TRANSVERSE (HARRIS) LINES IN THE TIBIAE OF A PREHISTORIC COSTA RICAN POPULATION

A Thesis

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ABSTRACT

Transverse (Harris) lines are lines of opacity that extend across the medullary cavity in long bones; they are sometimes are also found in irregular bones. Predominantly, Harris lines are seen in radiographs of the tibiae. Many scholars believe that these lines of opacity are caused by nutritional interruptions during growth, while others believe these lines to be indicators of stress recovery, rather than interruption. This study examines the incidence of transverse lines in a Pre-Columbian Costa Rican population, called Vidor, located on the northwest Bay of Culebra. The burials of this population, originally excavated in 1977, contained more than 40 skeletons. Subsequent excavations at the site revealed a total of 192 individuals, most of which were juveniles and neonates and dated as far back as A.D. 300.

Tibiae and ilia from 39 individuals of the Vidor population were radiographed in order to determine if any transverse lines were present and, if so, what the implications of nutritional status might be. The results showed that none of the ilia revealed any transverse lines in the x-rays and only seven of the tibiae exhibited opacities. Two of the seven tibiae exhibiting transverse lines contained multiple lines. A study conducted on the Vidor population by Obando (1995) included analysis of enamel hypoplasias and cortical bone thickness. The study showed that there were high frequencies of enamel hypoplasias and a loss of cortical bone starting as early as 1.0 years of age and lasting until six years of age, coinciding with weaning ages. Obando's study concluded that there were some nutritional deficiencies occurring in the Vidor population. The current study on transverse lines did not produce the same results. This study showed that, while there were some bands of opacity occurring in the tibiae, they could not be directly attributed to a dietary response.

CHAPTER ONE: INTRODUCTION

H.A. Harris, who conducted research on rickets in adolescent children, first studied transverse lines in the radiographs of long bones in 1923. Research on transverse lines had been conducted on rabbits and chickens in France as early as 1874 (Harris 1931: 561). Harris attributed the cause of these lines in the long bones to arrested growth resulting from malnutrition or disease. A century later, Harris lines, as they are commonly referred to now, are associated with several diseases and nutritional deficiencies. However, current research attributes transverse lines to the acceleration of appositional bone growth rather than cessation of said growth (Goodman et al. 1984; Hummert and Van Gerven 1985; Magennis 1990).

In 1977, an excavation began in the northwest region of Costa Rica on the Bay of Culebra at a site called Vidor. This excavation revealed a burial of at least 40 individuals, mostly juvenile. Continued excavation some years later revealed a total of 192 individuals, most of whom were juveniles, including neonates, buried in varying positions. Some of the infants were buried in urns; some urns had more than one individual; and some of these urns were inverted.

Many researchers (Acton and Frankel 1977; Kerbis 1980; Lange 1978; Norr 1996; Obando 1995) have conducted studies on the human remains from this site. These studies include stable isotope analysis, enamel hypoplasias, cortical bone thickness, and archaeological studies such as ceramic and faunal analysis. The collection, housed at the Museo Nacional de Costa Rica, is in excellent condition, providing an excellent opportunity for analyzing this population of prehistoric Costa Ricans.

The current study on transverse lines focuses on the evidence of radiopaque lines transecting the medullary cavity of the tibiae and ilia. X-rays, or radiographs, were taken of selected individuals to determine if there was an association between the frequency of Harris lines and the presence of other health status markers noted in previous nutritional studies conducted on these remains. The initial assessment of the skeletal collection from Vidor revealed that both the ilia and tibiae of these juveniles were in excellent condition. Therefore, an attempt was made to locate transverse lines in the ilia as well as the tibiae in order to conduct a more thorough study on transverse lines in both long bones and irregular bones.

This thesis contains archaeological background on the Vidor site such as social order and dietary analysis. Information dealing with literature on transverse lines, past studies as well as present studies, is included in order to gain some understanding of the development of new theories of the origin of these lines. Understanding the process by which bone grows and remodels is discussed in the literature section in some detail. The material in the remaining chapters discusses the collected data and results and includes tables and results arrived at with this study.

A comparative section is included in the discussion, which is necessary to understanding the importance of the transverse line results and their implications when discussing nutrition and bone growth. A previous study conducted by Obando (1995) included the same population from Vidor and has relevance to the present study. Obando’s study focused on enamel hypoplasias, which are bands of enamel that reveal growth interruptions, and cortical bone thickness. Obando attributed both of these growth anomalies to nutritional deficiencies in this population of pre-Columbian Costa Ricans.

The discussion integrates the information obtained in this study with research previously conducted to give a more well-rounded picture of the overall health and nutritional status of the populations occupying this region of Cost Rica. Final comments include a discussion of the information gathered in this study, an analysis of the results, and the implications of the results on further research in this region.

CHAPTER TWO: ARCHAEOLOGICAL BACKGROUND

The Vidor site lies on the bay of Culebra on the northwest Costa Rican coast (Figure 2.1) and dates as far back as A.D. 300 (Norr 1996: 255). Evidence of at least two periods of prehistoric

Figure 2.1 Map of Costa Rica. Arrow Indicates Vidor Site
Source: Central Intelligence Agency 1987

volcanic activity, resulting in a deposition of volcanic ash, is present in the area of Vidor, and may have caused abandonment of the settlement region at times. There is also evidence that the site may have been periodically flooded, which may have also caused episodic abandonment of the region (Lange 1978: 104).

The two periods referred to in this analysis are the Bagaces Period, which dates from A.D. 300 to A.D. 800, and the Sapoa Period, which dates between A.D. 800 and A.D. 1350. Evidence of occupation of the Vidor site during the Bagaces Period includes adobe fragments, suggesting wattle-and-daub structures (Lange 1978: 107). The evidence collected from the Early Bagaces Period reveals a transition in pottery style from that of the previous Tempisque Period. Stone metates also discovered revealed a diet at least partially composed of maize (Lange 1978: 109).

Lithic accumulations in this area of Costa Rica during the Bagaces Period increase suggesting a population increase over that of the previous Tempisque Period (dating from 500 B.C. - A.D. 300). Trade activity expanded in this region to include the Maya area (Obando 1995:15) and also to South America. "The Bay of Culebra, with it's [*sic*] subdued waters, short cresentic beaches, rocky coves, and alluvial watersheds, represents one of the few safe anchorages along the entire Central American coast; [*sic*] an important characteristic given evidence that there was pre-Columbian contact with South American cultures by sea" (Acton and Frankel 1977: 6).

Subsistence strategies had begun to change in the Late Bagaces Period as trade networks spread into this coastal zone and these changes continued through the Sapoa Period. Hunting continued, but there was a greater reliance on mollusks and offshore fishing (Lange 1978: 109).

Based on isotopic analysis from five individuals from Vidor during the Bagaces Period (A.D. 300 to 800), four adults and one child, Norr (1996) demonstrated that there was greater consumption of foods in the C3 and C4 categories (temperate and tropical plants, respectively) at the beginning of the Bagaces Period (Norr 1996:260). However, at some point during the Bagaces Period there was greater intake of marine life, which is reflected in the stable isotope analysis. This shift in consumption may have been a result of environmental stresses due to volcanic eruptions and flooding (Norr 1996: 264).

Magoon et al. (2001), in a study of the Snow Beach Site, have suggested that isotope analysis based on apatite carbonate is a better reflection of dietary trends, including both carbohydrates and proteins in coastal populations, than collagen-based studies. If the ratio between the 13C of the apatite carbonate groups and the collagen was less than 1-2%, there was a greater reliance on marine life than maize. If the ratio were larger than 7-11%, there would have been a greater reliance on terrestrial life and maize (Magoon et al. 23: 2001). Much like that of Vidor, the Snow Beach Site apatite carbonate study conducted by Magoon et al. showed that there was a variety of subsistence activities in the coastal population. Unfortunately, no apatite carbonate study has been conducted on the remains from Vidor.

Kerbis' (1980:126) faunal analysis of the Vidor site lists the types of terrestrial and marine fauna that were available to the populations in the region of Vidor during various times: rattlesnakes (*Crotalis durissus)*, cotton rats (*Sigmodon hispidus*), spiney pocket mouse (*Liomys salvini),* the anuran (*Rhin dorsalis),* rabbit *(Sylvilagus floridianus),* and armadillo *(Dasypus novemcinctus)*, as well as the white-tailed deer *(Odocoileus virginianus)* and agouti (*Dasyprocta punctata).* Kerbis also recovered remains indicative of an intake of marine life. The remains listed in his research include pelagic fauna, which consisted of 99% tuna, the *Caranx* group and unidentified fish groups. These same animals are representative of today's fauna in that region (Kerbis 1980: 126).

Kerbis' analysis incorporates the end of the Bagaces Period through the Sapoa Period, about AD 800-1200. His reconstruction of the diet showed that the middle of the Bagaces Period showed a large faunal intake with an increase in marine life consumption into the Sapoa Period. There is a 20% increase in the total fish intake from the Bagaces Period to the Sapoa Period (Kerbis 1980: 127). He attributes the variety of food procurement to seasonal availability, environmental effects such as volcanic ash, demographics of increased terrestrial exploitation, and technological invention (Kerbis 1980: 128).

The Vidor site has produced one of the largest burial populations in Pre-Columbian Pacific Coast regions. The preliminary excavations in 1977 revealed a burial of at least 40 individuals, most of which were infants buried in inverted urns. The few adults that were unearthed in this series of excavations were female (Lange 1978: 109). Due to the large number of juvenile and infant burials in this site, some suggest that the cemeteries in this population were segregated by age (Obando 1995: 64).

There were four basic positions in which the burials were oriented. Primary, extended burials were positioned in the same anatomical position as when they were alive, lying on their backs, extended and in proper articulation. Flexed burials were bent at the waist, hips, or knees. Multiple, secondary burials referred to numerous skeletons in one grave, which were disarticulated or incomplete. Finally, urn burials were usually infants and fetuses placed in large mouthed, globular ceramics and then turned upside down (Acton and Frankel 1977: 14).

Some observations were made regarding the urn burials upon excavation. The first observation was that all of the urns were inverted. Four of the urn burials were situated at the four cardinal points of the largest female skeleton (one at the head, two at each lateral position, and one at the feet). Four other urns were in pairs, and additional urns had infant bones in the immediate vicinity, but not in vessels (Acton and Frankel 1977: 14).

The Nacascolo cemetery is located across the Bay of Culebra from Vidor. Nacascolo is located on the northern boundary of the bay (Obando 1995: 67). Like Vidor, Nacascolo was heavily populated during the Bagaces and the Sapoa periods. Although Vidor has better representation of the lifeways of the population, with analysis on ceramics, middens, and fauna, both cemeteries correspond to the same periods (Obando 1995: 68). It is also clear that the sites were occupied during the same time periods and shared the same subsistence patterns (Kerbis 1980:126). The Nacascolo cemetery contained a majority of adults with less than half of the burials belonging to juveniles. The Vidor site had 82.8% belonging to sub-adults while the Nacascolo site had only 43.3% sub-adults (Obando 1995: 69). The difference in the demographics of the two burial populations is not completely understood at this time.

To better understand the health implications of Harris lines in the Vidor population, the following chapter presents an overview of Harris lines as health indicators. This literature review includes a discussion of enamel hypoplasias and cortical bone thickness to help substantiate the nutritional assessments made in this study.

CHAPTER THREE: LITERATURE REVIEW

Harris lines, also known as transverse radiopaque lines, bone scars, natural bone markers, and opaque lines of density, are parallel lines of increased opacity that transect long bones and are visible through x-rays.   These lines are observed across the medullary cavity, commonly in the proximal or distal end of the tibiae and femora (Figure 3.1). Harris lines in the long bones run parallel to the epiphyseal disc (Hummert and Van Gerven 1985: 297).   In some instances, these transverse lines are observed in irregular bones, such as the ilia and ischia. The transverse lines in the irregular bones do not transect the bone but follow the natural contour of the bone (Garn et al. 1968: 58).

H.A. Harris (1931) was one of the first researchers to attribute transverse lines to arrested growth due to nutritional factors. Harris investigated the relationship to severe illness with regard to lines of arrested growth in children. He attributed transverse lines to starvation, acute infection, or metabolic diseases such as diabetes (Harris 1931: 635). Most research since then has determined that transverse lines can be indicative of episodic nutritional deficiencies or abnormalities during growth, while some researchers argue that they are signs of stress recovery rather than stress indicators (Dreizen et al. 1956: 487). Although the findings of previous reports treating transverse lines as nutritional interruptions are not conclusive, most of the research conducted with regard to stress recovery do show lines (Allison et al.1974; Garn et al. 1968; Gindhart 1969; Lee 1968; McHenry and Schultz 1976; Maat 1984.).

Bone grows appositionally, through osteoclastic and osteoblastic activity. Appositional growth allows long bones to enlarge at a constant rate until a “growth spurt” occurs during adolescence. Bone growth stop when all of the cells at the growth plates stops dividing and the centers of ossification fuse together (White 2000:29).

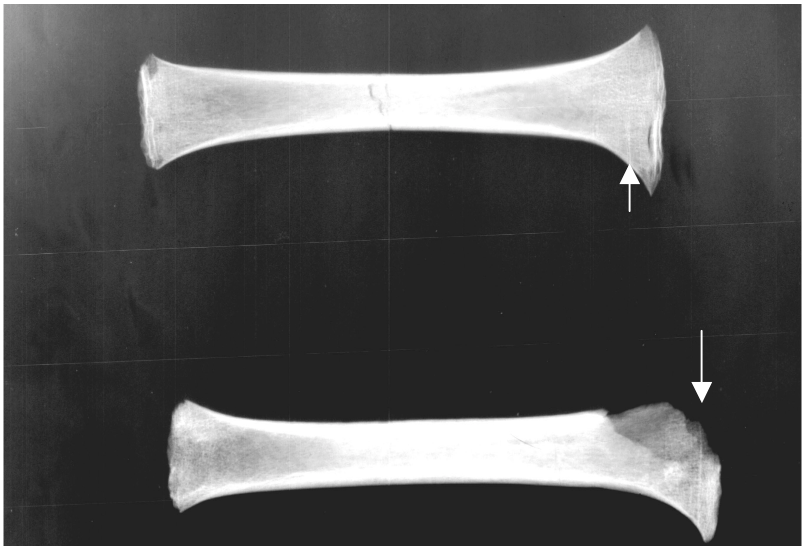

Figure 3.1 Radiograph showing a tibia with a single line and multiple transverse lines in AP view.
Top Tibia Right Side #74-44
Bottom Tibia Right Side #77-97

Epiphyseal growth may be slowed down when there are metabolic interruptions, and this can result in a collagen-matrix buildup that creates transverse lines (Clarke and Gindhart 1981: 574). Once longitudinal bone growth has ceased, osteoblasts and osteoclasts continue to remodel bone so that transverse lines may disappear through absorption.

A study by Clarke and Gindhart (1981: 574) shows that the greatest number of lines in individuals occurs between the ages of one and three. They attribute the presence of lines to the age at which weaning occurs. Weaning deprives the child of nutrients and antibodies from a nursing mother, which leaves the child susceptible to bacterial infections and diarrhea.

Dreizen et al. (1956: 486-487) discussed the significance of puberty on transverse lines and concluded that once puberty has been reached, at approximately age 11, the occurrence of transverse lines decreases significantly. According to Gindhart (1969: 18), the formation of transverse lines never occurred after age 14 in boys and after age 12 in girls.

In a study of 107 boys and 94 girls in a Fels longitudinal study on well-nourished children from southwestern Ohio, Gindhart (1969: 20) found that the boys showed a greater prevalence of transverse lines than the girls. In contrast, the girls showed evidence of longer persistence of lines than boys. This study also revealed that although there was a high association of transverse lines and disease, there was not a positive, direct relationship. Goodman et al. (1984: 283), in their study of the Dickson Mounds prehistoric populations (ca. A. D. 950-1300), found that there is a tendency for males to have a higher frequency of transverse lines than females. However, their analysis found that females have a higher frequency of lines during adolescent growth and males have a higher frequency of lines during the first seven years of growth (Goodman et al. 1984: 283). Goodman et al. hypothesized that during growth, males have a higher susceptibility to stress than females (Goodman et al. 1984: 283).

In a study among prehistoric populations of southern Peru, Allison et al. (1974: 413) found that coastal populations had a higher frequency of transverse lines in the first eight years of life than mountainous populations. One of the reasons these coastal populations may have had more lines is that malaria was rampant on the pre-Columbian coast. Spongy hyperostosis, a condition characteristic of the effects of malaria, was present in populations dwelling in coastal regions of Central and South America during pre-Columbian periods (Allison et al. 1974: 413). The effects of malaria also corresponded with the presence of chronic infantile anemia in Peruvian children dating as far back as A.D. 700.

Some researchers believe that transverse lines are the result of protein deficiencies, which can cause diseases such as kwashiorkor and anemia (Allison et al. 1974; Cook and Buikstra 1979; Himes et al. 1975; May et al. 1993; Murchison et al. 1984). This has been disputed by others (Himes et al. 1975; Hummert and Van Gerven 1985). Hummert and Van Gerven (1985: 305) declared the study of transverse lines in relation to nutritional distress problematic in that bone remodels quickly in juveniles, and the absence of lines can be misleading. They studied skeletal samples from a medieval Nubian population dating from A.D. 550 to 1450. This study showed that the peak age for transverse line formation was at four years old. The oldest age at which a line persisted was 10 years in a 13-year-old whose line formed at age three. They concluded that the absence of transverse lines can mean that there were no growth interruptions or that the bone remodeled quickly due to resorption. Hummert and Van Gerven (1985: 303) concluded that there must have been resorption occurring in this population, due to the amount of lines that increase with age categories but decrease from previous years.

Based on the Denver Child Research growth study, Magennis (1990) found that transverse lines were indicative of growth spurts rather than growth interruptions. Magennis asserted that transverse lines are a result of the chondrocytic activity responsible for regulating bone length. Magennis recognized that nutritional or psychological stress under specific circumstances might cause transverse lines and noted that the difficulty in determining the cause of lines lies in the ability to differentiate which lines might be from stress and which lines might be indicative of growth (1990: 188-189).

Though there are clearly opposing views of the etiology of transverse lines, the absence or presence of these lines can provide a clearer understanding of the nutritional importance played out in the growth of long bones. Whether or not transverse lines are indicative of growth interruptions or recovery, it is generally agreed that nutrition does have a vital role in the growth of both long bones and irregular bones.

Previous pathology studies on the skeletal remains from Vidor provide valuable insight with regard to the health of this population. They also afford an opportunity for comparison of the results of the current study to those studies previously published. As noted earlier, enamel hypoplasias are bands of metabolic disruptions resulting from an ameloblastic interruption in tooth enamel. Because enamel is primarily an inorganic material, remodeling does not occur in this matrix. Therefore, any disruptions to the proper growth of enamel are permanently embossed in the enamel (Goodman and Armelagos 1988: 936). Since the disruption in enamel matrix usually affects more than one tooth in an individual, these markers are presented more often than transverse lines would be in the same individual.

Obando (1995) conducted a study on the Nacascolo cemetery and compared it to that of the Vidor site. She found that the subsistence and funerary patterns were the same in both sites. The difference in the two sites was that the Vidor burials were mostly subadults, infants and neonates 0-14 years of age, while the Nacascolo site contained fewer subadults. Among the findings of that research, Obando (1995: 71) found that fourteen individuals from the Vidor site exhibited enamel hypoplasias, with 194 of the 358 teeth showing hypoplastic markers. The intervals for the hypoplasias were calculated and reflected 18.8 months of interrupted growth between the ages of 0.5 and 6 years (Obando 1995: 144). Obando found no direct association between the number of enamel defects and the mean age at death for the individuals at Vidor (Obando 1995: 149). She did, however, discover a correlation between the duration of hypoplastic events and the mean age at death in that the longer the interval of hypoplastic events, the shorter the lifespan of an individual (Obando 1995: 133).

Maat (1984: 291) concluded, from his study of Dutch whalers from the seventeenth century, that enamel hypoplasias correspond significantly with the transverse lines on the same individual. Larsen (1987: 362-363) also argued that growth interruptions could be seen in skeletal remains with transverse lines and enamel developmental defects. Larsen attributed transverse lines to indicators of stress caused by malnutrition and declared that lines decrease with age and appear most frequently between the ages of two and three years in the Dickson Mounds populations.

Obando also looked at percent cortical bone area in the femora to determine nutritional status in the individuals from the two sites. Forty-three individuals from Vidor were analyzed with most of the major bone loss occurring between the ages of two and four years, resulting in a total reduction of 11.27% (Obando 1995: 171). These individuals maintained cortical thickness from age four until age nine when another reduction was detected. During the ages of 14 through age 20, there is a subsequent increase in endosteal apposition and an increase in percent cortical area (Obando 1995: 172). This would be indicative of an absence of hormonal bone growth at that age and possibly a low endosteal resorption rate which could reflect a nutritional deficiency in these subadults.

While the etiology of Harris lines is still unclear and the problem of resorption precludes definitive statements, other data such as enamel hypoplasias and cortical bone thickness add to the information available for assessing bone growth and subsequent growth interruptions. In conjunction with these mentioned anomalies, Harris lines can add to the data regarding the health status of historic and prehistoric populations.

CHAPTER FOUR: METHODOLOGY

Since transverse lines can be observed at an early age in tibiae (Clark and Mack 1988; Garn et al. 1968), the Vidor site appeared to be well suited for the current study due to the abundance of juveniles. The ilia were also chosen to be radiographed to show any transverse lines that might occur in these irregular bones. The sex of these children was undetermined in most cases because the mean age is less than 12 years old. Without a reliable method for sexing sub-adults, an attempt to show sexual differences in the rate of bone growth or growth retardation was not incorporated into this study.

Because of the condition and age of the bones, only those tibiae with a complete distal or proximal end were included in this research, and only those ilia with a mostly complete crest were included. Because of the limited availability of tibiae and ilia viable for radiographs, in some cases, both the left and the right bones were used. Because some of the tibiae were missing the distal end and some were missing the proximal end, both the left and right bones were used if the condition of the bone was suitable for x-rays. Although transverse lines are more commonly recognized in the distal aspect of tibiae (Garn et al. 1968; Gindhart 1969), again, due to the condition of the bones, no discriminations were made regarding distal or proximal preference.

Tibiae and ilia were examined in 35 individuals with at least one bone per individual included (Appendix). Of the 77 individual bones x-rayed, 38 of those were ilia and 39 were tibiae. Maximum bone lengths were measured for tibiae. The ilia were measured for maximum width of the crest, anterior to posterior, and maximum height from the anterior portion of the acetabulum to the maximum point on the crest (Figure 4.2).

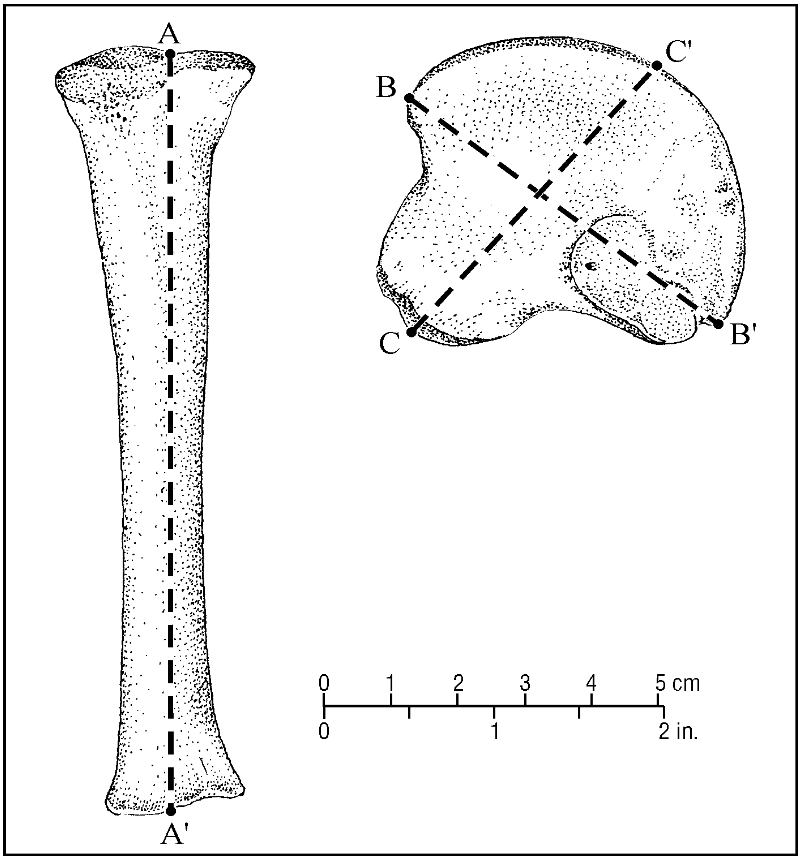

Figure 4.1 Illustration of Measurements Taken of Tibiae and Ilia.

The radiographs were taken with a portable x-ray unit using 44 kilovolts, at 0.06 seconds and at a distance of one meter. Several settings were tested to determine the best tube height and distance. The tibiae and ilia were placed in an AP orientation with the posterior surface touching the cartridge. The AP orientation is recommended by the Paleopathological Association (1991: 6). They were again x-rayed in the mediolateral position for opposing views. . Since the bones being x-rayed were juvenile bones and, therefore, less dense than those of adults, the same calibrations were used for both the tibiae and ilia. Once the radiographs were developed, sliding calipers were used to measure the distances between lines on the film itself.

Using the standards set by Ubelaker (1978: 49), maximum length of the tibia was used to determine age at death. In cases where either end was not complete, the measurement taken from the available end was used to determine approximate minimum age categories. Epiphyses were not included in the measurements since the specimens used in the study had not yet formed fused epiphyses. The maximum length of the ilia was measured to determine minimum and maximum ages, based on age standards set by Bass (1987: 247).

Many formulae have been developed to determine the age at which transverse lines occur (Allison et al. 1974; Byers 1991; Garn et al. 1968; Gindhart 1969; Hunt and Hatch 1981; Maat 1984). In determining the age increments of osteoblastic activity, Hummert and Van Gerven (1985: 405) allowed for bone growth minus the length at birth. Allison et al. (1974: 410) used an arbitrary 90 mm birth length, applying this base measurement for all of the tibiae to keep a measure of error consistent throughout the study. Using this arbitrary 90 mm, Hummert and Van Gerven determined that 43% of growth occurred in the distal aspect of the tibia in children with known sex. The other 57% of growth can be associated with proximal contribution (Hummert and Van Gerven 1985: 301). Allison et al. (1974: 410) attribute the growth rate of the tibia at 60% growth in the proximal end and 40% for the distal end. Due to the fragmentary condition of the bones, and the lack of reliability in determining the sex of these subadults, no attempt was made to approximate the age in which lines occurred in this study.

Only lines extending at least one-fourth of the distance to the medullary cavity were used for this study. Another criterion for the lines to be counted was that they must be visible without the aid of magnifying tools. The method of quantification was to divide the tibiae into categories of presence of lines, absence of lines, multiple lines, and frequency of lines. Figure 4.2 shows a radiograph comparing tibiae with multiple lines to tibiae absent of lines.

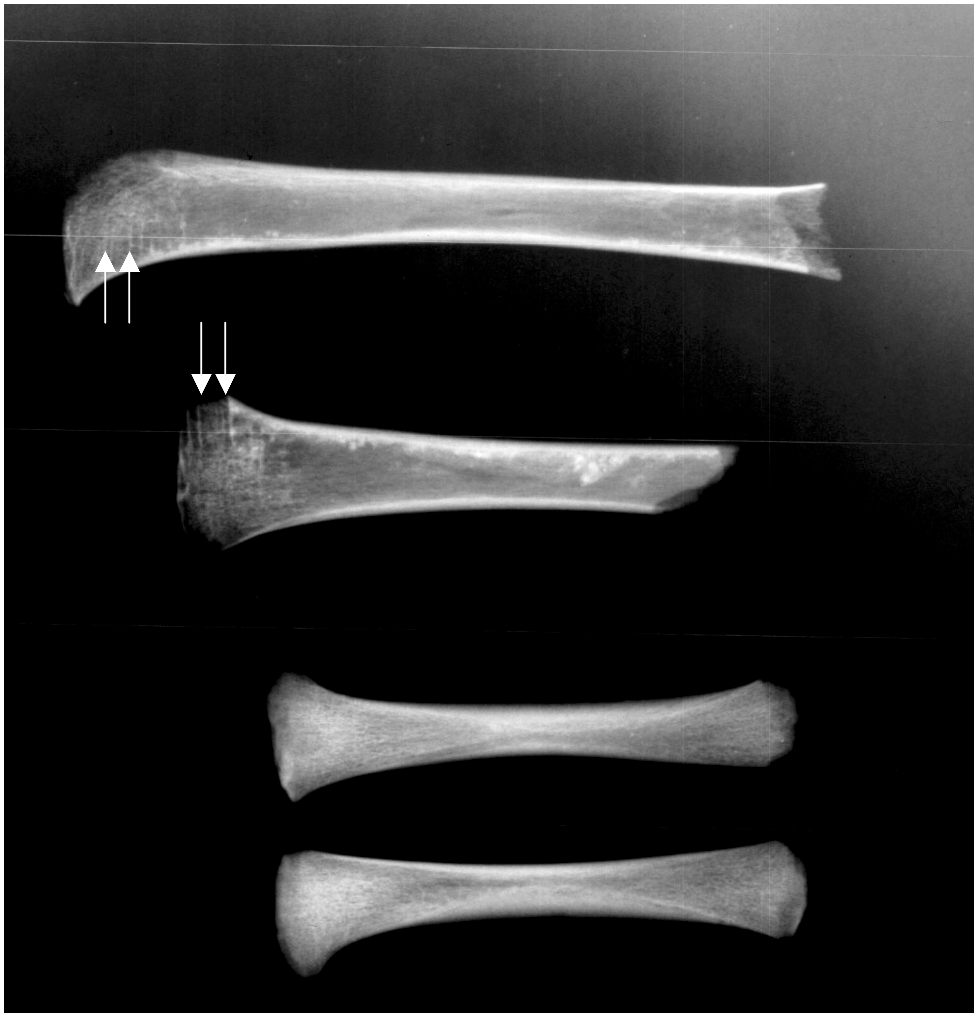

Figure 4.2 Radiograph of juvenile tibiae showing the differences between those with lines and those without.
Top to Bottom: Individual #'s 82-184, 78-102, 78-104, and 77-98/99

CHAPTER FIVE: RESULTS

Seven of the 39 tibiae exhibited transverse lines, while none of the 38 ilia had lines. Although in some instances there was visible opacity at the anterior portion of the acetabular growth plate in the ilia, there was not enough distinction to clearly identify the marks as Harris lines (Figure 5.1).

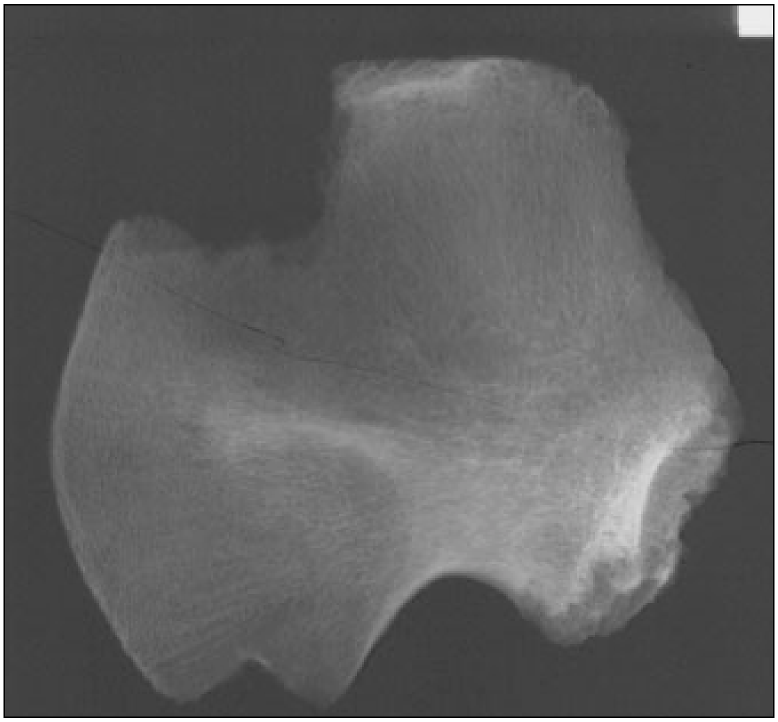

Figure 5.1 Radiograph of ilium showing no lines #76-73.

Table 5.1 shows the summary of measurements for the tibiae in this collection and the mean length of the tibiae per age group.

Table 5.1 Summary of the Mean Measurements in Millimeters Used to Age the Tibiae of the Juveniles from the Vidor Site

Years	Range	Mean
N.B.-0.5	34-72	60.1
0.5-1.5	67-75	72.3
1.5-2.5	104	104.0
2.5-3.5	95-152	132.3
3.5-4.5	159-170	162.8
4.5-5.5	194	194.0
5.5-6.5	-	-
6.5-7.5	-	-
7.5-8.5	239-254	248.3
8.5-9.5	254-265	259.5

Table 5.2 shows a listing of the sample by age category and element used. Figure 5.2 shows an example of the Newborn-0.5 age group that showed no lines present. Table 5.3 summarizes the information on the presence or absence of lines by age group. The majority of Harris lines in the tibiae occurred in the age group 2.5-3.5 with three bones, representing two individuals, having only one line each. The 3.5-4.5 age group had one bone with one line, and the 7.5-8.5 age group had one bone with one line. The two bones with multiple lines fell into the 0.5-1.5 age group and the 1.5-2.5 age group. The two individuals that showed multiple lines represent

children from six months old to 2.5 years old, which could represent weaning ages. The x-rays showed no evidence of opacity across the distal end or the proximal end of these complete tibiae in the Newborn-0.5 age group (Figure 5.3).

Table 5.2 Summary of Age Categories of Tibiae and Ilia of Vidor Sample Representing 35 Individuals

Age in Years	**Tibiae**		**Ilia**	
Individual #	**Left**	**Right**	**Left**	**Right**
Newborn –0.5				
74-46	X			
74-50		X	X	X
75-68	X	X	X	
75-69			X	
77-98	X	X	X	X
78-103	X		X	X
78-104	X	X		X
78-105			X	X
78-106	X	X	X	X
78-108			X	X
78-109	X	X	X	X
78-117	X	X		X
79-118	X	X		X
79-119	X	X	X	X
79-139		X	X	
80-144	X			
0.5-1.5				
75-58				X
78-102	X			
78-114			X	X
80-147-2		X		
80-147-3		X		
1.5-2.5				
70-16			X	X
82-184		X	X	
2.5-3.5				
74-44	X	X		
77-97		X	X	

(table cont'd)

3.5-4.5				
73-42	X		X	
74-43	X	X		
4.5-5.5				
74-47	X	X		
5.5-6.5				
72-34			X	X
74-49	X			X
6.5-7.5				
83-00				X
7.5-8.5				
68-01	X	X	X	X
73-41	X			
8.5-9.5				
76-73			X	X
76-72	X	X		
Totals	39		38	

Figure 5.2 Subadult Ilia and Tibia Age Group Newborn-0.5 #74-50

Table 5.3 Summary of line Occurrence in the Vidor Sample

Age Group	Absence of Lines	1 Line	Multiple Lines
N.B –0.5	21	0	0
0.5-1.5	2	0	1
1.5-2.5	0	0	1
2.5-3.5	0	3	0
3.5-4.5	4	1	0
4.5-5.5	0	0	0
5.5-6.5	1	0	0
6.5-7.5	0	0	0
7.5-8.5	2	1	0
8.5-9.5	2	0	0
Totals	32	5	2

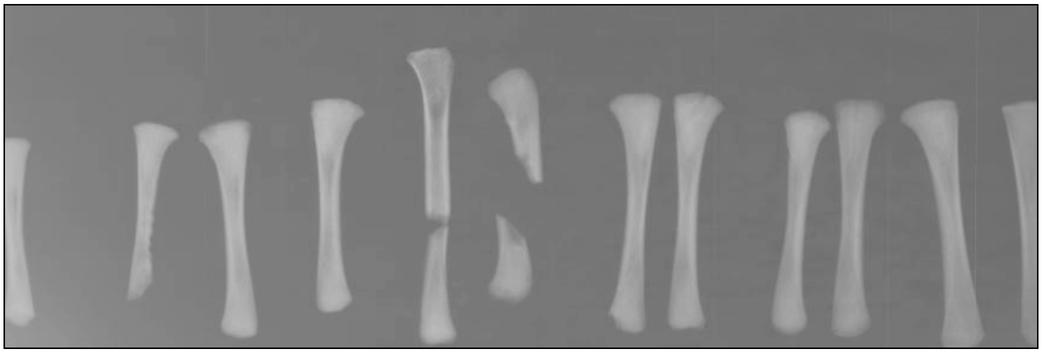

Figure 5.3 Radiograph of Tibiae in the Newborn-0.5 Age Group.

CHAPTER SIX: DISCUSSION

The current study on transverse lines has shown that while there are Harris lines in seven of the tibiae, it is unclear what those lines indicate. There is not sufficient evidence to identify these lines as due to growth interruption or growth cessation. The evidence of these lines supported with previous pathological studies, by Obando, allows an excellent insight into this population's health during pre-Columbian times. Unfortunately, in Obando's published data there are no corresponding burial numbers with which a direct comparison can be made between Obando's study on enamel hypoplasias and cortical bone thickness and the current study on Harris lines on the Vidor population. Attempts to locate the raw data were unsuccessful.

The population from the Vidor burial examined during excavation showed that 45 of the 192 individuals exhibited evidence of active porotic hyperostosis at the time of death (Vazquez and Weaver 1980: 101). The site report also indicated that some individuals had recovered from hyperostosic events. Porotic hyperostosis, often associated with anemia possibly due to diarrhea and infection, is yet another indicator that this population was suffering from disease and iron deficiencies. Figure 6.1 shows an individual with severe cribra orbitalia, an effect reflecting iron deficiencies in populations. This individual did not show evidence of transverse lines in the tibia.

The stable isotope analysis of the Vidor sample shows that they were once dependent on maize and then changed their main subsistence focus to marine life (Norr 1996: 264). Transverse lines, in the past, have been attributed to malnutrition episodes or disease. If the Vidor population had subsisted on maize throughout their existence, and there was not a large consumption of legumes, fruits and nuts, a lack of protein may have resulted, thereby possibly creating transverse lines.

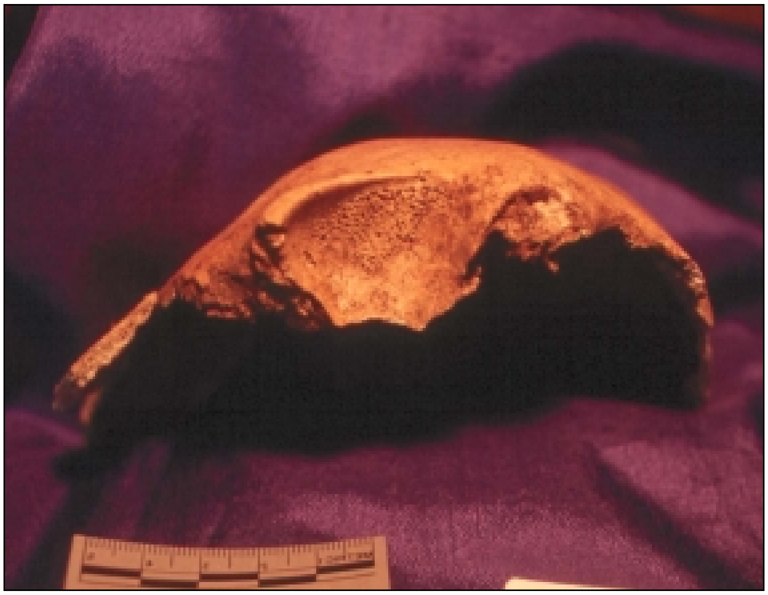

Figure 6.1 Photograph Showing Cribra Orbitalia in One Specimen Used for Comparison of Nutritional Status #73-41

The majority of tibiae with transverse lines in this collection are missing the distal aspect. Since the distal aspect is the most frequent portion of the long bone producing lines, Harris lines may be underrepresented in this study. In addition, the absence of lines could merely be a result of the youth of the sample. In other words, these individuals may not have had time to develop any pathology. They may have died at birth or shortly thereafter.

A comparison of the prevalence of enamel hypoplasias, porotic hyperostosis, and Harris lines provides some information on the overall nutritional status of this group of prehistoric Costa Ricans. Table 6.1 refers to the summation of pathologies found in this sample. This table shows enamel hypoplasias as the most frequent pathology occurring in this group. This high frequency is most likely a result of the nutritional deficiencies, and indicates that, in this sample at least, transverse lines underrepresented the prevalence of nutritional deficiencies.

Table 6.1 Summary of Pathology Frequencies in the Vidor Sample.

Pathology	**Frequency/Total**	**Percentage**
Transverse Lines	7/39	3.64%
Porotic Hyperostosis*	45/192	23.44%
Enamel Hypoplasias**	14/15	93.33%

*Initial Site Report
**Obando (1995)

The previous studies, discussed in the literature review, demonstrate the correlation between enamel hypoplasias, cortical bone loss, porotic hyperostosis, and transverse lines and how these pathologies relate to nutritional status. Obando’s study on enamel hypoplasias and cortical bone thickness established that the Vidor population suffered from some kind of nutritional deprivation. Because the Vidor population experienced these nutritional abnormalities, a higher incidence of transverse lines was expected.

CHAPTER SEVEN: CONCLUSION

This study concentrated on showing an association between the presence of Harris lines and the nutritional assessment made from previous studies on this prehistoric Costa Rican population. A preponderance of evidence has shown that these individuals suffered from occurrences of disease and nutritional stress. The isotope analysis showed that this population, over a period of more than 1000 years, had moved from an agriculturally based diet to a diet with more marine life intake.

Since the individuals studied in this research are juveniles, the most obvious factor contributing to nutritional anomalies can be best associated with weaning. The presence of transverse lines in the juveniles between birth and 9.5 years of age corresponds with the ages at which weaning occurs and growth spurts begin. Obando's study indicated an overall picture of systemic stress during the weaning years. The cortical bone resorption along with hypoplastic activity that developed in this population was during the weaning years, or until age six. The few Harris lines that were present occurred during approximately the same period as weaning.

The results of the current study add to the existing knowledge about long-term health and disease in Pre-Columbian Costa Rica and provide insight into those conditions that have contributed to the mortality rate in the past. The radiographs do show evidence of growth anomalies during weaning years; these may be attributable to growth interruptions.

APPENDIX: DATA

Individual	**Age**	**Element**	**Side** Left Right Both	**Complete Or Incomplete Element**	**Transverse Lines** None Single Multiple	**Pathology**
68-01	10-12	Tibia Ilia	Left Both	Complete Complete	----	Porotic Hyperostosis**
68-02	8*	------	------	Incomplete	----	Porotic Hyperostosis**
68-03	-----	----	----	Incomplete	----	Porotic Hyperostosis**
68-04	8*	----	----	Incomplete	----	Porotic Hyperostosis**
68-05	5.5-6.5*	----	----	Incomplete	----	----
69-06	6.5-7.5*	----	----	Incomplete	----	----
69-07	6.5*	----	----	Incomplete	----	----
69-08	2.5-3.5*	----	----	Incomplete	----	----
69-09	6.5-7.5*	----	----	Incomplete	----	Porotic Hyperostosis**
69-10	7.5-8.5*	----	----	Incomplete	----	Porotic Hyperostosis**
69-11	----	----	----	Incomplete	----	----
70-12	----	----	----	Incomplete	----	Porotic Hyperostosis**
70-13	----	----	----	Incomplete	----	Porotic Hyperostosis**
70-14	----	----	----	Incomplete	----	Porotic Hyperostosis**
70-15	----	----	----	Incomplete	----	Porotic Hyperostosis**
70-16	1.5-2.5	Ilia	Both	Incomplete	----	----
70-17	----	----	----	Incomplete	----	----
70-18	----	----	----	Incomplete	----	----
70-19	----	----	----	Incomplete	----	----
70-20	----	----	----	Incomplete	----	Porotic Hyperostosis**
70-21	----	----	----	Incomplete	----	----
70-22	----	----	----	Incomplete	----	----
70-23	----	----	----	Incomplete	----	Porotic Hyperostosis**
70-24	----	----	----	Incomplete	----	Porotic Hyperostosis**

Individual	**Age**	**Element**	**Side** Left Right Both	**Complete Or Incomplete Element**	**Transverse Lines** None Single Multiple	**Pathology**
70-25	----	----	----	Incomplete	----	----
70-26	----	----	----	Incomplete	----	----
70-27	----	----	----	Incomplete	----	----
70-28	----	----	----	Incomplete	----	----
70-29	----	----	----	Incomplete	----	----
70-30	----	----	----	Incomplete	----	----
70-31	----	----	----	Incomplete	----	----
72-32	----	----	----	Incomplete	----	----
72-33	----	----	----	Incomplete	----	----
72-34	5.5-6.5	Ilia	Both	Incomplete	----	----
72-35	----	----	----	Incomplete	----	----
72-36	----	----	----	Incomplete	----	----
72-37	----	----	----	Incomplete	----	----
72-38	----	----	----	Incomplete	----	----
72-39	----	----	----	Incomplete	----	Porotic Hyperostosis**
72-40	----	----	----	Incomplete	----	Porotic Hyperostosis**
73-41	7.5-9.5	Tibia	Left	Incomplete	----	Cribra Orbitalia and Porotic Hyperostosis**
73-42	3.5-4.5	Tibia Ilia	Left Left	Incomplete	----	----
74-43	3.5-4.5	Tibia	Both	Incomplete	L-Single R-Single	----
74-44	2.5-3.5	Tibia	Both	Incomplete	L-Single R-Single	----
74-45	5-7*	----	----	Incomplete	----	----
74-46	N.B.-0.5	Tibia	Left	Incomplete	----	----
74-47	3.5-5.5	Tibia	Both	Incomplete	----	----
74-48	6.5*	----	----	Incomplete	----	----
74-49	5.5-6.5	Tibia Ilia	Left Right	Incomplete Incomplete	----	----
74-50	N.B.-0.5	Tibia Ilia	Right Both	Complete Incomplete	----	----
74-51	----	----	----	Incomplete	----	Porotic Hyperostosis**
74-52	>30*	----	----	Incomplete	----	Porotic Hyperostosis**

Individual	**Age**	**Element**	**Side** Left Right Both	**Complete Or Incomplete Element**	**Transverse Lines** None Single Multiple	**Pathology**
75-53	----	----	----	Incomplete	----	Porotic Hyperostosis**
74-54	----	----	----	Incomplete	----	----
75-55	----	----	----	Incomplete	----	----
75-56	----	----	----	Incomplete	----	----
75-57	0.5-0.9*	----	----	Incomplete	----	----
75-58	0.5-1.5	Ilia	Right	Incomplete	----	----
75-59	----	----	----	Incomplete	----	Porotic Hyperostosis**
75-60	----	----	----	Incomplete	----	----
75-61	----	----	----	Incomplete	----	----
75-62	----	----	----	Incomplete	----	----
75-63	----	----	----	Incomplete	----	Porotic Hyperostosis**
75-64	----	----	----	Incomplete	----	----
75-65	----	----	----	Incomplete	----	----
75-66	----	----	----	Incomplete	----	----
75-67	----	----	----	Incomplete	----	----
75-68	N.B.-0.5	Tibia Ilia	Both Left	Incomplete Complete	----	----
75-59	N.B.-0.5	Ilia	Left	Complete	----	----
75-70	----	----	----	Incomplete	----	----
76-71	25-30	----	----	Incomplete	----	Porotic Hyperostosis**
76-72	14-16*	Tibia	Both	Incomplete	----	Porotic Hyperostosis**
76-73	8.5-10.5	Ilia	Both	Incomplete	----	----
76-74	1.0-2.5*	----	----	Incomplete	----	----
76-75	----	----	----	Incomplete	----	----
77-76	4-5*	----	----	Incomplete	----	Porotic Hyperostosis**
77-77	5-6.5*	----	----	Incomplete	----	Porotic Hyperostosis**
77-78	7.5*	----	----	Incomplete	----	Porotic Hyperostosis**
77-79	8*	----	----	Incomplete	----	Porotic Hyperostosis**
77-80	7*	----	----	Incomplete	----	Porotic Hyperostosis**
77-81	6*	----	----	Incomplete	----	----
77-82	4*	----	----	Incomplete	----	----

Individual	**Age**	**Element**	**Side** Left Right Both	**Complete Or Incomplete Element**	**Transverse Lines** None Single Multiple	**Pathology**
77-83	----	----	----	Incomplete	----	----
77-84	----	----	----	Incomplete	----	----
77-85	3*	----	----	Incomplete	----	----
77-86	----	----	----	Incomplete	----	----
77-87	----	----	----	Incomplete	----	----
77-88	----	----	----	Incomplete	----	----
77-89	0.5-1.0	----	----	Incomplete	----	----
77-90	----	----	----	Incomplete	----	----
77-91	----	----	----	Incomplete	----	----
77-92	8*	----	----	Incomplete	----	----
77-93	----	----	----	Incomplete	----	----
77-94	----	----	----	Incomplete	----	----
77-95	----	----	----	Incomplete	----	----
77-96	----	----	----	Incomplete	----	----
77-97	2.5-3.5	Tibia Ilia	Right Left	Complete Complete	R-Single	Porotic Hyperostosis**
77-98	N.B.-0.5	Tibia Ilia	Both Both	Complete Complete	----	----
77-100	----	----	----	Incomplete	----	----
78-101	----	----	----	Incomplete	----	----
78-102	0.5-1.5	Tibia	Left	Incomplete	Multiple	----
78-103	N.B.-0.5	Tibia Ilia	Left Both	Complete Incomplete	----	----
78-104	N.B.-0.5	Tibia Ilia	Both Right	Complete Complete	----	----
78-105	N.B.-0.5	Ilia	Both	Incomplete	----	----
78-106	N.B.-0.5	Tibia Ilia	Both Both	Complete Complete	----	----
78-107	----	----	----	Incomplete	----	----
78-108	N.B.-0.5	Ilia	Both	Incomplete	----	----
78-109	N.B.-0.5	Tibia Ilia	Both Both	Incomplete Incomplete	----	----
78-110	----	----	----	Incomplete	----	----
78-111	5*	----	----	Incomplete	----	----
78-112	----	----	----	Incomplete	----	----
78-113	----	----	----	Incomplete	----	----
78-114	0.5-1.5	Ilia	Both	Incomplete	----	Porotic Hyperostosis**
78-116	6.5-7.5*	----	----	Incomplete	----	----
78-117	N.B.-0.5	Tibia Ilia	Both Right	Complete Complete	----	----

Individual	**Age**	**Element**	**Side** Left Right Both	**Complete Or Incomplete Element**	**Transverse Lines** None Single Multiple	**Pathology**
79-118	N.B.-0.5	Tibia Ilia	Both Right	Complete Complete	----	----
79-119	N.B.-0.5	Tibia Ilia	Both Both	Complete Incomplete	----	----
79-120	0.9*	----	----	Incomplete	----	----
79-121	----	----	----	Incomplete	----	----
79-122	----	----	----	Incomplete	----	----
79-123	----	----	----	Incomplete	----	----
79-124	----	----	----	Incomplete	----	----
79-125	----	----	----	Incomplete	----	----
79-126	----	----	----	Incomplete	----	----
79-127	----	----	----	Incomplete	----	----
79-128	0.6*	----	----	Incomplete	----	----
79-129	----	----	----	Incomplete	----	----
79-130	----	----	----	Incomplete	----	----
79-131	30-35*	----	----	Incomplete	----	Porotic Hyperostosis**
79-132	7-8*	----	----	Incomplete	----	Porotic Hyperostosis**
79-133	----	----	----	Incomplete	----	----
79-134	----	----	----	Incomplete	----	----
79-135	----	----	----	Incomplete	----	----
79-136	----	----	----	Incomplete	----	----
79-137	----	----	----	Incomplete	----	----
79-138	30-35*	----	----	Incomplete	----	----
79-139	N.B.-0.5	Tibia Ilia	Right Left	Complete Complete	----	----
79-140	----	----	----	Incomplete	----	Porotic Hyperostosis**
79-141	----	----	----	Incomplete	----	----
80-142	----	----	----	Incomplete	----	----
80-143	5*	----	----	Incomplete	----	----
80-144	N.B.-0.5	Tibia	Left	Incomplete	----	----
80-145	----	----	----	Incomplete	----	----
80-146	----	----	----	Incomplete	----	Porotic Hyperostosis**
80-147-1	5*	----	----	Incomplete	----	----
80-147-2	0.5-1.5	Tibia	Right	Incomplete	----	----
80-147-3	0.5-1.5	Tibia	Right	Incomplete	----	----
80-147-4	----	----	----	Incomplete	----	----

Individual	**Age**	**Element**	**Side** Left Right Both	**Complete Or Incomplete Element**	**Transverse Lines** None Single Multiple	**Pathology**
80-147-5	1*	----	----	Incomplete	----	----
80-148	4*	----	----	Incomplete	----	Porotic Hyperostosis**
80-149	----	----	----	Incomplete	----	----
80-150	18-20*	----	----	Incomplete	----	Porotic Hyperostosis**
80-151	----	----	----	Incomplete	----	Porotic Hyperostosis**
80-152	----	----	----	Incomplete	----	----
80-153	----	----	----	Incomplete	----	----
80-154	----	----	----	Incomplete	----	----
80-155	----	----	----	Incomplete	----	Porotic Hyperostosis**
81-156	----	----	----	Incomplete	----	----
81-157	----	----	----	Incomplete	----	----
81-158	----	----	----	Incomplete	----	----
81-159	----	----	----	Incomplete	----	----
81-160	----	----	----	Incomplete	----	----
81-161	----	----	----	Incomplete	----	----
81-162	----	----	----	Incomplete	----	----
81-163	----	----	----	Incomplete	----	----
81-164	----	----	----	Incomplete	----	----
81-165	----	----	----	Incomplete	----	Porotic Hyperostosis**
81-166	----	----	----	Incomplete	----	Porotic Hyperostosis**
81-167	----	----	----	Incomplete	----	Porotic Hyperostosis**
81-168	----	----	----	Incomplete	----	Porotic Hyperostosis**
81-169	----	----	----	Incomplete	----	----
81-170	----	----	----	Incomplete	----	----
81-171	----	----	----	Incomplete	----	----
81-172	----	----	----	Incomplete	----	----
81-174	----	----	----	Incomplete	----	----
82-175	----	----	----	Incomplete	----	Porotic Hyperostosis**
82-176	----	----	----	Incomplete	----	Porotic Hyperostosis**
82-177	----	----	----	Incomplete	----	Porotic Hyperostosis**

Individual	**Age**	**Element**	**Side** Left Right Both	**Complete Or Incomplete Element**	**Transverse Lines** None Single Multiple	**Pathology**
82-178	----	----	----	Incomplete	----	----
82-179	----	----	----	Incomplete	----	Porotic Hyperostosis**
82-180	----	----	----	Incomplete	----	Porotic Hyperostosis**
82-181	----	----	----	Incomplete	----	----
82-182	----	----	----	Incomplete	----	----
82-183	----	----	----	Incomplete	----	----
82-184	1.5-2.5	Tibia Ilia	Right Left	Incomplete Incomplete	Multiple	Porotic Hyperostosis**
82-185	----	----	----	Incomplete	----	Porotic Hyperostosis**
82-186	----	----	----	Incomplete	----	----
82-187	----	----	----	Incomplete	----	----
82-188	----	----	----	Incomplete	----	Porotic Hyperostosis**
82-189	----	----	----	Incomplete	----	----
82-190	----	----	----	Incomplete	----	----
82-191	----	----	----	Incomplete	----	----
83-00	6.5-7.5	Ilia	Right	Complete	----	----

** Age reported on initial site report*

*** Pathology reported on initial site report*

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