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Elliott, Beth Ferguson, M.S.

San Jose State University, 1992

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THE ONTOGENY OF PRE-PUBESCENT SKELETAL GROWTH,
AS SEEN IN A PREHISTORIC
CENTRAL CALIFORNIA INDIAN COLLECTION

A Thesis
Presented to
The Office of Graduate Studies
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

By
Beth Ferguson Elliott
May, 1992

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Abstract

THE ONTOGENY OF PREPUBESCENT SKELETAL GROWTH, AS SEEN IN A PREHISTORIC CENTRAL CALIFORNIA INDIAN COLLECTION

by Beth Ferguson Elliott

This study proposes developmental guidelines for a prehistoric California Indian population including long bone growth, long bone width, dental development and eruption patterns; moreover general "stress" indicators as revealed by the incidence of dental hypoplasias and Harris lines are also evaluated. A sub-adult sample was drawn from a total burial population of approximately 440 individuals. These burials were excavated from the Ryan Mound (CA-Ala-329) located along the southeastern rim of the San Francisco Bay, California.

Methods employed in this study include standard anthropometric analyses, dental x-rays, long bone x-rays and CT scans. Dental development was the most heavily weighted criterion in approximating ages.

It has been shown that growth curves in the Ca-Ala-329 sample are similar to those exhibited by the Arikara (Ubelaker, 1989). Intra-sample curves demonstrate that linear growth does not stress cortical growth and remodeling.

Two suspected environmental stress indicators, Harris lines and dental hypoplasias, could not be positively correlated with each other, however the number of Harris line manifestations were correlated with age.

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Every person I have named here plus all of those that have helped me gain a better understanding of this subject are all appreciated by this student and those that follow.

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CHAPTER I

Introduction

The human remains and associated grave goods from prehistoric cultures are windows into human history. The information that can be gleaned from skeletal remains offers a biological perspective about body size, genetics, nutritional status, trauma, and disease patterns, all of which can be further enhanced by archeological analysis of cultural components.

In an effort to interpolate the growth and development of this prehistoric California Indian population, CA-Ala-329, this study analyzes, describes, and measures a variety of skeletal indicators, including: Harris lines, femoral cortical area, femoral mineral content, long bone lengths, dental formation, dental eruption patterns, and dental hypoplasias. Correlation analyses of these data may offer insight into normal growth and possible stressors which disrupt the normal growth pattern of this population. From these data we are able to estimate age, identify trauma, describe and evaluate the incidence of certain nutritional and disease related insults.

The concentration of this study is sub-adult (under 12 years of age) skeletal remains. While adult remains are often assigned open-ended age estimates such as 25+ years, sub-adults have various developmental skeletal indicators that allow for more precise age estimates than for adults. Based on long bone length of a protohistoric Arikara Indian collection, Ubelaker (1989) has assigned age estimates with as little

variation as plus or minus 2 months at birth. By comparison, a plus or minus 30 month range has been assigned the 10 year old age category. The rapid growth an infant experiences from birth is demonstrated by the doubling of the femoral length between birth and the fourth year and doubling again by the eighth year. (Ortner and Putschar, 1985).

When examining sub-adult skeletal remains from an archeological context, it should be remembered that the ante-mortem, health and/or nutritional status of these youngsters is questionable at best. When evaluating sub-adult remains it is safe to assume the individual was constitutionally unsound with possible etiological explanations such as, congenital defects, birth trauma, malnutrition of the child or the lactating mother, or disease. High infant mortality between 0-2 years has been suggested to be a result of maternal death (Doran, 1980). During the first two years of life, since the child is not weaned, it is assumed that the infant is totally dependent upon the mother. The challenge, thus, is to identify the insults that shortened the life of the individual.

The mechanism of skeletal growth is a susceptible, genetically programmed balance between osteoblastic and osteoclastic activity. This balance, in turn, determines the rate of growth and development. If this balance is insulted by environmental stressors such as malnutrition, undernutrition, disease, or trauma, then the resulting skeletal tissue may be altered. Such alteration may be temporary or permanent.

CHAPTER II

Description of Population and Sample

The Ryan Mound, officially recorded by the State of California as CA-Ala-329 is located one-half mile east of the Coyote Hills and currently within the boundaries of the Coyote Hills Regional Park (Figure 1). The mound measures 133m x 90m x 4m (high). Archeologists (Leventhal, 1991) have concluded by means of a series of radiocarbon dates (Gillett, 1987) that the cemetery activities (Haldemann, 1986) at the Ryan Mound occurred between 550 A.D. and 1500 A.D., referred to as the Middle Late Periods. The most recent radiocarbon determinations suggest the basal levels may be as early as B.C. 150 (Jurmain, 1992a).

Figure 1. Location of the Ryan Mound (CA-Ala-329), southeastern San Francisco Bay, California.

The research sample is drawn from a well-preserved (Figures 2 and Appendix A-1) skeletal collection of prehistoric Central California Indian remains excavated from the Ryan mound. In 1935, W.R. Wedel conducted the first recorded excavation at this site and retrieved twelve burials. C.E. Smith followed in 1948 removing 38 burials. Both Wedel and Smith were excavating for the University of California.

The actual collection from which this study is conducted was excavated by Stanford University and San Jose State field schools led by Dr. Bert Gerow (1959 and 1967) and Dean Pritchett (1962 - 1968) respectively (Pierce, 1982). The San Jose State field school burials were curated by Stanford University shortly after excavation, and were later moved to San Jose State University in 1982. The Stanford burials were loaned by Stanford to San Jose State in 1987. The Stanford burials were reinterred in June, 1991.

Opinions vary concerning the cultural activities that may have occurred at the Ryan Mound. Traditionally, mounds such as this were believed to be habitation mounds (Jurmain, 1990). But, more recently, Leventhal (1991) has argued that this mound was a specialized burial site where mortuary activities occurred, perhaps serving a variety of adjacent tribal groups. More details on site description and excavation history can be found in Jurmain (1990 and 1991); Gillett (1987); Haldemann (1986); and Pierce (1982).

The Ryan Mound was believed to be within the low, salty perimeter of the San Francisco Bay (Margolin, 1978) where pickleweed and cordgrass

Figure 2

Well preserved burial, (CA-Ala-329, ST-#134)

swamps were abundant. Waterfowl such as geese, ducks, herons, curlews, sandpipers, dowitchers, and other shore birds (Margolin, 1978) bred within the confines of the cordgrass swamps, providing a constant source of animal protein for the inhabitants. While this damp climate was labeled the land of "inexpressible fertility" (Margolin, 1978), exposure to this environment most assuredly contributed to life threatening viral infections (Pierce, 1982).

The local population did not depend upon one primary food source. Their diet was diverse and plentiful, including an annual acorn harvest in the fall (Baumhoff, 1963), berries, seeds, shellfish, birds (listed above), fish, sea mammals including the harbor seal, California sea lion and sea otter, and land mammals including the rabbit, beaver, pronghorn antelope, mule deer, coyote and mountain lion. (Geary, 1982; Margolin, 1978). It has been suggested that, since acorns can be stored (Dickel, et al., 1986; Baumhoff, 1963), the acorn harvest was a strategic adaptation to seasonal shortages of food .

It is imperative to remember that this sample is from a burial population. Anthropologists and archeologists can, thus, only hypothesize as to the nature of this burial mound and whether it represents accurately the surrounding population, or if it is status-biased, or otherwise a non-representative sample.

CHAPTER III

Overview and Discussion of Related Literature

A. Dental Development

As tooth development is more closely related to chronological age than most other skeletal components, dental development is regarded as the preferred method for aging and evaluating sub-adult skeletons. (Mann, *et al.*, 1990; Ubelaker, 1987; Goodman and Armelagos, 1985). Since dental eruption patterns have a greater degree of variability, Moorrees', *et al.*, (1963a) and Fanning (1961) suggest that tooth development is the most desirable dental aging technique . Dental development, including both individual tooth development and eruption pattern, is under considerable genetic influence. It has been demonstrated that diseases such as hypopituitarism, syphilis (White, 1991), and osteogenesis imperfecta (Pappanastos, 1992) have affected dental development slightly.

Teeth preserve well in an archeological setting because dental enamel is the most durable of all remains of the skeleton. This unique quality of preservation is the result of the chemical composition being almost entirely inorganic (Hillson, 1986), composed of a calcium phosphate also found in bone, called hydroxyapatite (Taber's, 1989). This renders enamel the hardest tissue in the human body (Goodman and Rose, 1990).

Tooth formation begins during the 6th week *in utero* (Goodman and Rose, 1990). At this stage of development the first tooth buds appear, and enamel and crown formation continues through the sixth year for all deciduous and permanent dentition.

Amelogenesis is the biological process of enamel formation. Different areas of enamel start to form at different times, beginning with the tip of the crown and gradually working towards the last area to be enameled, the cervix (Hillson, 1986; Brothwell, 1963). Hypoplasia is the most common defect that occurs during amelogenesis (Hillson, 1986). It is believed that some insult causes ameloblasts to cease their matrix formation early, while surrounding areas proceed at a normal rate. Dental enamel cannot remodel like bone (Goodman and Rose, 1990). Thus, around the hypoplastic ridges higher areas of enamel occur, which are the specific areas of insult.

Aging macerated skeletons from dental development involves not only evaluating eruption patterns of deciduous and permanent dentition, but, more importantly, evaluating the crown and root formation. These evaluations would be extremely difficult with small, prehistoric samples such as CA-Ala-329, if it were not for the extensive research done by Ubelaker (1989) on the Arikara Indians and Moorrees', et al., (1963 a & b) clinical studies on modern American white children. Valuable references have been developed for future osteologists from the joint efforts of Moorrees', et al. (1963 a & b) clinical studies and Ubelaker's (1989) bioarcheological analysis.

Evolutionarily, as seen in our early hominid ancestors (Oxnard, 1987) as well as in several non-human primate species, the canine tooth demonstrates the greatest degree of sexual dimorphism in development and eruption (White, 1991; Ubelaker, 1989). However, Hunt and Gleiser (1955) found that sexual dimorphism was more pronounced in the growing

skeleton than in the development of the permanent teeth. Since sexing sub-adult skeletons is an unrefined science, the canine tooth is referred to only to confirm other conclusions in this research project. Conversely, the canine tooth is best referred to when looking at other developmental clues, such as hypoplasias.

Dental hypoplasias are considered stress markers during enamel development and are manifested as ridges, pits and grooves in permanent teeth (Figure 3). There are different types of hypoplasias. One type, *hypoplasia imperfecta*, is a hereditary form distinguished by the involvement of all of the teeth (Goodman and Rose, 1990; Hillson, 1986) and the entire crown from birth (Goodman and Armelagos, 1985). This form was not observed in this sample. Enamel defects can also be trauma-related, resulting in asymmetrical bands. This pattern, however, is unlike systemic metabolic interruption, where the hypoplasia reveals the stage of crown development at the time of insult (Goodman and Armelagos, 1985).

Dental hypoplasias are not a phenomenon unique to recent human populations. White (1978) described a hypoplastic first permanent molar on an early hominid, an australopithecine dated between 1.5 and 3.0 M.Y.B.P.

Stress induced/systemic metabolic interruption enamel hypoplasia has been identified in all deciduous and permanent teeth except for the third molar (Lanphear, 1990). The mandibular canine and central maxillary incisor render the best growth-insult data related to stress induced hypoplasias (Goodman, et al., 1990).

It is believed that each hypoplastic band is related to particular episodes or insults during ontogeny of the individual (Hillson, 1986).

Although Rose, et al., (1985) found that enamel hypoplasia cannot be attributed to any specific disease, etiology, or nutritional insufficiency, they concluded that hypoplasias are indirectly associated with nutritional inadequacies. The association was demonstrated by analyzing hypoplasias over time (cultural horizons) from a prehistoric population, Dickson Mounds, Illinois (ca. A.D. 950 - 1300). Rose, et al. (1985) found that the frequency of hypoplasias reflected episodes of nutritional inadequacies. Increased population density, a cause of inadequate nutrition, can be inferred (roughly) through archeological analyses of prehistoric populations.

Figure 3
Hypoplastic Upper Right Central Incisor
CA-Ala-329 (ST-Burial # 119)

Charcoal sketch at 500% microscope lucida.

A variety of techniques for scoring hypoplasias has been developed, such as Sarnat and Schour's (1941) scoring of the width, texture and number of ridges. Massler, et al., (1941) designed a system for identifying the age of occurrence with a variety of shaded "zones" for all deciduous crowns and all permanent crowns, excluding the third molar. Some researchers (Clarke, 1982; Massler, et al., 1941) prefer the canine crown for hypoplastic analysis, since it develops between 4 months and 6 years of age, a period when childhood stress and disease presumably are major factors in a prehistoric population. From a 19th Century historic sample Lanphear (1990) determined that stress induced hypoplasia in the maxillary incisor occurred between 2.5 and 3 years of age, while hypoplasia in the mandibular canine manifested itself between 3.5 and 4 years of age. Clarke (1982) concluded that hypoplastic insults peaked between the second and fourth year and suggested a correlation to the stress of weaning (Clarke, 1980). Hypoplastic lines in incisors suggest some type of insult early in life as these crowns develop at 2.0 - 2.5 years. Likewise, lesions in later developing teeth, such as the second molar, imply a problem at approximately 5 or 6 years of age. (Goodman and Armelagos, 1985).

Goodman (1991) concluded that developmental defects such as enamel hypoplasias may in fact be indicators of a predisposition to early death. He suggests that the stressors causing the dental defects may have drained the biological resistance of affected individuals to such a level that they were more susceptible to life threatening insults.

When the analysis of dental development is impossible, the second most common aging technique that investigators choose is the analysis of epiphyseal union. Epiphyseal union is not considered in this study, because, within this sample, long bone data are limited to the union of only four epiphyses prior to the twelfth year. These are: the greater tubercle, trochlea and lateral epicondyle of the humeri, and the ischium to the pubis (Ubelaker, 1989).

B. Femoral Cortical Area

In bioarcheological analysis, the development of cortical bone has been considered to be a reliable indicator of growth (Goodman et al., 1984), nutritional status (Owsley, 1988; Garn et al., 1969), and disease patterns (Ortner and Putschar, 1985). Cortical thickness is genetically influenced; however, the genotypic developmental process can be altered by malnutrition and disease. The depth of the bone cortex can provide developmental clues on the nutritional status and health status of the individual. Thin cortices in growing children are a "clear indicator of stress" (Goodman et al., 1984: 24) and have been suggested as a sign of Vitamin C deficiency (Huss-Ashmore, et al., 1982).

Cortical thickness is a composite measurement determined by the size of the medullary cavity and the subperiosteal diameter. Cortical bone thickness can be measured in a variety of ways with many, more sophisticated, developing histological analyses on the horizon (Martin, 1988). These histological advances are intriguing, but not possible with this

collection, as these analyses require invasive techniques, currently not permitted with these remains.

One measurement was developed to estimate actual cortical area that would have been tedious in application and would provide only an approximation of bone area (Garn, 1970). CT scans calculated the actual cortical area, and thus eliminated the tedious and less accurate measurements (Chumlea, et al., 1984) that make the inaccurate assumption that the femur is perfectly circular in shape. Fortunately, in 1986, former San Jose State students Joyce Bizjack and Linda Repke arranged for, and assisted CT technician Daniel McClendon from Valley Radiology Group of San Jose, California to scan femora on a Phillips 60TX CT Scanner. The scans also recorded actual mineral content anteriorly, medially and posteriorly. These mineral contents are reflective of the density of the actual bone matrix (Goodman, et al., 1984). If a thin cross section were viewed under a microscope, the bone matrix with a higher mineral content would appear denser, while that with a lower mineral content would exhibit a lattice-like matrix.

It is inaccurate to assume that growth proceeds at a constant rate. In fact, it is conceivable that longitudinal growth and cortical growth alternate in the cessation and resumption of growth. It is also likely that periosteal and endosteal activity occur at different rates (Scheuer, et al., 1980). Analysis of prehistoric juveniles from Sudanese Nubia demonstrated that cortical thickness is affected by the maintenance of long bone growth (Huss-Ashmore, et al., 1982). The decreased bone mass in growing children is reflective of active long bone growth and the resultant demands

on the required minerals and nutrients for bone and soft tissue maintenance.

A clinical study of Guatemalan boys hospitalized for kwashiorkor revealed a marked reduction of cortical bone at the endosteal surface and an enlarged medullary cavity, while the subperiosteal surface was unaffected (Garn *et al.*, 1969). Another clinical study of 710 mildly to moderately malnourished rural Guatemalan children found a correlation between the cortical integrity of the second metacarpal and overall body size (Himes, *et al.*, 1975). These findings revealed retarded growth in the periosteal diameter and the cortical thickness; thus, overall cortical area was reduced in comparison to better-nourished children. Retarded cortical bone growth was demonstrated throughout the skeleton in the undernourished Guatemalan children.

It has been assumed that the people, who prehistorically occupied the CA-Ala-329 site, were healthy, and they exhibit very little skeletal evidence of certain diseases, especially those of inflammatory etiology (Jurmain, 1992b). The cortical boundaries visible through CT scans can provide sound, scientific evidence of trauma and marrow communicating diseases such as osteomyelitis, otherwise not easily visible through gross examination or normal radiographic techniques.

C. Long Bone Measurements

Long bone lengths are not only a clue as to the age of sub-adults, but they also provide information regarding developmental stages. These

stages are reflected in epiphyseal and apophyseal formation and union, the correlation between long bone length and cortical area, and an analysis of robusticity of the individual.

All skeletal remains in this sample are those of individuals prior to significant epiphyseal union (see above); therefore, all long bone maximum lengths are diaphyseal, even in the event of preserved, unfused epiphyses. Steggerda (1932) compiled data from clinical studies on living North American Indians that indicated a genetic tendency towards short stature in comparison to American whites (Johnston, 1962). Steggerda (1932) suggested that the estimated stature for Native Americans in the San Francisco Bay area region was 165 - 169.9 cm. In comparison, the shortest stature (155 - 159.9 cm) was found in South Mexico and Central America, while the tallest populations (170 - 174.9) were located east of the Mississippi. When measuring the maximum lengths in samples such as CA-Ala-329, it is imperative to make note of the suspected shorter adult stature but also not rule out any possible etiological explanations beyond genetics.

It has been demonstrated through clinical studies of fetuses from The Bristol Royal Hospital for Sick Children and the London University Institute of Child Health Data that long bone lengths may be used to estimate late fetal or neonatal age from macerated skeletons. The results of these studies validate the use of long bone measurements as an aid in aging sub-adult skeletal remains (Scheuer et al., 1980) .

Growth rates of some prehistoric populations have been shown to be slower than those for modern whites, especially between the ages of 2 - 5

years (Ubelaker, 1989). Goodman, et al., (1984) suggest this retarded growth is a stress indicator. The application of clinical studies to diverse prehistoric populations is limiting, since the majority of clinical studies have studied exclusively, living European/white populations. Countering this limitation, to some degree, however, is the work of Steggerda (1932) which brings together numerous data on living North American Indians.

D. Harris Lines

Harris lines are striations visible on x-ray film. These striations have been referred to by a variety of terms, including radiopaque transverse lines, periodic stress markers, growth arrest lines, and lines of increased density (Maat, 1984; Clarke, 1982; Hummert and VanGerven, 1985 ; McHenry, 1968; Hewitt, et al., 1955), transverse bony striations (Harris, 1926), natural bone markers (Gindhart, 1969) and recovery lines (Huss-Ashmore, et al., 1982) . They are caused by dense disks of cancellous bone extending across the marrow cavity (McHenry, 1968). In this study, the terminology "Harris lines" will be used.

Harris (1926) likened the growth rings visible in deciduous trees to the skeletal striations visible on x-ray. He pointed out that when a deciduous tree is subjected to unsuitable nourishment (ie. drought), the cessation and resumption of growth can be easily seen in the rings.

Harris lines are believed to be caused by the recovery following a disease or nutritional stress and are manifested at the end of the diaphysis or metaphysis where normal osteoblastic activity occurs during rapid

growth (Murchison, et al., 1984). Thus, such markers provide the location of the epiphyseal cartilage at the time of insult (Greulich and Pyle, 1959). Acute malnutrition, chicken pox, whooping cough, measles, influenza (Gindhart, 1969), and scurvy (Harris, 1926) have all been linked to Harris lines. Marshall (1967) found a relationship of disease episodes and line formation but was unable to correlate the number of disease episodes with the number of Harris lines.

Both Harris lines and enamel hypoplasia appear to be caused by an insult to normal growth. The incidence and implications of Harris lines, however, have limitations that the hypoplasias do not. Once a tooth is mature, it does not have any renewable capabilities, so disturbances can be diagnosed on an unchanged surface from the time of ameloblastic activity. The main diagnostic problem with Harris lines is that bones have an ongoing remodeling process (McHenry and Schulz, 1976; Garn, et al., 1968) and thus Harris lines can be resorbed in both childhood and adulthood (Hummert and Van Gerven, 1985; Hunt and Hatch, 1981).

If long bone growth occurs at a constant rate proximally and distally, then Harris lines would be equidistant from the long bone midpoint, both proximally and distally. Biology is not so straightforward though, as growth at the two ends of the bone is usually not equal (Byers, 1991).

Since Harris lines and enamel hypoplasias are presumably similar in etiology, in that they represent interruptions of the metabolic formation of new bone and enamel during the growth years, it is reasonable to suspect similar patterns of expression. Accordingly, researchers have attempted to correlate enamel hypoplastic and Harris line insults (Clarke, 1980;

McHenry and Schulz, 1976). In a study focusing on young adults, McHenry and Schulz (1976) found little significance in the relationship of these two variables in a prehistoric California Indian site from the lower Sacramento-San Joaquin Valley of Central California. A hypothesis McHenry and Schulz (1976) offer for the lack of association between the two indicators suggests Harris lines do not persist throughout adulthood and oftentimes show recovery and remodeling; conversely, and as noted above, the enamel insults do not recover and do not have the capacity to remodel (Goodman and Rose, 1990). It has also been suggested that Harris lines manifest from an initial infection and hypoplasias result from the concomitant undernutrition and diarrhea (Clarke, 1980).

Garn (1968) showed that growth rates in the tibia are almost equal proximally and distally (43% distally), and among long bones there are more radiopaque lines usually found in the tibia (Clarke, 1982). This finding explains why the tibia has often been the bone of choice for Harris line studies. However, some researchers have chosen the distal radius (Hummert and Van Gerven, 1985; Greulich and Pyle, 1959), since the radiocarpal joint is not a major mechanical stress bearer in comparison to the stress on the proximal tibia.

Earlier studies by McHenry (1968) suggested that Harris lines were nutritionally related in Early and Late Horizon California Indians. He found that more transverse lines occurred in the Early Horizon population and prompted the suggestion that the Early Horizon peoples did not develop the acorn harvest as did the Late Horizon peoples. Horizon markers refer to cultural changes over time in associated grave goods, burial positions

and practices (Heizer, 1949) and are designated by the Central California Taxonomic System (CCTS). The association of Harris lines to improved nutrition is reiterated by the evidence that chronically malnourished children do not display significant transverse lines, since their malnutrition was ongoing with no recovery period (Greulich and Pyle, 1959). Malnourished children developed Harris lines only after their diet was improved.

McHenry and Schulz's (1976) subsequent longitudinal studies on the Fels Longitudinal Studies of Growth and Development showed temporary Harris lines in 93% of the children. However, clinical studies such as Greulich and Pyle (1959), reiterates the difficulty in applying Harris line analyses to archeological populations.

Since significant variability exists with the individual age of prehistoric remains, determining the age at insult is problematic at best. Additionally, Clarke (1982) found that the incidence of Harris lines is sex biased. Researchers have developed techniques and calculations that can estimate age at the time of insult (Maat, 1984) by determining location of the primary ossification centers (Hummert and Van Gerven, 1985). These particular studies have fascinating potential but are not feasible with the available x-rays taken on this sample, since several bones were exposed on one plate (and the exposure is not ideal for every bone). Since the Stanford collection was reinterred in June, 1991, those x-rays unfortunately cannot be repeated. Additionally, measurements on the actual bone to help determine primary ossification center (Hummert and Van Gerven, 1985) would also not be possible on the Stanford sample.

Individuals have different reactions to stress. While severe illnesses have been linked to the incidence of Harris lines in some individuals, the same illnesses may not cause Harris line formation in other individuals. Greulich and Pyle (1959) offer two explanations for this differential response. They suggest individual differences in the susceptibility of the skeletal tissue. Alternatively, individual variability in skeletal growth rate may affect Harris line formation; i.e., the skeletal tissue may not be in a rapid growth stage at the time of insult, and thereby not as susceptible to Harris line manifestation. Thus, either genetic predisposition or the timing of environmental insult can affect Harris line formation.

CHAPTER IV

Methodology and Materials

Before analysis and measurement of the gross specimens could take place, records on CA-Ala-329 had to be reviewed so to determine which individuals fit within the age criteria of this study. Each burial is accompanied by extensive paperwork. The burial records were completed in the field by archeologists, documented with measurements and photographs, position of burial, location, and documentation of associated grave goods. Inventory sheets were completed within the osteology lab by graduate students and lab technicians under the direction of Dr. Robert D. Jurmain. These inventory sheets record every bone and tooth present, their condition, and frequently also note the presence of pathological lesions. Ages were assigned independently by Dr. Robert D. Jurmain and Dr. Lorna Collins Pierce for the San Jose State collection, and Dr. Jurmain and Rhonda Gillett for the Stanford University collection, using standard (sub-adult) osteological methods of dental development (Ubelaker, 1989), epiphyseal union (Ubelaker, 1989; Bass, 1989) and long bone lengths (Ubelaker, 1989). All these ages have been further reviewed and refined as of 1987 (Gillett, 1987) and are identified as the preferred age estimate in this study.

Although sub-adults are regarded here as 12 years and under, all burials that had been previously aged at 15 years and under were examined. This procedure was followed so that any specimen falling on the upper end of the age bracket would not be inadvertently excluded. Since the

the absolute age of these individuals is not verifiable, a set point had to be determined to qualify individuals as being within the age range or too old. This set point was any occlusal wear on the second permanent molar (upper and lower) based on a dental development chart compiled by Ubelaker (1989). All burials confirmed to be over 12 years of age were not included in this study.

Although the total number of burials is over 400 in the combined Stanford Collection and the San Jose State Collection, the total sub-adult sample from this population is 148. There are 87 individuals from the San Jose State excavations and 61 individuals from the Stanford excavations. Since the burials were excavated from the same site and believed to be from the same population, this study will combine the totals of both San Jose State and Stanford. When applicable, identity of burial will be noted.

A. Dental Development

All observations were recorded on a dental scoring form designed for this study. Present teeth, in situ and loose, were individually analyzed and recorded. The distribution of deciduous and permanent teeth is presented in Appendix A, Figures A-23 and A-24 respectively. Developmental observations were also recorded such as: bud in crypt, erupted, non-occluded, occluded, fused mesially, and fused distally.

Periapical view dental x-rays were taken on all maxillae and mandibles with in situ teeth. A portion of the x-rays were taken in the dental offices of Dr. Leon Pappanastos on a Phillips Oralix machine and Kodak Dental Film, Ultra-speed (size 2, DF-57). The remaining x-rays were

coordinated by Joyce Bizjak, former San Jose State Student; thus the type of equipment and identity of the dental office was unavailable. The x-rays were compared to Ubelaker's (1989) dental eruption and development chart, and Moorrees', et al., (1963 a & b) data depicting stages of crown, root, and apex of deciduous mandibular molars and permanent molars. Each individual burial with dental x-rays was assigned minimum and maximum age estimates to the nearest month in the following categories: occlusal dental eruption, incisal root formation, retained deciduous teeth, and development of unerupted teeth. These categories were determined under the capable guidance of Dr. Leon E. Pappanastos, retired oral maxillo-facial surgeon. Using Ubelaker's (1989) dental development chart, age ranges were assigned to the the range that provided the best "fit" to the following criteria. Occlusal dental eruption involved evaluation of the degree of occlusion (from non-occluded to fully occluded) of all erupted deciduous and permanent teeth visible on available x-rays. Incisal root formation was the least represented x-ray view with only seven individuals. The degree of incisal root formation from the dento-cementum junction to the apex was compared to Ubelaker's (1989) dental development chart from which age ranges were assigned. Retained deciduous teeth were evaluated for their relationship to the replacement permanent dentition. Development of the unerupted teeth involved evaluating degree of crown formation and root formation. The amount of crown and root formed was compared to Ubelaker's (1989) dental development chart, and each tooth was assigned the age range that provided the best fit.

Since not all x-ray views fit within one age range for each individual, the best fit was determined by the majority of elements most represented within an age range for each x-ray view. By classifying age by month in a variety of categories, it is possible to make reasonable inferences on developmental age. Perhaps in this way more statistically significant ranges can be obtained in contrast to the inherent wide range of variation in bioarcheological samples.

Additionally, non-metric dental observations including dental hypoplasias were recorded that are potential indicators of stress. For this study, visible transverse hypoplasias were recorded as present or absent on all anterior teeth.

B. Femoral Cortical Area

The left femora of CA-Ala-329 were scanned on a Phillips 60TX CT Scanner in 1986. The cross sectional views made by the CT scanner, represent mirror images of the cortical thickness, by delineating subperiosteal and medullary areas; and recorded the actual measurements to the nearest tenth of a square millimeter. The medullary area was subtracted from the subperiosteal area to reach an actual cortical area measurement.

In addition, the CT Scanner measured the bone mass, not density (Martin, et al., 1985) by analyzing the mineral content in three locations (medial, anterior and posterior) on the femoral cross sections. The three mineral content measurements were recorded by the scanner to the nearest tenth of a gram. The average mineral content was computed for analysis.

C. Long Bone Measurements

Each postcranial long bone element was analyzed as follows:

Complete long bone diaphyses were measured for maximum length on an osteometric board and recorded to the nearest millimeter; secondly, the midshaft was marked and the maximum midshaft medio-lateral and antero-posterior measurements were taken with a Mitutoyo Digimatic digital caliper. The measurements were recorded to the nearest one-hundredth of a millimeter. Iliac were measured for maximum breadth with Mitutoyo Digimatic digital calipers to the nearest hundredth of a millimeter and recorded.

All bone measurements, 21 measurements on seven bones, were recorded on a data collection form designed for this study. The left side is the preferred side for all measured bones in this research project; however, when the left was not present or too fragmentary, the right side was used. Sides of all measured bones were recorded. Figures A-16 through A-22 (Appendix A) present the percentage of complete elements for each age category.

D. Harris Lines

All long bones were to be included in this study; however, there was only one x-ray including a complete fibula (CA-Ala-329 Stanford #134); therefore the femur, tibia, humerus, ulna and radius were scored for Harris lines. The presence or absence of lines was initially macroscopically recorded on x-ray followed by confirmation using a 5-power magnifying glass. Only lines that were transverse to the axis of the

bone and extended at least half way across the shaft were counted. The number of proximal and distal Harris lines was recorded for each radiographed element. In some cases the radiographic exposure was compromised with all elements exposed on one plate, resulting in a mixture of overexposed and underexposed images. These cases were not included in this study. Additionally, x-rays of bones that were missing a significant part of the metaphysis were also disregarded. Since Harris lines are often obliterated during adulthood, the analysis of these striations on sub-adult remains will be instrumental in evaluating the incidence of Harris lines in this sample and evaluating the health status of this population as a whole. (Maat, 1984).

CHAPTER V

Results

The foundation for all subsequent analyses was the assignment of a refined mean age to each burial. This mean age was attained by computing a mean from the preferred age estimate derived by Drs. Jurmain and Pierce, and a mean from each of the four different dental x-ray criteria. The four dental x-ray age estimates were determined by occlusal dental eruption, incisal root formation, retained deciduous teeth and development of unerupted teeth. Not all burials had all five age indicators; thus the mean age estimate was computed from available data. In some cases only one age indicator was available, and this provided the mean age for this study.

Table 1 lists the burials with the preferred mean age and the dental x-ray mean age, and the mean age estimate in chronological order. All dental x-ray ages were strongly correlated to the preferred age estimate as shown in Table 2. Appendix Figure A-2 displays the distribution of burials by age category. There were twelve burials that were too fragmentary (or cremated) and thus precluded age assignment (Appendix Figure A-1). These burials are not included in Table 1.

Figures 4 and 5 plot the differences between the preferred age estimate and the dental x-ray age estimate for all individuals. Figure 4 includes all individuals estimated to be under 1.5 years of age, and Figure 5 includes those individuals estimated to be between 1.5 and 14.5 years of

Table 1
Mean Age Estimates

Mean of Means (Age in months)	Preferred Age Estimate* (months)	Dental X-ray Mean Age (months)	Burial Number (SJS or ST)
-1.5	-1.5		16 (ST)
-1.5	-1.5		73 (SJS)
0	0		6A (SJS)
0	0		125A (SJS)
0	0		164 (SJS)
0	0		254B (SJS)
0	0		62B (ST)
0	0		123 (ST)
0	0		62 (ST)
0	0		79 (ST)
0	0		87 (ST)
0	0		106A (ST)
0	0		115 (ST)
0	0		116 (ST)
0	0		116A (ST)
0	0		139 (ST)
0	0		144B (SJS)
0	0		43 (ST)
0	0		122A (ST)
0	0		8A (SJS)
1.5	1.5		221 (SJS)
1.5	1.5		44 (SJS)
1.5	1.5		121 (SJS)
1.5	3	0	22 (ST)
1.5	1.5		44 (ST)
1.5	1.5		84A (SJS)
3	3		28A (ST)
3	3		40A (ST)
3	3		59 (SJS)
3	3		83 (SJS)
3	3		113A (SJS)
3	3		138 (SJS)
3	3		146A (SJS)
3	3		171A (SJS)

(* After Jurmain and Pierce, 1982; and Gillett, 1987)

Table 1 (continued)
Mean Age Estimates

Mean of Means (Age in months)	Preferred Age Estimate* (months)	Dental X-ray Mean Age (months)	Burial Number (SJS or ST)
3	3		214 (SJS)
3	3		262 (SJS)
3	3		14 (ST)
3	3		34 (ST)
3	3		37A (ST)
3	3		37B (ST)
4.5	4.5		258 (SJS)
4.5	4.5		285 (SJS)
4.5	4.5		142A (SJS)
6	6	6	45 (ST)
6	6		80 (SJS)
6	6		66A (SJS)
6	6		159A (SJS)
7.5	6	6	62A (ST)
9	9		42 (SJS)
9	9		138 (ST)
12	12		96 (ST)
12	12		41 (ST)
12.75	15	10.5	79 (SJS)
13.5	18	9	63 (ST)
14	18	10	72 (SJS)
15	15		166 (SJS)
15	15		171 (SJS)
15	15		236 (SJS)
15	15		144A (SJS)
15		15	8 (ST)
15.5	15	16	4 (SJS)
15.5	15	16	165 (SJS)
16.5	18	15	45 (SJS)
17.25	15	19.5	10 (ST)
18	18		228 (SJS)
18	18		248 (SJS)
18	21	15	237 (SJS)

(* After Jurmain and Pierce, 1982; and Gillett, 1987)

Table 1 (continued)
Mean Age Estimates

Mean of Means (Age in months)	Preferred Age Estimate* (months)	Dental X-ray Mean Age (months)	Burial Number (SJS or ST)
18	18	18	68 (SJS)
18	18		159 (SJS)
18	18		163A (SJS)
18	18		259B (SJS)
18	18		40D (ST)
18	18	18	46 (ST)
21	21	21	47 (SJS)
21	21		125B (ST)
24	24		35A (SJS)
24	24		95 (SJS)
24	24		160 (SJS)
24	24		43 (SJS)
24	24		17 (ST)
24.75	30	19.5	134 (ST)
25.5	27	24	123 (SJS)
25.5	27	24	246 (SJS)
27	27		233 (SJS)
27.5	27	28	247 (SJS)
29	30	28	240 (SJS)
30	30		187 (SJS)
30	30		35 (SJS)
30	30		82 (SJS)
30	24	36	114 (ST)
31.5	27	36	156 (SJS)
39	30	48	272 (SJS)
39	30	48	50 (ST)
51	54	48	135 (ST)
51	48	54	19A (SJS)
54	54		143A (SJS)
58	48	68	264 (SJS)
60	72	48	54 (ST)
60		60	74A (ST)
60	60		153A (SJS)
62	62		94 (ST)

(* After Jurmain and Pierce, 1982; and Gillett, 1987)

Table 1 (continued)
Mean Age Estimates

Mean of Means (Age in months)	Preferred Age Estimate* (months)	Dental X-ray Mean Age (months)	Burial Number (SJS or ST)
63	54	72	29 (SJS)
66	66		99 (ST)
67	78	56	271 (SJS)
70	72	68	41 (SJS)
70	72	68	17 (SJS)
80.67	78	83.33	107 (SJS)
86.5	84	89	170 (SJS)
90	90		241 (SJS)
90	84	96	270 (SJS)
90	90		108A (SJS)
96	96		193 (SJS)
99	102	96	105A (ST)
109	114	104	119 (ST)
111	114	108	118 (ST)
114	114		119A (ST)
117	126	108	15 (ST)
126	126		126 (SJS)
126	126		121A (ST)
129	138	120	255 (SJS)
132	144	120	42 (ST)
132	144	120	230 (SJS)
132	144	120	5 (ST)
138	156	120	40 (ST)
138.5	144	133	48 (ST)
144	144		76 (ST)
144	144		179 (SJS)
144	168	120	63 (SJS)
144.5	156	133	152 (SJS)
150	150		207 (SJS)
150	150		89B (ST)
162	162		89 (SJS)
168	168		185 (SJS)
168	168		66 (ST)
168	168		128 (ST)
174	174		147A (SJS)
Total = 136	Total = 134	Total = 48	Total = 136

(* After Jurmain and Pierce, 1982; and Gillett, 1987)

age. The plots distinguish if only one age estimate, preferred or dental x-ray, is available. Figure 4 indicates a large proportion of individuals without dental x-rays, but Figure 5 indicates a larger proportion of individuals with both types of age estimate.

The mean age estimate suggests the youngest individual to be approximately 1.5 months premature. Modern clinical studies suggest known causes of death in premature infants and neonates as: abnormal pulmonary ventilation, infection, intracranial hemorrhage, abnormal blood conditions, congenital anomalies, weakness of the suckling and swallowing reflexes, small capacity of the stomach, impairment of renal function, incomplete lung development, and inadequate regulation of the body temperature (Taber's, 1989). Certainly, in addition to the above listed clinical findings, poor nutrition, infectious diseases (including parasites), septic surroundings, and lack of prenatal care contributed to the mortality of premature and newborn infants of this sample.

Doran's doctoral dissertation (1980) focused on a Sacramento Valley Miwok Indian ethnolinguistic group exploiting the same food items and believed to have lived the same semi-sedentary hunter-gatherer lifestyle as this study population, the CA-Ala-329 Ohlone. Both the Miwok (Doran, 1980) and the Ohlone (Leventhal, 1991) occupation occurred in the Early, Middle, and Late Horizons. The CA-Ala-329 sample has been classified as Middle to Late Horizon.

The mean age estimate suggests that the oldest individual in this sample is 174 months (14.5 years). This estimate surpasses the maximum

144 month (12 years) age designated as the maximum age limit for this study. There are seven individuals that surpass the 12-year-age ceiling; which strengthens the representativeness of this sub-sample, as including all individuals 12 years and under.

Based on the mean age estimates in Table 1, Appendix Tables A-3 through A-9 respectively present proposed developmental lengths for the humeri, ulnae, radii, ilia, femora, tibiae and fibulae of this sample. As expected, when considering archeological preservation (completeness of elements), more than 50% of the population is represented by the more robust elements (femora, humeri, and ilia), and the least robust of the elements, the fibula, is represented by only 29% of the sample. The tibia is present in only 40% of the sample.

Table 2
Correlations of
Preferred Age Estimate: X-ray ages

Age Estimate Source	Pearson's Correlation Coefficient	Approximate Significance Level	Number Valid Observations
occlusal dental eruption	.97	<.00001	44
incisal root formation	.98	.00011	7
retained deciduous teeth	.95	<.00001	34
development of unerupted teeth	.96	<.00001	39
x-ray mean age	.97	<.00001	46

Figure 4
Preferred Age Estimate and Dental X-Ray Age Estimate
Plot for All Individuals Under 1.5 Years of Age
CA-Ala-329 Sub-Adults

Figure 5
Preferred Age Estimate and Dental X-Ray Age Estimate
Plot for All Individuals from 1.5 to 14.5 years of Age
CA-Ala-329 Sub-Adults

The femora were tested for Ortner and Putschar's (1985) hypothesis that the femur length doubles in the first four years, and doubles again by the eighth year. Femora in the three applicable age categories were compared. The CA-Ala-329 femora increased in length 211% by the fourth year and another 192% by the eighth year. In comparison, Ubelaker's (1989) Arikara data suggested a 206% increase by the fourth year and a 145% increase by the eighth year.

These statistical findings demonstrate similar growth rates between the Arikara Indians (Ubelaker, 1989) and the CA-Ala-329 sample. Additionally, they confirm Ortner and Putschar's (1985) hypothesis and contradict Johnston's (1962) suggestion of slower growth rates for Indians.

From the developmental guidelines in Appendix Tables A-3 through A-9, generalized growth curves are constructed and appear in Figures 6 - 12. These curves compare the suggested developmental guidelines of the CA-Ala-329 sub-adult sample to the standards suggested by Ubelaker (1989) for the Arikara Indian sub-adult sample. As mentioned earlier, Jurmain and Pierce (1982) arrived at the preferred age estimates for each individual by using standard osteological methods. In some individuals, the Arikara (Ubelaker, 1987) data was, either the only reference used, or heavily weighted, because of available elements. Thus, a third curve is provided in Figures 6 - 12. This additional curve representing individuals with a dental x-ray age only, demonstrates that the Arikara and CA-Ala-329 samples are consistently similar, even without the incorporation of the preferred age estimate.

Figure 6
Sub-Adult
Comparative Growth Curves
Humerus

Figure 7
Sub-Adult
Comparative Growth Curves
Ulna

Figure 8
Sub-Adult
Comparative Growth Curves
Radius

Figure 9
Sub-Adult
Comparative Growth Curves
Ilium

Figure 10
Sub-Adult
Comparative Growth Curves
Femur

Figure 11
Sub-Adult
Comparative Growth Curves
Tibia

Figure 12
Sub-Adult
Comparative Growth Curves
Fibula

The CA-Ala-329 sample consistently exhibits slightly shorter long bone lengths than the Arikara sample. However, the almost identical curves in Figures 6 - 12 show an insignificant size difference between the Arikara and the CA-Ala-329 sample.

Slight inter-sample differences in the growth curves in Figures 6 - 12 are due to the small size of the sub-sample. These differences are apparent in Figure 6 in the 6.5 - 7.5 year age category (with only one element) and the 10.5 - 11.5 year age category (with only two elements). These curves suggest that the available elements are from a child shorter than expected, from this population. Conversely, Figure 9 demonstrates that larger than expected individuals represent the one element in the 4.5 - 5.5 year age category and also explains the two elements from the 8.5 - 9.5 year age category.

Appendix Tables A-10 through A-15 outline proposed developmental guidelines of the mid-shaft widths of the humeri, ulnae, radii, femora, tibiae and fibulae of the CA-Ala-329 sub-adult sample. Ubelaker (1989) does not provide these same measurements for the Arikara sample, so inter-population comparative growth curves cannot be provided for the mid-shaft widths.

The comparative curves in Figures 13 - 18 show that long bone lengths and mid-shaft widths increase equilaterally. These curves demonstrate identical relationships between linear growth and midshaft widths. These relationships appear unaffected by small sample size, or the over-representation of small or large individuals.

Figure 13
Comparative Growth Curves
Mean Width and Mean Length
Humeri
CA-Ala-329 Sub-Adults

Figure 14
Comparative Growth Curves
Mean Width and Mean Length
Ulnae
CA-Ala-329 Sub-Adults

Figure 15
Comparative Growth Curves
Mean Width and Mean Length
Radii
CA-Ala-329 Sub-Adults

Figure 16
Comparative Growth Curves
Mean Length and Mean Width
Femora
CA-Ala-329 Sub-Adults

Figure 17

Comparative Growth Curves
Mean Width and Mean Length
Tibiae
CA-Ala-329 Sub-Adults

Figure 18
Comparative Growth Curves
Mean Length and Mean Width
Fibulae
CA-Ala-329 Sub-Adults

Figure 19
Comparative Growth Curves
Mean Length, Mean Width
and Mean Medullary Diameter
Femora
CA-Ala-329 Sub Adults

Figure 20

Comparative Growth Curves
Medullary Area, Sub-Periosteal Area,
and Cortical Area Femora
CA-Ala-329 Sub Adults

Figure 21
 Comparative Growth Curves
 Mean Medullary Diameter and
 Mean Sub-periosteal Diameter
 Femora
 CA-Ala-329 Sub Adults

Alternatively, Figure 19 suggests variability in the size of the medullary cavity in comparison to long bone length. Although not conclusive, owing to the small (46 of the 73 complete femora) sample of CT scans performed on femora, these data are suggestive of linear bone growth continuing at a steady pace -- while the size of the medullary cavity fluctuates.

Comparative growth curves in Figure 20 show the differences in the femoral length, width and medullary diameter for each age category. Additionally, the comparative growth curves in Figure 21 demonstrate the relationship between the medullary and subperiosteal diameters for each age category.

Mineral content was both averaged and totaled. Pearson's correlation coefficients were calculated comparing average and total mineral content to age category, femur length, femur mid-shaft width, and cortical area. All relationships tested resulted in a low correlation. One would expect mineral content to correlate with cortical area and/or midshaft width. Perhaps bone mass has a high degree of variability due to individual variation, thus age as well as bone length can not be positively correlated due to individual adaptation to growth, stressors, and predisposition.

Cortical area was correlated in 46 cases to the mean age with a coefficient of .89 at a .001 level of significance. Cortical area was also strongly correlated to femur length in 40 cases with a .95 coefficient (.001 significance level), while the medullary cavity was more strongly correlated

Figure 22
Comparative Growth Curves
Mean Length and Cortical Area
Femora
CA-Ala-329 Sub Adults

to femur length (.70 at a .001 level of significance) than to mean age (.54 at a .001 level of significance).

The square root of the femoral cortical area was strongly correlated to femoral mid-shaft width and maximum length. At a .001 level of significance, the coefficient was .94 between the square root of the cortical area and the midshaft width; and the coefficient was .96 between the square root of the cortical area and maximum length.

Figure 22 demonstrates the fluctuation in cortical area in comparison to linear growth. These curves demonstrate that while linear growth continues at a steady pace, a significant loss in cortical area occurs in the 4.5 - 5.5 year age category. The cortical area increase in the 5.5 - 6.5 year age category is followed by yet another loss in cortical area. This fluctuation may be due to the small sample size of four individuals in the 5.5- 6.5 year age category, two individuals in the 6.5 - 7.5 year age category, and five individuals in the 7.5 - 8.5 year age category. The 4.5 - 5.5 year age category is slightly larger with seven individuals. Alternatively this fluctuation could be interpreted as cortical area loss as a result of long bone growth, as suggested by Huss-Ashmore, *et al.* (1982).

The suspected skeletal indicators of stress in this population are skeletal size, dental hypoplasias, and Harris lines. As indicated above, the CA-Ala-329 sub-adult sample is skeletally slightly smaller than the Arikara. There is not a demonstrated, statistically significant difference between the two populations.

Harris lines and dental hypoplasias are both observed in this sample. Figure 23 demonstrates the comparison between available x-rayed elements

Figure 23
Harris Line Incidence
CA-Ala-329 Sub-Adults

Figure 24
Harris Line Incidence
Percentage Affected
CA-Ala-329 Sub-Adults

and those elements with at least one Harris line. The numbers are greatly reduced, as not all elements were x-rayed and not all x-rayed elements are affected. The larger proportion of affected elements is between the ages of 3.5 and 12.5 years, as shown in Figures 23 and 24. However, there are 42 affected elements in the nine age categories between 3.5 and 12.5 years, while there are 59 affected elements in the four age categories between newborn and 3.5 years. The higher proportion in the nine older age categories may be, in part, due to the small number of elements x-rayed, as demonstrated in Appendix Figures A-25 - A-29.

The number of Harris lines was correlated to the age of the individual (46 valid observations), with a .63 coefficient at a .00000 level of significance. The distribution of Harris lines by average age is plotted on Figure 25. Individual elements, distinguished between proximal and distal manifestations, resulted in a variety of weak negative correlations; and the strongest positive correlation was in the distal tibia (.54 at a .00013 level of significance). Table 3 shows the coefficients for each element, proximal and distal. The coefficient for the proximal ulna could not be calculated because of the small number of valid observations and no Harris lines scored.

Figure 26 suggests that Harris lines are manifested more often in the distal ends of the long bone shaft. As mentioned earlier, some researchers (Hummert and Van Gerven, 1985; Greulich and Pyle, 1959) prefer to evaluate Harris line incidence in the radius. They suggest that the tibia may display Harris lines resulting from the weight borne by the tibia, thus the radius is the preferred element in Harris line evaluation. This study

Figure 25
 Number of Harris Lines Per Individual
 CA-Ala-329 Sub-Adults

Table 3
Harris Line by Element and Location: Age Correlations

Bone and location of Harris lines	Pearson's Correlation Coefficient	Approximate Level of Significance	Number of Valid Observations
Proximal Humerus	-.09	.53333	46
Distal Humerus	-.03	.86783	46
Proximal Radius	.26	.09230	43
Distal Radius	.86	.00185	43
Distal Ulna	-.24	.65070	6
Proximal Femur	-.0003	.98353	59
Distal Femur	.86	.00008	59
Proximal Tibia	.63	.03254	46
Distal Tibia	.54	.00014	45

found that in 90 x-rayed radii, there was only one proximal and 43 distal Harris lines. Of the 44 x-rayed tibiae, there were 98 proximal and 109 distal Harris lines. These findings do not support the preference for the radius in Harris line studies. The tibia has been shown to grow almost equally proximally and distally (Garn, 1968), and these data show almost equal Harris line insults at the proximal and distal ends.

The most Harris lines (proximal and distal) were observed in the 1.5 - 2.5 year age category. This age category is the second largest and is also represented by the largest percentage of x-rayed elements. However, Figure 27 shows that the 6.5 - 7.5 year age category has the highest mean number of Harris line occurrences. Appendix Figures A-25 to A-29 show that the tibia, femur and the radius are the most affected elements, with the ulna being the least affected.

Figure 27
Mean Number of Harris Lines Per Individual
CA-Ala-329 Sub-Adults

The percentage of mandibular and maxillary hypoplasias is presented in Figure 28. Goodman and Rose (1990) and Goodman and Armelagos (1985) found the maxillary central incisor to have the largest percentage of hypoplastic insults. A slight prevalence for hypoplastic central maxillary incisors is also noted in this population as demonstrated in Figure 29.

Since the affected anterior teeth from this sub-sample are both of the maxillary incisors, and the maxillary and mandibular canines, the age range of developmental stress in this sub-sample can be approximated to be from 2.5 to 4 years of age (Lanphear, 1990). If the assumption is made, that weaning occurs in this population between the second and fourth years of life; this supports Clarke's (1980) hypothesis that dental hypoplasias may be manifested because of the stress of weaning. The distribution of anterior teeth that are unaffected and affected by hypoplasia is shown in Tables 4 and 5 . Maxillary teeth are shown in Table 4 and mandibular teeth are shown in Table 5.

Dental hypoplasias were found only in permanent anterior teeth. This finding is additional support for Clarke's (1980) hypothesis that hypoplasias may be manifested as a result of the stress of weaning. This is apparent because the enamel formation of the deciduous teeth occurs between 5 months *in utero* to three months of age (Ubelaker, 1989), suggestive of good nutrition of the pregnant mother.

Figure 28
Distribution of Maxillary and Mandibular Hypoplasias
Anterior Permanent Dentition
CA-Ala-329 Sub-Adults

Figure 29
Distribution of Affected Hypoplastic Teeth
CA-Ala-329 Sub-Adults

Table 4
Frequency of Maxillary Hypoplasias
CA-Ala-329 Sub-Adults

Age Category	I1		I2		Canine		Total
	+	-	+	-	+	-	
4.5 - 5.5	1	-	1	1	-	2	5
5.5 - 6.5	-	1	-	-	-	2	3
6.5 - 7.5	-	2	-	2	-	2	6
7.5 - 8.5	2	4	2	3	-	2	13
8.5 - 9.5	2	-	1	-	2	-	5
9.5 - 10.5	2	-	-	2	-	-	4
10.5 - 11.5	4	2	3	4	5	2	20
11.5 - 12.5	4	4	2	2	2	5	19
13.5 - 14.5	-	-	-	1	3	-	3
Total =	15	13	8	15	12	15	78

("+ " = affected teeth, "- " = unaffected teeth)

Table 5
Frequency of Mandibular Hypoplasias
CA-Ala-329 Sub-Adults

Age Category	I1		I2		Canine		Total
	+	-	+	-	+	-	
6.5 - 7.5	-	1	-	2	-	-	3
7.5 - 8.5	-	7	-	5	-	2	14
8.5 - 9.5	-	2	-	2	2	-	6
9.5 - 10.5	-	1	-	2	1	-	4
10.5 - 11.5	-	6	-	6	7	-	19
11.5 - 12.5	-	6	-	6	1	6	19
13.5 - 14.5	-	-	-	3	2	-	5
Total =	0	23	0	26	13	8	70

("+ " = affected teeth, "- " = unaffected teeth)

Correlation tests were computed on the association of Harris lines to dental hypoplasias in this sample. The result shows an inverse relationship between these two variables. These results possibly reflect the fact that the majority of this study population has deciduous teeth and only permanent anterior teeth were observed with hypoplastic bands. However, these results are similar to those attained by McHenry and Schulz (1976) and can be explained similarly. As mentioned earlier, Harris lines can be resorbed. It is conceivable that stressors that caused hypoplastic ridges also resulted in Harris line formation, but the resorptive process erases those Harris lines that have the potential to correspond chronologically to hypoplastic ridges. Figure 30 compares the incidence of dental hypoplasias and Harris lines by age category and demonstrates that, while hypoplasias increase with age, the occurrence of Harris lines is less predictable.

Although teeth preserve well archeologically, recovery is often challenging, as teeth are so small. Additionally, the majority of the teeth in this study sample are deciduous which are smaller than permanent teeth. Therefore, missing teeth may be absent because of lack of recovery. They also may be absent because of ante-mortem shedding. While the reason for absence can sometimes be determined from skeletal clues, conclusive evidence is not always available.

Figures 31- 44 propose developmental guidelines for all age categories in this study except for neonate and the 12.5 - 13.5 age category. These exclusions result from the neonate sample (2) having no teeth present and the 12.5 - 13.5 sub-sample includes only one individual. The Newborn to .5

Figure 30
Incidence of Hypoplasias and Harris Lines
CA-Ala-329 Sub-Adults

year age category shows that there are no occluded teeth. In Figures 24 through 37, the teeth have been identified on the x-axis as follows: U = upper, L = lower, P = permanent, d = deciduous, I = incisor, C = canine, PP = premolar and M = molar. The deciduous and permanent teeth represented in this sample are shown in Appendix A Figures A-23 and A-24 respectively.

The proposed developmental guidelines in Figures 31 - 44 were designed from developmental data recorded on each tooth. All deciduous and permanent left and right maxillary, as well as left and right mandibular teeth, were totaled in three different developmental stages. These stages were: bud in crypt, non-occluded and occluded. Percentages for each developmental stage for each tooth were calculated. The stage representing the largest percentage of teeth in each age category was scored as the developmental guideline of that tooth for that age category. All teeth were calculated in this manner. In the event of equal distribution between two of the three different developmental stages, the third outlying developmental stage assisted in determining which age was assigned to the age category.

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Figure 32
Proposed Dental Developmental Guidelines
CA-Ala-329
.5 - 1.5 years

Figure 33

Figure 34
Proposed Dental Developmental Guidelines
CA-Ala-329
2.5 - 3.5. years

Figure 35
Proposed Dental Developmental Guidelines
CA-Ala-329
3.5 - 4.5. years

Figure 36
Proposed Dental Developmental Guidelines
CA-Ala-329
4.5 - 5.5. years

Figure 37
Proposed Dental Developmental Guidelines
CA-Ala-329
5.5 - 6.5. years

Figure 38
Proposed Dental Developmental Guidelines
CA-Ala-329
6.5 - 7.5. years

Figure 39
Proposed Dental Developmental Guidelines
CA-Ala-329
7.5 - 8.5. years

Deciduous and Permanent Teeth

Teeth	Occluded	Non-Occluded	Bud in Crypt
LAI1	1	0	0
UIA1	1	0	0
LAI2	1	0	0
UIA2	1	0	0
LDC	1	0	0
UDC	1	0	0
LDM1	1	0	0
UDM1	1	0	0
LDM2	1	0	0
UDM2	1	0	0
LPI1	1	0	0
UPI1	1	0	0
LPI2	1	0	0
UPI2	1	0	0
LPC	1	1	0
UPC	1	1	0
LPP1	1	1	0
UPP1	1	1	0
LPP2	1	1	0
UPP2	1	1	0
LPM1	1	1	0
UPM1	1	1	0
LPM2	1	1	0
UPM2	1	1	0
LPM3	1	0	1
UPM3	1	0	1

Figure 41
Proposed Dental Developmental Guidelines
CA-Ala-329
9.5 - 10.5 years

Figure 42
Proposed Dental Developmental Guidelines
CA-Ala-329
10.5 - 11.5 years

Figure 43
Proposed Dental Developmental Guidelines
CA-Ala-329
11.5 - 12.5 years

Figure 44
Proposed Dental Developmental Guidelines
CA-Ala-329
13.5 - 14.5. years

CHAPTER VI

Summary

The purpose of this study was to investigate skeletal and dental development and to identify the occurrence of possible environmental stressors affecting normal development in a prehistoric sub-adult sample. The sample was a burial population from the Ryan Mound (CA-Ala-329) located along the rim of the southeastern corner of the San Francisco Bay, California. This sample was drawn from two different excavations of over 400 burials conducted by Stanford University and San Jose State University in the 1950's and 1960's. From these excavations there are 148 individuals designated as sub-adults to be included in this study.

Dental development was heavily weighted in computing estimated age of each individual by assigning a mean age computed from the preferred age estimate, and dental x-ray age estimates from views of incisal root formation, development of unerupted teeth, retained deciduous teeth and occlusal dental eruption. The mean age, and the age categories built upon it, became the foundation of this study. Established guidelines for skeletal maturity were established based upon the mean age estimates for this population.

The anthropometry suggested the CA-Ala-329 sub-adult sample to be only slightly smaller than Ubelaker's (1989) Arikara sample. Long bone widths increased equilaterally with linear growth, demonstrating that the subperiosteal width is not sacrificed to accommodate linear growth. A

more varied growth pattern is demonstrated by the fluctuation of the relationship of the size of the medullary cavity to long bone length and width.

This study offers proposed guidelines for dental development, long bone lengths and midshaft widths for age categories from neonate through 14.5 years. The lack of any correlation between Harris lines and dental hypoplasias prevents these suspected environmental stress indicators from being included in the proposed developmental guidelines herein.

The size of the overall sample is very adequate, based on both total burials and preservation quality. Unfortunately, the numbers needed for valid correlation analyses were not always present within respective age categories. Moreover, as the Stanford collection was reinterred June, 1991, further gross analyses is impossible with this portion of the sample.

A final consideration must be noted regarding the representation of this sub-adult sample. The temporal similarities of the Miwok (Doran, 1980) and the CA-Ala-329 study sample were discussed earlier. Doran (1980) found the highest Late Horizon sub-adult mortality rate to be around 4 years of age. In comparison only 2% of the CA-Ala-329 study sample fall within the 3.5 - 4.5 year age category, and 49% are under 3.5 years.

This variation may have different explanations. First, the Miwok (Doran, 1980) population may have been more dissimilar to the CA-Ala-329 population than suspected. But more importantly, it is prudent to consider that the sub-adult sample from CA-Ala-329 may be underrepresented in the 3.5 - 4.5 age category, and possibly additional age categories as well. Additionally, high neonate and infant mortality is not unusual in

prehistoric populations such as CA-Ala-329. (Doran, 1980; Acsadi and Nemeskeri, 1970)

Developmental studies of prehistoric sub-adult samples are an assessment of the growth process of the parent population. Further studies, using similar analyses, comparing this sample to other prehistoric sub-adult samples have the potential to provide additional insight into the multi-cultural perspective of human ontogeny.

This thesis explored the developmental aspects of the CA-Ala-329 sub-adult sample. Tooth development and eruption patterns, long bone measurements, femoral cortical growth, enamel hypoplasias and Harris lines were analyzed and summarized. The long bone measurements were compared to the Arikara (Ubelaker, 1989) population and were found to be similar. Results of this study can be used as a guideline for aging similar populations. Future cooperative efforts, in analyzing and interpreting the CA-Ala-329 site, between archeologists, cultural anthropologists, physical anthropologists and mammologists offers the best promise for a bio-archeo-cultural understanding of the CA-Ala-329 population.

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Appendix A

The following tables and figures provide comprehensive data on the study sample including: burial condition, age distribution, bone length and mean widths with standard deviations, and age distribution of skeletal and dental elements, and incidence of Harris lines per element. All tables and figures in this Appendix are referred to in the thesis.

Figure A-1
Sub-Adult Burial Condition
CA-Ala-329

Figure A-2
Age Distribution of Sub-Adult Burials
CA-Ala-329

Table A-3

Proposed Developmental Guidelines
CA-Ala-329 Sub-Adults
Mean Length (* = only one individual)
Humeri

Estimated Age (years)	Mean Length (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	55	5.66	51 - 59	2
Newborn - .5	65.54	6.51	43 - 83	24
.5 - 1.5	98.5	8.7	82 - 110	10
1.5 - 2.5	112.33	9.22	96 - 127	12
2.5 - 3.5	121	3.47	119 - 125	3
3.5 - 4.5	131	16.97	119 - 143	2
4.5 - 5.5	169	16.52	150 - 180	3
5.5 - 6.5	167.5	13.44	158 - 177	2
6.5 - 7.5	175 *	-	-	1
7.5 - 8.5	190	-	-	2
8.5 - 9.5	212.5	9.19	206 - 219	2
9.5 - 10.5	-	-	-	0
10.5 - 11.5	211	8.72	205 - 221	3
11.5 - 12.5	245 *	-	-	1
12.5 - 13.5	-	-	-	0
13.5 - 14.5	236.5	24.58	216 - 269	4
				Total = 71

Table A-4

Proposed Developmental Guidelines
 CA-Ala-329 Sub-Adults
 Mean Length (* = only one individual)
 Ulnae

Estimated Age (years)	Mean Length (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	55 *	-	-	1
Newborn - .5	62.13	4.33	55 - 71	16
.5 - 1.5	86.13	7.02	73 - 91	8
1.5 - 2.5	95.67	5.68	89 - 105	9
2.5 - 3.5	105	5.66	101 - 109	2
3.5 - 4.5	120	7.07	115 - 125	2
4.5 - 5.5	137	18.92	114 - 159	4
5.5 - 6.5	142 *	-	-	1
6.5 - 7.5	140 *	-	-	1
7.5 - 8.5	163 *	-	-	1
8.5 - 9.5	173.5	9.19	167 - 180	2
9.5 - 10.5	163 *	-	-	1
10.5 - 11.5	172.5	10.61	165 - 180	2
11.5 - 12.5	203.33	6.03	197 - 209	3
12.5 - 13.5	-	-	-	0
13.5 - 14.5	194 *	-	-	1
				Total = 54

Table A-5

Proposed Developmental Guidelines
 CA-Ala-329 Sub-Adults
 Mean Length (* = only one individual)
 Radii

Estimated Age (years)	Mean Length (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	47 *	-	-	1
Newborn - .5	54.11	4.32	43.62	19
.5 - 1.5	77.25	5.31	69 - 83	8
1.5 - 2.5	85.9	4.89	78 - 94	10
2.5 - 3.5	99.75	7.89	91 - 109	4
3.5 - 4.5	110	5.66	106 - 114	2
4.5 - 5.5	126.25	18.55	103 - 144	4
5.5 - 6.5	136 *	-	-	1
6.5 - 7.5	126 *	-	-	1
7.5 - 8.5	149 *	-	-	1
8.5 - 9.5	151 *	-	-	1
9.5 - 10.5	-	-	-	0
10.5 - 11.5	159	7.94	150 - 165	3
11.5 - 12.5	183.75	7.46	173 - 190	4
12.5 - 13.5	-	-	-	0
13.5 - 14.5	179 *	-	-	1
				Total = 60

Table A-6

Proposed Developmental Guidelines
 CA-Ala-329 Sub-Adults
 Mean Breadth (* = only one individual)
 Ilia

Estimated Age (years)	Mean Length (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	31.33 *	-	-	1
Newborn - .5	34.67	3.21	29.07 - 41.83	21
.5 - 1.5	49.06	6.06	40.54 - 59.08	12
1.5 - 2.5	57.27	5.15	48.17 - 70.31	12
2.5 - 3.5	71.35	1.85	69.75 - 73.38	3
3.5 - 4.5	76.93 *	-	-	1
4.5 - 5.5	83.42	11.6	67.7 - 94.57	4
5.5 - 6.5	82.07	4.49	77.89 - 86.81	3
6.5 - 7.5	84.71	.43	84.4 - 85.01	2
7.5 - 8.5	94.17	8.26	85.5 - 102.31	3
8.5 - 9.5	96.42	.28	96.22 - 96.62	2
9.5 - 10.5	94.35 *	-	-	1
10.5 - 11.5	96.72	5.07	93.13 - 100.3	2
11.5 - 12.5	116.45	2.64	113.14 - 118.68	4
12.5 - 13.5	-	-	-	0
13.5 - 14.5	106.72	8.81	99.23 - 116.42	3
				Total = 74

Table A-7

Proposed Developmental Guidelines
 CA-Ala-329 Sub-Adults
 Mean Length (* = only one individual)
 Femora

Estimated Age (years)	Mean Length (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	68 *	-	-	1
Newborn - .5	76.86	6.75	66 - 91	21
.5 - 1.5	114.64	14.55	91 - 131	14
1.5 - 2.5	141.14	11.75	119 - 166	14
2.5 - 3.5	157.75	24.03	128 - 183	4
3.5 - 4.5	194.5	3.54	192 - 197	2
4.5 - 5.5	220.5	45.65	180 - 270	4
5.5 - 6.5	235.67	12.1	222 - 245	3
6.5 - 7.5	240 *	-	-	1
7.5 - 8.5	299 *	-	-	1
8.5 - 9.5	297.5	9.19	291 - 204	2
9.5 - 10.5	-	-	-	0
10.5 - 11.5	290.33	12.58	277 - 302	3
11.5 - 12.5	344.5	7.85	336 - 353	4
12.5 - 13.5	-	-	-	0
13.5 - 14.5	338 *	-	-	1
				Total = 75

Table A-8

Proposed Developmental Guidelines
 CA-Ala-329 Sub-Adults
 Mean Length (* = only one individual)
 Tibiae

Estimated Age (years)	Mean Length (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	58 *	-	-	1
Newborn - .5	67.79	7.18	59 - 86	19
.5 - 1.5	98	10.57	81 - 110	7
1.5 - 2.5	118	9.04	107 - 136	11
2.5 - 3.5	131	14.14	121 - 141	2
3.5 - 4.5	160	-	-	2
4.5 - 5.5	212 *	-	-	1
5.5 - 6.5	193 *	-	-	1
6.5 - 7.5	192 *	-	-	1
7.5 - 8.5	-	-	-	0
8.5 - 9.5	239.5	12.02	231 - 248	2
9.5 - 10.5	218 *	-	-	1
10.5 - 11.5	240	14.73	224 - 253	3
11.5 - 12.5	285.33	4.93	283 - 291	3
12.5 - 13.5	-	-	-	0
13.5 - 14.5	278 *	-	-	1
				Total = 55

Table A-9

Proposed Developmental Guidelines
 CA-Ala-329 Sub-Adults
 Mean Length (* = only one individual)
 Fibulae

Estimated Age (years)	Mean Length (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	-	-	-	0
Newborn - .5	65	5.03	50 - 74	13
.5 - 1.5	97.8	7.05	86 - 103	5
1.5 - 2.5	114.63	10.01	103 - 133	8
2.5 - 3.5	118 *	-	-	1
3.5 - 4.5	156.5	2.12	155 - 158	2
4.5 - 5.5	175 *	-	-	1
5.5 - 6.5	195.5	7.78	190 - 201	2
6.5 - 7.5	190 *	-	-	1
7.5 - 8.5	242 *	-	-	1
8.5 - 9.5	227	11.31	219 - 235	2
9.5 - 10.5	-	-	-	0
10.5 - 11.5	223	11.31	215 - 231	2
11.5 - 12.5	270 *	-	-	1
12.5 - 13.5	-	-	-	0
13.5 - 14.5	266 *	-	-	1
				Total = 40

Table A-10

CA-Ala-329 Sub-Adults
Proposed Developmental Guidelines
Midshaft Width (* = only one individual)
Humeri

Estimated Age (years)	Mean Width (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	4.7	.99	4.00 - 5.40	2
Newborn - .5	5.52	.78	3.56 - 7.18	24
.5 - 1.5	8.88	1.11	6.90 - 10.47	10
1.5 - 2.5	9.89	1.04	7.55 - 11.52	12
2.5 - 3.5	10.44	.86	9.49 - 11.16	3
3.5 - 4.5	10.5	.85	9.90 - 11.10	2
4.5 - 5.5	11.56	1.1	10.32 - 12.35	3
5.5 - 6.5	9.95	.2	9.81 - 10.09	2
6.5 - 7.5	10.34 *	-	-	1
7.5 - 8.5	11.68	.72	11.17 - 12.19	2
8.5 - 9.5	13.04	1.28	12.14 - 13.95	2
9.5 - 10.5	-	-	-	0
10.5 - 11.5	12.61	.77	11.90 - 13.42	3
11.5 - 12.5	13.18 *	-	-	1
12.5 - 13.5	-	-	-	-
13.5 - 14.5	14.25	.9	13.33 - 15.42	4
				71

Table A-11

CA-Ala-329 Sub-Adults
Proposed Developmental Guidelines
Midshaft Width (* = only one individual)
Ulnae

Estimated Age (years)	Mean Width (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	3.71 *	-	-	1
Newborn - .5	4.36	.45	3.75 - 5.19	16
.5 - 1.5	6.03	.82	5.00 - 7.06	8
1.5 - 2.5	7.05	.78	5.58 - 8.06	9
2.5 - 3.5	6.46	.1	6.39 - 6.53	2
3.5 - 4.5	8.52	1.5	7.46 - 9.57	2
4.5 - 5.5	7.65	1.31	5.97 - 8.92	4
5.5 - 6.5	8.23 *	-	-	1
6.5 - 7.5	8.79 *	-	-	1
7.5 - 8.5	8.74 *	-	-	1
8.5 - 9.5	9.2	.58	8.79 - 9.61	2
9.5 - 10.5	-	-	-	0
10.5 - 11.5	8.91	.07	8.86 - 8.96	2
11.5 - 12.5	8.95	.49	8.43 - 9.40	3
12.5 - 13.5	-	-	-	0
13.5 - 14.5	10.1 *		-	1
				54

Table A-12

CA-Ala-329 Sub-Adults
Proposed Developmental Guidelines
Midshaft Width (* = only one individual)
Radii

Estimated Age (years)	Mean Width (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	3.76 *	-	-	1
Newborn - .5	4.08	.42	3.64 - 4.89	19
.5 - 1.5	5.86	.59	5.09 - 6.57	8
1.5 - 2.5	6.47	.4	5.82 - 6.99	10
2.5 - 3.5	6.77	.87	6.06 - 7.99	4
3.5 - 4.5	7.65	.22	7.49 - 7.81	2
4.5 - 5.5	7.56	1.09	6.30 - 8.79	4
5.5 - 6.5	7.04 *	-	-	1
6.5 - 7.5	8.19 *	-	-	1
7.5 - 8.5	8.47 *	-	-	1
8.5 - 9.5	8.85 *	-	-	1
9.5 - 10.5	-	-	-	0
10.5 - 11.5	8.82	.55	8.32 - 9.41	3
11.5 - 12.5	9.99	.42	9.37 - 10.22	4
12.5 - 13.5	-	-	-	0
13.5 - 14.5	10.53 *	-	-	1
				60

Table A-13

CA-Ala-329 Sub-Adults
Proposed Developmental Guidelines
Midshaft Width (* = only one individual)
Femora

Estimated Age (years)	Mean Width (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	5.5 *	-	-	1
Newborn - .5	6.6	.49	5.70 - 7.49	21
.5 - 1.5	9.47	1.02	7.54 - 11.28	14
1.5 - 2.5	11	1.12	8.91 - 12.78	13
2.5 - 3.5	11.85	.66	11.18 - 12.49	3
3.5 - 4.5	13.31	.36	13.05 - 13.57	2
4.5 - 5.5	14.18	2.48	11.08 - 16.52	4
5.5 - 6.5	13.46	.73	12.63 - 13.94	3
6.5 - 7.5	13.79 *	-	-	1
7.5 - 8.5	17.79 *	-	-	1
8.5 - 9.5	17.92	.81	17.35 - 18.49	2
9.5 - 10.5	-	-	-	0
10.5 - 11.5	17.18	1.93	15.65 - 19.35	3
11.5 - 12.5	19.62	.98	18.38 - 20.43	4
12.5 - 13.5	-	-	-	0
13.5 - 14.5	19.63 *	-	-	1
				73

Table A-14

CA-Ala-329 Sub-Adults
Proposed Developmental Guidelines
Midshaft Width (* = only one individual)
Tibiae

Estimated Age (years)	Mean Width (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	6.1 *	-	-	1
Newborn - .5	6.53	.73	5.51 - 8.57	19
.5 - 1.5	9.21	.86	8.10 - 10.43	7
1.5 - 2.5	10.25	1.12	8.77 - 12.23	11
2.5 - 3.5	10.89	.62	10.46 - 11.33	2
3.5 - 4.5	13.32	1.1	12.55 - 14.10	2
4.5 - 5.5	16.24 *	-	-	1
5.5 - 6.5	14.65 *	-	-	1
6.5 - 7.5	14.45 *	-	-	1
7.5 - 8.5	-	-	-	0
8.5 - 9.5	17.91	1.22	17.04 - 18.77	2
9.5 - 10.5	14.66 *	-	-	1
10.5 - 11.5	16.93	.98	16.25 - 18.06	3
11.5 - 12.5	19.03	.73	18.49 - 19.86	3
12.5 - 13.5	-	-	-	0
13.5 - 14.5	18.6 *	-	-	1
				55

Table A-15

CA-Ala-329 Sub-Adults
Proposed Developmental Guidelines
Midshaft Width (* = only one individual)
Fibulae

Estimated Age (years)	Mean Width (mm)	Standard Deviation	Range of Variation	Size of Sample
Neonate	-	-		0
Newborn - .5	3.32	.36	2.80 - 4.12	13
.5 - 1.5	4.71	.57	3.93 - 5.35	5
1.5 - 2.5	5.38	.71	4.69 - 6.46	8
2.5 - 3.5	6.24	-	-	1
3.5 - 4.5	7.26	.98	6.57 - 7.95	2
4.5 - 5.5	7.96 *	-	-	1
5.5 - 6.5	7.09	.13	7.07 - 7.11	2
6.5 - 7.5	6.81 *	-	-	1
7.5 - 8.5	10.19 *	-	-	1
8.5 - 9.5	9.94	.4	9.66 - 10.22	2
9.5 - 10.5	-	-	-	0
10.5 - 11.5	8.22	.2	8.08 - 8.37	2
11.5 - 12.5	9.74 *	-	-	1
12.5 - 13.5	-	-	-	0
13.5 - 14.5	9.87 *	-	-	1
				40

Figure A-16
Percentage of Sub-Adult Burials with Compete Ilia
CA-Ala-329

Figure A-17
 Percentage of Sub-Adult Burials with Complete Femora
 CA-Ala-329

Figure A-18
Percentage of Sub-Adult Burials with Complete Tibiae
CA-Ala-329

Figure A-19
Percentage of Sub-Adult Burials with Complete Fibulae
CA-Ala-329

Figure A-20
Percentage of Sub-Adult Burials with Complete Humeri
CA-Ala-329

Figure A-21
 Percentage of Sub-Adult Burials with Complete Ulnae
 CA-Ala-329

Figure A-22
Percentage of Sub-Adult Burials with Complete Radii
CA-Ala-329

Figure A-23
 Deciduous Teeth Present
 CA-Ala-329 Sub-Adults

Figure A-25
Incidence of Harris Lines - Humeri
CA-Ala-329 Sub-Adults

Figure A-26
Incidence of Harris Lines - Radial
CA-Ala-329 Sub-Adults

Figure A-27
Incidence of Harris Lines - Ulnae
CA-Ala-329 Sub-Adults

Figure A-28
Incidence of Harris Lines - Femora
CA-Ala-329 Sub-Adults

Figure A-29
Incidence of Harris Lines - Tibiae
CA-Ala-329 Sub-Adults