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Consequences of Contact: An Evaluation of Childhood Health Patterns Using Enamel Hypoplasias Among the Colonial Maya of Tipu

Amanda R. Harvey
University of Southern Mississippi

The University of Southern Mississippi

CONSEQUENCES OF CONTACT: AN EVALUATION OF CHILDHOOD HEALTH PATTERNS USING ENAMEL HYPOPLASIAS AMONG THE COLONIAL MAYA OF TIPU

by

Amanda R. Harvey

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Approved:

Dr. Marie Danforth, Director

Dr. H. Edwin Jackson

Dr. Jeffrey Kaufmann

Dean of the Graduate School

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ABSTRACT

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Located in western Belize, Tipu was occupied from 1541-1704. This Colonial Maya population from a Spanish visita mission church was analyzed to investigate health disturbances associated with European contact. Dental defect called enamel hypoplasias were scored to assess childhood health. Standard methods of scoring (Buikstra and Ubelaker 1994) were employed to assess frequency, severity, and type of episode in the permanent anterior dentition. For analysis, 325 individuals were placed into age groups of subadults (6-17 years), younger adults (18-35 years), and older adults (36-50+ years). The population was also considered for differences by sex and tooth type.

Results showed a mean of 1.89 hypoplasias per tooth with canines averaging 0.36 more episodes than maxillary central incisors. 79.3% of central incisors were affected and 87.3% of canines displayed lesions. Individuals dying as younger adults had significantly more episodes than older adults. Only a slight difference between means and individual tooth frequencies were present between the sexes. Over 90% of the episodes recorded were of mild severity. Subadults demonstrated a higher frequency of moderate and severe hypoplasias. Mean age at formation was consistent across sex and age groups with most forming from 2-3 years on incisors and 3-4.5 years on canines. These data suggest that

overall the population at Tipu was relativity healthy despite European contact, which is also reflected in low frequencies of other indicators, such as anemia and infection. Similarly, they do not reflect extensive presence of epidemic disease, instead showing adaptation despite notable culture change.

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CHAPTER I

INTRODUCTION

The Yucatán peninsula during the 16th Century was a time of change for the Maya. However their degree of contact with the Spanish varied. Those residing on the northern coast, which was critical for travel and trade with the Valley of Mexico, had the greatest exposure, and this devastation to their precontact lifeways. This area has been relatively well documented in the historical records compared to the southern portions. Those more inland, however, managed to escape this acculturation to a larger degree, but less is known about their experiences. Located in the west central lowlands of Belize, the frontier town of Tipu is an excellent opportunity to assess changes in lifeways as a result of contact between the Maya and Spanish (Farris 1983, 1984; Graham et al. 1989; Jones 1989; Jones et al. 1986).

Tipu was occupied from the Classic to the Colonial period ranging from A.D. 250 to 1707 (Jones 1989). Archaeological investigations of the site suggest that the most intensive period of use was during the Colonial period, A.D. 1540-1700 (Cohen et al. 1994a). It was a site of major political importance because of its position at the boundary between two spheres of regional powers (Jones 1989). Areas to the north and the east were controlled by the Spanish. Economically, coastal trade and fishing were the main activities which allowed for control of the flow of goods and resources from the coast towards the inland. On the opposite side of Tipu, to the south and the west, was an area controlled by the Itzá Maya. Intensive focus on cacao production and internal trade dominated the Itzás economic sphere (Pendergast et al. 1993). Thus, the placement of Tipu in between these two different economic strategies allowed its inhabitants regular access to goods and resources. In general, its strategic position on the frontier allowed Tipu, compared to most other Colonial Maya towns, to be able to better negotiate its interaction with the Spanish, and its residents likely benefited from this status.

The pivotal location of Tipu potentially resulted in complex effects on the health of its Colonial residents. Its location between the Northern Yucatán Mérida and Lake Petén Itzá allowed for it to become one of the principal centers of anti-Spanish activity (Jones 1989). As a result, alternative periods of peaceful tolerance of Spanish control and active resistance were experienced (Jones et al. 1986). Turbulent times during the fight against Spanish power could have resulted in an elevated stress upon the population during these periods. Factors such as the restructuring of food sources because of the Spanish tribute system, warfare, and the disruption of social networks are all possible catalysts of non-physiological stress upon the body and teeth. On the other hand, periods of Maya control of Tipu and/or peaceful times of limited Spanish control could have resulted in better trade with the Itzá Maya to the south and west and therefore a diet with a wider variety of foods. Along with the maintenance of typical Maya social networks, passive political periods at Tipu could have been less stressful on the overall health of the people.

This cycle of political control can be evaluated through the archaeological and ethnohistoric records, but arguably the osteological record offers the most direct and reliable source of data. A skeletal population was recovered from a Christian church cemetery at Tipu and is the largest known collection of Colonial period Maya skeletons (Jacobi 1996; 1997). Previous studies suggest a generally healthy population (Cohen et al. 1994a). However, changes in method and theory since these studies may present a new understanding of the different osteological manifestations of stress from natural, biological, and cultural changes. It has been documented that juvenile morbidity rates are the best indicator of an overall population's wellbeing (Armelagos et al. 2009; Buikstra and Cook 1980; Herndon 2004; Larsen 1994, 1995). Therefore, a detailed study of stress as expressed in dental defects known as enamel hypoplasias gives insight to childhood health patterns. The understanding of juvenile fitness creates a comprehensive report on the consequences of contact upon the general salubrity of a population living on the Spanish frontier. Also, by understanding the variation in the severity of the defects between certain portions of the sample, the interpretations of any internal population differences in childhood health of the inhabitants of Tipu can be explored (Cohen et al. 1994a; Herndon 1994).

Contributions of the Research

The frontier nature of Tipu creates a unique atmosphere to compare to sites under direct Spanish control because of the varying degrees of Spanish power. Additionally, it provides data that is highly comparable with studies on the effects of Colonialism among populations from other areas around the world since this population is baseline data for health populations in this area. This study aims to create a better understanding of the effects of Colonialism on the inhabitants from Tipu in regard to age and sex groups, and over time. A more current and comprehensive examination of the frequency of enamel hypoplasias and their associated age at formation yields a more easily comparable results and create more comprehensive knowledge of the overall stress experienced by the individuals living in the Spanish frontier. Last, these data suggest the residents of Tipu are representative of a healthy population and managed successful adaptation, despite notable culture conquest and change.

CHAPTER II

THE MAYA EXPERIENCE

The accomplishments of the Maya in the areas of architecture, the arts, writing, and astronomy rival many other civilizations that were living at that same time (Willey 1982). Many scholars argue that the Maya were the most successful culture in the Mesoamerica area in terms of population size, cultural longevity, area occupied, and diversification of language (Colunga-Garcia and Zizumbo-Villarreal 2004). The population density during the Classic period from A.D. 200 to A.D. 900 was the highest for any pre-industrial, agrarian cultures in the Americas (Willey 1982). These inhabitants were spread out over a 250,000 km^2 in the Southern and Northern Lowland territories that encompass what is today known as Belize, some parts of northern Honduras, northeastern Guatemala, and the Yucatán peninsula of Mexico (Webster 1997).

Precontact Cultural Phases

Scholars traditionally divide the history of the ancient Maya into three large time periods- the Preclassic, the Classic, and the Postclassic. Each period is defined by the culture's technological advancement. The Preclassic period is dated to roughly 1800 B.C. to A.D. 200 (McKillop 2004; Webster 1997). The existence of pottery sets this period apart from the Archaic. This period was also the time when feasting as a sign of social status and power arose. Along with the rise of social status, the Late Preclassic is the beginning of trade for elite items, such as jade and obsidian, and the start of monumental architecture (McKillop 2004). Leaders began to have an achieved status that was earned through warfare and rituals (Stewart 1953). Additionally, exotic items and public works helped to further stratify the classes (McKillop 2004).

Dating from roughly A.D. 200 to 900 the Classic period was the height of Maya civilization (Willey 1982). During this period, leadership became hereditary, and kings codified their lineage on stelae. Status markers such as jade adornments and painted ceramics were commonly buried with the dead during this time. Many forms of public architecture, such as stelae or carvings on monuments to display certain rulers' power, praise gods, and keep accounts of the history of the society, were built during this time. Occupational specialization, the ball game, and a larger trading network also took root during the Classic period (McKillop 2004). Typically, archaeology of the region has been focused on this period of Maya history (Graham et al. 1989).

The Terminal Classic period (A.D. 800 to 1000), a transition between the Classic and the Postclassic, can be considered the start of the Classic Maya Collapse. The characteristics of the Late Classic are all signs of a failing society. Warfare, malnutrition, the dismantlement of the elite, general population and resource decline from extreme environmental abuse, and sociopolitical reorganization into different smaller cities dominated by religion helped bring this culture to the end of the Maya golden age. Yet, there is no skeletal evidence of decimating diseases or large scale warfare in the populations since bodies were not hastily buried together, or found outside of traditional burial disposal (Saul 1973). This implies a slow, multi-factorial decline of the Maya (McKillop 2004). Factors such as population relocation, reorganization of the elite, forced labor, and dietary changes all contributed in the Classic Maya cultural decline (Larsen 1994). As new centers arose, old ones fell. Warfare placed many towns in opposition of each other, and others allied creating new social networks, therefore leveling towns in terms of sociopolitical status for the start of the Postclassic.

The Postclassic period dates from roughly from the end of the Maya collapse at A.D. 1000 until the Spanish conquest, an event whose time varied around the region but roughly occurred in the 1520s. Sometimes classified as a period of historical hiatus, the Postclassic period was really a time of transition (Jones 1989) with renovations in technology and social organization, though this does not necessarily imply demographic changes in every population. After the Maya collapse, its subsequent after-effects resulted in the rise of new, non-local elites in many towns. An increase in autonomy of the Maya community is suggested based upon the growing intersite variability from the new ruling class. Villages instead of large ceremonial and political centers became the organizing force for political-economic sphere and social relations (McKillop 2004). This settlement pattern continued into the Colonial period (Farriss 1984).

Subsistence Practices

The Precontact Maya diet was based primarily on multiple agricultural techniques depending on the size of the population. For many small sites, milpa agriculture was practiced across the lowlands. A triad of maize, beans, and cucurbits were the primary vegetable grown in the milpa plots (Colunga-GarciaMarin and Zizumbo-Villarreal 2004). In larger towns, farmers would employ intensive agricultural techniques of terraced landscapes. Rejuvenated by alluvial deposits, terraced agricultural land that remained in continuous production was able to supply enough crops to support bigger populations (Freidel 1983; Wilken 1971). Wilken (1971) suggested that intensive agricultural systems could have been sensitive to social or political change.

Agriculture was supplemented by hunting and gathering in many instances. Wild game such as turkey and peccary were hunted in the inland areas, while along the coast, marine resources, such as a variety of fish, sharks, sting rays, turtles, crabs, and shellfish, were exploited to supplement a low protein, high carbohydrate-based maize diet (Lange 1971; McKillop 1984). Salted fish was traded to inland communities, possibly in return for tubers grown in some inland terraced milpas (Colunga-GarciaMarin and Zizumbo-Villarreal 2004; Lange 1971; Wilken 1971). Additionally, inland communities took advantage of fresh water resources. High frequencies of jute or fresh water mollusk shells in cave contexts and sites in the Belize River Valley have been reported (Healy et al. 1990).

Archaeological focus on agricultural systems, however, it is not the only way to assess precontact diet. Isotopic analysis of human bone and enamel allow additional support to archaeological investigations. During the Classic, the consumption of maize made up over 50% of their diet at some sites with other animal proteins and crops playing supporting roles (Magennis 1999; White 1997). Yet, it is important not to forget that food consumption is always to be divided by sex and class (Danforth 1999).

The Colonial Maya

The Spanish first entered the Yucatán in 1517 when one of their ships was blown off of its original course (Jones 1989). After an initial investigation of the region, the Spanish left the peninsula and conquered central Mexico in 1519 and then the Yucatán region by 1528. Unlike the open desert where the Aztecs lived, the Maya benefited, in multiple ways, from the dense jungle environment of the Yucatán. First, it helped to reduce the efficiency of the efforts of the Spanish conquistadors. This created a slow conquest of the Maya, and many regions in the southern part of the peninsula were never under Spanish control. The topography of the Yucatán resulted in a dispersed settlement pattern of many Maya towns typically with one larger regional ceremonial and political center which was unlike the huge centralized settlement patterns of the Aztecs. Widely spread small communities along with milpa agriculture did not allow for large population levels to develop, which resulted in few enslavement opportunities for the Spanish. Additionally, the thick jungles of the Yucatán helped the Maya to successfully employ guerrilla style tactics against the Spanish including ambushing them at night. Lastly, the Yucatán is a poor area for agriculture and lacked many natural resources, especially gold. Thus, the Crown's focus was not on this barren land, and this allowed for cultural continuity throughout many Maya towns before and after conquest (Farris 1984; Jones 1989; Jones et al. 1986).

What overall cultural continuity within the political and economic spheres left after Spanish conquest would not have been successful without the Maya's ability to assimilate foreign customs (Farriss 1984). The lowlands of Belize are an extremely tenacious, yet less heavily populated, region compared to the northern parts of the Maya lands (Jones et al. 1986). With its more amiable climate, the Spanish focused most of their efforts on the Yucatán to the north of current day Belize. Hence, the southern portion of the Yucatán and the lowlands of Belize had higher degrees of cultural and social stability (Pendergast et al. 1986). Both town isolation caused by environmental barriers and cultural flexibility allowed for the Maya to continue being "Maya" even under Spanish attempts at ethnocide.

Cultural Characteristics of the Colonial Period

Within the Maya system, trade and socio-political integration were mutually supportive of each other (McKillop 2004). Interruption to either of these systems would weaken the other and in turn the social structure of many sites along that trade route. When the Spanish sought to dismantle the larger Maya political structure and reform it into smaller units, they took control of the Maya trade routes. In doing so, the authority of the ruling class and elites became undermined (Farriss 1983). Additionally, the Spanish incorporated the *reducción* system in many areas which caused some splitting of kinship groups and the social network as well.

The *reducción* system consisted of three types of population migration which were identified by Farris (1984): flight, drift, and dispersal. Flight consists of larger numbers of Maya relocating to areas beyond or with little Spanish control. This is the most important of the three because of "its effects on the long-term inability of the Spanish to govern the southern lowlands" (Jones 1989: 120). Drift is a less dramatic form of migration in which the Maya would leave their current community to move to another community within Spanish territory. Farris (1984) speculates that the most likely reason for this aimless movement could have been for kinship reasons, avoiding creditors, marriage, or even new economic opportunities. Lastly, the idea of dispersal is contrary to the *reducción* system in which the larger, Spanish ruled towns became fragmented by families or individuals who moved from these large towns to rural hamlets. This form of migration resulted in the formation of new towns and may be considered the first steps to fleeing Spanish controlled towns altogether (Jones 1989).

Along with remodeling the socio-political structure of the Maya, one of the main goals of Spanish conquest was religious transformation. Upon contact, the Maya were introduced to a new set of religious beliefs that was then forced upon them. Franciscan priests smashed, burned and forbade the manufacture of Maya idols, which helped to facilitate the quick eradication of Maya pagan religious objects. European contact results in not only the change of previous social and political structures of the Maya, but also religious practices (Jones 1989). Religious syncretism of Maya gods into Catholic saints easily hid old religious practices. "Like the pagan gods of earthen elements during Classic Maya times, Catholic saints in many areas represented local personages and were the intercedents between humans and God. Maya 'saints' were not of the divine sense as in Catholicism, but represented genuinely creative or protective powers" (Watanabe 1990:137). Many offerings of incense, flowers, candles, rum, and specialty foods continued to be given to these 'saints' in return for good fortune upon the town's people (Watanabe 1990). Christian burial practices such as heads facing west, bodies wrapped in shrouds, and a supine body position were incorporated into mortuary practices (Farriss 1984; Jones et al. 1986; Sanders 1992; Taylor 1992).

The Colonial method of political control enforced by the Spanish also allowed for some cultural continuity of the Maya. The fall of the Classic Maya in the ninth century and its subsequent political organization of multiple small autonomous chiefdoms with large regional political and ceremonial centers resulted in a change of political structure. The Spanish introduced an *encomienda* system that gave regional power to representatives of the Spanish crown to whom the community paid tribute to twice a year for his religious services and security (Farriss 1984; Jones 1989; Jones et al. 1986), although ethnohistoric records do confirm the continuation of some of indigenous political economy and social systems at some Maya sites. *Encomenderos* controlled the indigenous elites or *caciques* who managed the rest of the population and utilized the native structures (Deagan 1985; Farriss 1984).

A simplification in the agricultural practices of the Maya and a reduction of the population is a result of the Spanish's "scorched-earth" policy. There was a switch from intensive agricultural techniques, such as terracing, to the more extensive practices of family based milpa agriculture in the Colonial period (Reina and Hill 1980). A focus on the triad of corn, beans, and squash, along with r*amón* trees, were employed in order to meet Spanish demands of surplus (Helmuth 1972). Lentz (1999) claims that *ramón* trees were famine food, yet the paleo-ethnobotanical record does not support intensive use of this plant in the past (Colunga-GarciaMarin and Zizumbo-Villarreal 2004). Additionally, ethnohistoric records suggest that *chultunes* were used for maize storage (Reina and Hill 1980). During many instances of famine, the rural Maya resorted to foraging and hunting in the jungle. Many colonial texts speak of bread made from the *pich* tree fruit and the *cumche* fruits. Also, Landa (1941) comments on the killing of manatees and other marine resources such as sharks, sting rays, and fish for food (Lange 1971). There is no way to compare mortality rates from famine before and after contact (Farriss 1984).

A significant factor that worked to the advantage of the Spanish during the Colonial period was the introduction of epidemic diseases. With transmission facilitated throughout the trade routes, from 1535 to 1700 there were at least eight epidemics noted in Colonial Yucatán (Farris 1984; Patch 1993). European crowd diseases such as smallpox, yellow fever, typhus, and measles all wiped out large numbers of the Maya in phases. With Spanish control of the trade routes, the spread of these diseases was rapid. This new disease load also took a toll on the juvenile portion of the population resulting in an unequal birth to death ratio within the Colonial period (Farriss 1984). After only 60 years of contact of the Spanish in Central America, Mesoamerica population sizes were dramatically reduced (Larsen 1994) to the point of a demographic catastrophe (Farriss 1984). Most of the time, epidemics coincided with famine from hurricanes, crop failures and droughts. Yet, many outbreaks typically followed times of food shortages and drought, giving a double punch to many Maya communities.

New ways of life introduced by the Spanish were not the only hardships faced by the Maya. Nothing has the wrath of Mother Nature, and the location of the Maya Lowlands is an area highly susceptible to all kinds of weather. Natural disasters such as hurricanes, flash floods, or drought could kill an entire year's crop, causing widespread famine, increased stress, and possibly the loss of life (Farris 1984). Even though it would seem that during Colonial times, a more centralized ruling system and superior modes of transporting goods by the Spanish should have helped to spread surplus food into areas with food shortages, it was not necessarily the case. The *encomienda* system demanded the same tribute with good and bad crop yields (Patch 1993). Also, the restriction placed upon trade from the Spanish political structure limited the spread of goods. This often resulted in many rural Maya communities never receiving aid from the grains brought from Spain and other New World colonies. Additionally, social stratification and sex played a role limiting in the distribution of emergency goods (Danforth 1999). During the first signs of an oncoming famine, provincial and municipal governments would forcefully "buy" all the excess maize from country settlements for the Spanish elites. This affected not only the rural communities, but also the urban communities, just not as severely (Farris 1984; Patch 1993). Changes such as these have been documented at Colonial sites throughout Spanish territory. As demonstrated, the Maya faced not only cultural changes with Spanish contact and conquest, but were also experiencing many natural aliments at the same time creating environments that are hard to live in.

Colonial Tipu

Ethnohistoric documents pinpoint the establishment of colonial rule at Tipu and other Colonial sites in Belize, such as Lamanai, Tancah, or Campeche, after the violent conquest of the region by Pacheco in 1544. During this same year, two Spanish cousins, Alonso and Melchor Pacheco, were deeded the territory from Chetumal, on Corozal Bay at the mouth of the New River (and possibly the site of Santa Rita Corozal), to the Verapaz region of Guatemala. This region, which included the site of Tipu, was ruled collectively through the Spanish headquarters at Salamanca de Bacalar. Smaller territories were controlled by *encomenderos*, which fueled a long period of hostility between the Maya and the Spanish (Jones et al. 1986).

The Maya believe that events at Tipu corresponded to prophecies from the Chilam Balam occurring during *katun* cycles, roughly 256 years (Jones 1989). Consequently, during *Katun* 9 *Ahau* (A.D. 1567-68) there were extensive fits of Maya rebellion in the Tipu area, even through the Spanish attempted to use Tipu as a pacification base to resettle Maya from all over. Idol smashing, book burning, and the arresting of the rebellion's leaders helped the Spanish to keep some form of order during this particular episode (Jones 1989). Yet, this set the stage for the rest of Tipu's history as a *reducción* town, or one in which runaway Maya, or even whole villages, were either forcibly relocated by the Spanish or willingly moved there themselves.

In 1618, two new *encomenderos* were introduced to Tipu, Franciscans Bartolome de Fuensalida and Juan de Orbita; they governed the area until 1637 (Jones 1989). Also, during the mid sixteenth century, Tipu experienced heavy immigration from forced migration from the *reducción* system, religious and political refugees, and as a result of people fleeing towns from the northern Yucatán that were under direct Spanish control. The immigration of people produced a skewed demographic profile for many *reducción* towns, such as Tipu, since gender roles and child care inhibited travel for many women. This "flight" (Farris 1984) migration pattern created a new social system at Tipu that consisted mostly of exiles from Spanish controlled towns (Jones 1989), which created a ripe environment for revolt and conflict. Spanish greed, the increased demand of cacao, along with idol smashing, lead to a period of pervasive resistance and rebellion, and in 1638 widespread revolution broke out. During this time, Tipu's leaders were successful at forcing the abandonment of eight towns in Belize. This resulted in only six small towns still remaining under Bacalar's control (Jones 1989), which drastically diminished Spanish territory and allowed for Maya control of Tipu.

From 1544 to 1638, Tipu continued to functioned as at least nominally Catholic community as reflected in the archaeological evidence, though ethnohistoric documents make little mention of the Christian influence in the towns at this time. Tipu was even considered a "spiritual garrison" which was used to help convert many Maya to Christianity, with accounts of around 600 conversions during one short period of time (Jones 1989:138). Christian burial practices were evidently strictly followed at the cemetery of Tipu. Most were buried extended in the supine position with their heads to the west, and their hands placed over their stomach or chest which suggested at least widespread nominal acceptance of Spanish rule and cultural practices (Cohen et al. 1997; Jacobi 1996, 1997). The placement of a censer with one individual implies her special place within the community compared to the rest of the population, though this item has not been extensively researched by scholars (Jones 1989). Yet, anthropomorphic effigies in caches of buildings and refuse deposits suggest that pagan religious practices were not completely eradicated (Cohen et al. 1997; Graham et al. 1989; Herndon 1994; Jacobi 1996, 1997).

The cobble-stone 16th century church at Tipu confirms Spanish influence despite the general lack of other Spanish architecture at the site. The exact year that church at Tipu was built is unknown, but its construction indicates that it likely was sometime in the last half of the 16th century. Its relatively large size suggests that the initial Spanish commitment to Tipu was strong (Jones et al. 1986). The long, narrow shape of the church could easily be confused with a standard Classic residential platform. Yet the relatively low height of the mound and the building's east-west orientation give clues to the construction period since these are characteristics of Spanish architecture. The sanctuary at the east end is slightly raised compared to the nave of the church. Also, the western portion of the church may have been flanked by two stairs which would have served as access to the nave. Wall construction was made of an "un-coursed" mixture of large and small river cobbles, and is a primary source of identification of Colonial period habitation. Intrasite settlement patterns at Tipu also indicate Spanish habitation, yet this has not been very extensively investigated (Cohen et al. 1997; Graham et al. 1989; Jacobi 1996; Pendergast et al. 1993).

European goods such as glass bead necklaces and bracelets, shroud pins, brass needles, silver earrings, and copper rings were introduced to the trade system. These became fashionable to both men and women and, consequently, they were buried with several individuals at Tipu (Cohen et al. 1997). The presence of Spanish olive jars and other earthenware imply that, at some point, direct trade with the Spanish (Jones et al. 1986) was possible during period of peaceful Spanish control at Tipu (Cohen et al. 1997; Graham et al. 1989; Jacobi 1996).

Inhabitants of Tipu were successful in expelling the Spanish for over a 60-year period from 1638 to1695 (Graham et al. 1989), though they still had to pay *encomienda* tribute (Jones 1989). Unlike Lamanai, Tipu was unaffected by the demise of other Colonial towns from the Spanish *reducción* system and scorched-earth policy, and remained a frontier missionary town. Many refugees from Lamanai and other northern Maya towns increased the population at Tipu. Yet, to date it is impossible to distinguish skeletally refugees from the original Tipuan inhabitants based on the skeletal remains (Jacobi 1996; Jones 1989). After the violent conquest of the Itzá s from the south in 1697, Spanish interest in Tipu waned until 1707 when the occupants of Tipu were forcefully moved to the Petén and hence ending Tipu’s major occupation (Jones 1989).

The archaeological site of Tipu was initially identified based on ethnohistorical documents by Grant Jones and David Pendergast in 1978 (Jones 1989). There have been three main phases of archaeological research at Tipu. In the first, Robert Kautz and his colleagues from Hamilton College concentrated on the prehistoric and Colonial periods locating the foundation of the church in 1980. During the second, from 1982 to 1987, Mark N. Cohen and Sharon Bennett excavated the skeletal collection in its entirety (Graham 2011). In the final phase, Elizabeth Graham assumed direction of research in 1984 and directed four seasons of field excavations with concentration on the buildings which bordered the Colonial central plaza (Graham 2011; Jones et al. 1986). The best archaeologically understood period of Tipu was during the Middle and Late Postclassic periods within the civic, domestic, and ceremonial contexts; however osteologically, the Colonial period is better known. The continuous occupation of Tipu allows for the rare chance to study a population that experienced early Spanish contact along with survival into the early 1700s (Jones 1989).

Demographics of the Cemetery Population

The total population at Tipu is roughly 588 individuals with only 492 sufficiently preserved for age-at-death estimates (Cohen et al. 1997; Jacobi 1986). Table 1 illustrates the demographics of the Tipu skeletal population which consist of 339 Colonial period adults with 173 males, 119 females, 47 adults of unknown sex and 249 subadults.

Table 1

Age and Sex Distribution of the Tipu Population (Cohen et al. 1994a 123-125; Jacobi 2000:104)

Sex	Total
Male	173
Female	119
Unknown Adults	47
Subadults	249
Total	588

There is a general absence of infants and older individuals with only two individuals 50 years or older. Cohen and colleagues (1994a) suggest that reasons for the possible underrepresentation of older individuals ranging from religious practices, methodological problems, and epidemics to immigration patterns which show the characteristics of the *reducción* system. Whatever the reason may be, an overwhelming number of individuals were found in the 18-35 year age-at-death group.

Keith Jacobi (1996) conducted a study of the genetic structuring of the cemetery at Tipu. In an attempt to identify the Maya refugees from the northern Yucatán as suggested by ethnohistoric documents, Jacobi (1996) used both morphological and metric variation to assess biodistance from the teeth of 518 individuals. Using methods developed by Turner and colleagues (1991), it was determined that the population at Tipu was homogeneous with no patterns of metric or non-metric differences between individuals buried within and outside of the church walls. Additionally, based on mostly non-metric traits, some individuals can be placed into family groups. No evidence was found to suggest that Spanish friars or Spanish-Maya admixtures were buried at Tipu.

Previous Paleopathological Investigations at Tipu

Mark N. Cohen and numerous other investigators have done paleopathological analysis on the skeletal collection of Tipu. They reported on lesions from anemia, hypoplastic activity and other dental defects (Cohen et al. 1997); stature and Harris lines of arrested development (Danforth 1991); trauma and long bone pathology (Armstrong 1989); cortical thickness (Bennett et al. 1985; Cohen et al. 1997; Danforth 1991); microenamel defects (Danforth 1989); and juvenile health (Herndon 1994). Each of these studies concluded that levels of pathological infections investigated were minimal, resulting in a healthy overall population. However, a contrary conclusion could be said in that this population died before many diseases could manifest in the skeleton (Cohen et al. 1994a).

An important indicator of health status is skeletal modification as a result of reduced iron bioavailability. Typically developed during early childhood, these lesions are pin-prick like modifications to the skull known as porotic hyperostosis and exostosis bone growth to the roof of the eye orbits called cribra orbitalia. The one-to-one etiology of these lesions is highly debated, yet a general acceptance of iron deficiency or general infections can be found (Goodman 1994; Larsen 1995). Walker and colleagues (2009) claim a deficiency in B-12 and B-9 vitamins can also lead to either porotic hyperostosis or cribra orbitalia. Additionally, a general increase in the consumption of maize or a general decline in the living conditions of a population may have also attributed to the frequency of this pathology (Larsen 1994).

In the population at Tipu, cribra orbitalia occurs in 39 of the 214 individuals (18.2%) with cranial orbits available for analysis affecting 8.8% of adult men (8 out of 91), 5.4% of adult women (3 out of 56), and 30.5% of children (18 out of 59). The frequency of cribra orbitalia is over-shadowed by the prevalence of porotic hyperostosis. Some 304 individuals had skulls available for analysis, and a frequency of 25.3% of the population displayed this infection. Of the 304 individuals, 16 (5.3%) displayed active lesions and 61 (20.1%) displayed healed lesions which suggested a chronic prevalence during childhood. Of these, 116 males were scored and only 29 (25%) contained lesions, unlike the women of which only eight of 69 (11.6%) displayed lesions. Among the children of the sample, 15 out of 106 (14.2%) showed signs of healed or healing lesions. Active anemia was found in 10 out of 37 (27%) of the children who died at age nine or older with remodeled lesion occurring in 15 of the 37 individuals in this age group. Of the children who died before the age of 8, only five of 69 (7.2%) showed signs of active anemia, and only eight of 69 have remodeled lesions (Cohen et al. 1994a). Based on the high frequency of anemia related lesions, an endemicity of iron deficiency anemia at Tipu can be assumed (Larsen 1994). This is comparable to the frequencies found at sites such as Baton Ramie and Seibal, yet none quite like the severity of lesions found at Altar de Sacrificios (Cohen et al. 1994a).

An initial examination of dental enamel hypoplasias was conducted by Cohen and colleagues (1989). Focusing solely on the upper central incisors and the mandibular canines, only 180 of the 588 individuals were analyzed. Methods introduced by Goodman and colleagues (1980) were used to score and the dentition through an X7-X30 binocular dissecting microscope. Their results yielded a frequency of 69% of incisors and 90.4% of canines exhibiting at least one hypoplasia. Of the 105 individuals with both the incisors and canines observable, 100 or 95% had at least one hypoplasia. Yet, 88% of these episodes were of mild severity with only 2.2% of incisors and 10.3% of canines displaying severe hypoplasias. Also, only two of the 105 individuals (1.9%) with all observable teeth had severe defects on multiple teeth. Age at formation was determined using methods introduced by Goodman et al. 1980, which calculated the peak age at formation for the incisors was between two-and-a-half and three years of age, and a mild peak on the canines between the ages of four to four and a half years old. Following in the footsteps of Saul (1972), Cohen and colleagues (1989) used Landa's (1978) account of Colonial Maya weaning practices to attribute the cause for the peak during these ages. Lastly, only 30 of the 180 individuals sampled showed three or more defects on one tooth suggesting regularly occurring stress did not play a large role in the overall health of the population (Cohen et al. 1994a; Cohen et al. 1997).

Stature is a good indicator of the population's overall nutritional intake (Danforth 1994; Larsen 1995). The stature for the population at Tipu was not affected by the changes that were introduced from Spanish contact. Averages heights for both males (160.3cm, n=149) and females (148.3cm, n=106) fell well between the ranges of stature found across time and space of the Maya culture (refer to Table 2 in Cohen et al. 1994a:129). This adds support to the hypothesis that Tipu was a generally healthy population.

Danforth (1991) also analyzed the Harris lines of arrested development from 58 femurs and 44 tibias. Stress markers formed on the bones are not caused by acute disruption in the growth of the diaphysis, but are considered a product of the recovery phase from stressful events (Waldron 2009; Larsen 1995). She concluded that the frequency of this defect was rare, and males displayed more lines than females. There was no peak age of formation for the Harris Lines, which indicates stress scattered over time within the population (Cohen et al. 1997; Danforth 1991). However, new studies on Harris Lines have resulted in new perspectives of the etiology of this condition. They suggest that Harris lines can also form "during normal periods of accelerated growth in which a heightened number of saltatory growth events are punctuated by an amplified number of stasis events" (Alfonso-Durruty 2011:2). With this new light on the etiology of Harris Lines, the health profiles of the mortuary sample from Tipu remain the same.

Armstrong (1989) conducted the analysis of trauma and infection in 457 individuals from the population. High frequencies of trauma can be a reflection of social tensions at either inter- or intra-site levels (Martin and Frayer 1997). He found that infectious lesions occurred in less than ~5% of the individuals. As with most other cultures (Cohen and Armelagos 1984; Larsen 1995), males tended to display more trauma at 10.4% (16/159) compared to females at 6.9% (8/116) and juveniles at only 0.5% (1.182). The tibia was the most common site for injury with only 13 out of 710, or 1.89%, bones infected. This includes one juvenile (0.4%). Likewise other long bones displayed low frequency of trauma, such as the fibula at 1.19% (7/610) and the humerus at a low 0.2% (1/649). Additionally, there is little evidence, as displayed by the bones, of brute Spanish violence from weapons. The low occurrence of trauma implies that those buried in the cemetery at Tipu did not experience the ongoing warfare and large scale conflict that resulted in the social change that happened elsewhere in the region. This is also suggestive of an overall political and social stability at Tipu (Armstrong 1989; Cohen et al. 1994a; Cohen et al. 1997).

Infectious lesions in the form of periosteal reactions are a reaction to an inflammation of the periosteum marked by irregular lesions and an increase in cortical thickness (Larson 1995). A low frequency of infectious lesions is seen within the population at Tipu. Even though it is slightly higher than the frequency of trauma, periostitis affects less than 0.1% of most bones with the tibia (8.4% or 59/704) and humerus (5.5% or 33/601) showing the most infection. Between the sexes, males displayed higher frequencies with 36 of 159 males, (22.6%) showing lesions as compared to females with only 16 of 116 (13.8%) scored exhibiting periosteal reactions. As with trauma, juveniles exhibited few infectious reactions with only four of the 182 scored displaying some form of periostitis. Overall, only 19 of the 457 individuals scored showed systematic infection (reactions on more than one bones) with most changes being relatively minor.

Cortical bone thickness is representative of the population's protein-calorie nutritional intake. Danforth and colleagues (1985) sectioned the femurs of 127 adults and 37 juveniles (under 12 years of age) immediately distal to the midshaft to examine cortical thickness. The thickness of the cortex was measured at 12 points along the circumference of the shaft. Nordin's index (Nordin 1962) was used to express the mean cortical thickness as a function of femur length and the percent of the cortical area. They found only 3% of adult individuals displayed osteoporosis. A healthy maintenance of bone thickness is attributed to good calcium/phosphorous ratios from the methods of maize preparation and *matate* use. Sampling error may play a role in this low frequency of osteoporosis, in that most of the population is comprised of young adults. Additionally, there is a lack of sexual dimorphism in Nordin's index which results in low absolute levels of cortical thickness in males. As for the juvenile sample, cortical thickness and diaphysis length increased regularly with age (Danforth et al. 1985). Bennett and colleagues (1995) confirmed the general trends of good protein-calorie intake reported by Danforth and colleagues (1985) (Bennett et al. 1995; Cohen et al. 1994a).

As a Master's thesis, Herndon (1994) assessed differences in health between male and female juveniles. She confirms the findings of Danforth (1991) that the juvenile period of life at Tipu was relatively a healthy time. Out of the 249 identified juveniles in the collection at Tipu, only 36 (18 males and 18 females) were available to be analyzed because of poor preservation and the availability of the canine needed for sexing. Herndon (1994) concluded that male children experienced slightly more privileged lives compared to females. Differences in health between the sexes were demonstrated by the lower frequency of enamel hypoplasias and anemia in males, and cortical bone thickness within natural variation for both sexes. Herndon's (1994) study concurs with the other paleopathological investigations that the skeletal assemblage of Tipu has a population in good physical shape.

Epidemic diseases such as treponemal infection and tuberculosis (TB) do not appear to have been present within the mortuary sample of Tipu. Low frequencies of pathognomic markers of TB such of the absence of biological cranial modifications, unilateral episode of periosteal reactions, dental stigmata, and the absence of collapsed lumbar vertebrae (Cohen et al. 1994a; Cohen et al. 1997). Even though the population shows low frequencies of both trauma and infection, it does not necessarily reflect a stress-free environment that experienced little social change. Wood and colleagues (1992) suggest that the skeletal populations that appear "healthy" from low infection frequencies could have actually died from the infection before it manifested in the bone, since it typically takes extended periods of contamination to modify bone (Cohen et al. 1994b; Cohen et al. 1997). This osteological paradox still plagues bioarchaeologists.

In summary, the Colonial period was a time of big change. Not only did changes in the political and economic systems occur, but also significant alteration of the religious and social sectors created a new Maya world. Along with the change in disease load, it is not surprising that those living during this era experienced stress on multiple levels. For Tipuans, some effects were felt more heavily in certain areas than others, such as religion. Yet, a consistent income from cacao production, trade with the Itzá Maya, and the previous elites ruling during periods of little Spanish control allowed for some cultural continuity at the site. The previous pathological investigations upon the population have all concluded that Spanish contact and control left minimal influence upon the health and diet of Tipuans. Most of these studies focus on the manifestation of these affects on the bones. Chapter III will focus on the dentition and will shed light on how these small, but significant parts of the body can sometimes tell just as much, or even more than the bones.

CHAPTER III

TEETH

Teeth are one of the most useful elements of the skeleton for bioarchaeologist because of the diversity of data that can be obtained from them. Enamel is one of the hardest portions of the human body (Goodman and Rose 1990) and hence, survives longer than bone and soft tissues. Teeth have a lower than normal variability in their development compared to bones (May et al. 1993), but any defects formed are permanent and do not remodel. Since teeth form systematically under genetic control (Scott and Turner 1988:117), tooth development is one of the best skeletal aging techniques (Reid and Dean 2006), because developmental timing can continue at normal rates even with biological deficiencies (May et al. 1993). Therefore, the dentition gives valuable information on growth and adaptation. Its specific role of mastication, along with its specialized structure, could explain the sensitivity to physiological stressors on the body (Goodman and Rose 1990).

Enamel Formation and Tooth Development

Amelogenesis, or the formation of enamel, starts with by ameloblasts (enamel-forming cells) lining up opposite of odontoblasts (dentin-forming cells) along an inner enamel epithelium. It is typically a two step process (Hillson 1986; Skinner and Goodman 1992). The first step is the secretion of an organic matrix. Beginning at the dentin horn, the odontoblasts lay, in a cervical direction, the dentin foundation, and then the ameloblasts secrete enamel across this surface (Ritzman et al. 2008: 349), forming a prism-like structure. However, teeth do not grow in a linear manner from cusp to root end (Reid and Dean 2000). Cuspal enamel formation for anterior teeth is similar for all tooth types (Reid and Dean 2006). Enamel is deposited over first the dentine, and then again over the previous layer of enamel until the desired thickness (about 1-2mm) is reached. Because of this layering method, dental crowns grow outward for a period of time and later deposits are focused on the sides of the crown, extending cervically. Last, the enamel matrix develops into an inorganic entity, which forms a matured tooth. Yet, the mineralization process does not have a set schedule, and complete maturation of the tooth can continue after eruption and upwards of six to 20 months (postnatal) in anterior teeth (Skinner and Goodman 1992). Figure 1 illustrates the parts of a tooth.

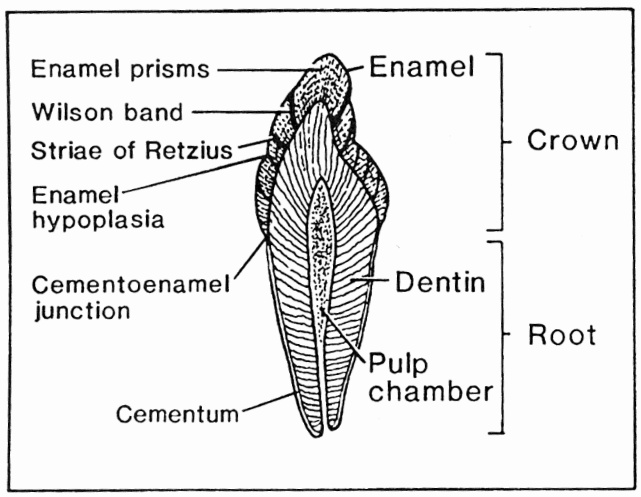

Figure 1. Macroscopic and Microscopic Features of Tooth Morphology (adapted from Rose and Colleagues 1985:85).

The enamel of a tooth is made up of a series of perikyma, or wave-like lines that are regularly spaced grooves which run the circumference of the tooth (Guatelli-Steinberg et al. 2004; Hillson and Bone 1997). Hillson and Bond (1997: 91) have defined three different kinds of perikyma based on the geometry of the crown formation. The occlusal type is confined to the occlusal surface; the mid-coronal type or wave like impression in the middle portion of the tooth and the most commonly affected ones, the cervical type. (Hillson and Bond 1997). Perikymata are representative of between six and 12 days of enamel growth with most populations average nine, and their spacing varies over the entire tooth crown and between individual tooth classes (Hubbard et al. 2009; Reid and Dean 2006). Brown striae of Retzius or the dark concentric lines crossing the enamel prisms of the tooth, seen only in axial cross section of the enamel, run from the dentoenamel junction (DEJ) to the tooth surface in longitudinal sections and mirror the perikymata along the enamel surface (Wright 1990). Once fully formed, mature enamel is completely inorganic, composed of salts (97%+) and small traces of protein and water.

Dean (1987) has shown that enamel matrix deposit varies not only by tooth but also by the three regions of the crown. Enamel is deposited at the greatest rate in the cusp area of the tooth (the occlusal surface) in comparison to the cervical portion, where the slowest matrix deposition occurs. This correlates with Osborne's (1973) theory that the enamel organ is a hydrostatic structure, one in which the period of fastest growth corresponds with the portion of the tooth that is the most robust (and vice versa). Therefore, enamel created late in the formation of the tooth that in the cervical portion, is more sensitive and less physiologically stable than the cuspal region (Condon and Rose 1992). An increase in enamel defects in the cervical region of the tooth can be explained by this theory.

Even though tooth development is controlled by genetics and not highly affected by environment, tooth and enamel development can vary by sex. Some studies (Anderson and Thompson 1973; Demirjian and Levesque 1980) have demonstrated that dental formation is somewhat more advanced, usually less than one month, after the age of five to six in females, as compared to males (Goodman and Rose 1990). It is important to remember, though, that age at completion of crown formation remains independent of tooth length (Reid and Dean 2000). Another fact to consider is that the appositional zone of crown formation, which consists of brown striae in a series of dome-like increments piled on top of each other (Hillson and Bond 1997:93). They are capable of hiding 10 to 20% of the crown formation time of the anterior teeth.

In summary, there are three key stages to tooth development: 1) Age at initiation of tooth mineralization, 2) Time taken to complete enamel creation, and 3) Age at gingival eruption (Reid and Dean 2006: 329). Cusp enamel formation occurs after the initial mineralization (Reid and Dean 2000). Total crown construction time is then the sum of cuspal enamel formation time and lateral enamel formation time. Enamel development is a continuous process, and its end depends on how cuspal enamel thickness is defined (Reid and Dean 2006). Long periods of ameloblast secretion of enamel matrix can afford a more vulnerable period to insults (Lewis and Roberts 1997). Last, it is important to note that only those ameloblasts at the end of their secretory life are the ones stunted during stressful events creating enamel hypoplasias (Skinner and Goodman 1992).

Dental Enamel Hypoplasias

The term *hypoplasia* was first coined in 1893 by Otto Zsigmondy (Hillson 1986: 169). Hypoplasias provide a permanent record of stress during a child's developmental period (Hillson 1986; Limbo 2006; Lukacs 1989).They appear as linear furrows that run transversely around the circumference of the tooth crown and are created when growth disturbances affect the secretion of enamel matrix during growth and development of teeth (Corruccini et al. 2005; Goodman et al. 1980; Goodman and Armelagos 1985b;

Hillson 1986; Hutchinson et al. 1997; Larsen 1995; Ritzman et al. 2008; Wright 1990). They are also considered an ameloblast's nonspecific response to physiological stress and hence illustrate the frailty of individuals in a population (Katzenberg et al. 1996) as they attempt to adapt to environmental, socio-cultural, and physical changes (Cucina 2002; Skinner and Goodman 1992).

Enamel hypoplasias are often found in similar locations on the left and right tooth antimeres, suggesting concurrent metabolic disruption of the matrix secretion and maturation during amelogenesis (Buikstra and Cook 1980). Yet, other studies (see Condon and Rose 1992: 72-75) show that teeth developing at the same time can exhibit different frequencies of defects. Variation occurs not only by tooth type, but also by the three regions of the enamel crown, previously noted, such that lesions occur more commonly on the cervical region of the tooth than the mid-coronal region and almost never on the occlusal portion of the tooth (Condon and Rose 1992). Differences depend largely on the timing of enamel development and maturation (Hutchinson et al. 1997). Defect size can range from microscopic to several millimeters wide (King et al. 2002). Variation in depth (Suckling 1989; Suckling et al. 1986) and breadth (Blakey and Armelagos 1985) has been attributed to the severity of the stressful event.

Recent studies on the size of defects (Hubbard et al. 2009; Suckling 1989) concluded that the duration of the lesion cannot be determined by the width. This is contrary to the long held assumption presented by Blakey and Armelagos (1985) that wider defects resulted from a longer period of stress (Hubbard et al. 2009; King et al. 2005). The new hypothesis is supported by the fact that each individual perikyma can represent anywhere between six and 12 days of enamel growth (Reid and Dean 2006).

Additionally, individual tooth classes have differing perikymata spacing (Guatelli-Steinberg et al. 2004; Hillson and Bond 1997), and sometimes perikymata cannot be individually distinguished, nor can the width of the lesion be correlated to a certain number of perikymata (Hubbard et al. 2009). Hence, the idea that total width of the defect does not equal duration holds true.

Genetics may have an effect on hypoplasia formation. *Amelogenesis imperfecta* is the term for genetic malformations manifested as hypoplasias or hypocalcification (Hillson 1986). Yet, this type of defect is easily differentiated from fluorosis or excess fluorine in water at low doses (Brunet et al. 2002) as well as hereditary causes as they manifest in a single band around the tooth's circumference instead of appearing on the entire tooth (Goodman and Armelagos 1985a; Hillson 1986).

Most permanent tooth hypoplasias are manifested during tooth development in childhood, usually between the ages of five months *in utero* until 13 years old (Corruccini et al. 2005; Limbo 2006) with a hiatus around the ages of eight and nine when no enamel is formed (Skinner and Goodman 1992). Hypoplastic events before the first year of life are unlikely to form on any anterior tooth type because of the length of time of initial mineralization (Reid and Dean 2000). Depending on the tooth, a cross-cultural pattern is found with the highest frequency of defect development between the ages of four to six (Danforth and Cook 1994; Goodman et al. 1980; King et al. 2002; King et al. 2005), yet others argue that the tooth is most vulnerable to defects during the ages of two and three (Skinner and Goodman 1992). Hypoplasias form on incisors from *in utero* to three years of age; canines provide the best records for ages one to six years old, and the mandibular lateral premolars from age three and a half to seven years

(Goodman et al. 1980). The third molars are the least likely teeth for enamel hypoplasias to occur yet are representative of ages ten through thirteen (Goodman and Armelagos 1985b).

Histological studies suggest that duration of the event is reflected by the number of perikymata along a certain portion of the lesion— the occlusal wall. Stunted deposits of enamel create two walls of a lesion— the occlusal wall or an area with wider than normal perikymata, and the cervical wall or the area of catch-up growth with standard sized perikymata (Guatelli-Steinberg et al. 2004). Defects in the enamel are the effect of the variation of spacing between one and 30 perikymata (Guatelli-Steinberg et al. 2004; King et al. 2002). The internal layering of the brown striae of Retzius and its corresponding, external perikymata are strongly influenced by periods of stress (Hillson and Bond 1997). Minor or major growth disruptions both create the same structure of an enamel defect.

Etiology of Dental Enamel Hypoplasias

The etiology of hypoplasias is not completely understood, and a one to one ratio of insult to defect cannot yet be determined (Buikstra and Cook 1980; Molnar and Molnar 1985). So far, both biological and cultural factors have been associated with enamel defects (Goodman and Armelagos 1985b; Goodman and Rose 1990). Non-physiological stress is suggested as a main etiology (Limbo 2006) which could be increased by the interaction of nutritional deficiency and disease. King and colleagues (2005) review various systemic and infectious diseases known to result in enamel defects. Diseases such as rubella, tetanus, syphilis, enteropathies, neurological disturbances, and even maternal diabetes can cause enamel hypoplasia. There are also peri- and neonatal disturbances linked to episodes (King et al. 2005; Schultz et al. 1998). Additionally, some research suggests that allergies, genetic factors, changes in dietary habits, local trauma and intoxication all can lead to a disruption of the enamel matrix (Brunet et al. 2002; Goodman and Armelagos 1985b; Goodman and Rose 1990; Hillson 1986; King et al. 2002; Limbo 2006; Schultz et al. 1998; Suckling 1989). Although hypoplasias can be caused by infectious diseases and other conditions in modern populations, in the prehistoric Americas, there is a strong association between nutritional dependence on maize agriculture and hypoplasias (White 1997). However, malnutrition and micronutrient deficiencies (King et al. 2002; Larsen 1995), parasites (Suckling 1989; Suckling et al. 1986), and weaning (Cook 1979; Katzenberg et al. 1996) can also cause lesions.

Changes in many cultural systems can have biological effects on the body. Cohen and Armelagos (1984) suggests that enamel hypoplasias are caused by cultural factors, such as technological innovations, changes in subsistence patterns, which is supported by the work of Cucina (2002) and Wright and Schwarcz (1998), and as a response of environmental pressures or stress. The effects of agriculture on bones and teeth have been highly debated (Cohen et al. 1994b; Wood et al. 1992) between whether or not agriculture as the main subsistence created healthier populations or those with a heavier disease load. Studies (see Scott and Turner 1988:118) suggest an increase in the frequency of enamel defects with the shift to an agriculturally focused diet. This change in subsistence patterns could have altered the levels of stress from malnutrition and other diet related factors. Studies of prehistoric and historic dentitions indicate hypoplastic defects tend to be narrower in the precontact, non-agricultural natives suggesting which might suggest shorter stress durations or less severe stress levels prior to introduction of agriculture. It has been demonstrated in ethnohistoric records of the increase in infectious diseases, starvation, crowded living conditions, and warfare during contact periods (Larsen 1994).

Considering general non-physiological stress has been identified as a main etiology, Figure 2 is the model for interpreting its biological manifestation, outlined by Goodman and colleagues (1984:14), and adapted from Selye (1956) is the theoretical framework for this study. In order to answer processual questions of how cultural evolution and adaption to the environment influence the body, three factors affecting the amount of stress are suggested. The primary catalyst for stress in the model is environmental constraints. Characteristics such as hostile climates, low natural resources, dangerous terrains, or natural disasters all test human ability to adjust and adapt to where they reside. Second, culture generates modes for environmental adaptation. It allows for the manipulation of available resources and may provide a buffer to harsh climates, or inversely, can add additional stress from gender roles and biological differences by sex. Last, host resistance can limit the amount of stress an individual experiences, but this varies by age and sex. These three factors each vary across time and space and therefore have diverse affects on the different portions of the population. It is important to note, though, that if stress is a constant contingent among the people, then differences in the amount are culturally created (Cohen and Armelagos 1984).

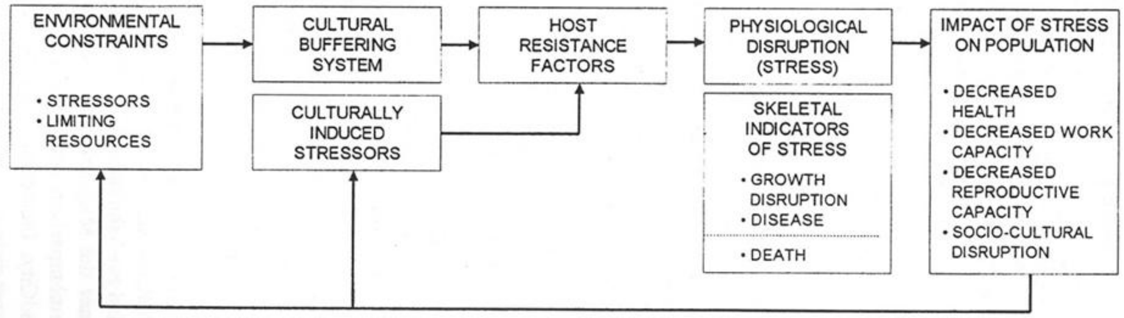

Figure 2. Model for Outlining the Possible Causes of Stress in Populations, Adapted from *Paleopathology at the Origins of Agriculture* Goodman and Colleagues (1984:14).

Previous Enamel Hypoplasia Studies of Precontact Sites

In order to fully understand the frequency of defects within the population of Tipu, it is necessary to investigate previous studies of enamel hypoplasias throughout the cultural periods. Thus, all previous studies of enamel hypoplasias within the Maya lowlands, shown in Figure 3, have been examined with attempts to compare methods (reported in another section) and results with the study at hand. They are reported in chronological order. A general overview of the population and other relevant mortuary patterns are presented below on the studies of Cuello (Saul and Saul 1997), Caracol (Chase 1997), Lubaantun (Saul 1973) & (Hammond et al. 1975), Colha (Massey 1989; Massey and Steele 1997), Moho Caye (Lund 2003), Copan (Storey 1992, 1997, 1998; Whittington 1992), Santa Rita Corozal (Chase 1997), Tayasal-Paxcaman (Chase 1997), Seibal (Saul 1973), and Altar de Sacrificios (Saul 1972). Each study allows for a different perspective on the frequency of enamel hypoplasias compared to the collection from Tipu.

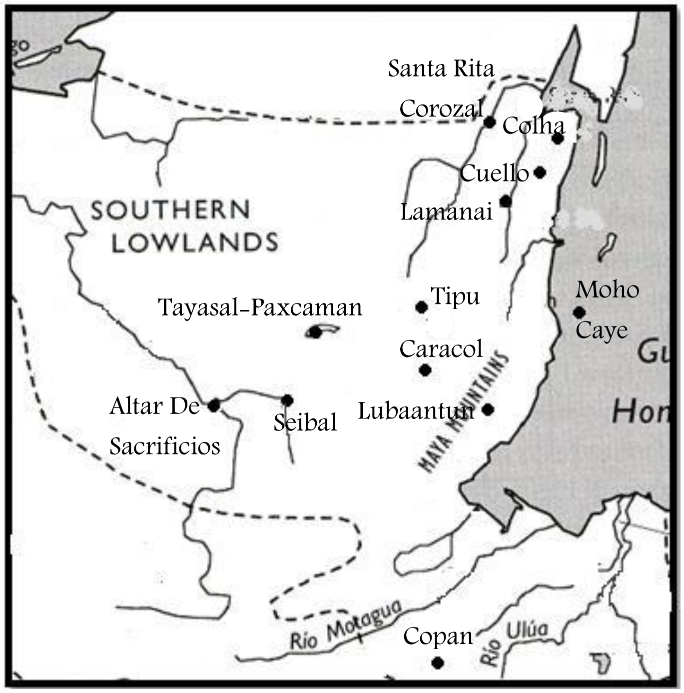

Figure 3. A Map of the Precontact Sites in Relation to Tipu.

Cuello is located in Northern Petén between the Rio Hondo and the New River. It was first excavated by Hammond in 1975, who recovered 122 individuals consisting of 103 adults and 19 subadults. This predominantly Preclassic site (1000 B.C. – A. D. 200) can be further broken down into smaller cultural time periods. Linear enamel hypoplasias (LEH) were evaluated in the population by Saul and Saul (1976) using unreported methods. The general age of formation was given as 3-4 years old. Using evidence from ethnohistoric records (Landa 1978), Saul concluded that these ages correspond to the weaning age for the Colonial Maya. A clear change over time in the incidence of LEHs can be seen at Cuello. The earliest of these subgroups, the Swasey phase (1200-650 B.C.), generally has a low frequency of LEH at 29% of the individuals with scorable dentitions displaying episodes. Between the sexes, 60% of females and 43% of men exhibited defects during the Swasey phase. A slight increase in frequency in LEH during the Mamon phase (650-400 B.C.) can be found, with 40% of the population infected resulting in 100% of females and 56% of males displaying some form of a hypoplasia. This is still lower compared to the last phase, Chicanel (400 B.C. - A.D. 250), in which 57% of the population exhibited LEHs (including two mass burials: Mass burial I at 60% and Mass Burial II at 100%). During this phase the sex distribution of hypoplasia became closer to an equal distribution with 48% of females and 56% of men showcasing some lesions. This is concurrent with the adaption and intensification of maize horticulture in the Maya culture. Overall, a frequency of 59% (57/96) of the total Preclassic population at Cuello exhibited defects (Saul and Saul 1991; Saul and Saul 1997: 34). They do not report on the severity levels of the defects or age at formation, providing information only on the frequency of the defect within the period's sample. Overall, females have higher frequencies than males, and there was an increase over time in occurrence. Though Saul and Saul (1997) list the number of total subadults from the population, they do not describe their results in the same manner. Last, data from juveniles are not reported, and therefore the complete picture of the overall population's health is not established.

Caracol is located along the Belize-Guatemala border on the Vaca Plateau of Belize in the foothills of the Maya Mountains. Excavations started in 1985 by Diane Chase and Arlen Chase are still ongoing with burial statistics changing each year. The earliest settlement at the site dates to 300 B.C., and occupation continued until A.D. 1100. The population of Caracol peaked during the Classic period. Some 183 recorded interments from the site represent more than 300 individuals with more than 80 of these burials located in a formally constructed tomb (Chase 1997). The majority, though are located on residential architecture compounds or "plazuela groups" which tend to have an eastern focus. Chase (1997: 24) only reports that 16% of the burials sampled at Caracol displayed some form of enamel hypoplasia. She does not give the time period of which this 16% is representative, nor the raw population numbers from which this percentage was derived. Also, data on the age at formation of the defect and their associated severity levels were not reported for the Caracol sample.

Lubaantun is located on the flank of the Maya Mountains and is a small ceremonial center in the southernmost part of Belize near the Rio Grande. It was initially investigated in the 1920s by Gann and Merwin. There were two additional sessions of excavation, one in the 1920s by Joyce and the other in the 1970s by Normand Hammond and Katy Pretty (Saul and Hammond 1973). These resulted in the two samples from this site which have two completely different circumstances. One study was based on a Late Classic period tooth cache and the other from a Classic family tomb. With the varying mortuary contexts for each sample, the social status of the individuals could be drastically different. For example the cached teeth could represent individuals who underwent rites of passage rituals, prisoners of war, or scarified victims, as compared to those from the tomb who might be possible elite or member of the ruling family.

Saul and Hammond (1973: 124) report that there were a total of 59 teeth in the cache from Lubaantun, and all seem to be from two, middle aged (25-35 years) adults. Of the 59 total teeth, enamel hypoplasias were noted on only two teeth. Age at formation was concluded as three to four years old, and using unspecified ethnohistoric documentation was attributed to the age at weaning. Though the teeth from this cache are the only skeletal evidence for this sample, the researchers attempted at sexing based on robustly and reported all visible pathologies as follows:

> Both seems to have been of young middle age (c.25-35 years), and Individual I based on the basis of dental morphology possibly male, Individual 2 possibly female. Both lacked caries, but both suffered a single episode of linear enamel hypoplasia, indicating illness and growth arrest, the male to a slight and the female to a severe degree. (Hammond et al. 1975:65)

The low incidence of hypoplasias is drastically different from that seen in the Classic sample from a multi- individual tomb at Lubaantun. Saul evaluated the second sample. Within the tomb, 15 adults were present, four males, four females, and seven of unknown sex. Fourteen of the 15 individuals displayed at least one hypoplasia (Hammond et al. 1975:65). Saul does not break the sample down by sex, and does report of the severity levels claiming there were no severe episodes, only six moderate and seven slight episodes. The mortuary context of each sample contrast in that the individuals from the tomb seem to have been multiple, single inhumations over time, whereas the teeth from the cache were a part of one single ritual deposit. The potential social status variation of the individuals from the tooth cache as possible prisoners of war or other factors could lead to the difference in frequency of enamel hypoplasias between the samples, yet Hammond and colleagues (1975) do not speculate upon them. Lastly, it was reported that 19 of the 24 individuals, or 79% of the total population, from Lubaantun displayed hypoplasias (Hammond et al. 1975). There is no further explanation of how this ‘population’ total was tabulated, since it does not seem to be solely consisting of the tooth cache (two individuals) and the family tomb (15 individuals).

Colha, located in Northern Belize, was a small Classic site that specialized in regional stone-tool-production (McAnany 1989:332). The initial mapping at Colha was completed by Norman Hammond in 1973 and 1976 in the Corozal Project (Hammond 1981:161). Excavations in 1980s by Hester and colleagues (1980, 1982, 1983, 1994) uncovered a collection of human remains next to the staircase on a monumental structure's second terrace. It was a pit about 110 cm long, 80 cm wide, and 20 cm deep containing skulls of 30 decapitated people arranged in two layers and separated from one another by fragments of Late to Terminal Classic pottery. The skulls were represented by 10 children (six months to seven years), 10 females, eight males, and two adults of undetermined sex; all adults were aged into rough groups consisting of three young adults, 13 middle adults and four older adults. Of the 30 skulls, only seven individuals exhibited any hypoplasias: two older adults (one male and one female), four adults (one male, two females and one of unknown sex), and one young adult female. This is suggestive of no sex differences or change through time of physiological stress with this sample (Massey and Steele 1997:62-64). Massey and Steele (1997) do not report on the severity levels of the defects or age at formation, but provide information of the presence or absence of the defect.

Moho Cay is an island at the mouth of the Belize River. This trading post town was occupied from the Late Preclassic to the Postclassic. Its strategic location between the major riverine and coastal transportation routes allowed for it to regulate both local marine resource trade and exotic ritual good to the inland Maya sites (Lund 2003:13). This study examined 141 teeth (10 were excluded because they were unerupted or impacted), representing 13 individuals from a population of 27, all of whom dated to the

Late Classic period (A.D. 600-800). Only seven teeth (four maxillary incisors, one maxillary canine, and two mandibular incisors) exhibited an enamel hypoplasia, and all were from one juvenile aged six to ten. “Thus, this juvenile suffered three major event of severe nutritional stress or disease during their life time” (Lund 2003:59). All of the teeth were incomplete in their development and were possibly still in the dental crypt upon the individual’s death. There are no other reported episodes and an overall moderate dental health rating was concluded as characterizing for the population as a whole. Lund (2003) failed to report on the age at formation and the severity levels for this individual’s defects.

Copan, located in Honduras, was an area of great political and ceremonial control during the Late Classic period (A.D. 700-1000). It was occupied continuously though, from the Preclassic until the Late Classic period and like many other large Maya sites, fell with the Maya cultural collapse during the Late Classic. Excavations from Copan have resulted in samples from different portions of the population, such as elite children, elite adults, and non-elite adults. One of the largest Late Classic populations, the skeletal collection of Copan is divided by status; 264 individuals were from an elite compound and 160 people from a residential compound and plazas groups (Storey 1997).

Storey (1997) conducted a study of childhood morbidity and mortality from a sample of 122 elite subadults. The sample was divided into age sets of one year old, two years old, and five through nine years old (Storey 1997). Of the 122 subadults from Copan, the morbidity frequencies based on the analysis of enamel hypoplasias and other infections were reported for only 32 interments with a total 169 enamel defects found. The average number of defects for each group indicated that the older children (n=6) have the highest mean number of hypoplasia at 6.5 per individual, compared to the two years old group (n=15) with 5.5 hypoplasia per individual and the one year old group (n=11), with only a slighter lower mean number of hypoplasias at 4.4 per individual. Additionally, the two year old group had higher frequencies of healed infection and even some with no pathology present, possibly indicating a time of catch up growth or a period of continued (though short) good nutrition and health. This is unlike the one year old group who had the highest frequencies of active infection and anemia at death (Storey 1997). Storey reported that 60 of these individuals exhibited defects on both their deciduous and permanent dentition, reflecting not only continued poor health of the children, but also severe maternal morbidity.

A few patterns emerged from this study. First, all individuals having at least one pathological episode present displayed other pathological lesions, and second, a higher frequency of defects was found in the youngest age group (Storey 1997:124). There was no group for three or four years old, and it can be assumed that no children of this age were present in the sample. This study only notes absence or presence of the defects and reports the hypoplasia rate for each individual based on a full set of dentition, not by individual tooth. Also, it does not report on the severity levels, age at formation, nor the proportion of the population not affected with enamel hypoplasias within each group.

In another study, Storey (1998) attempted to identify paleopathological manifestation of gender preference in a sample of 134 individuals from three social classes. This sample was further divided by sex resulting in 75 females and 59 males examined for differences in osteological changes from stress. She uses the individual tooth as the method of evaluation, and focusing on the upper central incisors and lower canines from which, found no statistical differences to emerge between the sexes. Males and females had the same percentage of affected canines, with very similar frequencies seen on the central incisor as well (male 78%, female 76%). Therefore, no preference to a by sex was given during childhood, and boys and girls experienced equal levels of stressors (Storey 1998).

Whittington (1992) conducted a study of the non-elite individuals at Copan from a series of residential compound mounds. He divided the sample by status based on the burial location and by cultural period in attempt to explore differences in the amount of stress through time and between classes. An additional goal of Whittington (1992) was to find variation in the age at formation of defects among groups. Subadult males had a higher frequency of lesions than subadult females; therefore females were not neglected. Males and females experienced the greatest defect occurrence around the same period of life, between three and six years old. Yet, peak female levels were delayed a half of a year compared to those in males (3.5 to 3.0), possibly from female genetic buffering. Also location of residency did not affect the quality of life of the Copan inhabitants from this sample since there were no statistical differences in episode rates (Whittington 1992).

Santa Rita Corozal, located on the Chetumal Bay between the New River and Rio Hondo, was also analyzed by Chase (1997) as part of a comparative study with Caracol and Tayasal-Paxcaman. The site’s population peaked during the Postclassic period (A.D. 950- 1700) at about 7,000, yet, surprisingly only one of the 69 burials sampled from Late Postclassic period individuals showed signs of dental calculus and zero displayed hypoplasias.

Tayasal-Paxcaman, in the heart of the Maya lowlands at Lake Petén Itzá, Guatemala, was continually occupied from the Middle Preclassic through the Postclassic period. Excavations of the site were started by Carl Guthe in the 1920s, yet under the guidance of Arlen Chase and the University of Pennsylvania additional work was completed in the 1970s. Tayasal-Paxcaman had only one individual out of the twelve that displayed a single case of distinguishable hypoplasia (Chase 1997). Hence, with 16% of Caracol residents showing LEHs, it had significantly higher amounts of stressful periods in the life cycle of its inhabitants compared to those residing at Santa Rita Corozal or Tayasal-Paxcaman, at which less than 1% were affected. For all three sites in this study, Chase (1997) does not describe the distribution of hypoplasias in the sample by sex or age group, report on age at formation or severity levels, nor does she give the number of individuals not affected by the defect. The lack of details of these three studies leaves them almost useless for comparative purposes.

Altar de Sacrificios is located in the southern Petén at the confluence of the Pasión and Salinas Rivers. Saul (1972) analyzed 90 of the 136 burials composed of a mortuary sample spanning all time periods at Altar de Sacrificios. As with most Maya sites, skeletal preservation is poor, and hence the sample size is only 90 individuals. This sample is then divided by age into 63 adults and 27 subadults, and again separated by sex. Saul (1972) found that hypoplasias are present on the deciduous teeth on four of the 27 juveniles in the sample, indicating severe maternal distress. Within the adult subgroup, 37 of the 63 exhibited lesions and only 2 of the 63 had no signs of enamel defects at all. Adults in the sample were broken down by sex. Only 5% (3/63) of the males in the sample displayed defects. This contrast greatly with females, among whom 59% (37/63) exhibited hypoplasias. Lastly, 37% (23/63) of the indeterminate sex group exhibited lesions. He also noted that most hypoplasias formed between three and four years old, and attributed this period of stress to weaning based on information from ethnohistorical evidence (Landa 1978; Saul 1972).

Seibal, also evaluated by Saul (1972), is a large site located in Pasion Valley region of Guatemala. It was occupied from the Preclassic into the Terminal Classic times. Even with a population of only 8,000 at end of Classic, this site was a premier power in its region during Late Classic (A.D. 700-1000). Analysis determined that 80% (36/45) of females and 7% (3/45) of males displayed hypoplasias. These rates closely resembled those seen in the sample at Altar de Sacrificios. The higher frequency of hypoplasia in females compared to males follows the trend seen in most agricultural societies (Larson 1995).

Previous investigations of enamel hypoplasias from Maya site around the Southern Lowlands show varying degrees of the reported information. Most scholars provide information on the presence or absence of the defect for each person and not for the individual tooth. A general trend is seen with almost all researchers failing to calculate the age at formation for the defects (except for one of the four sites Saul analyzed), nor do they description severity levels of the defects (except again for one of Saul's four studies). Even the same researcher does not conduct analysis or state results in the same way for multiple sites. Most also do not break their sample down by age or sex, but mainly report on the total frequency by individual from the population as a whole.

During the Preclassic the females had overall lower frequencies than males. During the Classic, hypoplastic activity varied by site. At some sites (Lubaantun), the population had high overall frequencies of defects, and others with low occurrence rates (Colha and Caracol). During Late Classic (Moho Caye and Lubaantun) similar result with the adult portion of the population has lower frequencies of hypoplasias. Lastly, two Postclassic sites had less than 1% of the population with lesions. Therefore, no temporal patterns can be drawn because of the intersite variability of reported results. Yet, throughout the periods, females had higher frequencies compared to males.

Previous Enamel Hypoplasia Studies of Colonial Sites

Apart from Lamanai and Tipu, there are 12 to 15 other reported sixteenth and seventeenth century towns in Belize. Yet, the precise location of most is unknown or current cities are built over others; hence research concerning these towns is very limited (Pendergast et al. 1993). Ethnohistoric documents provide some information, the entradas, or journeys of exploration and conversion as a main source of site identification. Secondly, the *reducción* system that assembled Maya into new villages and returned runaways to theses villages provide an insight to the location of the other Colonial towns (Farris 1984). Such documents, however, are written by town officials, military men, and missionaries. Language used to describe the location of said towns is generally telegraphic in such it referenced landscape changes. Documentations such as "this town is located on the water's edge" or "we reached it after marching twelve leagues in the other direction across marshes and impenetrable forest," make it difficult to decipher the exact location of other Colonial sites (Pendergast et al. 1993:60). As a cross comparison for Tipu, three other Colonial sites Lamanai, Tancah, and Campeche are investigated.

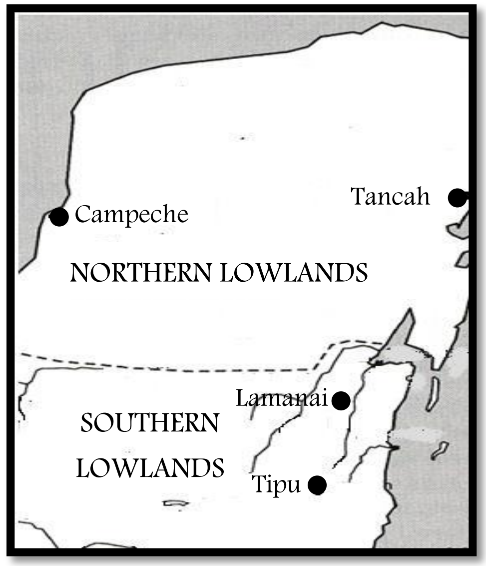

Figure 4. A Map of the Comparative Colonial Sites.

Lamanai is located about 70 miles inland along the northwestern shore of the New River Lagoon in Belize (Jones et al. 1986). Unlike most other Maya site, Lamanai flourished even after the Classic Maya collapse (White and Schwarcz 1998) and into Spanish contact after 1544. Only 100 kilometers north of Tipu, Lamanai has a similar population history, yet a shorter Colonial occupation. Contrary to what was known about Tipu, 17^{th}-century documents tell of the exact location of this community along with its associated architecture. Lamanai's placement on a riverine trade route is of great importance in the exchange of goods and ideas from the south to the north which allowed its boundaries to be flexible. Hence, it is difficult to pin-point the outer limits of the province of Lamanai (Graham et al. 1989; Jones et al. 1986; White 1997).

Unlike at Tipu, no attempts were made to establish a Spanish style town layout, even though Lamanai's location was more strategic for the trade route as the mid-way point between Bacalar and Tipu (Graham et al. 1989). An uprising against Spanish rule in 1641 left the site abandoned. Franciscan priests found the churches and buildings at Lamanai burnt to the ground from rebellion activities and its inhabitants retreated or joined the rebellion at Tipu. With this event, the ethnohistoric documentation at Lamanai ends. Yet, archaeological data does not suggest a clear stage of burning at Lamanai, which insinuates the presence of Maya communities there after Spanish rule ended (Jones et al. 1989). There have been multiple studies on enamel defects, both macroscopic (Wright 1990) and microscopic (White et al. 1994; Wright 1990) using the skeletal collection from Lamanai.

Wright (1990) conducted research on health patterns from macroscopic enamel hypoplasias at Lamanai based upon a sample spanning the Postclassic into the Historical or Colonial times. Using Condon's (1981) methods on a sample size of 23, she found 74 defects most of the shallow severity. Additionally, it can be said that childhood health decreased after contact since the Colonial period burials displayed more defects (N=53) compared to the Postclassic individuals (N=21) (Wright 1990: 32-34). She also suggests that the peak age of the formation of Wilson bands and hypoplasias occurred during the time of weaning, as recorded by Diego de Landa (1978), coupled with insufficient nutrition and increased susceptibility to diseases introduced by the Spanish (Wright 1990). A numerical value is not given for the actual age at formation for any of the defects. This study also does not break the sample down by age or sex.

Additionally, White and colleagues (1994) looked at microscopic lesions known as Wilson bands. A subset of the original population was used because of the destructive aspect of identifying and scoring Wilson bands. Therefore only 15 Colonial individuals (seven males and eight females) of the total 179 were scored, and an overall mean number of Wilson bands of 2.4 per tooth was reported. An average of 1.8 lesions per canine was calculated from a total of 43 identified microdefects on 23 teeth. Age at formation was not reported. Descriptive statistics by sex and age were not provided but it is mentioned that there were no differences in the mean number of enamel defects by sex. White (1997) and Wright (1990) both agreed that all incidents of microenamel malformation were a result of the weaning process during the ages of two to six. Additionally, Wright (1990) attributed malnutrition and Spanish introduced diseases as an additional etiology.

Tancah is located on the eastern coast of the Yucatán and was inhabited before and after Spanish contact. Most ethnohistorical documents refer to the town as Tzamá. It was once thought to be the site of Tulum, but archaeological evidence of the settlement patterns and information from ethnohistoric documents suggest instead it was the site of the Colonial town of Tzamá also known as Tancah. The main economic contribution to this site was that of trade. Therefore, contact with the Spanish happened early in the Colonial period. The site's chapel, built in 1543, had a Spanish design but was built with local materials in a Maya fashion. Unlike most Maya towns during the conquest, Tancah practiced passive resistance and hence, had peaceful contact with the Spanish. Only one noted massacre occurred; otherwise the inhabitants at Tancah accepted the Spanish *encomienda* system (Miller and Farriss 1979).

Excavations from two different structures comprise the skeletal population. Structure 42 unveiled 17 individuals ranging from the Early Classic to the Postclassic periods. For simplification, the interments from the structure are grouped together as precontact representatives. Also, Structure 71 (the chapel), exposed 27 other burials all dating to the Colonial period (Saul 1982:115). All age groups are represented in both samples (pre- and post- contact). From the precontact assemblage, only two individuals (Burials 1a and 1b) were available for analysis, and neither displayed enamel defects. From the chapel (Str. 71), 10 hypoplasias in total were reported- two slight, seven medium, and 1 pronounced. Saul (1982) does not report if these defects are from one individual or many nor does he give an age at formation for any of the lesions. He does, however, report that only one individual out of the 27 lacked enamel defects and those with episodes typically displayed more than one (Saul 1982:116).

All 19 of the individuals interred in the church nave (Str. 71) are male. Individual interments from the chapel at Tancah indicate a spatial division by sex. Saul (1982) identified one female from the pit directed south of the stairwell next to the nave. This is congruent with the ethnohistorical documentation of the separation of the sexes during Mass. Interment under plaster floors is a remnant of traditional Maya burial practices, but the east-west, supine body position and few grave goods are indicative of Spanish customs, confirming Str. 71 as a consecrated burial ground such as Tipu. Only one burial followed typical Maya customs of a flexed body orientation and a jade bead offering (Miller and Farriss 1979). Hence, the mortuary sample from Tancah seems to consist of religious converts, such as at Tipu, since Christian mortuary practices are more common than traditional Maya ones and could have been a great source for comparison and contrast had the results been reported differently.

Campeche, or Villa of San Francisco de Campeche, is a Colonial town in the Mexican Yucatán. It was established at the end of 1540/beginning of 1541 as the first

Spanish municipality and was used to consolidate domination in the region. Built as a shipyard and trade center, the population from Campeche consisted of mostly immigrants, either Spanish or African slaves, and few indigenous people. Its skeletal population was excavated from a church graveyard in 2000 by Vera Tiesler and the project supervisors, Heber Ojeda Mas and Carlos Miguel Huitz Baqueiro of the National Institute of Anthropology and History (Mexico). This site is unique in that, unlike at Lamanai, Tancah, or Tipu, the town was subject to pirate attacks and even a venereal syphilis epidemic. Many different ethnic groups as determined by dental morphology suggested by Scott and Turner (1979) and Cucina, Tiesler, and Wrobel (2005) were forced to assimilate in order to survive the precarious nature of Colonial life (Tiesler et al. 2010) and as a result a mestizo people emerged (Cucina 2010).

The population of Campeche consists of 180 interments from 150 graves. Only 86 individuals, 18 mestizos, 43 indigenous Americans, and 25 Africans were scored by Cucina (2010) because of the availability of their scorable permanent dentition. The tooth count method (as opposed to the individual person method) was used and special attention was paid to the maxillary central incisors and mandibular canines. He reported the percentage of hypoplastic defect per tooth for all populations. In the native group, 90.9% of the maxillary central incisors and mandibular canines had lesions. Strikingly though, the mandibular canines did not have any enamel hypoplasias present and the mandibular central incisors had the highest frequency at 91.7% (Cucina 2010:121). The data show that the native population experienced more frequent stressful events compared to the Africans (Cucina 2010:126). Statistics were not broken down by age or sex, severity levels were not reported, nor was age at formation calculated, but this sample provides single tooth data that may be compared to results at Tipu.

In summary, the three Colonial towns, Lamanai, Tancah, and Campeche each offer different variables for comparison. Lamanai proves to be a good site for comparison of severity levels because methods used in Wright's (1990) study are parallel to those of this study and the data is also reported similarly. Also, the contrasting Spanish influence between Lamanai and Tipu allowed for insight into the effects of direct and constant Spanish control. The lack of data presented in the articles on Tancah limit the available comparative material. Though Saul (1982) does mention the number of defects by severity degree, he does not divide the data by sex or age, making the information unsuitable for comparison. Lastly, Campeche would seem to be the best candidate as a cross site evaluation since the same methodology is used for analysis, yet the study does not report on the age or sex distributions at the site, but between the ethnic groups as a whole, so full comparisons cannot be made. However, single tooth frequencies and means help to contrast the health patterns of Northern Yucatán Lowlands and Southern Lowlands where Tipu is located.

As shown, frequencies of enamel hypoplasias across the Maya lowlands vary. Depending on the time period, some populations experienced more non-specific stress than others. Even into the Colonial period, differing degrees of Spanish contact and control resulted in contrasting amounts of stress upon the populations. A full discussion of the data is presented in Chapter V.

Scoring Methods of Dental Enamel Hypoplasias

General Methods of Scoring

Techniques for the evaluation of hypoplasias have evolved over the years. Primarily methods outlined by Condon (1981), Defect of Dental Enamel or DDE of the International Dental Federation called the (FDI 1982); Buikstra and Ubelaker (1994); or simple presence and absence, including the occurrence of more than one defect (Goodman et al. 1980) have been used in the past. It is also not unlikely to see population specific descriptions of defect characteristics in which the researcher attempted to use a more common technique but did not find it applicable to the population at hand. Each of these methods are described below.

Previous investigations of enamel hypoplasias from Maya sites around the Lowlands report a variety of data types Not only does the particular method vary, but authors can report the present of hypoplasias in many ways. The most common method is simply stating the overall population frequency which included all teeth scored. In contrast to the tooth count method, where over all averages are based on one certain tooth (i.e. the central maxillary incisor), which adequately represent both individuals with a few or all teeth available for analysis. Sometimes multiple defect frequency is reported in details, but often overlooked. Hypoplasia data can also be stated in degrees of severity and but the age a formation. A general trend, though, is seen with almost all researchers failing to calculate the age at formation for the defects, nor reporting the severity levels of the defects. Even the same researcher, though, does not report or conduct analysis the same on multiple sites. Furthermore, most also do not divide their sample down by age or sex, yet only report on the total frequency by individual from the population as a whole.

Hence, with no set international standard until recently, scoring and reporting of enamel hypoplasias has been very variable, and hence, inter-site comparisons are difficult.

Methods of Comparative Precontact and Colonial Sites

One advantage of bioarchaeology is the scientific method it embodies. Hence, techniques over the years have been tested and retested for the accuracy as new hypotheses on the possible etiologies arise, or a better understanding of enamel is discovered. Whatever the reason, previous studies of LEHs within the Lowlands of the Maya territory has resulted in a mixture of methods used to assess the defect. Many scholars frequently report methods by Krogman (1962), Stewart (1953), Condon (1981), two currently used methods—Buikstra and Ubelaker (1994) and the International Dental Federation (FDI 1982), some report presence and absence, while the rest remain unreported.

Krogman's book, *The Human Skeleton in Forensic Medicine,* is a commonly cited source for a methodology to score hypoplasias. This method was used by Massey and Steele (1997) upon the skeletal remains from the site of Colha. Additionally, Saul and Hammond (1973) use the methodology put forth by Krogman to assess hypoplasias from the tooth cache of Lubaantun. Lastly, Saul and Saul's (1997) state that methodology used in the analysis of the sample from Cuello is described by Krogman and Iscan (1986) who follow the guide lines described by Krogman (1962). To make matters worse, Saul and Saul (1997) also implemented their own methods "derived from our previous studies of large numbers of Maya skeletons" for the analysis of both Cuello and Lubaantun (Saul and Saul 1997:30). Therefore, no legitimate or easily identifiable method was used to analysis the skeletal collection from either of these sites. Even though this methods seems to be popular among previous scholars, this book only offers a description of methods used in aging, sexing, ancestry and other skull features but provides no data for scoring or describing enamel hypoplasias.

The same flaw can be found as with Krogman (1962), in that this book does not mention any applicable methodology for scoring hypoplasias. Another method commonly used is that from Stewart's *Skeletal Remains from Zaculeu, Guatemala. In The Ruins of Zaculeu, Guatemala.* Saul (1972) uses this different method to analysis the remains from Altar de Sacrificios and Seibal. Stewart even claims, "Dental pathology was not observed in detail. My impression is that tooth loss was moderate and in conformity with age. Attrition, too, was rarely excessive" (Stewart 1953:297). In this paper, a concentration on describing dental and cranial modification was the main objective, not the scoring of hypoplasias.

Buikstra and Ubelaker (1994) supply eight categories for defining enamel hypoplasias (labeled 0-7): 0). Absence, 1). Linear horizontal grooves, 2). Linear vertical grooves, 3). Linear horizontal pits, 4). Nonlinear arrays of pits, 5). Single pits, 6). Discrete boundary opacity, and 7). Diffused boundary opacity. This is accompanied by three degrees of severity— mild, moderate, and severe which are based on width, depth, and definition of the defects and a four point color system to help further define the lesions. Only two investigations, Lund (2003) at Moho Caye and Cucina (2010) at Campeche used methods presented by Buikstra and Ubelaker (1994). Yet, problems arose when comparison of result was attempted because of sample size of Lund (2003) and Cucina (2010) only broke his sample down into larger ethnic groups and not by age or sex making cross-site assessments difficult. On the other hand, both of these studies use total tooth count when presenting the frequency of hypoplasias within the population. This is a newer approach that the other studies do not use.

Similar to Buikstra and Ubelaker (1994), Condon's (1981) method for scoring hypoplasias and Wilson Bands was applied by Lori Wright (1990) to the mortuary sample from Lamanai. This scheme consists of the classification of three 'types' of hypoplasias labeled as followed: "(1) Class I-"shallow" pan-like depressions in the enamel surface, (2) Class II-"modal" repeated depressions marked by convergence of striae of Retzius at discrete modes, and (3) Acute-"acute" deep but isolated depressions. Condon's (1981) three class mirror Buikstra and Ubelaker (1994) degrees of severity they named mild, moderate, and severe hypoplasias and allow for easy comparison to current methods.

Cohen and colleagues used the methods introduced by Goodman and colleagues (1980) to analyze hypoplasias upon a small sample of Tipu population. This technique performed by Goodman and colleagues (1980) attempted to use two methods previously published by Sarnat and Schour (1941) and Farmer (1966) along with a binocular microscopic zoom to assess enamel hypoplasias upon 111 individuals spanning the Late Woodland and Mississippian periods along the Illinois River Valley. Yet, both methods had to be modified for their study. Sarnat and Schour (1941) described two types of hypoplasias as either continuous in a band or line form or discontinuous in the pit form. This technique was not used because most of the defects found by Goodman and colleagues were "clearly intermediate to their 'types'" (Goodman et al. 1980:518). Additionally, the method suggested by Mellanby's (1928) classification of severity found in Farmer (1966) [mentioned by Goodman et al. 1980 but not cited or explained] did not properly describe the severity of the defects from the Illinois population, because the "two most severe grades were highly underrepresented and the two least severe grades were not easily distinguished from each other" (Goodman et al. 1980:518). Therefore, Cohen and colleagues and Whittington (1992) followed Goodman and colleagues (1980) and only scored the presence or absence of the defect which does not allow for easy comparison of results with those other sites.

For the study of subadults at Copan, Storey (1992; 1997) used methods introduced by the International Dental Federation (FDI 1982) and even gives a chart with the description of the different types of defects. The DDE system classifies four types of hypoplasias: pits, horizontal grooves, vertical grooves, and areas of missing enamel which are accompanied by three degrees of severity— mild, moderate, and severe. These descriptions are the most similar to those used in the standards introduced by Buikstra and Ubelaker (1994) and the only difference is the lack of the category of missing enamel in SOD. Therefore, this study is one of the best for intersite comparisons.

Chase (1997) does not mention the methods that were applied to the analysis of enamel hypoplasias at Caracol, Santa Rita Corozal, and Tayasal-Paxcaman. Following the patterns of other, Chase (1997) could have employed their own techniques when assessing the frequency of enamel hypoplasias. For the family tomb sample scored by Saul (Hammond et al. 1975), no methodology was cited, nor was there a reference section for the paper. He reports the finding at Lubaantun a bit differently than those from Altar de Sacrificios and Seibal.

Methods used to evaluate hypoplasias in Maya populations varied greatly. Techniques introduced in the 1960's, made-up methods that are more appropriate for one particular collection, or common methods for the period can all be found throughout studies on hypoplasias within the Maya lands. Systems for general osteological analysis vary and many scholars have cited studies such as Bass (1971), Krogman (1962), Stewart (1979), Steele and Bramblett (1988), and for the analysis of pathological condition (which hypoplasias would fall under) Steinbock (1976), Ortner and Putschar (1985 [1981]), McKern and Stewart (1957), and Stewart (1953). After further investigations in this study show not one of these cited authors provide methodologies for scoring hypoplasias, and most totally neglect to mention enamel defects in their books. This leaves the methods used to analyzed health patterns as determined by hypoplasias more difficult to use in comparison to other sites and warrants a greater need for the use of more standard methodologies (such as those used by Lund 2003 and Cucina 2010) to assess linear enamel hypoplasias. Wright and White (1995) comment on the multitude of ways that results have been reported. “Hypoplasias have been reported by presence/absence mean number of defects/tooth, percent individuals affected, and mean number of defects/mm or 6-month unit of enamel” (Wright and White 1995:14). Then, they note that none of these have been converted to a scale on which defect incidence can be compared (Wright and White 1995). Along with interoberserver error which has always plagued the analysis of enamel hypoplasias (Danforth et al. 1993; Wright and White 1995), many biases are present when studying the effects of stress on dentition.

Age at Formation of Dental Enamel Hypoplasias

The age at which the hypoplasia is formed is theoretically easily determined since human teeth develop systematically with age and do not remodel (Goodman et al. 1980; Goodman and Rose 1990; Lewis and Roberts 1997; Lucy et al. 2002). Each individual has a constant rate of time elapsed between formation of brown striae of Retzius of roughly eight to ten days. After tooth formation completes, the position of the defect relative to crown-formation schedules can be used to access a systematic age group for each defect which gives a chronology of stress for an individual (Cucina 2002; King et al. 2002). Age at formation gives a more defined period of stress during childhood. Yet, methods are not free of bias. Attrition, or tooth wear, decreases the length of the tooth crown, which is used by most methods to calculate age at formation, and does not reflect accurate overall crown heights. Also, tooth wear results in the loss of early episodes of stress (Skinner and Goodman 1992). Secondly, "developmental, structural, and statistical problems" may affect macroscopic analysis of hypoplasias and can alter the computation of an age of an event (Katzenburg et al. 1996:186).

Clinical research on gingival eruption and its associated chronological age, as well as radiographic studies are methods frequently used in the past for determining age based on dental eruption. Yet, more recently, histological studies have established rate of enamel formation by weeks and days instead of just years (Reid and Dean 2006), giving a more accurate age based on dental maturity. Using this information, Reid and Dean (2000) have determined a more specific age at which enamel formation begins. Initial mineralization ages as determined by (Reid and Dean 2000:137) are as follows: 128 days upper in central incisors, 383 days in upper lateral incisors, 274 days in upper canines, 90 days in lower central incisors, 146 days in lower lateral incisors and 200 days in lower canines, and 1059 in second permanent molars (Reid and Dean 2006:336). In general, the canine takes the longest to form- up to six years (Reid and Dean 2000); others (Fitzgerald

1995) claim 7.0-7.9 year for canine completion. Therefore, a more precise timing of defects is deduced from this more accurate age at the end of enamel formation.

Age at Formation Methods

Determining the age at formation of enamel hypoplasias has been a tricky subject for bioarchaeology. Many scholars have attempted to come up with different methods to best derive the age at which the stressful events occurred (Goodman et al. 1980; Goodman and Rose 1990; Lewis and Roberts 1997; Reid and Dean 2006). Considering that tooth growth forages on even during periods when most bone growth would be stunted, theoretically it should be easy to assess the age at which the episode occurs.

Since the 1980s the technique introduced by Goodman and colleagues (1980) has been the most frequently used method of determining the age at formation of enamel hypoplasias. A chart of modern teeth formation intervals was first introduced by Massler and colleagues (1941) and later adapted by Swardstedt (1966) and is the basis of this method. Figure 1 in Goodman and Colleagues (1980:520) illustrates this method for assessing age at formation in a half year interval scale. To determine the age, measure the defect in millimeter from the CEJ and then compare its location to the age intervals in the chart; Therefore, age assessment is as simple as placing the defect's location within the boundaries of the appropriate tooth's intervals on the chart and reading the estimated age.

This technique is widely used and even recently as 2005, King and colleagues commented on using this method as follows:

> Using population average for age of onset and completion of tooth crown calcification to determine the age range during which a tooth crown forms. The tooth crown was then divided into a number of equal-sized increments considered to reflect a standard time interval (usually 6 months). Enamel defects are assigned to one of these time intervals by measuring the

> distance between the midpoint of the defect and the cemento-enamel junction. (King et al. 2005:548)

Possible errors in this method such as variation in tooth development times among individuals or attrition are noted (Hillson 1979). Buikstra and Cook (1980) suggest using tooth size to establish an age of occurrence since it is more dependent upon timing of initial and terminal amelogenesis. Additionally, Goodman and Armelagos (1985a) have shown that teeth developing at the same time do not have similar frequency of lesions; thus factors other than time of development are a cause of susceptibility to enamel deficiency. For teeth with high rates of attrition, an average for tooth crown height is used to infer the age of occurrence. More recently, though, Goodman and Song (1999) note that the relationship between the time it takes to form enamel and crown height is not well understood. Therefore, Reid and Dean (2000, 2006) have attempted to make more accurate intervals of enamel formation using histological analysis of multiple populations.

Goodman and Rose (1990) introduced a regression based technique for deriving age at formation of episodes of enamel distress. Their equation was based on mean crown heights derived from Swardstedt (1966) study and dental development standards in Massler and colleagues (1941). Age at LEH formation is then determined using the following equation:

- *[(1/velocity) X distance of LEH from CEJ] + age at crown completion*

An inherent bias in this method is the assumption that tooth crowns grow at constant rates and the sample used to derive this formula has been shown to have small crown heights (Ritzman et al. 2008). Additionally, the units of velocity are not clearly defined, but 1/velocity is given as 0.454 for the central incisors and 0.588 for the canines.

Lewis and Robert (1997) use the chart of age at formation intervals introduced by Goodman and colleagues (1980) within a formula to calculate age at formation of hypoplasias. Work done by Hodge and Wilkinson (1990) demonstrates how crown heights for the non-adult portion of the population are sufficient for determining age at formation from the chart introduced by Goodman and colleagues (1980). Yet, for the adult portion, because of attrition, it is insufficient and a mean crown height derived from teeth unaffected by wear for each sample should be used to estimate age at formation (Lewis and Roberts 1997). Then, the age at formation of the enamel hypoplasia can be determined using the formula as followed:

Age at crown completion – [(9 years of formation / crown height) X defect height]

This equation computes the age at formation for each defect, and when averaged with the other defects upon a single individual, the age at which the person experienced a non-specific stress event can be determined.

These three methods are the most commonly used techniques for determining age at occurrence. No standard way of calculating the age at formation is accepted in the bioarchaeological field, so researchers have used varying approaches to determine the most stressful period of life during enamel development.

Age at Formation Methods of Comparative Precontact and Colonial Sites

Few studies (Saul 1972, 1973, 1982; Saul and Hammond 1973; Storey 1992, 1997; White 1997; Whittington 1992; Wright 1990, 1997a) actually attempt to determine the age when the stress events created hypoplastic defects in their sample. First, Saul (1972) assessed the sample from Altar de Sacrificios by unreported methods and concluded all episodes of growth arrest occurred between ages three and four years old.

These results are similar to his study with Norman Hammond and colleagues (1975) evaluating the tooth cache from Lubaantun, which they concluded that, again, all enamel defects manifested between the ages of three and four years old (Saul and Hammond 1973). Again, they failed to state the technique used to evaluate the age at formation. For both studies though, general etiology of weaning was attributed to all hypoplastic lesions happening at that age, citing ethnohistoric documents such as De Landa's (1978) as evidence.

Others have used varying methods to determine age at occurrence of lesions. When scoring the micro-defects present in the Lamanai population, Wright (1990) used methods introduced by Rose (1977) that divided the labial surface into eights, roughly approximating half year units from ages six months to four and a half years old (Wright 1990:29). Since she scored micro-lesions, this study was the only one to use these techniques.

Only one study calculated age of formation by the most widely used technique introduced by Goodman and colleagues (1980). For the non-elite sample from Copan, Whittington (1992) used chart based methods to look at the age at death and its associated hypoplasia frequencies.

For more recent studies, a trend in methodology for determining age of occurrence is seen. Storey (1992, 1997) use the regression based technique suggested by Goodman and Rose (1990) for the elite sample from Copan. Not all researchers agree with the age at complete formation, so Wright (1997b) argued 4.5 years was more appropriate to use for the canine because it is a more accurate estimate for Amerindians.

Beyond all the methodological variation used throughout time, teeth still are great sources of information. Most of the time, poor bone preservation can result in many samples only consisting of dental remains. Since, teeth are highly controlled genetically; they provide information not only on the chronology of stressful life events, but also matters of biodistance and heredity. Additionally, many stable isotopes can be extracted from teeth to tell of diet and migration. Therefore, it is important to understand the process of tooth formation and how this may vary not only by tooth, but also by population. Chapter IV will address issues of methods and materials used in this study.

CHAPTER IV

MATERIALS AND METHODS

As noted by many scholars (Danforth et al. 1993; Skinner and Goodman 1992; Wright and White 1995) methods for assessing enamel hypoplasias are controversial and highly varied. Since patterns of tooth formation can vary by population, it is important to consider factors such as when the enamel mineralization is finished and tooth formation complete. Additionally, attrition from mastication can result in loss of early enamel defects and incomplete total crown heights (Skinner and Goodman 1992). In an attempt to help pacify these problems this study used standard methods of evaluation and notes cultural modifications and natural changes, such as postmortem breakage to the dentition.

Materials

The permanent anterior detention, in particular the maxillary, right central incisor and mandibular right, canine or their associated antimere, was selected for analysis because of its greater vulnerability to malformations during growth compared to posterior teeth (Goodman and Rose 1990; Goodman and Armelagos 1984a). All Colonial individuals with scorable dentition as well as those with at least half of the maxillary canine root developed (5 years old) were included. This provided a final sample of 325, ranging in age from roughly five to 51+, with a total of 2317 teeth analyzed. Table 2 is the demographics of the final, overall sample based on the parameters set.

Table 2

Sample Demographics and Number of Teeth Analyzed

Subgroupings	Total	Canine	Central Incisor
Male	136	100	96
Female	76	60	60
Subadults	89	70	77
Younger Adults	162	120	115
Older Adults	38	25	29
Sample Total	325	237	241

Enamel Hypoplasia Identification and Description

To assess the presence of enamel hypoplasias, a fingernail was run along the buccal surface to detect any type of depression. In certain instances the fingernail test was inconclusive, and a Silly Putty impression was used to better visualize the defect. The inspection of the lesion was conducted under normal light with no maginifcation.

For this study, the multiple methods were combined to get the most descriptive assessment of those enamel deficiencies identifed. Buikstra and Ubelaker (1994) supply eight standard categories for defining enamel hypoplasias (labeled 0-7): 0). absence, 1) linear horizontal grooves, 2) linear vertical grooves, 3) linear horizontal pits, 4) nonlinear arrays of pits, 5) single pits, 6) discrete boundary opacity, and 7) diffused boundary opacity. The Federation Dentaire International for Developmental Defect of Enamel (FDIDDE) (FDI 1982) provides a technique for scoring enamel that includes four of the eight provided by Buikstra and Ubelaker (1994). Yet, FDIDDE includes one other data category that was needed for this analysis: areas of missing enamel, which was considered post-mortem damage. Thus, an eight point scale based on the two systems was used for this study.

The location was then identified, and the distance from the CEJ to the middle of the defect measured in millimeters with a thin pointed sliding caliper. Crown height (distance from CEJ to occlusal cusp) was previously recorded by Jacobi (1996) and Danforth (1989) using a sliding caliper to the nearest millimeter. Using ages at complete crown formation and formulas for deriving the numerical age suggested by Goodman and colleagues (1980), age at formation of the lesions were calculated.

Defect severity was assessed using a three point scale— mild, moderate, and severe— which was based on width and depth of the defects (King et al. 2002). Mild is defined as a shallow defect that barely caught the fingernail; a moderate lesion would catch the fingernail and the nail fit fully inside the defect; and severe defects created wiggle room for the fingernail and were visually distinctive from the mild episodes.

Patterns of frequency and severity were analyzed by sex; by age groupings of subadults (5-17 years), younger adults (18-35 years), and older adults (36-51+ years); and tooth type. Data was collected based upon the tooth count method instead of the individual count. This helps to avoid biases created by poor preservation which plagues the Maya region. Instead of the individual as a basic unit of analysis, the tooth is the basis of analysis such that all frequencies are calculated out of the total number of teeth available (Cucina 2010). This method allows for the manipulations of different sample sizes within each group for each variable and is useful when individuals are only represented by a few teeth. Allowing for individuals with few or no teeth to not be under-represented and those with all possible teeth not over counted. Hypoplasia patterns were then compared with patterns of other health markers present in the population and also compared with hypoplasia patter seen at other Colonial sites. Statistical analysis was performed when possible. Using the program, SPSS, descriptive statistics, Independent t-test, a comparison of means, and chi-square determinations for contingency tables were calculated.

CHAPTER V

RESULTS

This chapter discusses the outcome of data analysis. Results are reported by single tooth frequencies, mean number of defects, multiple defect frequencies, age at formation and the severity rates within the population. Then differences in hypoplasia patterns between males and females, as well as between juveniles and adults, are compared. This will reveal whether cultural factors such as gender roles, migration limitations, or differential access to food, along with biological aspects such as genetic buffers and biological damage, had an effect on the amelogenesis of anterior teeth. By comparing these segments of the population to each other, a better understanding of intra-population differences can be concluded. Last, inter-site comparisons are made with precontact times and other Colonial towns to assess how the residents of Tipu coped on the Spanish frontier.

Frequencies of Hypoplasias

Single Tooth Frequencies

A total of 325 individuals were available for analysis based upon the parameters set in Chapter V, consisting of all persons with scorable dentition as well as those with at least half of the maxillary canine root developed. The results reported are calculated by individual tooth, either the mandibular right canine or maxillary right central incisor (or associated antimere). Of the 325, only 237 (73%) of individuals had scorable canines and 241 (74%) had scorable central incisors. Overall, 207/237 or 87% of canines displayed at least one defect with 30/237 or 13% of canines not have any episodes. Likewise, 191/241 or 79% of central incisors showed lesions, and 50/241 or 21% did not have any hypoplasias. Table 3 shows the distributions of episodes by age and sex for the mandibular canine.

Table 3

Frequency and Percentage of Canines Affected with Hypoplasias by Subgrouping

Subgrouping	Number of Canines Affected	Number of Canines Not Affected	Total	% of Canines Affected
Male	86	14	100	86.0%
Female	54	6	60	90.0%
Subadults	65	5	70	92.8%
Younger Adults	108	12	120	90.0%
Older Adults	17	8	25	68.0%
All Individuals	207	30	237	87.3%

In order to investigate changes in health during the lifespan and the prevalence of biological damage, the younger portion of the sample was compared to the older individuals. The younger adult (18-35 years old) subgroup had a significantly (X^2(1, N = 325) = 8.03, p = 0.01) higher percentage of affected canines, 108/120 or 90%, than the older adults of the sample with the lowest rate at 17/25 or 68% displaying lesions. To see if gender roles, migration limitations, or biological differences adversely effected health of males and females, a comparison of the sexes was conducted. Males had more defects on the canine with 86% or 86/100 canines showing lesions, but overall were less affected compared to females who had 90% or 54/60 canines scored with lesions.

Table 4 showcases the same data, but for the central incisors. An almost identical pattern by age and sex to that seen in canines was found in the central incisors. Subadults had the highest frequency at 84.4% (65/77) of teeth affected and the younger adults had 78.3% (90/115) of individual incisors with hypoplasias. Again, males had a higher percentage of affected incisors, with 80% or 77/96 showing episodes as compared to females, who had only 75% or 45 of 60 incisors with lesions.

Table 4

Frequency and Percentage of Central Incisors Affected with Hypoplasias by Subgrouping

Subgrouping	Number of Central Incisors Affected	Number of Central Incisors Not Affected	Total	% of Central Incisors Affected
Male	77	19	96	80.0%
Female	45	15	60	75.0%
Subadults	65	12	77	84.4%
Younger Adults	90	25	115	78.3%
Older Adults	22	7	29	75.8%
All Individuals	191	50	241	79.3%

Average Number of Defects by Tooth

The mean number of hypoplasias per individual tooth was calculated. Figures 5, 6, and 7 display the average number of lesions per tooth by sex, age, and individual tooth. Males had a higher mean number of defects with 1.93 insults per canine compared to females at 1.78 episodes per canine. Yet, on the central incisor, the females had essentially the same average number of lesions as males. Again, the younger portions of the population were more highly affected with both the subadult and young adult averaging 2.02 hypoplastic events per canines. For the central incisor, though, the subadult subgroup portion had the highest mean of 1.81 lesions per tooth.

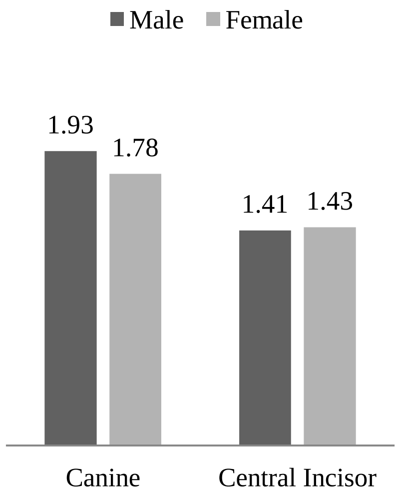

Figure 5. Number of Defects per Individual Tooth by Sex.

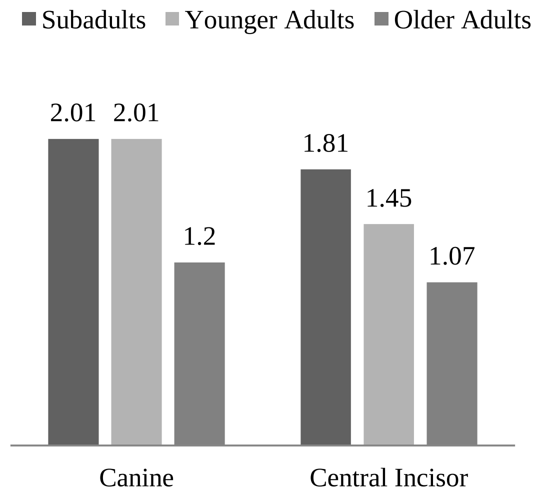

Figure 6. Number of Defects per Individual Tooth by Age.

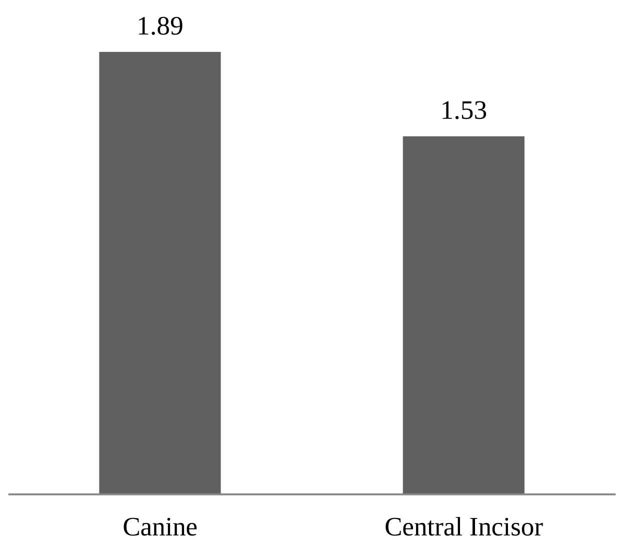

Figure 7. Mean Number of Defects per Tooth by Type.

Multiple Defect Frequencies

The frequency of individual teeth that have more than one enamel defect was also calculated. In most cases, the teeth had at least two hypoplasias but rarely did a tooth show five or more lesions. As seen Figures 8 and 9, male canines had the same percentage of teeth in both categories of *one defect* and *at least two episodes* as did the female canine. The analogous frequencies suggest similar childhood experiences from three to six years old. The central incisors, however, show different peak patterns between the sexes with females' highest in the *at least two lesions* group (12%) and males in the *one defect* group (14%), which indicates more periods of stress for girls from *in utero* to around three years old. Figures 10 and 11 display data concerning the differences in the presence of multiple defects by age groups. The younger adult portion of the sample was also the most likely to experience more than one episode of stress during both canine and central incisor formation. Younger adults peaked in *at least two defects* group whereas subadults and older adults were more likely to have only one defect even though the subadult group was the only one with a tooth in *at least five or more defects* group. Interestingly, though, the central incisor is more likely to have five or more defects than is the canine.

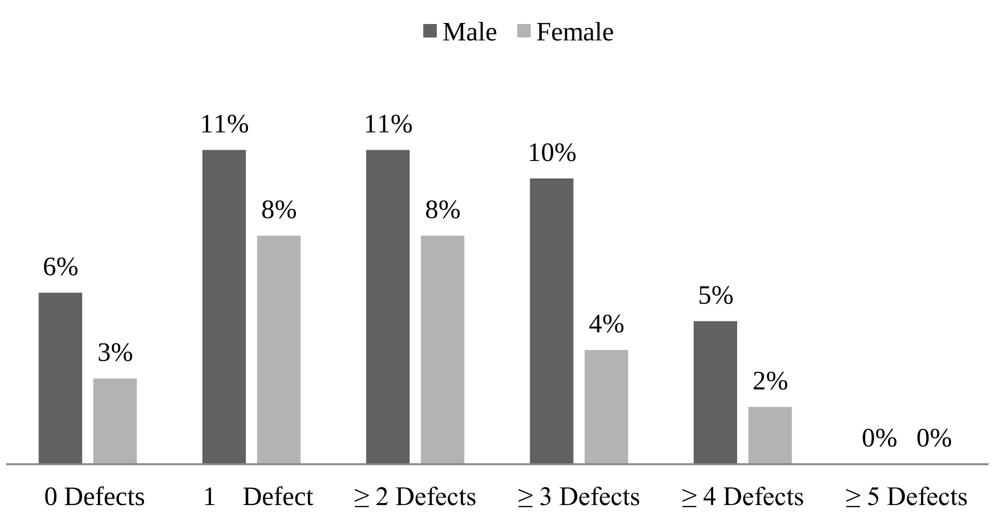

Figure 8. Frequency of Multiple Defects on the Canine by Sex.

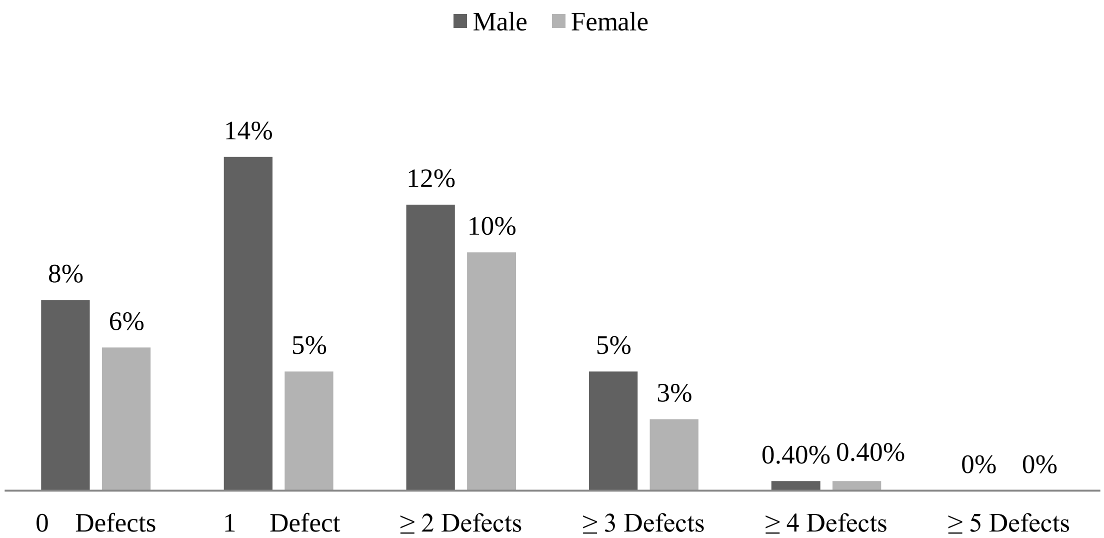

Figure 9. Frequency of Multiple Defects on the Central Incisor by Sex.

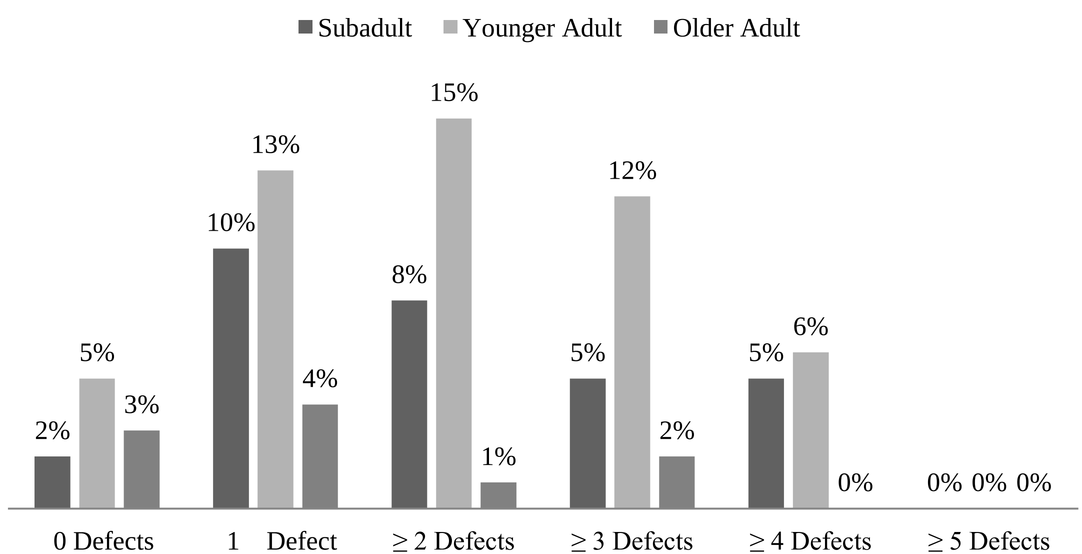

Figure 10. Frequency of Multiple Defects on the Canine by Age.

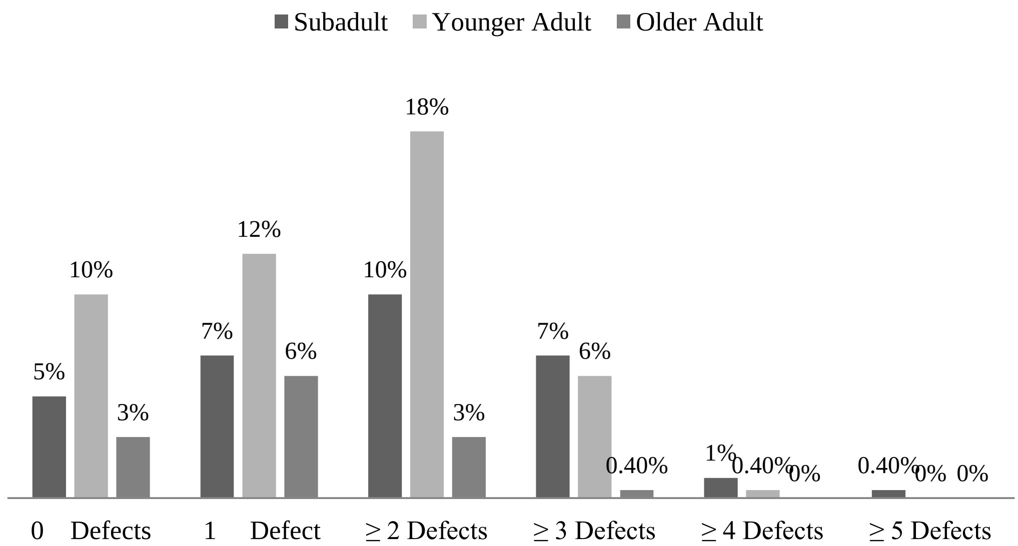

Figure 11. Frequency of Multiple Defects on the Central Incisor by Age.

Age at Formation

Age at formation was determined using the method most commonly used in bioarchaeology, which was introduced by Goodman and colleagues (1980). Overall the canine had a peak age range in hypoplasia formation from three to four and a half years old as indicated in Table 5. The mean age of occurrence of three and a half years old was found for all of the age groups and both sexes, except for older adults, which peaked at four years old. For the central incisor, the most stressful time was between the ages of two and three as shown in Figure 12. For the individual tooth was two and a half years old. This trend is found in all age and sex categories as well.

Table 5

Peak Age at Formation by Subgrouping

Subgrouping	Central Incisor	Canine
Male	2.50	3.50
Female	2.50	3.50
Subadults	2.50	3.50
Younger Adults	2.50	3.50
Older Adults	2.50	4.00
Individual Tooth	2 to 3	3 to 4.5

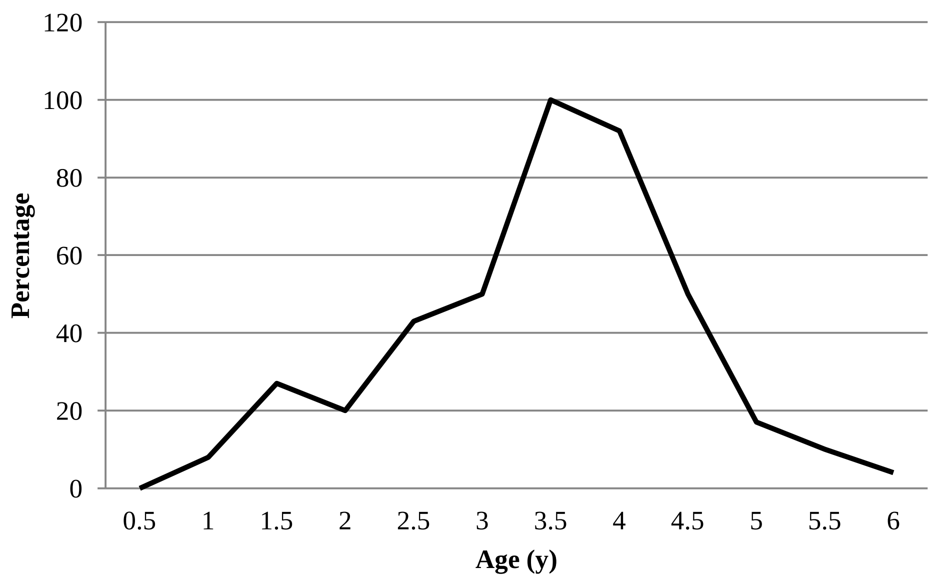

Figure 12. Hypoplasia Age at Formation for the Entire Population Based on the Canine.

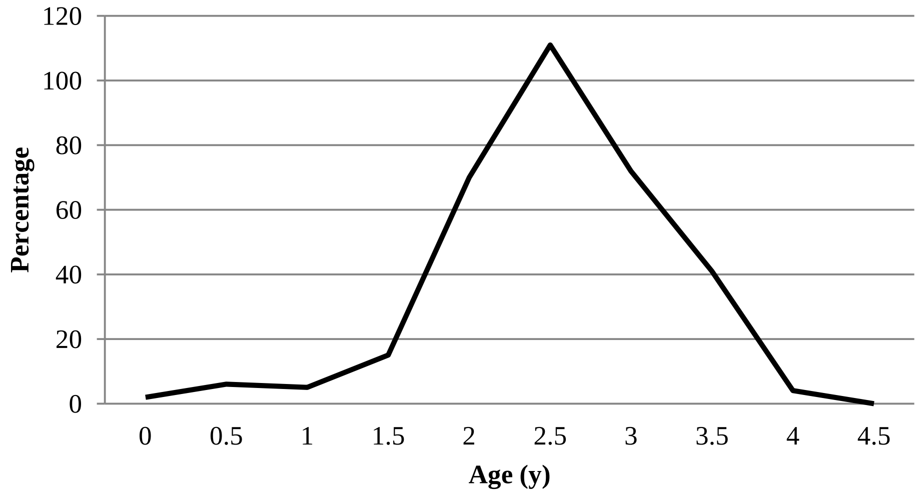

Figure 13. Hypoplasia Age at Formation for the Entire Population Based on the Central Incisors.

Severity

Frequency of the three severity levels scored were determined by using the overall number of defects found from all anterior teeth, and not by the individual canine or central incisor. Overall, 91.33% or 2621/2870 were mild, 8.32% or 239/2870 were moderate, and only 0.35% or 10/2870 were severe (Fig. 6.8). There were only four individuals with severe hypoplasias in the sample: MT 272, a young adult male; MT 169, a young adult female; MT 222, a juvenile; and MT 27, an individual of unknown age and sex; thus no pattern by age or sex can be determined. Figure 14 illustrates the total number of episodes in each of the three severity levels by sex and age. In regards to the severe lesions only, males had more such episodes than did females, and the younger portion of the sample, especially the younger adults, had more cases of severe defects compared to the older portion of the sample.

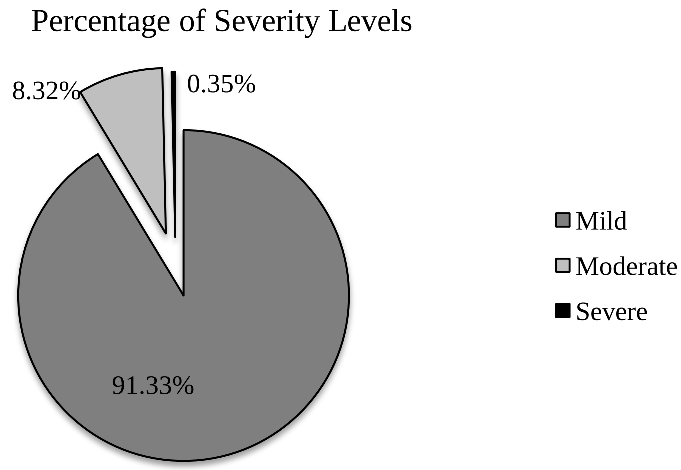

Figure 14. Distribution of Defects by Severity Level for Entire Population.

Table 6

Total Number of Defects and Percentage in Each Severity Level by Subgrouping

Subgrouping	Number Mild	Number Moderate	Number Severe	Total
Male	945 (91%)	91 (9%)	4 (0.38%)	1040
Female	600 (90%)	61 (9%)	3 (0.45%)	664
Subadults	1057 (94%)	63 (6%)	2 (0.17%)	1122
Younger Adults	1144 (89%)	133 (10%)	6 (0.47%)	1283
Older Adults	228 (92%)	20 (8%)	1 (0.4%)	249

For most of the defect characteristics analyzed, the male portion and the younger adult portion of the population were overall more frequently affected than were females and the older portion. Possible reasons for the distributions of the episodes in this manner are reviewed in the next section.

Intersite Comparisons

In order to make comparisons with findings seen in many previous studies on enamel hypoplasia in Maya populations, data had to be recalculated based on the total number of hypoplasias per individual. Thus, the number if episodes seen on all of the anterior teeth present were added together. Data had to be reported this way in order to put into perspective how the mortuary sample from Tipu relates to the other precontact sites in terms of childhood health. However, calculating frequencies of episodes per individual does not take into account variation in the number of teeth present. Some may have only a few teeth while others may be missing all anterior teeth, either post- or ante-mortem, and still others may have all teeth present. Hence it is better to discuss health patterns inferred from enamel defects in terms of a single tooth or two teeth that develop around the same time. The single tooth method allows for a more accurate understanding of discrete periods of stress during a certain window of childhood and does not over estimate the mean number of episodes unlike when the full dentition is used. However, it is not possible to use the data calculated this way at Tipu in any precontact site comparisons.

As displayed in Table 7, of the 325 individuals at Tipu, only 14 or 4.3% of the sample did not have at least one lesion on any tooth. Therefore, 95.6% or 311/325 inhabitants had hypoplasias. Males had a greater number of individuals affected at 40% or 130/325 and only 6/325 not affected or 1.8% of males, compared to the females with 23% or 75/325 of inhabitants with a least one episode and only 1/325 or 3% without any. Yet, females had a higher overall mean at 8.57 hypoplasias per individual than males, who had 7.73 defects per person. As seen in the single tooth data, the younger portion of the population is more highly affected than the older portion, and this holds true for the overall sample statistics. Subadults had a mean of 12.64 lesions and younger adults averaged 7.93 per individual, as compared to the older adults with an overall average of

6.55 per person. Again, the overall percentage of affected individuals is lower in the older adults at 11% or 37/325 exhibiting stress, compared to 48% or 155/325 of younger adults and 88/325 or 27% of subadults with at least one stressful growth disruption.

Table 7

Number of Individuals from the Overall Sample with Hypoplasias and Without Hypoplasias

Subgroupings	Total Number of Individuals Affected	Total Number of Individuals Not Affected	Percent of Total Population Affected	Overall Mean Number of Defects
Male	130	6	40%	7.73
Female	75	1	23%	8.57
Subadults	88	1	27%	12.64
Younger Adults	155	7	48%	7.93
Older Adults	37	1	11%	6.55
All Individuals	311	14	95%	8.85

Hypoplasia Patterns at Precontact Sites

Since data for the precontact period are variable in what is reported and sample size, large over-arching comparisons are displayed in Table 8. It seems that the Colonial period individuals experienced more childhood stress than those living in precontact times. Most sites have lower frequencies of defects than Tipu. By sex, precontact males had similar overall frequencies during all previous cultural periods and across sites. It is the female portion of the sample that varied the most. Preclassic women at Cuello had lower occurrence rates than Tipu women, but women living during the Classic period at Colha had more episodes of stress, possibly from gender constraints, compared to Colonial women. Yet, during the Late Classic no significant differences by sex in enamel hypoplasias frequencies on both the upper central incisors and lower canines were found (Storey 1998).

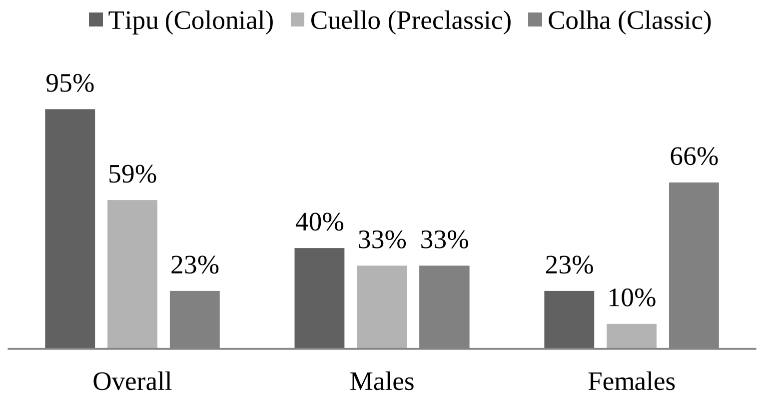

Figure 15. Overall Rates of Hypoplasias during Precontact Periods in Comparison to Tipu.

Many researchers attempted to calculate the age at defect formation (Saul 1972, 1973, 1982; Saul and Hammond 1973; Storey 1992, 1997; White 1997; Whittington 1992; Wright 1990, 1997a). Most studies found that defects manifest most intensely during the ages of three to four years old during all precontact periods. This is close to the age of occurrence for the canine in the Tipu sample which peaked from ages three and a half to four years old. Contrary to Whittington's (1992) etiology of weanling stress comprising homeostasis, no one reason for higher frequencies during this age was postulated for Tipu since one true etiology defects in crown amelogenesis has been documented.

Hypoplasia Patterns at Postcontact Sites

One of the most relevant comparisons is between the indigenous samples of the study from Colonial town of Campeche (Cucina 2010). Cucina (2010) divides the data by individual tooth, allowing for an apple to apple comparison to Tipu. The sample sizes are highly disparate, however, with only 21 maxillary central incisors and 17 mandibular canines from 43 individuals in the Campeche sample, and 241 upper central incisors and 237 lower canines representing Tipu. Overall, the residents of Campeche had a higher mean number of defects and therefore experienced more episodes of non-physiological stress than did the inhabitants of Tipu as shown in Tables 8 and 9.

Table 8

Rates of Maxillary Central Incisor Hypoplasia Frequencies for Campeche and Tipu

Subgroupings	Campeche Central Incisors	Tipu Central Incisors
N	21	241
Mean	2.52	1.93
Standard Deviation	1.50	1.09
Percent Affected	90.9%	79.3%

Table 9

Rates of Mandibular Canine Hypoplasia Frequencies for Campeche and Tipu

Subgroupings	Campeche Canines	Tipu Canines
N	17	237
Mean	2.94	1.41
Standard Deviation	2.01	1.21
Percent Affected	0.0%	87.3%

General health patterns for the inhabitants of Lamanai were determined using microscopic and macroscopic enamel defects. White and colleagues (1994) investigated Wilson Bands in 15 (seven males and eight females) out of 179 Colonial individuals. An average of 1.8 lesions per canine was calculated from a total of 43 identified Wilson bands on 23 teeth. Though a one to one relationship between microscopic and macroscopic enamel defects is unclear, the co-occurrence is documented (Danforth 1989; Wright 1990). This is very close to the mean number of macro-defects on canines from Tipu with 1.89 suggesting similar health experiences in childhood during the Colonial period. Interestingly, the average age at formation determined from Wilson bands was two to three and a half years old (Wright 1990). This is close to Tipu's mean age of occurrence of two to three years old which was determined based on the central incisors. The most comparable data reported by Wright (1990) was the number of macroscopic hypoplasias in the three respective severity categories as shown in Table 10. Even though the sample from Lamanai had a slightly lower percentage of mild/shallow defects, it also had almost 15 more times the rates of severe/acute defects than did the Tipuans. This may be indicative of greater or chronic stress for those individuals at Lamanai.

Table 10

Comparisons of Hypoplasia Severity Levels at Lamanai and Tipu

Severity Level	Percent of Total from Lamanai	Percent of Total from Tipu
Mild/Shallow	87%	91%
Moderate/Modal	8%	8%
Severe/Acute	6%	0.35%

Discussion

Even though the population from Tipu exhibited a high frequency of defects, the mild nature of their severity level and the low occurrence of multiple episodes indicate good health of these individuals. Low incidences of other pathological markers of stress, such as porotic hyperostosis and periosteal lesions, support the claim that Tipuans lived relatively healthy lives (Cohen et al. 1994a). This becomes especially evident when frequencies of growth disruptions at Tipu are compared to other Colonial samples. Unfortunately though, since there are multiple etiologies for hypoplasias other interpretations must be considered.

The Osteological Paradox creates a contradictory interpretation of the data collected from the skeletal manifestation of health and disease. Was the population truly healthy, with few to no defects on the bones or teeth, or did they die before lesions could manifest these tissues (Cohen et al. 1994b; Wood et al. 1992)? One central aspect of looking at childhood growth disruptions, specifically through enamel hypoplasias, is that teeth do not remodel with age. Thus, hypoplasias can paint a more accurate picture of childhood health than can bones lesions since they remain with the person in life and death. Considering that the entire sample lived through infancy, each individual survived long enough for stressors to affect the amelogenesis of their permanent, anterior dentition. Enamel defects are not a chronic disturbance, but rather manifest during a limited period of life and are a permanent record of stressful events during childhood. Therefore, they are not directly related to morbidity or mortality, but are the result of the general upset of homeostasis of the body. Hypoplasias are a small loop hole in this osteological paradox, because the manifestation of stress can develop very early in life appearing in all age groups and cannot be made up for in later years with good health.

Based on the work of Selye (1956), the model for stress developed by Goodman and colleagues (1984) was used to outline three factors in Figure 2, each having a unique expression on the effect homeostasis of the body. The first factor to consider is the environment. The Lowland areas of the Maya region are characterized by thick jungles cut by high mountain ranges surrounded by pine forest. The acidity of the soil is not well suited for growing large amounts of crops. Therefore, wild food sources were commonly exploited (Lange 1971; McKillop 2004) to help maintain a nutritionally balanced diet. In addition, the tropical atmosphere of the rain forest creates conditions for diseases such as malaria, dengue fever, and yaws, as well as an increased frequency of parasites. The Caribbean coast of the Maya region is a prime location for hurricane landfall, which could devastate crops and damage towns. Last, the marked dry and rainy seasons of the rain forest may result in periods of extended drought or flooding. Hence, the environmental setting for Tipu could have caused physiological stress on the population.

A second factor to acknowledge is culture ways that can either buffer or induce stress. Even though the location of Tipu was not the most amicable, cultural practices could have included protective measures against climatic problems. Considering Tipu was a mission town, kinship networks of the inhabitants could have remained intact and people from the north that migrated south would have done so in family units (Graham et al. 1989). Additionally, its location on the frontier of Spanish territory allowed for trade with multiple sources. Spanish trade from the northern coast of the Yucatán and southward gave Tipuans access to Spanish goods and food, along with the continued availability of coastal items. Trade with the Itzá Maya to the south and west allowed Tipu's residents have extended access to other precontact resources, as well as continued trade of cacao, an exotic, elite item (Jones 1989).

In the final factor of the model, host resistance, affects the degree of stress in an individual. People with a comprised level of health, either from malnutrition, disease, or biological damage would have experienced higher amounts of stress than those of the contrary. The Barker Hypothesis (Armelagos et al. 2009) asserts that people who have increased stress early in life will be negatively affected in their health later in adulthood and hence are biologically damaged. Studies have shown that those individuals who died at younger ages tend to have a marked increase in the amount of hypoplasias (Cook and Buikstra 1979; White 1978). Thus, individual differences to resistance of stress are the effect of neonatal and childhood health, and hence vary by age and individual.

When environmental constraints and host resistance are held constant, persistent stress in the population could be the result of intra-population cultural divisions (Cohen and Armelagos 1984). With the cultural advantages that Tipuans had, there are many other factors that could have resulted in a marked difference in frequency within one of the sexes or age groups, such as genetic buffers (Stinson 1985), descent patterns (Storey 1998), gender role limitations (Graham et al. 1989; Storey 1998), differential access to food (Danforth 1999), and biological damage (Armelagos et al. 2009). All of these aspects of society can create diversity in the amount of stress experienced in each group.

Strikingly, though, there were no marked differences in defect frequency between males and females. Typically, culture helps to create intra-population variation (Cohen and Armelagos 1984) because of the many cultural and biological factors that influence both health and diet. Thus, it would not have been surprising to find incident variation between males and females. Extensive literature has documented health difference by sex in many populations including current and past Maya groups (see Stinson 1985:123). Contrasting health profiles are attributed to female genetic buffering, possibly needed to support pregnancy and lactation, along with the biological effects of sexual dimorphism

(Guatelli-Steinburg and Lukacs 1999; Stinson 1985; Storey 1998). Family formation, child rearing and care, and descent patterns can also lead to a preference between the sexes (Storey 1998).

The patrilineal nature of the Maya would most likely have led to a male preference in the society, creating a better childhood for boys as they experienced fewer stressors (Herndon 1994). Division of resources, in particular food, has been shown as a cross-culturally phenomenon. Women and children do not get the same amount or quality of food as men and older adults. Also, boys tend to have later weaning periods and more frequently receive medical care (Danforth 1999; Goodman and Armelagos 1985a). The sample from Tipu follows other studies (see Guatelli-Steinburg and Lukacs 1999; 81; Larsen 1994; Storey 1998) with no significant difference in mean number of overall defects frequencies for both teeth by sex. There was possibly no differential access to food, or male favoritism at Tipu. Yet, the symmetry of health profiles of the sexes can be attributed to the continual access to resources from two economic spheres. Additionally, female genetic buffering could have aided in the adaptation to the possible changes in women's roles and forced migration. Yet, there was no evidence of differences in cultural treatment by gender of Tipuans. However, there is an unusually high number of young adult males in the cemetery at Tipu. One explanation may be that forced migration from the *reducción* system through the unfavorable environment could have made travel for women and children particularly difficult because of child care. Thus, most of the refugees would have been men.

As expected there was diversity in the occurrence of lesions between the younger and older portions of the population. The younger adults (18-35 years old) class had significantly higher occurrences of episodes than older adults. Biological damage accrued during the neonatal and early childhood periods could have resulted in more individuals dying at younger ages. The population pattern of enamel hypoplasias supports the Barker hypothesis (Armelagos et al. 2009) since younger adults with the greatest mean number of defects and consistently the highest frequencies of lesions of all age classes.

In comparison to most precontact Maya sites, the residents of Tipu experienced more frequent, stressful periods since they had a higher average number of defects. Therefore, it can be speculated that Spanish contact did negatively change lifeways correlating to health and diet. In contrast to these of other Colonial towns, though, the mortuary sample from Tipu had a lower occurrence of severe lesions, with most lesions being very slight in severity. The frequency of enamel defects correlated with mild frequencies of Tipu other stress indicators, concluding that the mortuary sample from the site was a relatively healthy population.

The difference in the health profiles of Lamanai and Campeche compared to that of Tipu could be related to the degree of intensity of Spanish contact and control. The site of Tipu was on the frontier, farther away from the Spanish center of control at Bacalar than Lamanai and Campeche. This allowed Tipu to have more stable subsistence patterns, continued trade networks with the Itzá, limited Spanish control of everyday affairs, little warfare and sustained kinship networks. Jones (1989) commented on the co-occurrence of events at Tipu with the Chilam Balam and *katun* cycles. One such instance in 1697, during *Katun 8 Ahau,* is when the Spanish overcame a submissive Itzá Maya, and then interest in Tipu waned. This lack of control could have resulted in less stress and a relatively lower mortality rate compared to other Colonial sites (Graham 1991; Larsen 1994).

Marked differences in Spanish control meant variation in the amount of trade and with whom each town traded. The more heavily controlled towns in the north, such as Campeche, and towns closer to Bacalar, such as Lamanai, could have had trade that was highly regulated by the Spanish. Perhaps these two towns received little to no inland luxury items and other food resources from the Itzá Maya to the south. Also, extensive Spanish presence at these towns could have disrupted typical Maya food distribution. Tipu's location on the frontier, along with its times of limited Spanish control, could have continued an extended trade system with the Itzá Maya allowing better access to additional food resources and elite trade items.

Constant and direct Spanish control of these two towns afforded a different ways of life for the inhabitants. It is possible that the residents of Tipu can be considered a 'mission population' or one as a result of Spanish conquest and reorganization. Considering the mortuary sample from Tipu is from the cemetery surrounding and under a catholic *visita* mission church, all persons buried there were individuals from the *reducción* system and of the Christian faith, as interpreted from the mortuary program. Those inhabitants who were not a part of this religious program would not have been buried in the cemetery or in a Christian manner. Inhabitants of mission populations could have been more protected and experienced less conflict than those who were not residing in mission villages but in towns of which the Spanish were trying to overthrow the current Maya rule and gain control.

Since Tipu was a *reducción* community, many Maya immigrated to the town and not from it, and the kinship relations of its residents could have remained intact. Graham (1991) argues that at Tipu "extended family networks so necessary to childrearing and to maintaining one's diet and health would not have been as severely disrupted; husbands would not have had to flee from Spanish tribute collectors, women would not have had to raise children on their own, mothers would not have lacked sufficient breast mild for their babies" Graham (1991:333). Thus, the continued family support allowed adequate child rearing.

Migration limitations from gender roles also could have skewed the population demographics, resulting in the larger numbers of younger adults and males, they consistently displaying more growth disruptions. It is important to remember that contact patterns in this period are variable, so it is hard to make broad statements about the Colonial experience. Each town was able to negotiate with the Spanish to differing degrees, which created varying experiences in each town and thus, had varying levels of acute and chronic stress.

CHAPTER VI

CONCLUSIONS

The purpose of this study was to evaluate the effects of contact in a Colonial Maya population. Tipu is particularly important because of its strategic location on the periphery of Spanish controlled lands. Explicit use of current standard methods presents data in a different fashion from those seen in most past Maya hypoplasia research and hence, created stark differences in hypoplasia frequency compared to the other sites. Since data were analyzed by individual tooth class, and not by the overall hypoplasia rate by individual, incident frequencies may seem high, but the 91% of defects of mild severity is reflective of short periods of limited stress. Additionally, results followed expected patterns with the younger portion of the population displaying higher frequencies of lesions than the older individuals; and like many other sites, males had a slightly greater number of incidences than females. Constant cultural changes during the Colonial period would have undoubtedly created stress for the population, but the degree of stress needs to also be considered when interpreting overall fitness Tipuans apparently had many cultural buffers, as well as cultural continuity from the precontact period in trade and kinship networks, along with sustained subsistence patterns which allow for very mild manifestations of growth disruptions.

From a methodological standpoint, one of the most important contributions of this study was the division of data by the tooth count method. It allows for those with few or no teeth to be accurately included in the population and those with all teeth present to be not over represented. It also creates a more accurate estimate of age at formation since it is derived from the occurrence of defects on one tooth, creating a tighter interval of ages.

Yet, considering the peak ages are very similar to older studies that used the whole dentition scored, the method used should be questioned for precision not only within Maya populations but also cross-culturally. This is why more research is needed in this area of the study.

The larger size of the sample illustrates a more accurate picture of childhood health than data generated from small sample sizes. It provides information about health and death on the fringes of Spanish controlled lands. Limited, indirect control, continued kinships, and support from trade with other groups helped to create a rich environment for people to live with little life stressors. It unveils more variability in the Colonial experience, and when compared to other New World contact population, a better picture of Colonialism can be made. Most importantly, this sample is representative of a healthy population and successful adaptation, despite notable culture conquest and change.

The large size of this population lends itself to more extensive future research and allows for many statistically analysis to be conducted. Therefore, an in-depth comparison of current methods for determining age at formation should be undertaken. Last, considering this is baseline data for indigenous Mesoamerican populations, it can be compared to other New and Old World contact populations to understand the variation in methods of negotiating and coping with Colonialism and conquest. The Colonial Maya residing at the *visita* mission town of Tipu during the 16th and 17th centuries were evidently successful at this adaptation.

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