates for AMTL, alveolar resorption, and advanced attrition are only given for the pooled phases at Ban Chiang. For this comparison the time range for the site is 4100 – 2400 BP, and the sample consists of 1094 teeth. Published rates for alveolar resorption were also not available for Noen U-Loke.

IV. RESULTS

a. Dental Pathology at Promtin Tai

Table 4 lists the individuals studied, the age and sex, and associated pathology. Tables 12 through 19 list data on tooth presence and absence as well as any dental pathology at Promtin Tai by individual and tooth count, as well as the pathology breakdown of Promtin Tai by sex. In the observed dentitions, there was no evidence of AMTL (0/14 individuals, 0/207 observable alveoli). Out of the 14 individuals analyzed, only one carious lesion (Figure 2) was identified (0.5%, 1/192 teeth). Because the carious lesion was identified as being from an individual of indeterminate sex and age, no comparison of caries rates by of sex or age was possible.

While there was generally low attrition overall, some advanced attrition was associated with individuals exhibiting signs of occupational wear. Because of the modification of the surface of the dentition due to occupational wear, and the association between advanced attrition and the utilization of the teeth as tools, individuals with advanced attrition and evidence of occupational wear will be counted in the overall attrition rates (Hillson 2003). However, this total is not indicative of pathological wear. The adjusted attrition rate, for individuals without occupational wear is 0% (0/12 individuals, 0/135 observable teeth). The rate, including individuals with occupational wear that exhibit wear greater that grade seven of Smith's (1984) scale or grade nine of Scott's (1979) scale, was 21 % by individual (3/14) and 6.8% by tooth (13/192). Because of the low number of individuals identified by sex, a comparison by sex is not yet possible (four males, three females, and seven indeterminate). Several alveolar wall defects without associated dental pathology were identified (3/14 individuals, 5/192 alveoli), with only one showing signs of advanced alveolar resorption (1/14 individuals, 1/192 alveoli).

b. Between Site Comparisons

To understand the relationship between Promtin Tai and other skeletal series within Thailand, the site needs to be considered in terms of its location and chronology. Table 1 shows the chronology of the sites available for study as well as the overall tooth count and pathology rates. As the table shows, the Iron Age component of Promtin Tai has been dated to between 1600 and 1400 BP (AD 350 – 550), making it the most recent site in an overall analysis of dental health in Thailand. Figures 3 and 4 show the pathology rate by site and the overall pathology rates associated with each region. Promtin Tai is the only site from central Thailand. It is compared with two coastal sites (Khok Phanom Di and Nong Nor) and five sites located on the Khorat Plateau (Ban Chiang, Ban Na Di, Non Nok Tha, Noen U-Loke, and Bon Lum Khao). The highest overall average caries rate is found in coastal Thailand (8.7%), followed by the Khorat Plateau (4.8%) and then central Thailand (0.5%). For AMTL, the coastal region (6.6%) and Khorat Plateau (6.2%) were represented by relatively similar rates, with central Thailand having a much lower rate (0.00%). For alveolar resorption, the Khorat Plateau had a much higher rate (7.1%) than either coastal Thailand (3.4%) or central Thailand (0.6%). For advanced attrition coastal Thailand had a rate of 12.6%, the Khorat plateau had a rate of 11.8% and central Thailand had the lowest rate of 6.8%. Averages for the regions can be seen in Figure 4.

i. Carious lesions

Neither Lukacs' (1995) "Caries correction factor" nor Duyar and Erdal's (2003) calibration methods were employed in this study, in part because it was not possible due to the lack of AMTL or advanced carious lesions (resulting in exposure to the pulp). In all cases, the observed caries count and percentage was available. For future comparisons the observed caries rate at Promtin Tai will also serve as the corrected caries rate. At sites without advanced caries lesions or AMTL the corrected caries rate is identical to the identified caries rate (Lukacs 1995). Comparisons based on Duyar and Erdal's (2003) method are not yet possible, but if more researchers utilize this method it will be a valuable tool in understanding differences in caries rates in Southeast Asia. Raw, or observed caries rates, were available in the published reports for most of the sites analyzed for this study.

Table 1, and Figures 3 and 4 show the overall differences in carious lesion frequencies between the sites, and by region. Overall, all of the sites analyzed at this time in Thailand have a higher rate of carious lesions than Promtin Tai. Generally over time, there is a shift toward a lower caries rate overall, with the exception of the early period at Non Nok Tha (1.5%) and the later period at Ban Chiang (7.7%) as shown in Table 1.

The results of a FET test between Promtin Tai and other sites in Thailand for carious lesions are found in Table 20. As the table shows, Promtin Tai is significantly different, by caries rate, from most of the sites in Thailand. However, the FET test shows that caries rates at Promtin Tai are not statistically different from the caries rates during the early period at Non Nok Tha (p-value = 0.1645). The post-hoc statistical power associated with this comparison indicated that there was a 48.3% chance of identifying a statistical difference if there was one present. When considering a non-significant result, the power value should be high if the absence of a difference is to be given much credence. When the power value is fairly low, it means that the probability of finding a significant difference was low given the sample size. A further analysis using the odds ration demonstrates that there is a significant difference in the odds between the two sites (odds ratio = 0.3118) indicating that at Promtin Tai there is a 0.3118 × the odds of acquiring carious lesions in the early phase at Non Nok Tha. While the relative odds of acquiring this pathology are unknowable, this indicates that there was a difference in the rates based on the available distributions of carious lesions at both sites.

ii. AMTL

Due to the lack of evidence of AMTL, no comparison by sex was conducted. Also because of the lack of antemortem tooth loss, ablation frequencies and patterns do not exist for Promtin Tai. Inter-site comparisons of AMTL were conducted with a 0.00% rate for Promtin Tai. Rates for AMTL were compared using a FET test, the results of the test and the associated p-value are presented in Table 20. In the case of AMTL, Promtin Tai is significantly different from all of the sites compared within this study. The odds ratio value of 0 indicates that the difference was too great to accurately measure.

iii. Advanced Attrition

Rates for advanced attrition were compared using a FET test, the results of which are found in Table 20 including the associated p-values and power values. For advanced attrition, Promtin Tai was significantly different from Ban Chiang, Nong Nor, Ban Lum Khao, and Noen U-Loke. However the comparisons between Khok Phanom Di, Non Nok Tha (Early), Non Nok Tha (Late), and Ban Na Di were not significantly different. However, if run without the advanced attrition associated with the utilization of the teeth as tools, Promtin Tai was found to be significantly different from all other sites.

For observed pathology rates, the early phase at Non Nok Tha had an increased rate for advanced attrition, which is also reflected in the odds ratio. For Khok Phanom Di and the late phase at Non Nok Tha, the odds ratio indicates that the ratio was not drastically different from all of the other sites. This indicates that the non-significant difference identified using FET is most likely valid in that the rates of advanced attrition between these sites are not drastically different.

iv. Advanced Alveolar Resorption

Rates for alveolar resorption were calculated only using significant amounts of resorption. These results can be found in Table 20. In this case, it meant that only one individual at Promtin Tai had a significant amount of alveolar resorption (1/207 alveoli). In a comparison between sites using a FET test, the rates of alveolar resorption, were not significantly different between Promtin Tai, Nong Nor, Ban Lum Khao, and Ban Na Di. The odds ratios for these sites indicate that Promtin Tai had a decreased chance, in relation to odds, of acquiring advanced alveolar resorption. Between Promtin Tai, Ban Lum Khao, and Ban Na Di, the odds ratios were significantly lower for Promtin Tai. For the odds ratio between Nong Nor and Promtin Tai, there was a 0.5794 × the odds difference between the two, indicating that the non-significant difference identified in a FET test was more accurate that with the FET test between Ban Lum Khao, Ban Na Di, and Promtin Tai.

V. DISCUSSION

The FET analysis provides a good indication of the differences between Promtin Tai and other sites within Thailand. Promtin Tai was found not to be significantly different from one out of nine of the sites for carious lesions, three out of seven of the sites for alveolar resorption, zero of the eight sites for AMTL, and two out of six of the sites for advanced attrition. The rate of carious lesions, and the lack of AMTL at Promtin Tai are all indicative of an extremely low pathology rate. Because no evidence of AMTL was found, there is no indication (thus far) that ablation was practiced at Promtin Tai, or that the use of teeth as tools resulted in differential rates of AMTL. Although the rate of advanced attrition is relatively similar to others found in Thailand, all of the advanced attrition found at Promtin Tai is associated with dentition that shows evidence of cultural modification through the use of teeth as tools. The odds ratio analysis also indicates that the pathology rates were significantly lower for all pathologies studied, except for advanced attrition for the early phase at Non Nok Tha.

While the sample size is relatively small (n = 14) a carious lesion rate of 0.5% is low for sites of this time period anywhere. Only six out of the sixty-three (9.5%) sites analyzed by Turner (1979) had a similar caries rate (or lower). All of the sites with a similar rate were from societies identified as hunting and gathering. Three of the sites identified by Turner (1979) were paleo-Arctic, and the remaining three were dated to 3000 BC or earlier. While Turner's (1979) analysis was global in perspective, the only Asian samples came from Japan and were agricultural societies. Using his analysis as a guideline, Promtin Tai fits in with the range of carious lesion rates for hunting and gathering groups or the mixed subsistence groups. When the living populations studied by Turner (1979) are removed, the carious lesion average percentages are lower for each subsistence strategy (1.1% for hunting and gathering, 4.9% for mixed, and 10.3% for agriculture). Using this, Promtin Tai fits in with the hunting and gathering groups. However, as previously noted, the sites from Turner (1979) do not feature any groups from Southeast Asia, living or skeletal.

One possible explanation for the overall low pathology frequencies at Promtin Tai is the relative young age of the skeletal samples. For the individuals who were aged using Brothwell's (1981) method the majority of the population was aged at 17 – 25 (50%). The majority of the sites used as comparisons to Promtin Tai did not have the same age or sex ratios as Promtin Tai. Because Oxenham et al. (2006) reported age distributions in different ranges than provided for in Brothwell (1981), the comparison will focus on the 17-25 age group at Promtin Tai, and the 15-29 age groups for the comparative sites. The ratio for the two age categories was not different between Promtin Tai (50%), Noen U-Loke (51.8%), and Ban Lum Khao (50.9%) (Oxenham et al. 2006). While this indicates that individuals identified as young adults dominate some sites within Thailand, Promtin Tai lacks the other age categories utilized in these samples. Only three individuals from Promtin Tai were identified as being outside of the young adult age category. Though only 71.4% (10/14 individuals) were able to be placed into an age category at Promtin Tai, this is comparable to many of the samples utilized in this study (4/7 sites utilized in this study) (Oxenham et al. 2006).

With further excavation and analysis, the age and sex information can be expanded to help determine if the low pathology rates at Promtin Tai extend to older age groups. Because not all of the skeletons could be thoroughly cleaned at the close of the 2009 field season, future analysis of this sample can improve the interpretation of the dental pathology results. Such an analysis should narrow the age ranges to those used by Oxenham et al. (2006) so a more accurate comparison of the age distributions by pathology can occur.

Tayles et al. (2000) and Oxenham et al. (2006) have suggested that differential rates of caries at sites may be caused by social stratification. A comparison between the sample of Promtin Tai and burials associated with grave goods at Ban Chiang (both phases pooled) resulted in a similar carious lesion rate between the sites. Individuals with burial goods at Ban Chiang exhibited a carious lesion rate of 1.1% by tooth or 20% by individual (2/177 teeth, 2/10 individuals). At Promtin Tai the rate was 0.5% by tooth and 7% by individual (1/192 teeth, 1/14 individuals). A statistical analysis of the differences resulted in a FET p-value of 0.36 indicating that there was not a significant difference between these two samples. However, research at Non Nor has demonstrated that there was no differential treatment of burials in regards to burial goods practiced at that site (Debreceny et al. 1998). Further research into the distribution and frequency of burial goods within Thailand can help to answer the questions regarding different pathology frequencies and their relationship to social stratification.

The similarity in carious lesion rates between Promtin Tai and the early phase at Non Nok Tha deserve further scrutiny. While the differences between caries rates for the early phase is not significantly different, the difference in the second phase is statistically significant. In Douglas' (2006) analysis of dental health at Non Nok Tha, the shift in the decline in dental health between the two phases was attributed to a general decline in female dental health. Caries rates at Non Nok Tha shifted from 1.3% in the early period to 5.7% in the later period. If such divisions of periods can be established from future excavations at Promtin Tai, it would be interesting to see if similar temporal trends occurred there as well. There is also a clear difference in the average rates of carious lesions by region (see Figure 4) with higher rates being found in the coastal region.

Such a comparison between these two specific sites is also interesting because of the distance between the two sites spatially and chronologically. Promtin Tai is located in central Thailand while Non Nok Tha is on the Khorat Plateau (see Figure 1). The early phase at Non Nok Tha began almost 2000 years prior to the earliest occupational sequences at Promtin Tai. The differences between these two sites cannot be based solely on diet. While the subsistence patterns at Promtin Tai have not yet been fully scrutinized, the majority of the diet visible in the archaeological record consists of hunting and gathering, with a large proportion of the material being from freshwater shellfish and fish (Lertcharnrit 2006). The diet at Non Nok Tha has been identified as being mixed hunting/gathering and agriculture (Oxenham et al. 2006, Douglas 2006). The differences in diet, here, could be because the subsistence strategies at Promtin Tai have not been solidified.

While rice agriculture may have been practiced at Promtin Tai, no archaeological evidence for harvesting or consumption has yet been identified. It would be surprising if rice had not reached this area of Thailand as it spread throughout mainland Thailand prior to the occupational sequences at Promtin Tai (Higham 2002). Evidence from the area also suggests that the river-ways were heavily modified in the region prior to known occupational sequences at Promtin Tai (Higham 2002). Rice agriculture was found to be present during all of the occupation sequences at Non Nok Tha so the similarities between Promtin Tai and Non Nok Tha presumably lie elsewhere.

The non-significant differences found for advanced attrition are intriguing because they do not follow any chronological or regional pattern. Generally, the sites that were not found to be significantly different are older. However, Ban Chiang stands out as an early site with a relatively higher advanced attrition rate. The problem with comparisons with Ban Chiang, beyond carious lesion rates, is that the early and late phases were pooled together for data on alveolar resorption, AMTL, and advanced attrition.

The advanced attrition rate was higher at Promtin Tai than the early phase at Non Nok Tha. The differences between the sites, as described above, include region, time, and diet. However, while the advanced attrition rate for the late phase at Non Nok Tha appears higher than at Promtin Tai, the difference is not statistically significant. While the differences in carious lesions have been attributed to sex, the cause of increased wear for the late period at Non Nok Tha has not been identified, though an increase in the use of the teeth did occur (Douglas 2006).

For alveolar resorption, the comparisons become more complex. Because alveolar resorption can be the result of other factors besides periodontal disease, it may not be possible to identify the cause of differences between sites (Hillson 2003). Though there was an increase in the amount of alveolar resorption over time at Non Nok Tha, this was attributed to a larger proportion of older individuals in the late phase compared to the early phase (Douglas 2006). It was also noted that alveolar resorption was more common in males than females (Douglas 2006). At Promtin Tai, the only individual identified with advanced alveolar resorption fell into the 17 – 25 age category, though only two out of the three individuals with any alveolar resorption could be identified by age, and only one could be identified by sex.

The significant differences between Promtin Tai and all other sites for AMTL is most likely a result of the younger sample at Promtin Tai. With no individuals losing any teeth post mortem, Promtin Tai has a drastically lower rate of AMTL than any other site compared. Due to the rates of AMTL reported at other sites in Thailand, it would be unlikely that Promtin Tai remained at such a low rate when more skeletons are analyzed.

Comparing similarities between Promtin Tai and other sites based on alveolar resorption is more difficult, as the processes involved in the disease are numerous (Hillson 1996). Some regional difference exists in the rates for alveolar resorption that do not seem to be correlated with either AMTL or carious lesion frequencies. However, FET demonstrates that individual sites from all regions were not significantly different. Further examination of the subsistence patterns at all sites as well as further scrutiny of the skeletal samples could lead to a better understanding of any trends that could explain the findings.

In the first modern comparison of sites within Thailand, Oxenham et al. (2000) found that pathology rates remained relatively the same over time within the region. Oxenham et al. (2000) believed that changes in health due to agriculture did not happen until larger settlements were possible during the Iron Age. Work by Oxenham et al. (2006) and Oxenham (2000) have suggested that in Vietnam, lowered pathology rates were tied to Chinese influence in the region and agricultural rice production being used only for export, rather than local consumption. The site of Vietnam Red River (2200 – 1700 BP) was shown to be under direct control of China, and because of the exportation of the agricultural product, had a drastically lower carious lesion rate (1.4%) than contemporary sites within Vietnam (Oxenham et al. 2006). The contemporary sites in Vietnam were not associated with rice production with export to China, and had double the carious lesion rate when compared with Vietnam Red River (Oxenham et al. 2006). With evidence of much of the iron and copper produced at Promtin Tai being used for export, the presence of modified river systems at the time of occupation, and a similar decrease in pathology rates, it remains possible that any rice agriculture (if identified) may also be for export.

An analysis of childhood stress conducted on the excavated non-adult remains, or future non-adult remains, could help to clarify the underlying context of low pathology rates at Promtin Tai. Further analysis in the field, and the recovery of more remains would allow for a more detailed comparison between age groups and sex. The condition of the individuals recovered made such an analysis difficult in the time available during the 2009 field season. Because excavations are likely to encounter new burial areas in the next few seasons, future analysis will likely clarify pathology frequencies at Promtin Tai.

In addition, because of issues addressed by Liebe-Harkort et al. (2009) about the scoring of caries, there may be problems in the comparisons between sites by different observers. Because of the low level of agreement found in the study by Liebe-Harkort et al. (2009) there may be issues with the calculations of overall rates by region that include observations by different observers. While Oxenham et al. (2006) suggest increasing the alpha level for statistical tests in order to account for interobserver error, or disagreement, these adjustments have not been made here. In future analysis, when a larger sample is available from Promtin Tai, such an adjustment should be considered in order to account for possible errors in between site comparisons.

VI. CONCLUSION

The analysis of dental pathology at Promtin Tai provides valuable information on the sequence of dental health in Thailand over time and provides the first look into the health of people within central Thailand during the Iron Age (after 2400 BP). While some of the findings may change with further excavation, the initial pathology rates suggest that the amount of caries and AMTL are much lower than for other sites within Thailand and the rest of the world.

Carious lesions were limited to only one tooth (1/192 teeth, 0.5%) and had a drastically lower rate than other sites within Thailand. Though no significant differences were found between Promtin Tai and the early phase of Non Nok Tha, the odds ratio statistical examination showed that Promtin Tai had decreased odds. At Promtin Tai there was no evidence of AMTL (0/207 alveoli, 9%) and this was significantly different from all other sites in Thailand studied thus far. Rates for advanced attrition at Promtin Tai (13/192 teeth, 6.8%) were comparable to other sites in Thailand, and higher than rates during the early phase at Non Nok Tha. The rates for advanced alveolar resorption at Promtin Tai (1/207 alveoli, 0.5%) were comparable to some sites analyzed, but had reduced odds overall, indicating that there was some difference between the rates at Promtin Tai and other sites in Thailand. The similarities between Promtin Tai and other sites for advanced attrition and alveolar resorption, should be explored further once analysis of the excavated burials is complete.

The role that diet plays in dental pathology within Thailand is still being explored. Using the diet information from the comparative sites used by Oxenham et al. (2006) and comparing it with the known types of subsistence at Promtin Tai did not reveal any similarities between pathology frequencies overall. The relative age of the skeletal sample from Promtin Tai, and the difference in time periods between the sites could be playing a larger role in the differential pathology rates than the influence of the food preparation or overall diet. Work in Vietnam during periods contemporary with Promtin Tai has shown that rice agricultural production could be for export. Due to the evidence that the metal goods produced at Promtin Tai were for non-local use, it remains a possibility that any rice produced here could also have been for export. If that were the case, lower pathology rates, such as those found at Vietnam Red River, would be expected.

Further analysis into spatial patterns within Promtin Tai as well as social stratification and sex differences will only be possible with further excavation. Continued excavation of the exposed burials, and exposure of new burials, will enable researchers to see if there is any difference in burial goods among individuals with or without dental pathologies, and those exhibiting different rates of dental pathology. A detailed analysis of dental pathology by social status has yet to be completed within Thailand and excavation and analysis now could provide valuable information about Thai dental health. The further analysis of excavated sites within different regions of Thailand that are not yet a part of this regional comparison will also help to provide valuable information on spatial and chronological patterns in dental health associated with the adaptation of rice-agriculture in Thailand and Southeast Asia.

The analysis of Promtin Tai provides the first glance at population health and dental pathology within central Thailand. With further excavation and analysis, more detailed comparisons can occur. With the addition of data from other excavations in the region, and other areas that have yet to be analyzed a complete picture of population health in prehistoric Thailand will surely emerge.

VII. TABLES

Table 1: Between Site Pathology Frequencies

Site	Year BP[6]	Diet[6]	Total Teeth	Total Individuals	Carious	AMTL	Alveolar Resorption	Advanced Attrition
Promtin Tai[1]	1600-1400[1]	Ha[7]	192	14	0.5%	0.00%	0.5%	6.8%
Khok Phanom Di[3]	4000-3500	Ha/t (A?)	1282	67	10.9%	8.90%	5.96%	7.95%
Non Nok Tha (Early)[2]	4800-3400	M	666	38	1.7%	5.00%	7.22%	5.45%
Ban Chiang (Early)[4]	4100-2900	M	534	27	6.2%	6.8%[a]	13.23%[a]	16.65%
Non Nok Tha (Late)[2]	3400-2200	M	539	41	4.1%	10.40%	11.67%	7.65%
Nong Nor[5]	3100-2700	A (Ha)	1017	68	6.5%	4.38%	0.83%	17.26%
Ban Lum Khao[5]	3000-2500	M	885	43	4.5%	5.10%	1.29%	12.96%
Ban Chiang (Late)[4]	2600-2400	M	560	37	7.7%	N/A	N/A	N/A
Ban Na Di[5]	2600-2400	A (H)	515	34	4.7%	5.37%	2.12%	11.96%
Noen U-Loke[3]	2300-1700	A	956	54	4.8%	4.48%	N/A[b]	16.02%

1) This study. 2) Domett (2006). 3) Tayles et al (2000). 4) Pietrusewsky and Douglas (2002). 5) Domett (2001). 6) Oxenham et al. (2006). 7) Lertcharnrit (2006). a) Raw data was only given for the complete site and not phases. b) Not available in the published data.

H, hunting/gathering; M, mixed agriculture and hunting/gathering; A, agriculture; a, aquatic; t, terrestrial.

Table 2: Carious lesion rates by subsistence type*

Subsistence	Status	Avg. % carious	# of samples	Range
Hunting and Gathering	Living	3.4	2	2.2 - 4.6
Hunting and Gathering	Skeletal	1.066	17	0.0 - 5.3
Hunting and Gathering	**Overall**	**1.316**	**19**	**0.0 - 5.3**
Mixed	Living	6.555	2	3.81 - 9.3
Mixed	Skeletal	4.867	11	0.44 - 10.3
Mixed	**Overall**	**5.127**	**13**	**0.44 - 10.3**
Agricultural	Living	11.091	6	2.14 - 26.9
Agricultural	Skeletal	10.279	26	2.3 - 26.5
Agricultural	**Overall**	**10.431**	**32**	**2.14 - 26.9**

* Modified from Turner (1979:625)

Table 3: Calibrated Radiocarbon Dates Associated with Promtin Tai

ID	Date	Calibrated Date*	Material	Context	Excavation Unit
OAPE2169	2430 ± 260	1211 BC – AD 73	Charcoal	Bronze Age occupation layer	PTT-S2
OAEP2168	1810 ± 220	357 BC – AD 645	Charcoal	Iron Age occupation layer	PTT-S2
OAEP2167	2170 ± 260	828 BC - AD 388	Charcoal	Iron Age occupation layer	PTT-S2
OAEP2166	3110 ± 230	1912 - 819 BC	Charcoal	Iron Age occupation layer	PTT-S2
OAEP2165	2220 ± 260	903 BC - AD 335	Charcoal	Iron Age occupation layer	PTT-S2
OAEP2163	2860 ± 220	1611 - 512 BC	Charcoal	Iron Age occupation layer	PTT-S2
Unknown	2652 +/- 79	1007 - 543 BC	Tooth from *Canis lupus familiaris*	Associated with Iron Age Burial	PTT-S2

* Calibrated by the S. Kirkland using OxCal 4.1

Table 4: Sex, age, and pathology information for Promtin Tai by individual

Burial	Age	Sex	Dental Age*	Total Teeth	Alveoli	Pathology	Teeth Affected	Pathology Score	Pathology Method
B2	**A**	**M?**	**35-45**	30	32	None	N/A	N/A	N/A
B5	**A**	**M?**	**17-25**	29	32	None	N/A	N/A	N/A
B7	**YA**	**F**	**17-25**	30	32	Alveolar Resorption	ULI2, ULM3, LLP2	2, 4, 5	Kerr 1991
B8	**A**	**?**	**35-45**	25	32	Alveolar Resorption	LRM1, LRM2, LLP2	3, 3, 3	Kerr 1991
B10	**A?**	**?**	**N/A**	1	6	Alveolar Resorption	LLM1, LLM2	2, 2	Kerr 1991
B12	**A**	**M?**	**17-25**	31	32	None	N/A	N/A	N/A
B13	**A?**	**?**	**17-25**	4	6	None	N/A	N/A	N/A
B16	**YA**	**M**	**17-25**	3	2	None	N/A	N/A	N/A
B17	**A**	**?**	**35-45**	6	7	None	N/A	N/A	N/A
B19	**A?**	**?**	**17-25**	10	0	None	N/A	N/A	N/A
B20	**YA**	**F**	**17-25**	20	26	None	N/A	N/A	N/A
B24	**A**	**F?**	**N/A**	1	0	None	N/A	N/A	N/A
B26	**A?**	**?**	**N/A**	1	0	Caries	LRC	6	Hillson 2001
B29	**A?**	**?**	**N/A**	1	0	None	N/A	N/A	N/A
Totals				192	207				

*Using Brothwell 1981

Table 5: Caries scoring (Based on Hillson 2008)*

Blank = Postmortem tooth loss and socket missing
0 = Tooth present without carious lesion
1 = white/stained opaque with smooth glossy/matte surface
2 = white/stained opaque with roughening or slight destruction of surface
3 = small cavity with no evidence of dentine exposure
4 = stained area that might be a cavity
5 = larger cavity with dentine exposure
6 = large cavity with pulp exposure or root exposure
7 = gross caries, it is not possible to determine the origin of the cavity
8 = gross caries, it is not possible to determine the origin of the cavity; root or dentine exposure
10 = postmortem tooth loss with empty socket
11 = tooth missing with slight remodeling to the alveolar process, well defined socket
12 = tooth missing with complete remodeling of the alveolar process
13 = no evidence of tooth eruption
14 = partial tooth eruption
15 = abnormal tooth eruption

* Bold scores were used in this study; the others are listed for ease of comparison with other sites

Table 6: Caries Correction Factor calculation from Lukacs (1995)

1) Estimated number of teeth lost due to caries.
[Number of teeth lost antemortem] X [proportion of teeth with pulp exposure due to canes]

2) Total estimated number of teeth with caries.
[Estimated number of teeth lost due to caries] + [number of carious teeth observed]

3) Total number of original teeth.
[Number of teeth observed] + [number of teeth lost antemortem]

4) Corrected Caries Rate.
[Total estimated number of teeth with canes] + [total number of original teeth]

Table 7: Dental Calibration Calculation modified from Duyar and Erdal (2003)

1. **Proportion of teeth with dentin exposure due to carious lesions**
   d_1 = Number of gross caries for anterior teeth ÷ total anterior teeth with pulp exposure
   d_2 = Number of gross caries for posterior teeth ÷ total posterior teeth with pulp exposure

2. **Estimated teeth lost due to caries for anterior (e_1) and posterior (e_2) teeth**
   $e_1 = d_1$ x number of anterior teeth lost antemortem
   $e_2 = d_2$ x number of posterior teeth lost antemortem

3. **Corrected total caries for anterior (f_1) and posterior (f_2) teeth**
   $f_1 = e_1$ + number of anterior carious teeth
   $f_2 = e_2$ + number of posterior carious teeth

4. **Total number of original teeth for anterior (g_1) and posterior (g_2) teeth**
   g_1 = total anterior teeth present + number of anterior teeth lost antemortem
   g_2 = total posterior teeth present + number of posterior teeth lost antemortem

5. **Adjusted corrected caries rates for anterior (h_1) and posterior (h_2) teeth**
   $h_1 = (f_1/g_1) \times 100$
   $h_2 = (f_2/g_2) \times 100$

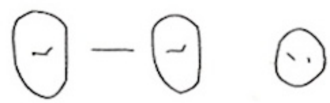
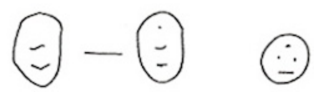
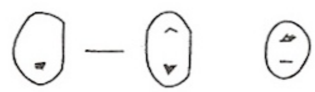
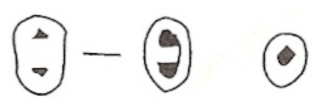
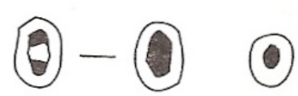
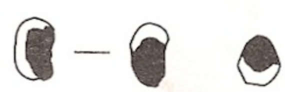
6. **Calculated caries rates for a population (i)**
   $i = (h_1 \times 0.375) + (h_2 \times 0.625)$

Table 8: Incisor and Canine Attrition Scoring Stages from Smith (1984)

Phase	Diagnosis	Image*
1	Unworn or small facets	
2	Point or hairline dentin exposure	
3	Distinct dentin line	
4	Moderate dentin exposure	
5	Large dentin exposure with enamel rim	
6	Large dentin exposure with thin enamel rim or partial loss of enamel rim	
7	Little or no enamel rim remaining	
8	Loss of crown, root exposure	

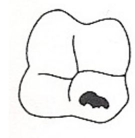
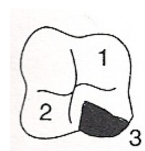
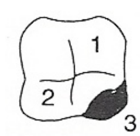
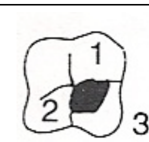
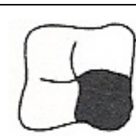
*Images from Buikstra and Ubelaker (1994)

Table 9: Premolar Attrition Scoring Stages from Smith (1984)

Phase	Diagnosis	Image*
1	Unworn or small facets	
2	Blunting of Cusp	
3	Dentine patches or cusp removal	
4	One large dentin exposure on one cusp	
5	Two large dentin exposure points	
6	Joining of dentin points into solid exposure area with enamel rim	
7	Little or no enamel rim remaining	
8	Loss of crown, root exposure	

*Images from Buikstra and Ubelaker (1994)

Table 10: Molar Attrition Scoring Method from Scott (1979)

Phase	Diagnosis	Image*
1	Not recordable (for any reason)	N/A
2	Unworn or small facets	N/A
3	Large wear facets, but cusps still visible and pronounced	N/A
4	Rounding of cusp	N/A
5	Cusp has been worn flat, less than 1/3 of the cusp with dentin exposure	
6	Larger dentin exposure. Greater than 1/4th of the cusp	
7	Enamel only present on two sides of the cusp	
8	Moderate enamel rim present, only on one side of cusp	
9	Life phase 8, but rim is slim	
10	No enamel on cusp, dentin or root exposure	

*Images from Buikstra and Ubelaker (1994)

Table 11: Categories of Alveolar Resorption from Kerr (1991) modified by Hillson (2003)

Category	Definition	Implication
0	Unrecordable	
1	Cortical surface smooth, uninterrupted.	Healthy
2	Cortical surface has grooves, foramina, or ridges. Some larger destruction.	Inflammation of soft tissue
3	Broad hollow, small discrete areas of destruction, edges have sharp ragged texture.	Acute burst of periodontitis
4	Similar to 3, but defects are rounded with porous or honey come texture	Inactive periodontitis
5	Deep bony defect, either sharp and ragged or smooth and honeycombed	More aggressive periodontitis in either acute or inactive phase

Table 12: Dental Inventory for Promtin Tai: Maxillary Dentition

Burial	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3
B2	1	1	1	1	1	1	1	1	X	1	1	1	1	1	1	1
B5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B8	X	X	1	1	1	1	0	1	1	1	1	1	1	1	1	X
B10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B13	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
B16	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0
B17	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B19	0	0	0	2	2	2	0	2	0	0	0	0	0	0	0	0
B20	4	1	1	1	1	1	X	X	X	X	X	1	1	1	1	4
B24	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
B26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B29	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0

0) Missing with no associated alveolar bone; 1) Present, in occlusion; 2) Present, no associated alveolar bone; 3) Missing with alveolar bone completely remodeled; 4) Un-erupted for any reason; 5) Present but damage obscures observation; X) Missing post mortem, alveolar bone present and unmodified.

Table 13: Dental Inventory for Promtin Tai: Mandibular Dentition

Burial	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3
B2	1	1	1	1	1	1	1	1	1	5*	1	1	1	1	1	1
B5	X	1	1	1	1	X	1	1	X	1	1	1	1	1	1	1
B7	X	1	1	1	1	1	1	X	1	1	1	1	1	1	1	1
B8	X	X	1	1	1	1	1	1	1	1	1	1	1	1	1	X
B10	X	X	X	5	X	X	0	0	0	0	0	0	0	0	0	0
B12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	X
B13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B16	1	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B17	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
B19	0	0	2	2	2	2	0	0	0	0	2	0	2	0	0	0
B20	4	1	1	1	1	1	1	X	X	X	1	1	1	1	1	4
B24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B26	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
B29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0) Missing with no associated alveolar bone; 1) Present, in occlusion; 2) Present, no associated alveolar bone; 3) Missing with alveolar bone completely remodeled; 4) Un-erupted for any reason; 5) Present but damage obscures observation; X) Missing post mortem, alveolar bone present and unmodified.
* Unscorable for carious lesions or wear.

Table 14: Dental Inventory for Promtin Tai: Maxillary Carious Lesions*

Burial	**LM3**	**LM2**	**LM1**	**LP2**	**LP1**	**LC**	**LI2**	**LI1**	**RI1**	**RI2**	**RC**	**RP1**	**RP2**	**RM1**	**RM2**	**RM3**
B2	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
B5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B8	10	10	0	0	0	0		0	0	0	0	0	0	0	0	10
B10																
B12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B13											0	0	0	0		
B16							0		0							
B17		0														
B19				0	0	0		0								
B20	13	0	0	0	0	0	10	10	10	10	10	0	0	0	0	13
B24					0											
B26																
B29										0						

*Scoring based on Hillson (2008) see Table 5.

Table 15: Dental Inventory for Promtin Tai: Mandibular Carious Lesions*

Burial	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3
B2	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
B5	10	0	0	0	0	10	0	0	10	0	0	0	0	0	0	0
B7	10	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
B8	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10
B10	10	10	10	0	10	10										
B12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
B13																
B16	0	10														
B17												0	0	0	0	0
B19			0	0	0	0					0		0			
B20	13	0	0	0	0	0	0	10	10	10	0	0	0	0	0	13
B24																
B26											6					
B29																

*Scoring based on Hillson (2008) see Table 5.

Table 16: Dental Inventory for Promtin Tai: Maxillary Attrition*

Burial	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3
B2	9	9	8	4	5	5	5	6	X	7	6	6	6	9	8	9
B5	1	3	5	3	3	4	2	6	6	6	5	3	3	4	2	1
B7	3	3	4	2	2	4	3	3	4	3	3	2	2	5	2	2
B8	X	X	9	5	6	5	0	5	5	5	6	X	5	9	X	X
B10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B12	1	2	5	2	3	4	4	4	4	4	4	4	4	4	3	1
B13	X	X	X	X	X	X	X	X	X	X	4	4	3	5	X	X
B16	X	X	X	X	X	X	2	X	1	X	X	X	X	X	X	X
B17	X	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B19	X	X	X	1	1	1	X	1	X	X	X	X	X	X	X	X
B20	X	1	2	1	2	2	X	X	X	X	X	X	1	2	X	X
B24	X	X	X	X	3	X	X	X	X	X	X	X	X	X	X	X
B26	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B29	X	X	X	X	X	X	X	X	X	6	X	X	X	X	X	X

* Scoring for molars according to Scott (1979) and scoring for incisors, canines, and premolars according to Smith (1984) see Tables 8 through 10. X) Unrecordable for any reason

Table 17: Dental Inventory for Promtin Tai: Mandibular Attrition*

Burial	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3
B2	7	7	9	6	X	6	6	6	X	X	6	7	6	9	9	9
B5	X	3	5	4	4	X	5	5	X	5	4	3	4	5	3	2
B7	4	5	5	4	3	3	4	X	4	4	3	3	3	5	5	X
B8	X	9	9	6	X	5	5	5	5	5	4	X	6	8	X	X
B10	X	X	X	X	4	X	X	X	X	X	X	X	X	X	X	X
B12	1	1	5	2	2	4	3	5	4	3	4	4	1	4	5	X
B13	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B16	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B17	X	X	X	X	X	X	X	X	X	X	X	4	4	6	6	5
B19	X	X	2	1	4	2	X	X	X	X	1	X	1	X	X	X
B20	X	2	2	1	2	X	X	X	X	X	2	1	1	2	3	X
B24	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B26	X	X	X	X	X	1	X	X	X	X	X	X	X	X	X	X
B29	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

* Scoring for molars according to Scott (1979) and scoring for incisors, canines, and premolars according to Smith (1984) see Tables 8 through 10. X) Unrecordable for any reason

Table 18: Dental Inventory for Promtin Tai: Maxillary Alveolar Resorption*

Burial	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3
B2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B7	4	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1
B8	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
B10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B13	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
B16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Scoring based on Kerr (1991) as modified by Hillson (2003) see Table 11.

Table 19: Dental Inventory for Promtin Tai: Mandibular Alveolar Resorption*

Burial	LM3	LM2	LM1	LP2	LP1	LC	LI2	LI1	RI1	RI2	RC	RP1	RP2	RM1	RM2	RM3
B2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B7	1	1	1	5	1	1	1	1	1	1	1	1	1	1	1	1
B8	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1
B10	1	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0
B12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B16	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B17	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
B19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B26	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Scoring based on Kerr (1991) as modified by Hillson (2003) see Table 11.

Table 20: Statistical Comparisons of Promtin Tai to Other Sites

Site	KPD	NNTE	BCE1	NNTL	NNO	BLK	BCL	BND	NUL
Caries (FET)	0.0000*	0.1645	0.0000*	0.0066*	0.0001*	0.0024*	0.0038*	0.0030*	0.0100*
Power	1	0.4830	0.9929	0.9359	0.9953	0.961	0.9987	0.9146	0.9729
Odds Ratio	0.0407	0.3118	0.0638	0.1223	0.075	0.11	0.096	0.1097	0.1374
A. Resorption (FET)	0.0000*	0.0000*	0.0000*	0.0000*	0.3288	0.2043	N/A	0.0756	N/A
Power	0.9956	0.9986	1	1	0.1233	0.3587	N/A	0.6557	N/A
Odds Ratio	0.0776	0.0624	0.0318	0.0453	0.5794	0.3686	N/A	0.2239	N/A
AMTL (FET)	0.0000*	0.0000*	0.0000*	0.0000*	0.0002*	0.0001*	N/A	0.0001*	0.0002*
Power	1	0.9992	0.9996	1	0.9941	0.9972	N/A	0.9976	0.9933
Odds Ratio	0	0	0	0	0	0	N/A	0	0
Adv. Attrition (FET)	0.1015	0.1058	0.00001*	0.1206	0.0000*	0.0047*	N/A	0.0145*	0.0003*
Power	0.0886	0.0969	0.9897	0.0759	0.9939	0.8434	N/A	0.225	0.9816
Odds Ratio	0.8407	1.2595	0.3636	0.8768	0.3482	0.4878	N/A	0.5346	0.3807

*Statistically significant difference

VIII. FIGURES

Figure 1: Map of Thailand with Associated Archaeological Sites

Figure 2: Carious Lesion from Burial 26. View of the distal surface of the mandibular right canine.

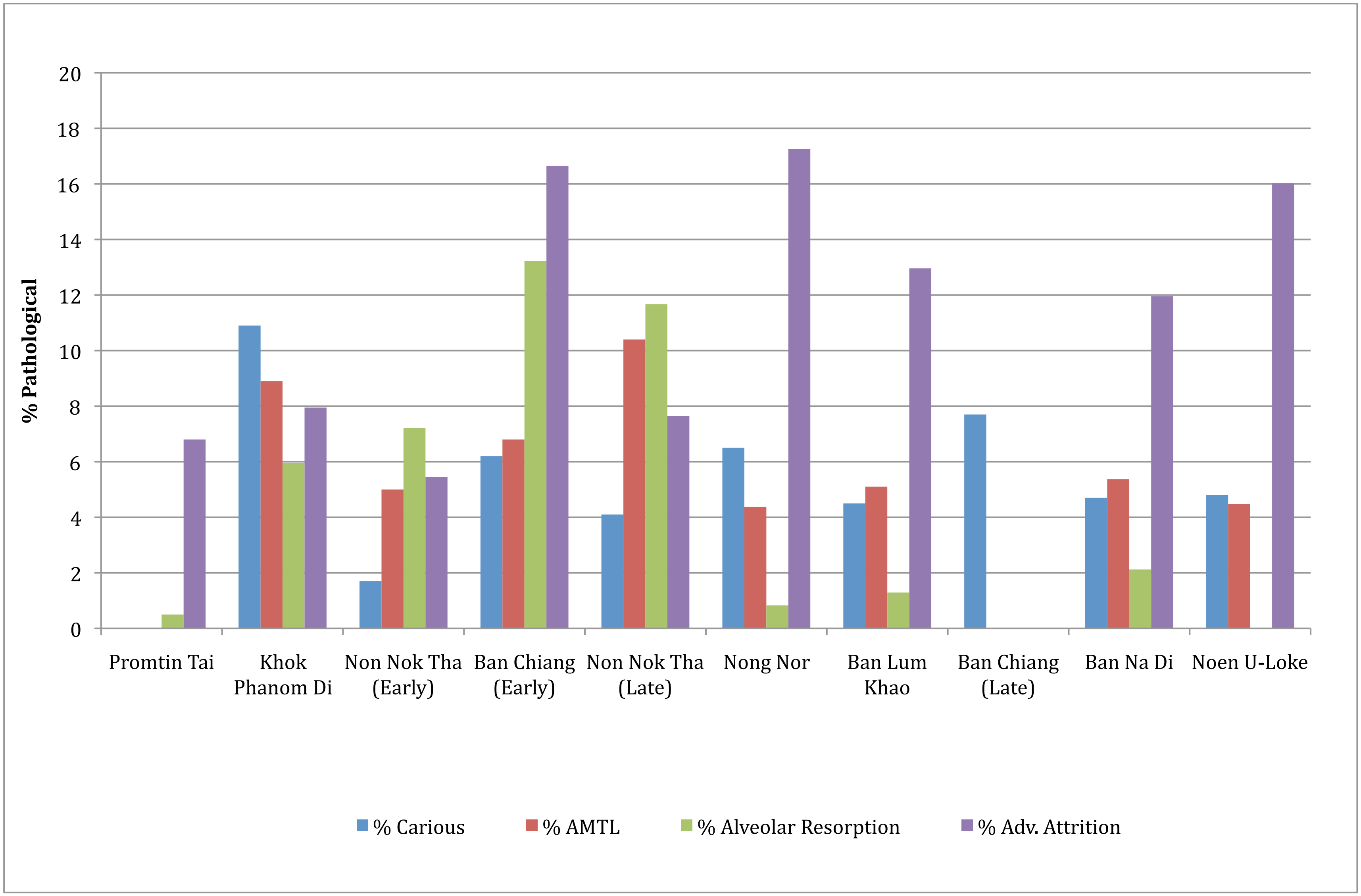


Figure 3: Between Site Pathology Frequencies

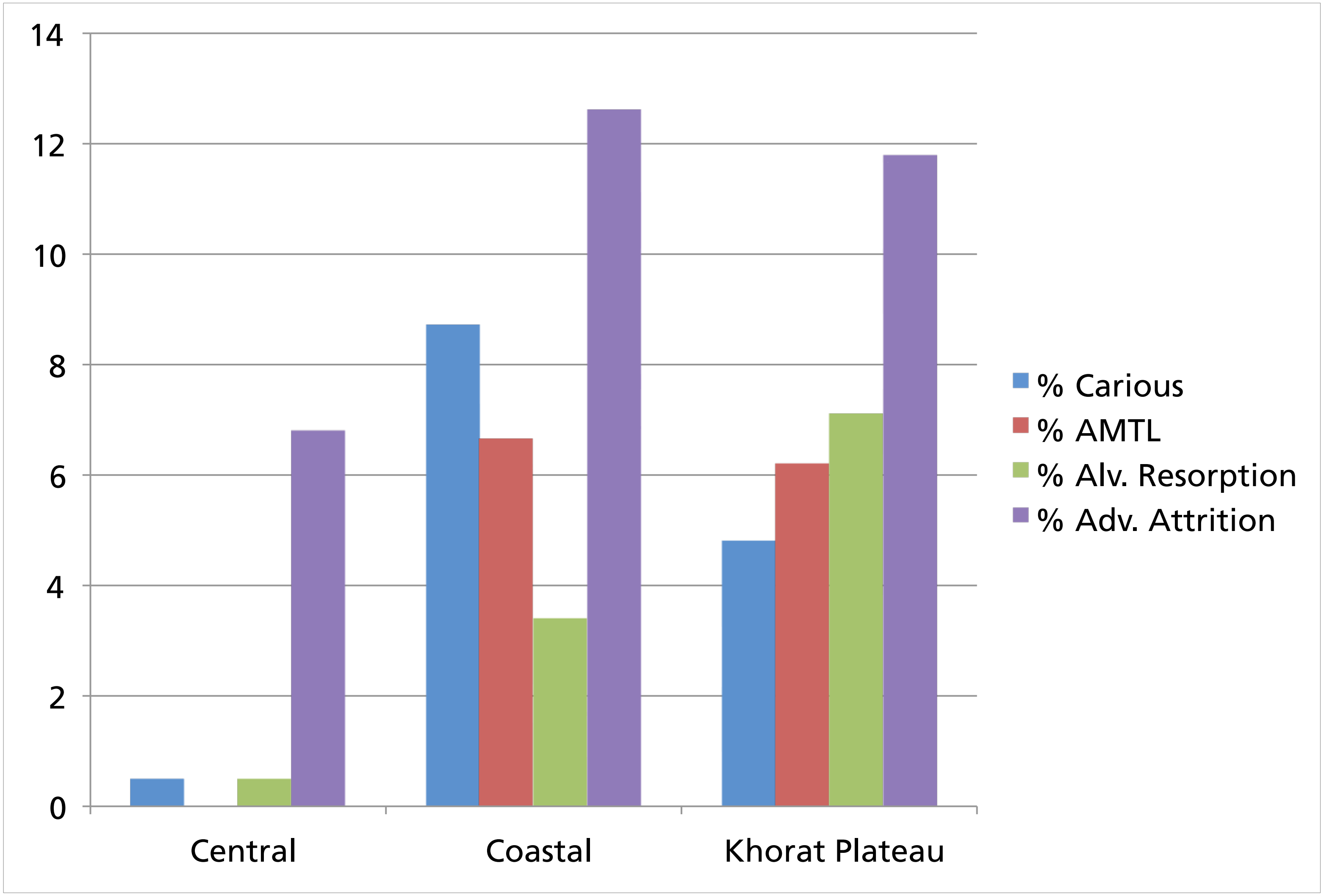


Figure 4: Dental Pathology Averages by Region

IX. REFERENCES

Baelum V., Nyvad B., Grondahl H.-G. and Fejerskov O. 2008. The Foundations of Good Diagnostic Practice. *In* Dental Caries: The Disease and its Clinical Management: Second Edition. Ole Fejerskov and Edwina Kidd eds. Pp. 103-120. Blackwell Publishing Company.

Bellwood P. 1997. Prehistory of the Indo-Malaysian Archipelago: revised edition. Honolulu. University of Hawai'i Press.

Bently R. A., Cox K., Tayles N., Higham C., Macpherson C., Nowell G., Copper M., and Hayes T. 2009. Community Diversity at Ban Lum Khao, Thailand: Isotopic Evidence from the Skeletons.

Bonfiglioli B., Mariotti V., Facchini F., Belcastro M., and Condemi S. 2004. Masticatory and Non-Masticatory Dental Modifications in the Epipalaeolithic Necropolis of Taforalt (Morocco). International Journal of Osteoarchaeology. 14:448-456.

Buikstra JE, and Ubelaker DH (eds.) (1994) Standards for Data Collection From Human Skeletal Remains. Fayetteville: Arkansas Archaeological Survey, Re- search Series No. 44.

Caglar E., Kuscu O.O., Sandalli N., and Ari I. 2007. Prevalence of dental caries and tooth wear in a Byzantine population (13^{th} c. A.D.) from northwest Turkey. Archives of Oral Biology. 52:1136-1145.

Debreceny J., Higham C.F.W., and Manly B.F.J. 1998. A Statistical Analysis of the Burials. *In* The Excavation of Nong Nor: a Prehistoric Site in Central Thailand. Higham C.F. and Thosarat R. Eds. Pp.321-368. Oxford. Oxbow Books Ltd.

Deter C. 2008. Gradients of Occlusal Wear in Hunter-Gatherers and Agriculturalists. American Journal of Physical Anthropology. 138:247-254.

Domett K. M. 2001. British Archaeological Reports International Series No. 946: Health in Late Prehistoric Thailand. Oxford: Archaeopress.

Douglas M. 2006. Subsistence change and dental health in the people of Non Nok Tha, northeast Thailand. *In* Bioarchaeology Southeast Asia. Marc F. Oxenham and Nancy Tayles, eds. Pp. 191-219. Cambridge Studies in Biological and Evolutionary Anthropology. Cambridge: Cambridge University Press.

Duyar I and Erdal Y. S. 2003. A new approach for calibrating dental caries frequency of skeletal remains. HOMO. 54(1):57-70.

Fejerskov O., Nyvad B. and Kidd E.A.M. 2008b. Clinical Appearances of Caries Lesions. *In* Dental Caries: The Disease and its Clinical Management: Second Edition. Ole Fejerskov and Edwina Kidd eds. Pp. 7-18. Blackwell Publishing Company.

Fejerskov O., Nyvad B. and Kidd E.A.M. 2008c. Pathology of Dental Caries. *In* Dental Caries: The Disease and its Clinical Management: Second Edition. Ole Fejerskov and Edwina Kidd eds. Pp. 19-48. Blackwell Publishing Company.

Fejerskov O., Kidd E.A.M., Nyvad B. and Baelum V. 2008a. Defining the disease: and introduction. *In* Dental Caries: The Disease and its Clinical Management: Second Edition. Ole Fejerskov and Edwina Kidd eds. Pp. 3-6. Blackwell Publishing Company.

Halcrow S. and Tayles N. 2008. Bioarchaeological Report from the 2008 Excavation Season, Promtin Tai, Central Thailand. Southeast Asian Bioarchaeology Newsletter **4**:5.

Higham C. 2002. Early cultures of mainland Southeast Asia. Chicago, River Books.

Higham C. and Thosarat R. eds. 1998. The Excavation of Nong Nor. Oxford. Oxbow Books Ltd.

Hillson S. 1979. Diet and Dental Disease. World Archaeology. 11(2):147-162.

Hillson S. 2001. Recording Dental Caries in Archaeological Human Remains. International Journal of Osteoarchaeology. 11: 249-289.

Hillson S. 2003. Dental Anthropology. New York. Cambridge University Press.

Hillson S. 2008. Dental Pathology. *In* Biological Anthropology of the Human Skeleton. M. Anne Katzenberg and Shelley R. Saunders, eds. Pp 301-340. New Jersey. Wiley-Liss.

Hintin R. 1982. Differences in Interproximal and Occlusal Tooth Wear Among Prehistoric Tennessee Indians: Implications for Masticatory Function. American Journal of Physical Anthropology. 57:103-115.

Hintin R. 1981. Form and Patterning of Anterior Tooth Wear Among Aboriginal Human Groups. American Journal of Physical Anthropology. 54:555-564.

Jackes M., Lubell D., and Meiklejohn C. 1997. Healthy but mortal: human biology and the first farmers of western Europe. Antiquity. 71:639-58.

Kealhofer L. 2003. Looking into the gap: Land use and the tropical forests of Southern Thailand. Asian Perspectives, 42(1), 72–95.

Kerr N.W. 1990. The Prevalence and Pattern of Distribution of Root Caries in a Scottish Medieval Population. Journal of Dental Research. 69(3):857-860.

King C. and Norr L. 2006. Paleodietary Change among Pre-State Metal-Age Societies in Northeast Thailand: A Pilot Study using Bone Stable Isotopes. *In* Bioarchaeology Southeast Asia. Marc F. Oxenham and Nancy Tayles, eds. Pp. 241-262. Cambridge Studies in Biological and Evolutionary Anthropology. Cambridge: Cambridge University Press.

Larsen C.S. 1995. Biological changes in human populations with agriculture. *Annual Review of Anthropology* **24**: 185-213.

Larsen C.S. 1997. Bioarchaeology: interpreting behavior from the human skeleton. New York. Cambridge University Press.

Larsen M.J. 2008. Erosion of the Teeth. *In* Dental Caries: The Disease and its Clinical Management: Second Edition. Ole Fejerskov and Edwina Kidd eds. Pp. 233-248. Blackwell Publishing Company.

Lavigne S. and Molto J. 1995. System of Measurement of the Severity of Periodontal Disease in Past Populations. International Journal of Osteoarchaeology. 5:265-273.

Lertcharnrit, T., 2006. The moated site of Promtin Tai and the transition from late prehistory to early history in Central Thailand. *In*: E. A. Bacus, I. Glover, V. C. Pigott (Eds.), Pp. 258-265. Uncovering Southeast Asia's Past: Selected papers from the 10th International Conference of European Association of Southeast Asian Archaeologists. Nus Press, Singapore.

Li Z., Saito Y., Dang P., Matsumoto E., and Vu. Q. 2009. Warfare rather than agriculture as a critical influence on fires in the late Holocene, inferred from northern Vietnam. PNAS. 106(28):11490-11495.

Liebe-Harkort C., Astavaldsdottir A., and Tranaeus S. 2009. Quantification of Dental Caries by Osteologists and Odontologists—A validity and Reliability Study. International Journal of Osteoarchaeology.

Littleton J. and Frohlich B. 1993. Fish-Eaters and Farmers: Dental Pathology in the Arabian Gulf. American Journal of Physical Anthropology. 92:427-447.

Lukacs J. 2008. Fertility and Agriculture Accentuate Sex Differences in Dental Caries Rates. Current Anthropology. 49(5):901-914.

Lukacs J. 1996. Sex Differences in Dental Caries Rates With the Origin of Agriculture in South Asia. Current Anthropology. 37(1):147-153.

Lukacs J. 1995. The ‘Caries Correction Factor’: a New Method of Calibrating Dental Caries Rates to Compensate for Antemortem Loss of Teeth. International Journal of Osteoarchaeology. 5:151-156.

Lukacs J. 1992. Dental Paleopathology and Agricultural Intensification in South Asia: New Evidence From Bronze Age Harappa. American Journal of Physical Anthropology. 87:133-150.

Lukacs J. and Largaespada L. 2006. Explaining Sex Differences in Dental Caries Prevalence: Saliva Hormones, and “Life-History” Etiologies. American Journal of Human Biology 18:540-555.

Maat G.J.R. and Van der Velde E.A. 1987. The caries-attrition competition. International Journal of Anthropology. 2(4):281-292.

Maloney, B.K. (1992). Late Holocene climatic change in Southeast Asia: The palynological evidence and its implications for archaeology. World Archaeology, 24, 25–33.

Merbs. C. 1968. Anterior Tooth Loss in Arctic Populations. Southwestern Journal of Anthropology. 24(1):20-32.

Miles A. E. W. 1962. Assessment of the Ages of a Population of Anglo-Saxons from Their Dentitions. Proceedings of the Royal Society of Medicine. 55:881-886.

Mjor A. 2005. Clinical Diagnosis of Recurrent Caries. The Journal of the American Dental Association. 136:1426-1433.

Molnar S., Barrett M.J., Brian L., Brace C., Brose D., Dewey J.R., Frisch J., Ganguly P., Gejvall N, Greene D., Kennedy K., Poirier F., Pourchet M., Rhine S., Turner III C., Van Valen L., Von Koenigswald G., Wilkinson R., Wolpoff M., and Wright G. 1972. Tooth Wear and Culture: A survey of Tooth Functions Among Some Prehistoric Populations [and Comments and Reply]. Current Anthropology. 13(5):511-526.

Molnar S. 1971. Sex, Age, and tooth Position as Factors in the Production of Tooth Wear. American Antiquity. 36:182-188.

Molnar S. 2005. Human Tooth Wear, Tooth Function and Cultural Variability. American Journal of Physical Anthropology. 34:175-190.

Moore,W. J. and E. Corbett. 1973. The Distribution of Dental Caries in Ancient British Populations. I. Iron Age, Romano- British and Medieval periods. Caries Res. 7:139-153.

Murphy T. 2005. The Changing Pattern of Dentine Exposure in Human Tooth Attrition. American Journal of Physical Anthropology. 17(3):167-178.

Nakbunlung S. and Wathanawareekool S. 2008. Whispering Teeth: Nutrition and Health of Wooden Coffin People in the Pang Ma Pha Cave Sites, Northwestern Thailand. IPPA Bulletin. 28:84-87.

O'Reilly D. 2001. From the Bronze Age to the Iron Age in Thailand: Applying the Heterarchical Approach. Asian Perspectives. 39(1-2):1-19.

Osborn J.W. 1982. Helicoidal Plane of Dental Occlusion. American Journal of Physical Anthropology. 57:273-281.

Oxenham M, Cuong N. and Thuy N. 2006. The oral health consequences of the adoption and intensification of agriculture in Southeast Asia. *In* Bioarchaeology Southeast Asia. Marc F.

Oxenham and Nancy Tayles, eds. Pp. 263-289. Cambridge Studies in Biological and Evolutionary Anthropology. Cambridge: Cambridge University Press.

Pechenkina E., Benfer R., and Zhijun W. 2002. Diet and Health Changes at the End of the Chinese Neolithic: The Yangshao/Longshan Transition. American Journal of Physical Anthropology. 117:15-36.

Penny D. 1999. Palaeoenvironmental Analysis of the Sakon Nakhon Basin, Northeast Thailand: Palynological Perspectives on Climate Change and Human Occupation. Indo-Pacific Prehistory Association Bulletin. 18(Melaka Papers, Volume 2):139-149.

Pietrusewky M. and Douglas M. 2002. Ban Chiang, a Prehistoric Village Site in Northeast Thailand I: The Human Skeletal Remains. Thai Archaeology Monograph Series Volume 1. University of Pennsylvania Museum of Archaeology and Anthropology: Philadelphia.

Sangvicheien S. 1966. Neolithic Skeletons from Ban Kao, Thailand, and the Problem of Thai Origins. Current Anthropology. 7(2):234-235.

Scott E. C. 1979. Detal Wear Scoring Technique. American Journal of Physical Anthropology. 51:213-218.

Scott R. and Turner C. 1988. Dental Anthropology. *Annual Review of Anthropology*. **17**: 99-126.

Smith B. H. 1984. Patterns of Molar Wear in Hunter-Gatherers and Agriculturalists. American Journal of Physical Anthropology. 63:39-56.

Stark M. 2006. Early Mainland Southeast Asian Landscapes in the First Millennium A.D. The Annual Review of Anthropology. 35:407-432.

Takaya Y. 1971. Physiography of Rice Land in the Chao Phraya Basin of Thailand. Tonan Ajia Kenkyu (The Southeast Asian Studies). 9(3):375-397.

Tayles N. 1996. Tooth Ablation in Prehistoric Southeast Asia. International Journal of Osteoarchaeology. 6:333-345.

Tayles N., Domett K. and Nelsen K. 2000. Agriculture and dental caries? the case of rice in prehistoric Southeast Asia. *World Archaeology* **32**: 68-83.

Tayles N., Domett K., And Hunt V. 1998. The People of Nong Nor. *In* The Excavation of Nong Nor: a Prehistoric Site in Central Thailand. Higham C.F. and Thosarat R. Eds. Pp.321-368. Oxford. Oxbow Books Ltd.

Temple D., Kusaka S., and Sciulli P. 2010. Patterns of Social Identity in Relation to Tooth Ablation Among Prehistoric Jomon Foragers from the Yoshigo Site, Aichi Prefecture, Japan. International Journal of Osteoarchaeology.

Temple D. H. and Larsen C. S. 2007. Dental Caries Prevalence as Evidence for Agriculture and Subsistence Variation During the Yayoi Period in Prehistoric Japan: Biocultural Interpretations of an Economy in Transition. American Journal of Physical Anthropology. 134:501-112.

Torres-Rouff C. 2003. Oral Implications of Labret Use: a Case from Pre-Columbian Chile. International Journal of Osteoarchaeology. 13:247-251.

Turner C. G. II. 1979. Dental anthropological implications of agriculture among the Jomon people of central Japan. American Journal of Physical Anthropology 51: 619-636.

Vincent B. 2003. Rice In Pottery: New Evidence for Early Rice Cultivation in Thailand. Indo-Pacific Prehistory Association Bulletin. Taipei Papers:1:51-58.

Vukovic A., Bajsman A., Zukic S., and Secic S. 2009. Cosmetic dentistry in ancient times—a short review. Bull Int Assoc Paleodont. 3(2):9-13.

Walker P., Dean G., and Shapiro P. 1991. Estimating Age From Tooth Wear in Archaeological Populations. *in* Advances in Dental Anthropology. M. Kelley and C.S. Larsen eds. Alan R. Liss, New York, pp. 169-178.

Walker P. and Erlandson J. 1986. Prehistoric Dietary Change on the Northern Channel Islands, California. American Antiquity. 51(2):375-383.

White J., Penny D., Kealhofer L., and Maloney B. 2003. Vegetation changes from the late Pleistocene through the Holocene from three areas of archaeological significance in Thailand. Quaternary International. 114:111-132.

White T., Degusta D., Richards G., and Baker S. 1997. Brief Communication: Prehistoric Dentistry in the American Southwest: A Drilled Canine From Sky Aerie, Colorado. American Journal of Physical Anthropology. 103:409-414.

Wilen R. 1992. Mortuary Traditions and Cultural Identity in the Khorat Plateau Piedmont, Northeast Thailand. Southeast Asian Archaeology 1990. 103-110.

Williams J. and White C. 2006. Dental Modification in the Postclassic Population from Lamanai, Belize. Ancient Mesoamerica. 17:139-151.

Wolpoff M. 2005. Interstitial Wear. American Journal of Physical Anthropology. 34(2):205-227.