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Wisdom Tooth Formation as a Method of Estimating Age in a New Zealand Population

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ABSTRACT Dental ageing relies on assumptions about the progression of tooth development from the middle trimester to adulthood and relative stability of this process in the face of adverse dietary, hormonal, disease or nutritional factors. Most studies of dental ageing employ the method of Demirjian *et al*., (1973), which is based upon an assessment of crown and root formation stages from dental radiographs. Unfortunately, this method has a ceiling effect at age 16, when the second molar attains full maturity. The aim of our study was to extend the window of ageing by using the development of the third molar teeth. Panoramic radiographs of 207 (105 males) children aged between 7 years, 6 months and 18 years formed the basis of this study. Upper and lower left wisdom teeth were scored according to Demirjian *et al.* (1973) by a single examiner. Intra-examiner reliability was evaluated by repeat scoring of a randomly selected (10%) sample one week after the initial staging. These showed a consistency of 76% for the mandibular data and 95% for the maxillary data, giving an overall percentage of 85%. When the re-scored teeth were not consistent with their original score, this differed only by one stage. In this population males were advanced in their third molar development and this trend was more marked for maxillary than mandibular wisdom teeth. Hence, the New Zealand population examined, males were more advanced in their third molar development and this trend was more marked for maxillary than mandibular teeth. *Dental Anthropology* 2011;24(2):33-41.

Tooth formation is a developmental process that is thought to be less influenced by environmental insults than other markers of development and is thus regarded to be an accurate method for estimating chronological age (Demirjian *et al*., 1985). A substantial body of research by the same author into the timing of development of the dentition has focused on well-described stages applied to large samples (Demirjian *et al*., 1973; Demirjian and Goldstein, 1976; Demirjian and Levesque, 1980; Demirjian, 1994). Our earlier research into dental ageing of New Zealand populations used Demirjian's method to record standards for dental development in European, Pacific Island and Maori children (Kieser *et al*.,2008; TeMoananui *et al*., 2008a, 2008b). More recently, we contrasted the use of Demirjian's method with that of Cameriere and co-workers (2006). While we found that both the methods reliably predicted chronological age in children aged 7-17 years, a disadvantage of using the Cameriere method was that all seven teeth reached maturity at 13.69 and 14.06 years in females and males, respectively, compared to age 16 using Demirjian (Timmins *et al*., 2011). Because neither method predicted age beyond 16 years, we decided to evaluate the usefulness of the Demirjian method when applied to third molar development in the same population sample.

MATERIALS AND METHODS

We sourced a total of 207 panoramic radiographs of children aged between 7 years, 6 months and 18 years from various orthodontic clinics throughout New Zealand, described previously (Timmins *et al*., 2011). Photographic images of the radiographs were captured using a Canon IXUS 870IS 10 mega-pixel camera with a 28 mm wide-angle lens and optical image stabilizer. The sex distribution of our sample was 105 males to 102 females. There were 20 participants (10 male and 10 female) in each age category up to age 17, but in the category for age 18 there were two females and five males. Some radiographs had to be excluded because the wisdom tooth of interest had been cropped out of the picture, the radiographic quality was too poor to adequately score the tooth, or the wisdom tooth had not yet started to develop and it was deemed to be congenitally missing. If the second molar displays parallel root canal spaces and the apex is half closed (converging root canal apices) or fully closed, then

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it is highly likely the third molar is congenitally missing and will not develop. If the second molar is less mature than this, then it is still possible that the third molar might develop. Armed with this knowledge we were able to exclude those whose wisdom teeth were congenitally missing from our data set. After all exclusions, we were left with 193 radiographs for the lower left wisdom teeth and 180 radiographs for the upper left wisdom teeth, a full breakdown of the age and sex distribution of our final sample can be found in Table 1.

The upper and lower left wisdom tooth was scored according to a modified version of Demirjian *et al.* (1973) for staging the formation of the dentition, as illustrated in Figure 1. A single examiner evaluated both the upper and lower left wisdom teeth according to these criteria using a standard zoom facility with contrast enhancement. When we were unable to score the wisdom tooth of interest because the photograph had been cropped, the antimere was scored instead when visible.

We examined intra-examiner reliability by repeating the scoring for a randomly selected 10% of the sample one week after the initial staging. For statistical analysis of the data set, age for each individual was recorded to two decimal places to allow for more accurate analysis of the correlation between chronological and dental age. The prediction of age from maturity status was done using polynomial regression with linear, quadratic and cubic terms. This required the assumption that the maturity stages are equally spaced.

0 Crypt outline visible, no calcification.
A Calcification seen, no fusion of points.
B Fusion of calcified points.
C Enamel formation complete, crown ½ formed,pulp chamber curved.
D Crown formation is complete, pulp chamber is trapezoidal, root formation commenced.
E Radicular bifurcation observed; root length less than crown height.
F Root endings flared; root length at least equal to crown height.
G Root canal walls parallel, apices open.
H Apex closed, uniform periodontal space.

RESULTS

Intra-observer validity tests showed a consistency of 76% for the mandibular data and 95% for the maxillary data, giving an overall percentage of 85%. When the re-scored teeth were not consistent with their original score, this differed only by one stage.

In this population, it appears that males are advanced in their third molar development as can be seen by the mean age of each developmental stage, this is more marked for maxillary wisdom teeth than mandibular wisdom teeth. After age 15, no stage lower than stage "C" was observed for both mandibular and maxillary wisdom teeth and thus it can be hypothesized that in this population the presence of wisdom teeth at stage B or lower is indicative of age <15 (Tables 2, 3). Stage "F" was observed in only one individual below the age of 16, thus if stage "F" is observed in an individual, it is highly likely that the individual is 16 years or older.

A considerable amount of disagreement existed between the staging of the mandibular wisdom tooth and the staging of the maxillary wisdom tooth and this disagreement was statistically significant (Table 4).

Figures 2 and 3 show actual age of male and female participants as a function of the developmental scores for mandibular and maxillary wisdom teeth respectively. Confidence intervals (95%) are given by the dotted lines. It is clear that females develop faster than males. Figures 4 and 5 show box-and-whisker plots of Demirjian's dental stages as well and chronological ages for mandibular and maxillary teeth in males and females. Outliers are depicted as small circles. Again, it is evident that boys

TABLE 2. Maxillary staging by chronological year of age

Stage	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Total
Size size:	15	15	6	4	6	2	1	-	-	-	-	49
A	2	1	3	-	-	-	-	-	-	-	-	6
B	2	4	5	1	4	3	1	-	-	-	-	19
C	-	-	3	6	5	3	6	2	1	2	-	28
D	-	-	1	5	3	10	7	8	6	5	-	45
E	-	-	-	-	1	1	1	5	6	2	-	16
F	-	-	-	-	-	-	-	-	4	4	1	9
G	-	-	-	-	-	-	-	-	-	3	4	7
H	-	-	-	-	-	-	-	-	-	-	1	1
total	19	20	18	16	19	19	19	18	18	20	7	180

Fig. 1. Modified staging method based on Demirjian *et al*. (1973).

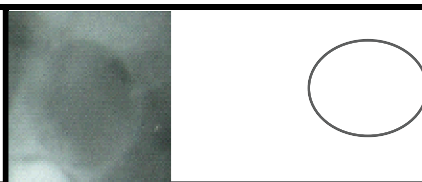
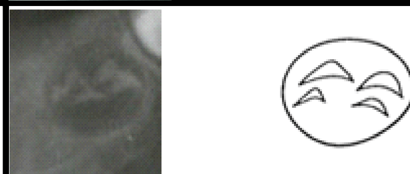
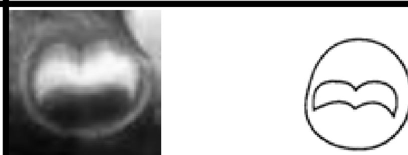
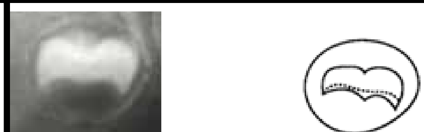
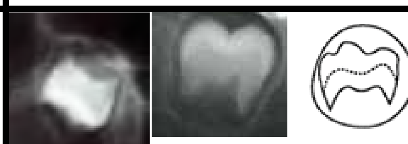
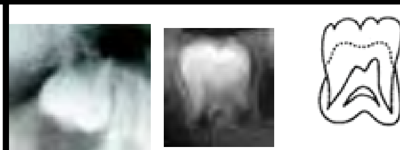
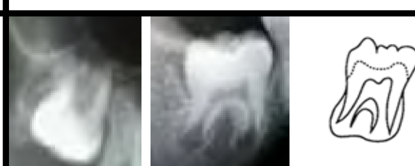
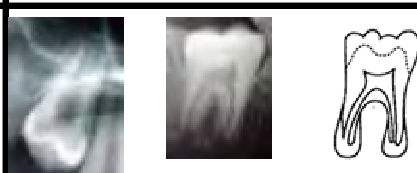
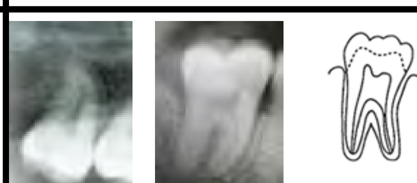
0		Outline visible, no calcification.
A		Calcification seen, no fusion of points.
B		Fusion of calcified points.
C		Enamel formation complete, crown ½ formed, pulp chamber curved.
D		Crown formation is complete, pulp chamber is trapezoidal, root formation commenced.
E		Radicular bifurcation observed; root length < crown height.
F		Root endings flared; root length >= crown height.
G		Root canal walls parallel, apices open
H		Apex closed, uniform periodontal space.

TABLE 3. Mandibular staging by chronological year of age

Stage	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Total
Sample size:	15	9	6	4	5	1	6	-	-	-	-	46
O	1	2	3	2	1	-	-	-	-	-	-	9
A	4	7	1	2	2	1	1	-	-	-	-	18
B	-	2	7	5	6	1	-	-	-	-	-	21
C	-	-	2	5	2	12	5	6	4	1	1	38
D	-	-	-	2	3	5	4	7	5	4	-	30
E	-	-	-	-	1	-	3	5	5	5	3	22
F	-	-	-	-	-	-	1	-	1	2	1	5
G	-	-	-	-	-	-	-	-	1	2	1	4
H	-	-	-	-	-	-	-	-	-	-	-	0
total	20	20	19	20	20	20	20	18	16	14	6	193

develop later than girls.

DISCUSSION

From these data, New Zealand population-specific prediction charts were developed to aid estimation of chronological age from wisdom tooth stage as shown in Figures 4 and 5. Normal development charts were also generated to aid orthodontic treatment planning to determine whether an individual's development is normal, advanced or delayed (Figs. 2 and 3). It must be noted, however, that these charts assume there is an equal distance between each of the stages; that is, the time difference between A and B is the same as the difference between D and E. It is highly likely that this is not the case, and these stages may in fact be staggered with one lasting only a few months and others maybe lasting a few years. Hägg and Matsson (1985) observed that earlier stages of tooth formation were generally of shorter duration than later stages with regard to teeth 41 through to 47 (FDI scoring system), and this is likely to be the case also with regard to the third molar.

Gunst *et al.* (2003) set out to calculate the chronological age of Belgian Caucasian individuals based on the development of the third molars using a 10-stage developmental scoring method proposed by Kohler and co-workers (1994). They found a slight sexual dimorphism with relation to timing of the stages (males had a younger mean age for each stage), and a trend for earlier development in maxillary third molars compared to mandibular. Generally, however, the relationship between chronological age and dental age of the third molars has been investigated using variations of Demirjian's stages. In 2004, Arany *et al.* used Demirjian's stages to estimate the probability of a Japanese adolescent being over the ages of 14, 16 and 20 (the relevant ages as determined by Japanese juvenile law). This study found

TABLE 4. Mandibular versus maxillary staging

	Maxillary stage										
	Grade	**O**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	Total
Mandibular stage	**O**	0	5	0	0	1	0	0	0	0	6
	A	0	1	7	0	2	0	0	0	0	10
	B	0	0	6	8	3	0	0	0	0	17
	C	0	0	4	12	18	0	0	0	0	34
	D	0	0	0	4	14	4	2	0	0	24
	E	0	0	0	0	3	8	3	4	0	18
	F	0	0	0	0	1	2	1	1	0	5
	G	0	0	0	0	0	0	2	1	1	4
	H	0	0	0	0	0	0	0	0	0	0
	Total	0	6	17	24	42	14	8	6	1	118

	X^2	df	P-value
Symmetry (asymptotic)	34.25	13	0.0011

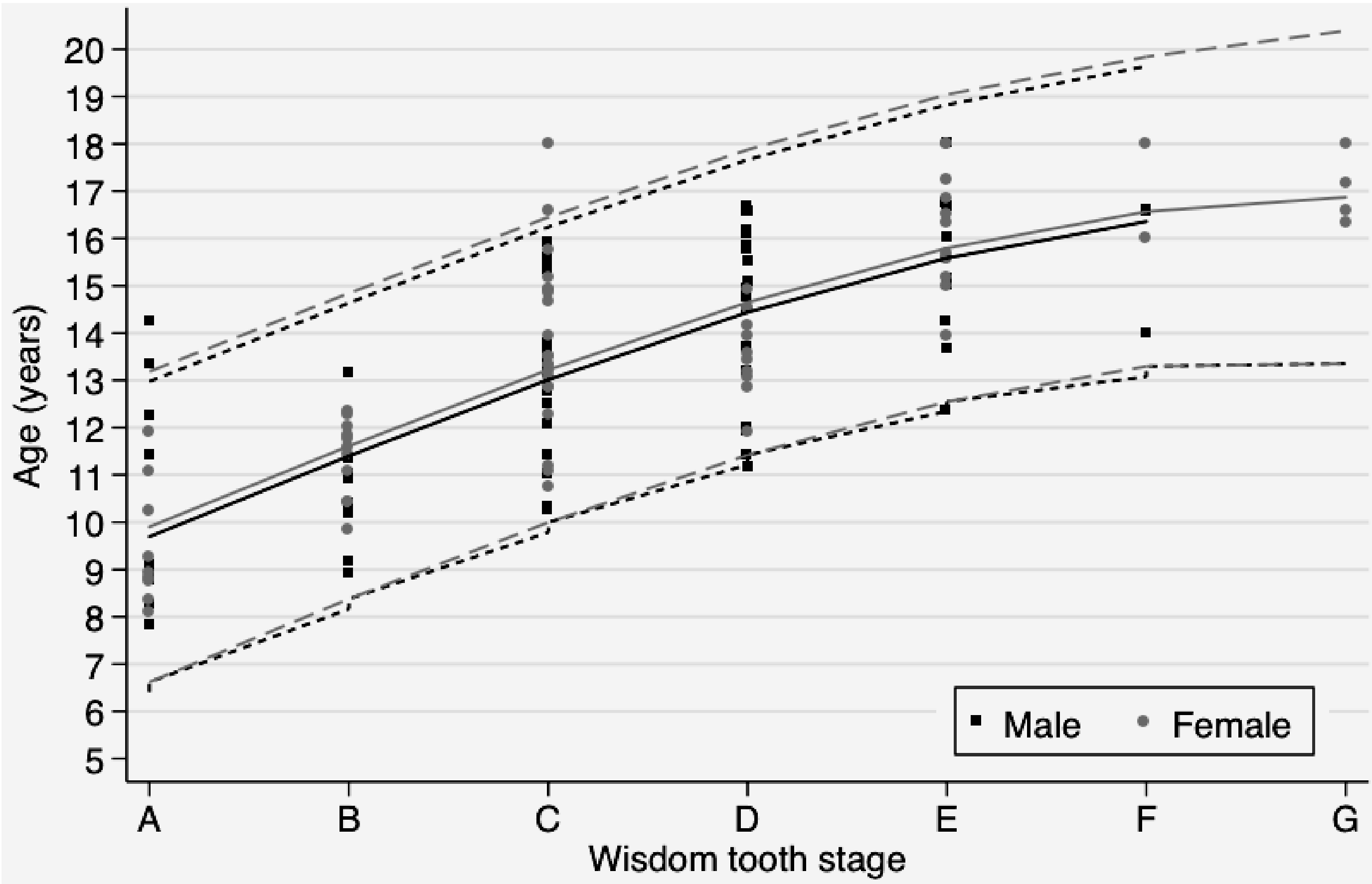


Fig. 2. Prediction of chronological age from mandibular third molar stage

that recognition of earlier stages (A-D) in an individual indicate that person is <20 years old. While the presence of stage F indicates it is highly likely the individual is over 14, and if stage H has been reached then it is almost certain that the person is >16 (Arany *et al.*, 2004).

Prieto *et al.* (2005) used Demirjian's stages to investigate the relationship between chronological age and dental age of the third molars in a Spanish population. They used a sample between the ages of 14 and 21 years of age, and as they at no time observed a stage lower than C, it may be assumed that observation of stage A or B would indicate an individual is <14 years in this population. They also investigated the probability of an individual being > or < 18 years based on third molar development. Stage D-E indicated a high probability a person was <18, stage F indicated it is likely the individual is <18, stage G was about 50/50, and stage H indicated a high probability the individual was ≤ 18 (Prieto *et al.*, 2005).

Orhan *et al*. (2007) used Demirjian's classifications to determine the relationship between developmental stages of third molars and chronologic age in a Turkish population sample for the purpose of age estimation. The relationship between third molar development and sex, age and location was also investigated. They found no statistically significant difference between left and right third molars but they did find that maxillary third molar development was commonly more advanced than mandibular third molar development, which is consistent with the findings from Gunst *et al.* (2003). Males showed advanced third molar development compared to females which is also consistent with other studies (Gunst *et al.*, 2003; Arany *et al.*, 2004; Prieto *et al.*, 2005). In accordance with the above-mentioned study (Prieto *et al.*, 2005) this study found that stage D-E indicated an individual was <18, and stage H indicated an individual was >18.

Knell *et al.* (2009) used only lower wisdom teeth to determine chronological age and found there was an 85% agreement on stages between left and right sides of the jaw. Of the 15% that were not the same on both sides of the jaw, the majority differed only by one stage. However, it was found that stage H was attained at ages less than 18 in some cases, so the above statement that attainment of stage H indicates the individual is over 18 may not hold true for all situations in all populations.

Third molar development has also been used to estimate chronological age in a Portuguese population (Caldas *et al.*, 2010). In this study the probability of an individual being at least 16 years was investigated. It

Fig. 3. Prediction of chronological age from maxillary third molar stage.

was found that while sexual dimorphism was not always present for every stage of third molar development; overall, third molar formation occurred earlier in boys, which is in agreement with Gunst *et al.* (2003). It was suggested that presence of stage D was perhaps the earliest indicator of an individual being over 16 years of age.

As has been discussed already, after the age of around 14 it becomes increasingly more difficult to determine age as there are fewer teeth undergoing development. There is some controversy in the literature about whether we should be using third molars for age estimation in this age group or whether we should be using skeletal development of the hands and wrists (Demisch and Wartmann, 1956; Engström *et al.*, 1983). A linear relationship between chronological age, skeletal development and third molar formation has been observed (Demisch and Wartmann, 1956). While the correlation between chronological age and third molar development and the correlation between chronological age and skeletal development are comparable (Engström *et al.*, 1983); third molars have the advantage of developing for longer and may be the only developmental marker available in late adolesence (Mesotten *et al.*, 2002).

It appears that the New Zealand population does not differ significantly in third molar development compared with other populations, as similar trends were found in this study as in other studies on different populations. A slight sexual dimorphism was found with males tending to develop earlier than females, probably because of post-pubertal development of this tooth. This trend was also documented in previous studies (Gunst *et al.*, 2003; Caldas *et al.*, 2010; Orhan *et al.*, 2007; Arany *et al.*, 2004; Prieto *et al.*, 2005; Harris, 2007; Sisman *et al.*, 2007). Additionally, Gunst *et al.* (2003) reported earlier development in maxillary, compared to mandibular third molars, which is mirrored in the present study. It has been quoted in the literature that the presence of stage F is indicative of an individual being over the age of 14 (Arany *et al.*, 2004). This trend can also be observed in our New Zealand sample. However, in our sample some individuals who were 18 presented with stage E or lower, which was not found in some other literature (Prieto *et al.*, 2005). Attainment of stage H indicating an individual is over the age of 18 was found in the present study and in others (Prieto *et al.*, 2005; Orhan *et al.*, 2007; Knell *et al.*,

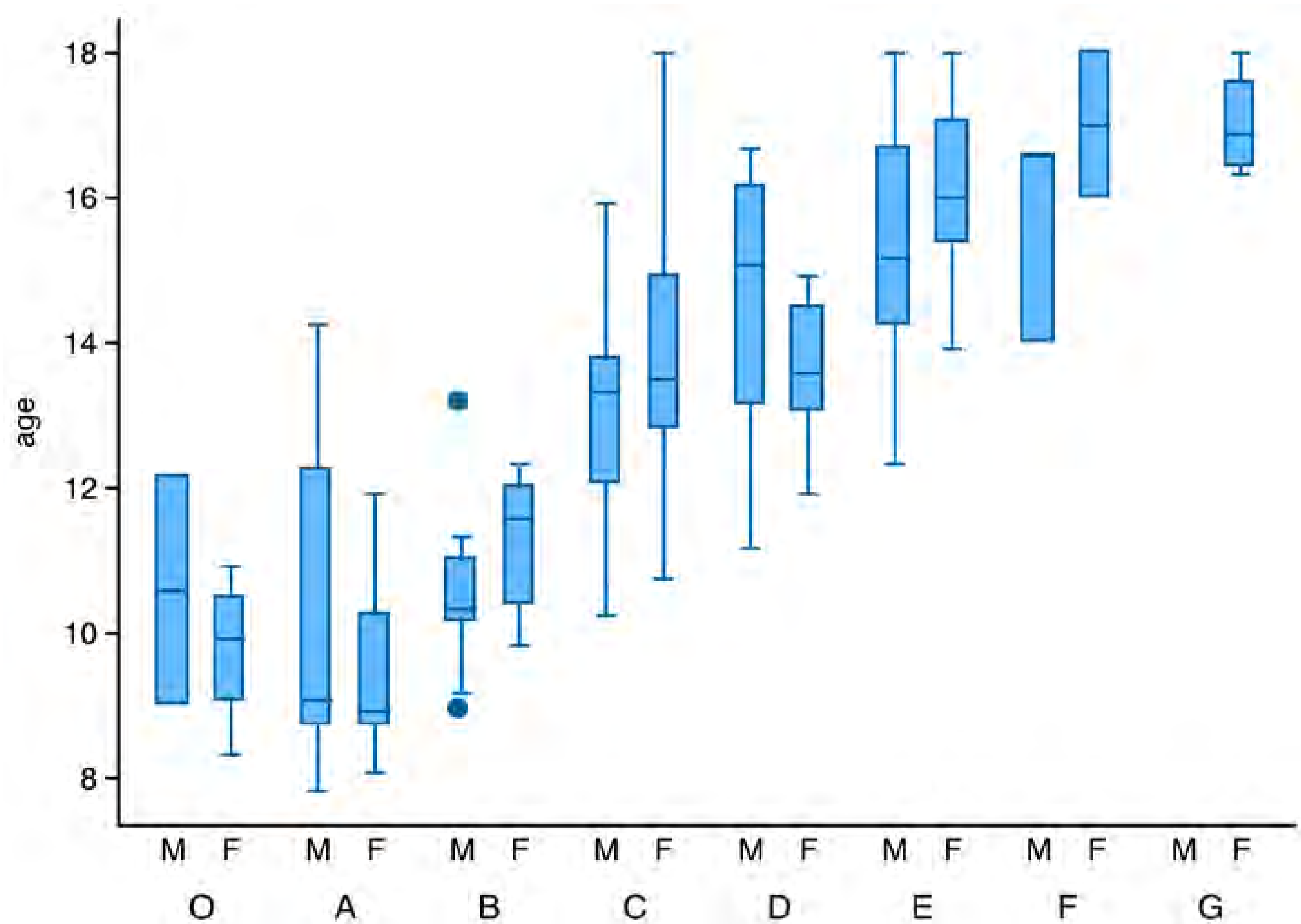


Fig. 4. Prediction of chronological age from mandibular third molar stage

2009).

The principal aim of our study was to evaluate the usefulness of the Demirjian method when applied to third molar development in a sample of New Zealand children. Although we have previously studied dental maturation and cervical vertebral development in three different ethnic groups from New Zealand (European, Maori and Pacific Island, TeMoananui *et al.*, 2008a,b), the present investigation focused on an older age group and made no attempt at recording ancestry. Our focus was on adolescence, a time of major hormonal, growth and secondary sexual changes (Bogin, 2001), rather than on ethnicity. We conclude that while chronological age can indeed be estimated from third molar development, the age range can be relatively broad for given developmental stages.

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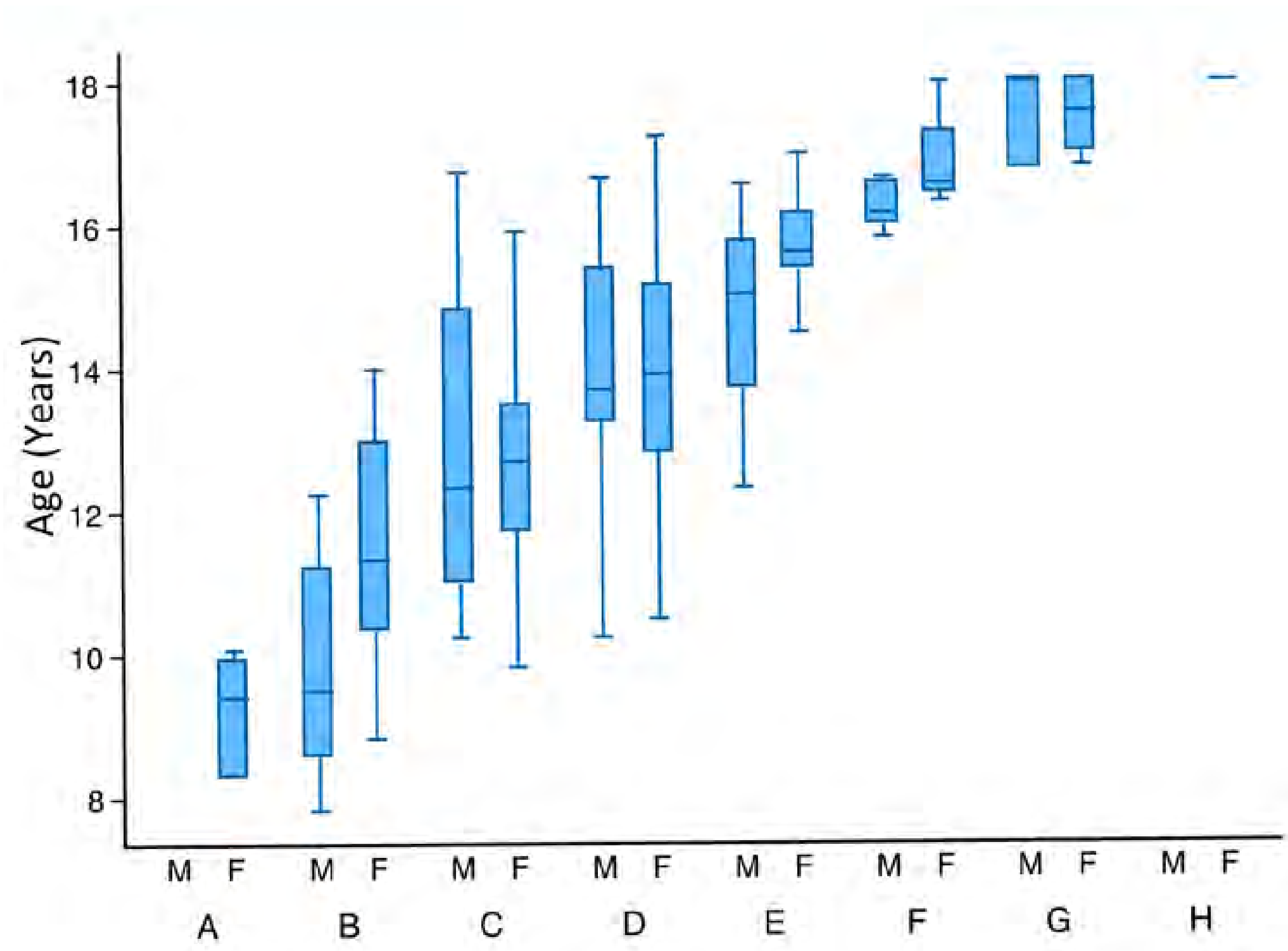

Fig. 5. Prediction of chronological age from maxillary third molar stage

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The Anthropology of Infectious Diseases of Bronze Age and Early Iron Age from Armenia

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ABSTRACT This study reviews the evidence for the presence of specific infectious diseases in Armenian skeletal series of Bronze Age and Early Iron Age. Throughout human history, pathogens have been responsible for the majority of human deaths. Factors such as age, sex, and nutritional status can influence whether an individual contracts and develops a particular infection, while environmental conditions, such as climate, sanitation, pollution, and contact with others will affect the susceptibility of a population. The frequencies of such signs as osteomyelitis, peridontal disease, leprosy, abscesses, and so forth, testify that the people experienced a variety of forces and durations—both internal and external—of stressful influences. Individuals from Sevan region may have had more chronic infections due to continued exposure to pathogens during their lives as well as traumatic injuries. Seven individuals had nasopharyngeal lesions consistent with a diagnosis of leprosy. Dental caries was less severe in the Sevan region, although dental abscesses (51 individuals) and antemortem tooth loss (87 individuals) were more prevalent. In contrast, periodontal disease (8/18 adults) and antemortem loss (8/18 adults) of the molars were more prevalent at the Shiraksky plain. Data focusing on climate influence, migratory, and cultural habits in the past are discussed. *Dental Anthropology* 2011;24(2):42-54.

Ortner and Putschar (1981) claim that infectious diseases were the single greatest threat to life of prehistoric infants and children. But this does not mean that adults were immune. Of people surviving into adulthood, many will die of infectious disease, whether it be direct or indirect (Ortner and Putschar, 1981). There are a host of biological and environmental factors that influence the prevalence of infectious lesions found in prehistoric skeletal samples. Early hominid populations likely were too small and dispersed to support many of the acute communicable pathogens common to densely populated sedentary communities (Burnet, 1962), especially those for which humans are the only disease pool (Cockburn, 1971; Polgar, 1964). Pathogens such as smallpox, measles, and mumps were unlikely to afflict early hominid groups (Cockburn, 1967a). Viruses such as chickenpox and herpes simplex may survive in isolated family units, suggesting that they could have been sustained in early dispersed and nomadic groups. The shift to permanent settlements created larger aggregates of potential human hosts while increasing the frequency of interpersonal contact within and between communities, likely fostering the spread and evolution of more acute infections (Ewald, 1994). Accumulation of human waste would have created optimal conditions for dispersal of macroparasites and gastrointestinal infections. The appearance of domesticated animals such as goats, sheep, cattle, pigs, and fowl provided a novel reservoir for zoonoses (Cockburn, 1971). Tuberculosis, anthrax, Q fever, and brucellosis could have been readily transmitted through the products of domesticated animals such as milk, hair, and skin, as well as increased ambient dust (Polgar, 1964).

The analysis of skeletal lesions resulting from infectious disease on prehistoric human skeletal material offers the osteologist insights into the interplay among many considerations, such as disease, diet, ecology, social structure, warfare, settlement pattern, plant and animal domestication, sanitation level, immunological resistance, and psychological stress (Larsen, 1997). When an individual is infected by an organism, there are three ways in which a bone can become involved. First, the infection can spread from its primary source to skeletal elements by way of the blood stream. Second, an injury (such as a penetrating wound) can leave a bone open to direct infection. Third, a localized soft tissue infection can be so severe that it spreads to the underlying bone (Aufderheide and Rodriguez-Martin, 1998).

The basis of the present study are four skeletal collections from the the Sevan region of Armenia, plus two from the Shiraksky plain. Figure 1 shows the spatial perspective of these sites. The Armenian Highland—also

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Fig. 1. Map of the Republic of Armenia.Main sites are discussed in text.

known as the Armenian Upland, Armenian plateau, or simply Armenia (Hewsen, 1997)—is the central-most and highest of three land-locked plateaus that collectively form the northern sector of the Middle East (Hewsen, 1997). The Armenian plateau has been a crossroads linking the worlds of East and West (Martirosyan, 1964). The areas surrounding the Black Sea coast at certain stages of history became a center of interrelations of multiple cultures. Overland lines of contact existed between the Near East through the Armenian highlands and the Caucasus and on to the Balkans, and through Caucasus and the Balkans to the north Black Sea coast and in the return direction. The ethnic history of the region developed under the interaction of various groups since the early Bronze Age, among which the Indo-European played a leading role, those tribes having created one of the most advanced cultures of the then-contemporary world (Khudaverdyan, 2011a,b). Late Bronze Age and Early

Fig. 2. A burial from the Black Fortress (photo S. Ter-Markaryan).

Iron Age also mark the time of contact between Eurasians in this area (Khudaverdyan, 2011a,b). According to the archeological record (Kyshnareva, 1990), it was a time of expanding population. Trade networks expanded and social systems grew more complex. Increasing migration and trade between state-level societies in Eurasia led to the convergence of regional infectious disease pools.

The economy in Armenia was based on forms of mixed agriculture. Analysis of the faunal remains indicates that cattle and sheep and goat herds were managed for many purposes such as milk, wool, skin, meat, and other secondary products. At the Armenian necropolis in the Late Bronze Age among the usual graves with human skeletons there were burials of a horses and a chariot burial (Khudaverdyan, 2009, 2011b). The exploitation of wild animals continued as hares and wild birds have been found at sites in the region. The rites of single or multiple inhumations started in the Bronze to Early Iron Age and were located in settlements, in well-defined burial areas. Individuals' remains were accompanied by grave goods of metalwork (jewelery and weaponry), pottery, and joints of meat.

Little is known about the health status and epidemiological aspects of historic Armenia (Khudaverdyan, 2010), but the quality of life of the members of past societies can be assessed by analyzing their remains (Larsen, 1997). Together with osteometric study, pathological examination can provide useful information on the biological aspects of a skeletal series. Burial grounds from the Lanjik and Black Fortress are located in the Shiraksky plain. Archaeological and anthropological monuments are common from in two time periods: the first half of the IV-III millennium B.C. (Lanjik) and the beginning of II millennium B.C. (Black fortress). The Yerevan Medical University had an archive of paleopathological specimens from A. Sarafyana, which had been taken for the Khudaverdyan report (2005; Sarafyan and Khudaverdyan, 1999). This provides 17 adults from Sarykhan (*ca*. XI-IX/ VIII B.C.), 126 adults from Lchashen (II-I millennium B.C.), 4 adults from Karmir (*ca.* IX-VIII B.C.), and a sample of 28 individuals from Akynk (*ca.* XIII-XII B.C.). It is only recently that these skulls have been studied for evidence of disease.

MATERIALS AND METHODS

The human remains that were analyzed for this article were excavated by a Gyumri team under the directions of Levon Petrosyan and Stepan Ter-Markaryan (the sites of Landjik and the Black Fortress). This is a most important culture of Early Bronze Age in Armenian highlands called the Kura-Araxes Culture (Landjik burial). One mass burial from the Landjik site (end of the fourth millennium and beginning of the third millennium) has been excavated, and it contained remains of at least 10 individuals, together with rich archaeological grave goods (Petrosyan, 1996). Most of these skulls were in a good state of preservation (2 males, 5 females). Two children (2-9 years) and 1 juvenile between 13 and 19 years of age were the only non-adults present in the sample.

TABLE 1 Number of individuals included in the study

	Males	Females	Total
Lanjik	2	6	10
Black Fortress	2	8	13
Sarykhan	8	9	17
Lchashen	62	23	85
Akynk	16	12	28
Karmir	1	3	4

The site of Black Fortress is remarkable due to the archaeological presence of two time periods of ancient Armenian history (Late Bronze Age and Ancient period, dating from the 1st century B.C. to the 3rd century A.D.). Many sites are found here with a very large cemetery. The Black Fortress site (2nd millennium B.C.) is a regular cemetery (Fig. 2) has been excavated since 1993, and the excavations are still ongoing (Ter-Markaryan, 1991; Ter-Markaryan and Avagyan, 2000; Avagyan, 2003). This cemetery was located near the Aleksandrapol tower in the city Gyumri. All of the burials appear to have been typical Late Bronze Age interments, oriented in an east-west direction. Intentionally interred remains of small animals were common. The majority of animal remains recovered at Black Fortress were horned livestock and reptiles (especially turtle) (Avagyan, 2003). A total of 13 skeletons were exhumed from a burial that included 2 males, 8 females and 3 children (4-9 years).

An excavator disinterred skulls in the village of Sarykhan. Due to this information, a survey was conducted, which led to the beginning of an archaeological excavation. It was supervised by A. Piliposyan (Yerevan), and the excavations were developed in 1984. Group Sarykhan contained some 17 individuals. The distribution of sex is predominantly female (9 individuals: 24% of young adults (20-40 years), 18% of middle 11.8% of old adult). Of these, 8 were male (6% adoolescent, 6% young adults, and 18% middle and 18% older adults) (sex and age from the unpublished data of A. Sarafyan) (Khudaverdyan, 2005).

The Lchashen site is a mass burial ($n \approx 500$) which includes at least 126 individuals of both sexes and all ages (Alekseev, 1974), accompanied with many stone and bone tools as well as ornamental objects. Many sites are found surrounding this large cemetery that was excavated in 1957-1967 (Mnacakanyan, Yerevan), and the excavations are ongoing. The distribution of sex is predominantly male (62 individuals), and 23 were females (Alekseev, 1974).

Group Karmir (archaeologist A. Piliposyan) contained 4 individuals. The distribution of sex is three female (middle adult) and one was male (old adult) (from the unpublished data of A. Sarafyan) (Khudaverdyan, 2005). The Akynk includes at least 28 individuals (Kochar *et al*,. 1989).

The analysis uses traditional approaches for the assessment of the general physical characteristics of the age at death and sex in the samples. Age-at-death and sex were assessed through the use of multiple indicators. Morphological features of the pelvis and cranium were used for the determination of sex (Phenice, 1969; Buikstra and Ubelaker, 1994). A combination of pubic symphysis (Gilbert and McKern, 1973; Katz and Suchey, 1986; Meindl *et al*., 1985), auricular surface changes (Lovejoy *et al*., 1985), degree of epiphyseal union (Buikstra and Ubelaker, 1994), and cranial suture closure (Meindl and Lovejoy, 1985) were used for adult age estimation. For subadults, dental development and eruption, long bone length, and the appearance of ossification centers and epiphyseal fusion were used (Moorrees *et al*., 1963a,b; Ubelaker, 1989; Buikstra and Ubelaker, 1994).

Dental inventory and recording of pathologies were collected using standards and forms found in Buikstra and Ubelaker (1994). Periodontal disease was assessed by measuring the amount of alveolar bone loss. Measurements were taken from the cemento-enamel junction to the surface of the alveolar bone. Only those measurements that exceeded 2 mm were recorded as evidence of periodontal disease (Tumer *et al*., 1991). Caries were recorded based on the system devised by Moore and Corbett (1971, in Buikstra and Ubelaker, 1994:55). Dental caries were recorded for each tooth and surface affected. Care was exercised in order to avoid confusing legitimate caries with pulp exposure due to severe wear. Abscesses were recorded based on their presence and location. Buccal or labial lesions were differentiated from lingual perforations (see Buikstra and Ubelaker, 1994:55; Tumer *et al*., 1991). Antemortem tooth loss (ATL) was based on evidence of resorption of alveolar bone around a tooth socket. If remodeling was evident and the socket was partially or fully filled in, then a tooth was considered to have been lost antemortem. Sockets that were open and smooth, with no evidence of remodeling, were recorded as postmortem loss (Tumer *et al*., 1991). Enamel

Fig. 3. Osteomyelitis. Materials from excavation of burial ground Akynk (burial 11, ♂ 35-40 years).

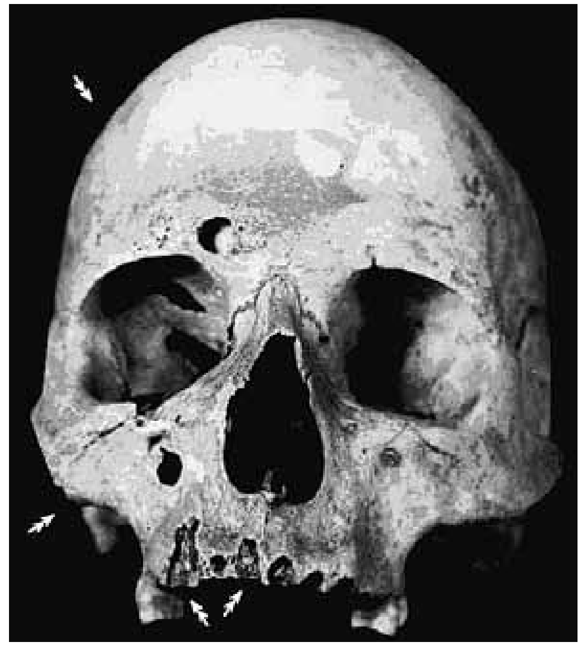

Fig. 4. Subacute osteomyelitis of the upper jaw; inflammation of an antrum of Highmore; facies leprosa. Materials from excavation of burial ground Lchashen (burial 52, ♀ 30-35 years old).

hypoplastic defects—a deficiency of enamel thickness, which is normally smooth, white, and translucent—were divided into linear, pit, and plane defect types (Hillson, 1996). To determine the effects of stress on the bone, special indicators can be used that allow one, with various degrees of accuracy, to speak of adaptive complexes within the populations (Goodman *et al*., 1984; Goodman and Rose, 1990).

RESULTS AND DISCUSSION

Skeletal Indicators of Health: Infection

Osteomyletis is a combination of inflammation of the bone (osteitis) and the bone marrow (myelitis) by pus producing bacteria (Aufderheide and Rodriguez-Martin, 1998). Severe osteomyelitis and osteitis are caused by the spread of Staphylococcus and Streptococcus microorganisms. Depending on the virulence of the microorganisms and/or host resistance, the reaction may be localized and acute or chronic and systematic (Goodman *et al*., 1984). Ortner (2003) points out that other infectious agents, such as viruses, fungi, and multicelled parasites can also affect the bone marrow. The skeletal changes consist of bone destruction along with new bone formation (involucrum) and necrotic bone (sequestrum) (Aufderheide and Rodriguez-Martin, 1998). Another typical manifestation of osteomyelitis is the formation of cloacae (drainage canals) that may be present in many cases. Osteomyelitis does not only occur in an acute form, but also in a subacute as well as a chronic form that can reappear over a period of several years and, according to Larsen (1997), it can be the response to systemic or localized stress. Death can occur if the infection spreads from the bone to the circulatory system and finally affects vital organs. If osteomyelitis heals, the bone becomes dense and becomes part of the normal cortical tissue and sclerotic scarring may occur (Larsen, 1997; Ortner, 2003). Aufderheide and Rodriguez-Martin (1998) discussed that acute osteomyelitis can result from infections due to compound fractures, injuries, or surgery, and it occurs most frequently in adults over 40 years of age.

Figure 3 shows a middle adult male approximately 40 years old in group Akynk, diagnosed with severe osteitis and periodontal disease. This unfortunate individual had lesions on his entire skull. The cranium of exhibits lesions on the frontal and left temporal bones. The frontal contains 2 lesions ranging in size from <0.2 mm to 0.3 mm in length and sclerotic reaction. The left temporal contains 1 small indentation on the side of the occipital bone along with a sclerotic reaction.

In the woman (30-35 years old) from Lchashen (burial 7), acute hematogenous osteomyelitis of the frontal sinus is revealed along with dental abscesses (Fig. 4). Periapical abscesses can be fatal if the resulting infection spreads into the sinuses. Development of odontogenic osteomyelitis is visible in the region of upper right incisors, and the canine tooth was the source of a secondary defect of an antrum of Highmore. The antritis was accompanied by an osteomyelitis and destruction of the forward wall of a sinus. The sharp antritis has been complicated by the distribution of inflammatory process on a trellised labyrinth of the frontal sinus. The margin of the main erosion was marked by a number of small distinctive sublesions in the outer table, comprising groups of small pits having an apparent sclerotic margin clustered around a small region of intact outer table. Some of these sublesions were present in isolation on other parts of the frontal bone (Fig. 4). The frontal bone is diploic with a marrow cavity capable of developing osteomyelitis. A typically fluctuant swelling

Fig. 5. Osteomyelitis and facies leprosa. Materials from the excavation of burial ground Sarykhan (burial 11/2, ♂ 50-55 years old).

Fig. 6. Osteomyelitis. Materials from excavation of the burial ground Lchashen (burial 27, ♂ 30-35 years old).

Fig. 7. Osteomyelitis in the temporomandibule joint and porotic hyperostosis on the skull. Materials from excavation of burial ground Lchashen (burial 7, ♂ 45-50 years old).

Fig. 8. Mandibular condyles with porous surface. Materials from excavation of the burial ground Lchashen (burial 62, ♂ 30-35 years old).

Fig. 9. Dental abscesses. Materials from excavation of burial ground of Akynk (burial 7/2, ♀ 40-45 years old).

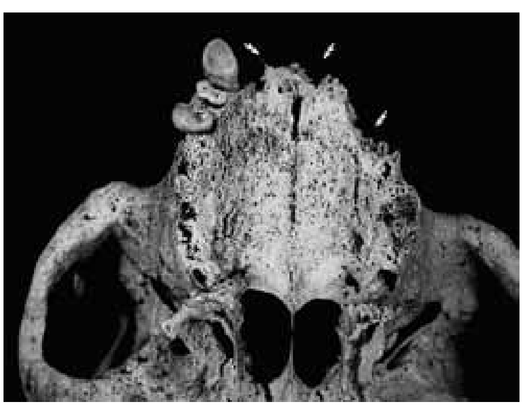

Fig. 10. Subacute osteomyelitis in the upper jaw. The adsorption is almost complete in numerous regions of the alveolus. Note the extreme pitting of the palatine bones and the extensive dental wear. Materials from excavation of the burial ground of Lchashen (burial 83, ♂ 50-55 years old).

over the forehead known as "Pott's Puffy Tumor" after Sir Percival Pott who described the condition in 1760, results from frontal sinusitis and osteomyelitis eroding the anterior table of the frontal bone. The term Pott's Puffy Tumor has been applied to any scalp swelling associated with frontal sinusitis. Some prefer to limit the term to the swelling overlying and area of osteomyelitis in a diploic bone and use the term "a ruptured frontal sinus" for those associated with frontal sinusitis (Thomas *et al*., 1977). It is a serious life-threatening complication of frontal sinus infection. Pott's Pufty tumor and its complications result from the unique anatomy of the frontal sinus. The sinus is separated from the frontal bone marrow by only 100 to 300 µm. The sinus mucosa, marrow cavity and frontal bone have a common venous drainage via valveless diploic veins (Breschet's canals). Frontal sinus infection can thus invade the marrow cavity causing osteomyelitis and erode through the thin anterior and posterior table, producing subperiosteal and extradural abscess, respectively (Feder *et al*., 1987; Lund, 1987).

Figure 5 shows a middle adult male approximately 50 years old in group Sarykhan (skull 2, burial 11), diagnosed with severe osteomyelitis and dental abscesses. The frontal bone contains 1 lesion about 2 cm in length with sclerotic reaction.

Chronic osteomyelitis occurs more frequently in the mandible than in the maxilla and is often associated with suppuration. It is usually diffuse and widespread (Lavis *et al*., 2002; Eyrich *et al*., 2003). Kazunori Yoshiura (Reinert *et al*., 1999) classified mandibular osteomyelitis into four patterns, as lytic, sclerotic, mixed, and sequestrum patterns. Our case presented with the last pattern. Chronic osteomyelitis will result in deformity of the affected bone (Fig. 6). With an infection of the bone, the subsequent inflammatory response will elevate the overlying periosteum, leading to a loss of the nourishing vasculature, vascular thrombosis, and bone necrosis, and ending in formation of sequestrae. Figure 6 confirmed the presence of a deep sequestra. Although most cases of chronic osteomyelitis of the jaws result from dental origins, other sources of infection are possible (Eyrich *et al*., 2003). It may also occur following penetrating trauma. Viral fevers (*e.g*., measles), malaria, anemia, malnutrition may also to contribute to the development of osteomyelitis. At Lchashen, 27 adults showed evidence of osteomyelitis in the mandible.

The inflammation of a mandible joint (Figs. 7-8) can arise as hematogen metastatic as a result of general infectious diseases such as scarlet fever, diphtheria, measles, dysentery, or typhus, and owing to contact distribution of an infection: an osteomyelitis of an ascending branch of the bottom jaw or a purulent otitis. The mandible joint of a skull (Lchashen: burials 7, 62, Figs. 7-8; Black Fortress: burial 9) expresses the presence of small sclerotic reactions.

Dental Abcesses

Abscesses of a tooth lead frequently to its exfoliation and cause a remodeling process that usually destroys the alveolus and reduces the size of the alveolar process at the site of the tooth loss (Ortner, 2003). Some researchers note that abscesses are caused by *Streptococcus milleri*, *Fusobacterium nucleatum*, or *Streptococcus mitis* (Lewis *et al*., 1986). Abscesses can be instigated by various conditions, such as pulp necrosis, periodontal infection, or trauma. Periapical abscesses can be fatal if the resulting infection spreads into the sinuses (Fig. 4). Although periapical abscesses can occur on the roots of any tooth, Herrera *et al*. (2000) conclude that molars are most frequently affected with an occurrence of 69%. Most abscesses happen in patients that already suffer from periodontal disease (Herrera *et al*., 2000). In Lchashen, 41 adults suffered from dental abscesses. Regarding the skeletons from Lanjik, three adults showed evidence of dental abscesses. At Sarykhan, seven adults showed evidence of dental abscesses, which was higher than in the Akynk group (Fig. 9), where only one individual was affected. In the group from the Black Fortress, one adult suffered from dental abscesses (Khudaverdyan, 2009). Two out of four dentitions from Karmir showed evidence of dental abscesses.

Periodontal Disease

Peridontal disease is the inflammation of the soft tissues of the mouth, namely the gums, and/or the peridontal ligament, and alveolar bone (Levin, 2003). Retraction of the gums exposes the vulnerable root of the tooth to attack by acidic plaques, commonly resulting in caries, abscesses and antemortem tooth loss. Periodontal disease is caused by several irritants such as bacterial plaque that becomes calculus due to calcification of plaque, and living or dead microorganisms (Clarke, 1990; Aufderheide and Rodriguez-Martin, 1998; Ortner, 2003). Another cause of periodontal disease can be gingivitis, an inflammation of the surrounding soft tissues (Ortner, 2003). Gingivitis can be caused by penetrating foreign bodies, major

Fig. 11. Teeth lost during life. Materials are from an excavation of burial ground Sarykhan (burial 3/12, ♂ 60-65 years old).

Fig. 12. Dental caries and antemortem tooth loss. Materials from the excavation of the burial ground at Lchashen (burial 13, ♂ 30-35 years old).

Fig. 13. Eample of dental caries. Materials from excavation of the burial ground of Black Fortress (burial 14 , ♂ 25-30 years old).

local trauma, or, indirectly, the loss of interproximal contacts (Aufderheide and Rodriguez-Martin, 1998). In a progressive phase of periodontal disease, the roots of the teeth may be exposed and tooth loss may occur. It occurs interdentally and creates vertical defects between the root of the tooth and the alveolar bone. Most commonly, the posterior teeth, the second and the third molars, are affected (Clarke, 1990; Aufderheide and Rodriguez-Martin, 1998). Clarke (1990) and Larsen (1997) point out that if periodontal disease is unchecked and untreated, the bony support for the teeth diminishes and exfoliation can occur. Once a tooth is lost, the alveolus will be remodeled. Furthermore, Larsen (1997) lists the influencing factors,

Fig. 14. Facies leprosa: rhinomaxillary changes. Materials from the excavation of burial ground Karmir (burial 1, ♂ 50-55 years old).

Fig. 16. Multiple lesions of the skull. Materials from the excavation of the burial ground Lchashen (burial 31, ♂ 30-35 years old).

such as bacteria, poor oral hygiene, malocclusion, nutritional status, pregnancy, and psychological stress.

There are four main types of periodontal disease, namely prepubertal, pubertal, rapidly progressive, and adult periodontis (Hildebolt and Molnar, 1991). Of these four, only the last was observed in skeletons from Armenia. In the samples from Armenia, peridontal disease was present in 35 individuals. Periodontal disease was the most common dental pathology among the Landjik burials. A total of 4 out of 10 observable dentitions possessed some form of alveolar bone loss. On average there was greater bone loss on the mandible than the maxilla. The trend of periodontal disease in Lchashen (24 adults) was one of slightly greater involvement than that observed in the Black fortress group. Four out of 13 dentitions showed evidence of alveolar bone loss. At Sarykhan, three adults showed evidence of periodontal disease. For the individuals from Karmir and Akynk periodontal disease was not noted. Those teeth lost during life (Fig. 11) were not counted as periodontal disease because other conditions can also cause tooth loss, such as accidents or interpersonal violence.

Antemortem Tooth Loss

Antemortem tooth loss is characterized by the presence of abscess and/or remodeling of the alveolar bone obliterating the tooth sockets. Specific etiologies of antemortem tooth loss are problematic, as evidence may have been lost, especially in instances of carious teeth; however, the close association between periodontal

Fig. 15. Facies leprosa: rhinomaxillary changes. Materials from the excavation of burial ground Lchashen (burial 73, ♀ 50-55years old).

Fig. 17. Multiple lesions of the skull. Materials from excavation of the burial ground Lchashen (burial 79, ♂ 45-50 years old).

disease, dental caries, and antemortem tooth loss is well established, especially in archaeological series (Larsen, 1997). The prevalence of antemortem tooth loss contributes to the overall picture of oral health in a sample. For the group from Landik, antemortem tooth loss occurred in 4 adults. Also, four adults from the Black Fortress met the criteria for antemortem loss. At Lchashen, 72 adults showed evidence of antemortem tooth loss. Antemortem tooth loss were observed in 7 people from Sarykhan, 2 from Karmir, and 6 from Akynk.

Dental Caries

Tooth analysis plays an important role in anthropological research. Teeth are a rich "archive" that tell us about health and nutritional status, individuals and collective ancient and modern habits and life styles (Powell, 1985; Moggi Cecchi and Corruccini, 1993; Milner and Larsen, 1991). Dental caries is an infectious disease that destroys the tooth structure, the root and the crown (Brothwell *et al*., 1967; Aufderheide and Rodriguez-Martin, 1998). Ortner (2003) mentions that caries are caused by acid-producing bacteria in dental plaque that initiate the destructive process. Larsen (1997) argues that caries do not refer to lesions in teeth resulting from the invasion of microorganisms, but that the disease is characterized by the focal demineralization of dental hard tissues by organic acids produced by bacterial fermentation of dietary carbohydrates, especially sugars. According to Larsen (1997), there are several modifying factors for the development of dental caries: crown size and morphology, enamel defects, occlusal surface attrition, food texture, oral and plaque pH, speed of food consumption, some systemic diseases, age, child abuse, heredity, salivary composition and flow, nutrition, periodontal disease, enamel elemental composition, and the presence of fluoride and other geochemical factors. In Lchashen, 2 adults suffered from dental caries (Fig. 12). Caries were observed in 6 people from Landjik (3/8) and the Black Fortress (3/10; Fig. 13) (Khudavedyan, 2009). In individuals from Karmir, Akynk and Sarykhan there was no instance of dental caries.

Leprosy (Hansen's Disease)

Leprosy is a chronic infectious disease caused by *Mycobacterium leprae* transmitted through contact with skin lesions or through inhalation of droplets containing the pathogen that are coughed or exhaled into the air by infected individuals (Roberts and Manchester, 2005). True leprosy is a chronic, debilitating, and disfiguring infection. This process can result in loss of fingers, toes, nasal tissue, or other body parts. Leprosy varies in expression from a mild, or tuberculoid, infection (also known as high-resistance leprosy) to the most severe infection, referred to as the lepromatous type (also known as low-resistance leprosy) (Andersen *et al*., 1994; Ortner, 2003). Skeletal involvement can occur with any degree of infection, but it is most acute in the lepromatous form. However, the skeleton is not affected in most cases; only 5% of individuals with leprosy develop bony lesions (Ortner, 2003). Changes in the bones of the face can accompany lepromatous leprosy and are collectively known as the rhinomaxillary syndrome or 'facies leprosa' (Møller-

Fig. 18. Multiple lesions of the skull. Facies leprosa: rhinomaxillary changes. Material from the excavation of the burial ground Lchashen (burial 46, ♂ 20-25 years old)

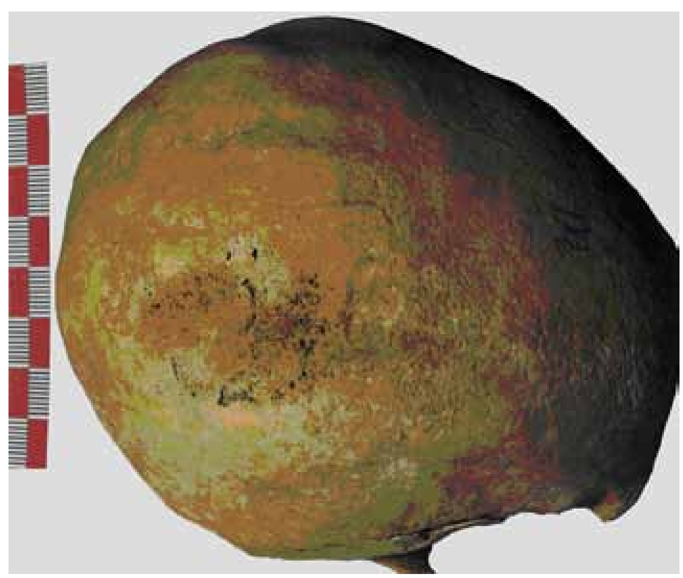

Fig. 19. Porotic hyperostosis. Material from the excavation of the burial ground the Black Fortress (burial 3/2, ♀ 45-50 years old).

Christensen *et al.*, 1952; Møller-Christensen, 1961, 1978; Andersen and Manchester, 1992).

Mycobacterium leprae prefers cooler areas of the body, leading to infection of mucosal tissues. Infection of the nasal area causes skeletal changes, such as loosening of the chondro-osseous junction at the bridge of the nose, which results in the characteristic 'saddle-nose' deformity. The nasal septum and hard palate are often perforated, and the anterior nasal spine, nasal aperture margins, and alveolar process of the maxillae are resorbed, the last of which leads to the loss of anterior maxillary teeth (Andersen and Manchester, 1992; Andersen *et al.*, 1994). There is evidence of leprosy in the adults, though one individual from Karmir (burial 1) has nasopharyngeal lesions, including significant remodeling of the nasal aperture margins (Fig. 14). And 6 individuals from Lchashen have nasopharyngeal lesions characteristic of leprosy (Figs. 15, 18).

Non-Specific Infections

Lesions on the cranial surface of the skull are indicators of non-specific infection or of trauma but they share similar difficulties with interpretation and identification in adults. Endocranial lesions can appear as 'worm-like' deposits of new bone, vascular depressions or ' 'hair-on-end' formations. This new bone is macroscopically identical to the 'woven' bone deposited during an infection or after trauma. The various appearances of endocranial lesions may indicate different aetiologies: meningitis, epidural haematomas, birth trauma, scurvy, venous drainage problems and tuberculosis, or syphilis (Virchow, 1896, in Hackett, 1976, p. 44) may cause inflammation or haemorrhage of the meningeal vessels (Schultz, 1993).

Individual 31 exhibits multiple lesions of the outer table of the parietal bones. On the right parietal bone there are several distinct lesions (Fig. 16), but two of these are particularly prominent. The surface is composed of smooth, cortical bone, suggesting a healed pathological process. The margins are rolled inwards towards the center of the lesion and fine grooves are present, compatible with the presence of small blood vessels. The inner table shows no evidence of pitting on the endocranial surface. Pathological changes observed in the cranial vault (burials 79, 46) include several focal cavitations that penetrate into the diploe but do not affect the inner table. There are also compact bone depressions with grooves (Figs. 17, 18). All these cranial vault injuries seem to be a reaction to an inflammatory process that affected the scalp and, consequently, the cortical cranial bone. Whether the inflammation was the result of blows, or local or systemic infections, cannot be determined.

Skeletal Indicators of Health: Systemic Stress

Anthropologists often consider porotic hyperostosis and cribra orbitalia as indicators of iron deficiency anemia, although these markers may have other, less-common etiologies, such as hemolytic anemia and thalassemia (Stuart-Macadam, 1989, 1992a,b; Schultz, 1993, 2001). Iron is an important element found in blood, as it assists in oxygen transport to tissues throughout the body. Iron deficiency, which can have detrimental consequences, results from a number of factors, including malnutrition, parasitic infection, blood loss, and disease (Stuart-Macadam, 1989, 1992b). A deficiency in iron produces an associated increase of red blood cell production in the marrow cavities to compensate for the decreased level of oxygen available to tissues. The resulting expansion of the marrow cavities in thin, flat bones such as the cranial and orbital bone causes the external, compact bone to erode, creating a porous surface on the cranial vault (porotic hyperostosis; Figs. 7, 18) and in the eye orbits (cribra orbitalia) (Stuart-Macadam, 1987).

The mild forms of this stress indicator (cribra orbitalia) were observed in all age and sex cohorts in the Armenian samples. The overall frequency of cribra orbitalia in the Lchashen is 8.0%. The prevalence of cribra orbitalia is 28.6% from Sarykhan and 9.1% from Akynk (Movsessian, 1990; Movsessian and Kotchar, 2001). Eight individuals out of 10 from Lanjik showed evidence of this marker. Seven individuals from the Black Fortress showed cribra orbitalia. It is also important to note that the temporal increase in prevalence of cribra orbitalia did not correspond to an increase in severity for groups from Lanjik and Black Fortress. In individuals from Karmir, criba orbitalia was not revealed as a stress marker.

A middle-adult female approximately 50 years old in group Black Fortress (burial 3/2) was diagnosed with porotic hyperostosis (Fig. 18). The external surface of the neurocranium exhibits a two large and irregular areas, lesions that cover most of the parietal bones. Manifestations developed on the portions of each parietal bone between the temporal crest and the sagittal suture. In the cranium are several grouped irregular cavities, furrowed by grooves and surrounded by porotic bone. Also, 4 adults from the Lchashen exhibited porotic hyperostosis (Fig. 7)

Enamel hypoplasias are indicators of growth disruptions during dental development and are visible on teeth as areas of enamel deficiency. Most of these hypoplastic defects are oriented horizontally across the tooth, and multiple grooves reflect multiple stress episodes. Like porotic hyperostosis and cribra orbitalia, these stress markers are indicative of a childhood condition, as tooth formation is complete before adulthood. The etiological factors implicated in the occurrence of a growth disruption and resulting in a hypoplastic defect, include disease, malnutrition, trauma, and hereditary conditions (Goodman and Rose, 1990, 1991; Hillson, 1996, 2000; Roberts and Manchester, 2005). However, malnutrition and disease appear to be a far more common cause of these defects, because hereditary defects and localized trauma are relatively rare occurrences (Goodman and

Rose, 1990, 1991). The prevalence of hypoplasia from the Black Fortress sample is 62% (n = 13) and 50% (n = 10) from Landjik. Six individuals from Sarykha showed evidence of enamel hypoplasias.

CONCLUSION

The Sevan region and Shiraksky plain (Armenia) was not an ecologically favorable place for human populations. The results of this study further this notion, as there are a number of significant trends for various skeletal indicators of health and lifestyle that suggest the population in Armenian experienced stress and biological changes over time. The developing economy—the rudiments animal husbandry—promoted the occurrence and spread of infections among the ancient population of Armenia. Bad hygienic conditions and dirt should render infections of cumulative influence on skeleton morphology. Anthropological examination revealed that the inhabitants in these areas in Bronze Age and Early Iron Age were subject chiefly to osteomyelitis, facies leprosa, dental diseases such as caries, abscesses, and periodontal disease.

Osteomyelitis of the skull may follow infection of one of the cranial air sinuses or the middle ear, dental disease, or an open skull fracture. Three individuals have evidence of osteomyelitis on the frontal bone. The bony lesion is classically composed of a central sequestrum surrounded by a lytic zone, and then an area of sclerotic response with periosteal new bone peripherally on both inner and outer tables (the involucrum). Individuals from the Sevan region may have had more chronic infections due to continued exposure to pathogens throughout their lives as well as to traumatic injuries. The unsanitary living conditions, pollution of the water supply, and population density all likely contributed bacterial infections to the population. Seven individuals had nasopharyngeal lesions consistent with a diagnosis of leprosy.

Dental abscesses have an important role in infectious processes, as they are propitious for the development of the bacteria that cause infection, not only in the alveolar bone but also in the rest of the body. Dental caries were less severe at Sevan (2 individuals from Lchashen), although dental abscesses (51 individuals) and antemortem loss (87 individuals) were more prevalent. In contrast, periodontal disease (8/18 adults) and antemortem loss (8/18 adults) of the molars were more prevalent at Shiraksky, although the small sample size may be a factor. Despite the lack of significant trends in periapical lesions and dental caries, the patterns that emerge indicate that a dietary change took place. However, this change may be associated with food preparation techniques, rather than dietary components. Antemortem tooth loss may reflect a softer diet in which there was less abrasion and attrition.

It is especially interesting that the prevalence rates for cribra orbitalia are rather similar between the two groups from Shiraksky plain. The lack of any trend for porotic hyperostosis and the presence of only the mild form of cribra orbitalia may be due to an overall milder form of anemia in the population. The higher prevalence of enamel hypoplasias may be due to a number of factors, including greater exposure to pathogens (other than parasites) or poorer nutrition (Goodman and Rose, 1990, 1991; Hillson, 2000). Poor nutrition in combination with exposure to infectious pathogens would have only heightened this problem, creating periodic episodes of growth arrest, leading to higher rates of enamel hypoplasias.

All these data can throw light on aspects of the conditions of the life of people during the Bronze Age and Early Iron Age in Armenia. The forms of infectious diseases illustrated in this article suggest perspectives that hold promise for future dental anthropological studies.

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A Horizontal Mesiodens in a Child Buried at Hank's Site (41RB109), a Prehistoric Plains Village Site in the Texas Panhandle

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ABSTRACT The mesiodens is the most common kind of supernumerary tooth; it is found in the midline of the maxilla. Horizontal orientation is the least common, accounting for about 6% of cases. During osteological analysis of the skeleton of a 3 to 5 year old child recovered from Hank's site (41RB109) in the northern Texas panhandle, an impacted horizontal, conical mesiodens was identified. The skeleton dates to the Plains Village period, *ca.* A.D. 1,200 to 1,500, when village-based peoples practiced a mixed hunter-gatherer/horticulture subsistence. This mesiodens is located in the right maxilla, just lateral to the midline of the hard palate and parallel to the intermaxillary suture. The root projects ventrally and protrudes through the external alveolar bone between the central incisors. The crown is conical. Although sometimes found in association with certain congenital disorders, the mesiodens appears to be idiopathic in this case. While possibly painful due to its proximity to the nasopalatine nerve, no sequela from the tooth growth and impaction are evident. *Dental Anthroplogy* 20111;24(2):55-58.

The mesiodens, the most common type of supernumerary tooth, is found in the midline of the maxilla, between and generally palatal to the central incisors. Its prevalence in the permanent dentition ranges from 0.1 to 3.6% and in the primary dentition from 0.2 to 1.9%, (summarized in Sykaras, 1975), occurring more commonly in Asians (Zhu *et al*., 1996), including presumably Native Americans, and at least twice as often in males (*e.g*., Liu, 1995; Tay *et al*., 1984). Three orientations have been described: vertical (similar to normal teeth); inverted (crown oriented cranially); and horizontal or transverse. Vertical or inverted are both common (Asaumi *et al*., 2004; Liu, 1995; Rajab and Hamdan, 2002; Tay *et al*., 1984). The horizontal orientation is rare. Asaumi *et al*. (2004) found only 6% of mesiodens to be horizontal, similar to the rates of 6-8% and 5-6% for all horizontal supernumeraries reported by Rajab and Hamdan (2002) and Tay *et al*. (1984), respectively. The present report describes the first known incidence of an impacted horizontal conical mesiodens in a child's skeleton, recovered during on-going investigations at Hank's site (41RB109), an archeological site in the northern Texas panhandle.

MATERIALS AND METHODS

The child was interred in a flexed position in a shallow pit filled mostly with caliche cobbles. A radiocarbon assay on human bone collagen from the burial yielded a conventional radiocarbon age of 630 ± 40 years B.P. (Beta Analytic, Inc., Sample No. Beta-223738). The 2-sigma calibrated date is A.D. 1,290-1,410. A burned pithouse and other archeological remains at this site are dated to the same time, the Plains Village period, *ca.* A.D. 1,200 to 1,500, during which village-based peoples practiced a mixed hunter-gatherer/horticulture subsistence (Lintz, 1986).

Standard osteological analysis was performed on the remains. The skeleton is largely complete and in a good state of preservation. Missing elements include most hand and foot bones, unfused epiphyses, the lumbar vertebrae, sternum, and patellae. All deciduous teeth are fully erupted into occlusion and many developing permanent tooth buds are visible partially or wholly in the alveoli due to damage to the maxillae and mandible. Based on development of the permanent dentition (Ubelaker, 1989) and epiphyseal fusion (Scheuer and Black, 2000), the child was 3-5 years old at the time he or she died. Due to the young age, no assessment of sex was attempted. The child's skeleton showed no evidence of illness at the time of death. The cranium exhibits positional plagiocephaly. A shallow carious lesion is present on the occlusal surface of the mandibular left first molar. A supernumerary tooth, a mesiodens, is present in the midline of the maxilla, between the deciduous central incisors.

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CASE REPORT

The mesiodens is located in the right maxilla, just lateral to the intermaxillary suture. It is perpendicular to the orientation of the natural teeth and parallel to the intermaxillary suture. The root points ventrally, protruding through the external alveolar bone at approximately the midpoint level of the central incisor roots, though it is unlikely to have protruded through the gingiva into the vestibule. Presence of the mesiodens has resulted in a lateral flaring of the roots of the deciduous central incisors (Fig. 1). This suggests the mesiodens developed from the primary dentition, as the mesiodens would have formed prior to formation of the roots of the central incisors. Mesiodens of the primary dentition are up to five times less common than those of the permanent dentition (Primosch 1981). The crown of the mesiodens points posteriorly and angles slightly superiorly. Growth of the mesiodens has led to resorption of bone in the incisive fossa of the hard palate, exposing part of its central crown (Fig. 2). This oval fenestration measures 4.28 mm (anteroposterior) by 2.95 mm (mediolateral). The incisive foramen (fossa) is also laterally widened on the affected maxilla. Similar resorption along the medial surface of the intermaxillary suture has exposed almost the entire length of the tooth, except the distal half of the crown (Fig. 3). A thin bridge of bone separates the palatal and sutural fenestrations. The mesiodens has also caused a slight depression on the intermaxillary suture surface of the left maxilla, anterior to the incisive foramen. There is no evidence of infection or inflammation associated with the mesiodens.

The mesiodens measures 11.7 mm in length. Its crown is conical in shape (Fig. 4) and slightly oval in cross-section at its widest, measuring 6.3 x 5.3 mm. The mesiodens root is incomplete (4.2 mm in length). Although there is some postmortem erosion at the root end, the mostly smooth, even margins indicate incomplete development rather than postmortem loss of the rest of the root. It is unclear if development had stopped, leaving an incomplete root, as often happens with a mesiodens (Primosch, 1981), or was still ongoing at the time of death.

DISCUSSION

The mesiodens is the most common type of supernumerary tooth, and horizontal mesiodens are the rarest subtype, accounting for about 6% of cases in the literature (Asaumi *et al.*, 2004). Mesiodens most often occur singly, but may be found in higher numbers. They can be primary or permanent, and normal (eumorphic, like other teeth in the morphogenetic field) or abnormal in crown shape, the latter also having a smaller root and crown (Primosch, 1981; Russell and Folwarczna, 2003; von Arx, 1992). The three morphological types of mesiodens with abnormal crowns are conical, tuberculate, and molariform, the first shape being most common (Primosch, 1981; Rajab and Hamdan, 2002).

Research suggests a multifactorial etiology for supernumerary tooth formation (Brook *et al.*, 2002; Sedano and Gorlin, 1969). A remnant or hyperactive dental lamina or abnormal division of a tooth bud

Fig. 1. Mesiodens root protruding through alveolar bone between the primary central incisors. Photograph by Jennifer McWilliams.

Fig. 2. Premortem fenestration of alveolus in the palate dorsal (posterior) to central incisor, exposing the mesioden's crown. Photograph by Jennifer McWilliams.

Fig. 3. View of mesiodens in intermaxillary suture of right maxilla. Ventral (anterior) is to left. Photograph by Jennifer McWilliams.

Fig. 4. Mesiodens after removal from maxilla. Each square equals 0.1 inch. Photograph by Jennifer McWilliams.

are proposed mechanisms (Buggenhout and Bailleul-Forestier, 2008; Russell and Folwarczna, 2003). Certain disorders, particularly cleft lip and palate (Milhon and Stafne, 1941) and cleidocranial dysplasia (Jensen and Kreiborg, 1990), are also associated with supernumerary tooth formation.

Mesiodens erupt less than one-third of the time (Liu, 1995; von Arx, 1992) but are often asymptomatic. An impacted mesiodens will usually be suspected due to problems in the development of the dentition (*e.g.* the angulated central incisors in this case) and is then diagnosed radiographically. Common clinical sequelae include delayed or lack of eruption of permanent teeth, deviation of eruption path, rotation, retention, root dilaceration, root resorption or loss of tooth, diastema, and malocclusion (*e.g.*, Asaumi *et al.*, 2004; Nazif *et al.*, 1983; Russell and Folwarczna, 2003; von Arx, 1992; Zmener, 2006). Eruption of an inverted mesiodens into the nasal cavity can also result in congestion or obstruction of the nasal passage, and development of rhinitis and, possibly, a nasal fistulae (Smith *et al.*, 1979).

CONCLUSION

The horizontal mesiodens recorded in this child from Hank's site in the northern panhandle of Texas appears to be idiopathic and not associated with any congenital malformation. While conceivably experiencing pain from the impaction of the tooth, particularly as it impinged on the nasopalatine nerve, the child did not suffer from any obvious problems in development of the primary dentition aside from some flaring of the deciduous central incisors. Anterior mesiodens, like the one reported here, tend to create more problems with the primary or permanent dentition than posterior (Buggenhout and Bailleul-Forestier, 2008). But a horizontal mesiodens with a crown distal to the arcade is perhaps less likely to complicate development than a horizontal mesiodens where the crown crowds the arcade, or a vertical or inverted mesiodens (*e.g.*, Zmener, 2006). The permanent dentition, particularly the right central incisor, may have eventually exhibited misalignment.

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Dental Age: Effects of Estimating Different Events During Mineralization

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ABSTRACT The extent of tooth mineralization affords a practical method for assessing an individual's biological age. Dental age is useful for evaluating a child's growth status, and for assessing the ages of subjects in anthropological, forensic, and medicolegal settings. Historically, some data have been collected from serial studies (*e.g.*, Stuart's Harvard Study, and the Burlington Study) while most studies are cross-sectional, where each child is examined just once. Serial and cross-sectional studies traditionally have been used to estimate different sorts of information, namely the onset at a stage and the average age in a stage, respectively. This paper discusses the differences of the analyses, and then presents an empirical comparison of two large sets of data on the lower third molar in American whites, showing how the conventional uses of serial data—that estimate the onset of an event—precede the age of occurrence derived from cross-sectional data (age at stage). Inter-group differences for tooth stages can exceed one year, so it is important to recognize the nature of the 'standards' available in the literature. *Dental Anthropology* 2011;24(2):59-63.

Tooth mineralization progresses in an invariant sequence, from crown tips through completion of the cementoenamel junction, and then through root formation, ending with closure of the root apices around the tooth's neurovascular bundles (*e.g.*, Slavkin, 1974; Corliss, 1976). Moreover, the rate at which these processes of dentinogenesis and amelogenesis progress are well-regulated (*e.g.*, Pelsmaekers *et al*., 1997; Parner *et al*., 2002; Merwin and Harris, 1998). Tooth formation is better buffered than bone formation (Greulich and Pyle, 1959; Garn *et al*., 1965), even though it can be modified by the environment (*e.g.*, Toverud, 1957; Berkey *et al*., 2000; Alvarez *et al*., 1988; Alvarez, 1995). Tooth formation is perhaps the least-biased tissue by which to estimate the biological age of a child (Demirjian, 1986; Harris, 1998). This often is done clinically using radiographs (*e.g.*, Liversidge, 2010) though direct examination can be used for archeological and forensic specimens (Johanson, 1971; Owsley and Jantz, 1983).

Tooth formation can be measured on a continuous scale as the mineralized portion lengthens (*e.g.*, Liversidge and Molleson, 2004; Cardoso, 2009), but because this is time-intensive, and because of the morphological complexity of the tooth's three dimensions, it generally is preferable to use visual criteria to determine the grade of development. Grades are arbitrarily devised, with the intent of differentiating as many stages as possible (so finer distinctions can be made), but not so many that the observer cannot distinguish accurately between them. The two commonly used grading schemes are by Moorrees, Fanning and Hunt (1963) with 14 stages and by Demirjian, Tanner and Goldstein (1973) with 8 stages, though many other schemes have been developed (*e.g.*, Nolla, 1960; Liliequist and Lundbert, 1971; Haavikko, 1973). The Moorrees scheme is popular but has been criticized because it requires the scorer to estimate final size (*e.g.*, root ½ formed, *etc*.). The Demirjian system, in contrast, uses only observable criteria and now is perhaps the method of choice though, with only 8 grades, it lacks the potentially finer discrimination of Moorrees' 14 stages.

A pertinent question is how to develop normative standards from the data regardless of the grading scheme, and, more specifically, what sort of data have been collected. That is, are the data from a longitudinal growth study where the same children are examined periodically, or are the data from a cross-sectional study where the children are only examined once? These two sources traditionally been used to create different kinds of data that estimate different features of the growth process. The purpose of this paper is to discuss the two kinds of estimates (Smith (1991) describes others) and give an example of the practical differences.

Longitudinal Studies

There have only been a handful of studies where children—generally healthy and financially well-off—have been studied longitudinally, with multiple sorts of data collected at fixed intervals, generally 6 months or a year. Data have consisted of anthropometrics, x-rays, dental casts, and various sorts of intellectual tests. Well-known examples are the Bolton-Brush study in Cleveland, Ohio (Behrents and Broadbent, 1984), the Denver Child Growth Study, Colorado (McCammon, 1970), the Burlington growth study, a suburb of Toronto, Ontario (Thompson and Popovich, 1977), and the University School Growth Study from the University of Michigan, Ann Arbor (Riolo

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et al., 1974; Moyers *et al.*, 1976), though there are others (*e.g.*, Jones and Bayley, 1941; Sanin and Savara, 1973). The complexity, commitment of money and manpower, and participant cooperation in such studies are enormous, and they are not likely to be repeated.

With longitudinal studies, each child is examined periodically, and the interest has been on identifying the *onset* of an event. Arbitrarily, consider Moorrees' stage 6 of crown completion (coded Cr_c) for the upper second molar. Each child's successive films are studied until that tooth exhibits Cr_c (Fig. 1). For example, examining a child, Cr_c had not been achieved at time n (t_n), but it is present at t_{n+1}. The actual event occurred sometime between t_n and t_{n+1}, and the convention is to set the event at the midpoint between the two examinations, which is:

$$t_n+(t_{n+1} - t_n)/2$$

It is unlikely that the achievement of Cr_c occurred exactly at t_{n+1}, and the midpoint between examinations is the best guess of when the true event occurred (Dahlberg and Menegaz-Bock, 1958). The point is that this method estimates the *onset* of the event. In this case, at what chronological age does Cr_c for the upper second molar occur in the sample under study? Onset cannot be determined from cross-sectional data (what Davenport (1931) termed "mass data"), but it can be approximated from the very low centiles of the age-at-occurrence.

Cross-Sectional Studies

Most studies do not have the luxury of following the same children over a span of time. In a typical anthropological setting, researchers examine subjects only once. It also is common to collect clinical records from a cohort of children where only one x-ray per child is available (*e.g.*, Harris and McKee, 1990; Liversidge, 2010; Tunc and Koyuturk, 2008). Consider stage Cr_c for UM2 again. Perusal of a group of children will show that A) some have not yet attained this stage, B) some do exhibit the stage, and C) some have matured beyond this stage into a later stage (or completed formation). Plotting the data by chronological age (Fig. 1) shows a density plot that generally has a normal (Gaussian) distribution: a few younger children (early maturers) will exhibit the stage, the stage commonly occurs along a certain age span, and a few, older children still retain this stage (slow maturers). This is a distribution of when—in this sample—Cr_c is extant; Smith (1991) terms this "age of subjects in a stage." It is the average age when this stage of this tooth occurs in the sample. This statistic is not the same as the initiation of the stage as garnered from serial data. Parenthetically, information for the age of occurrence can be gotten from serial data, but it seldom is, and there is a statistical problem scoring the same person multiple times.

Given these two kinds of data, how much difference does it make? Is this an important distinction, or can it be ignored as a statistical nicety? It ought to make a pretty obvious difference.

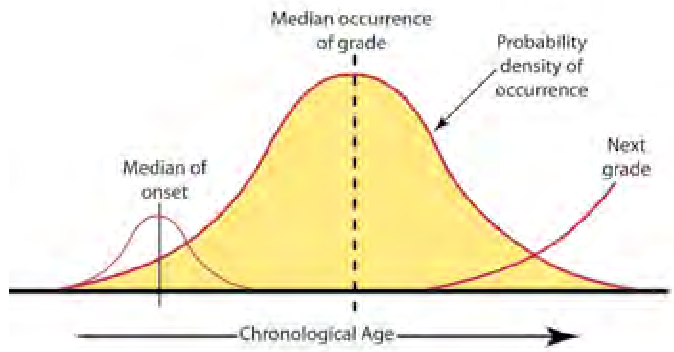

Fig. 1. Schematic showing the age distribution of when children exhibit a given stage of tooth formation. The probability density plot generally is normally distributed, ranging from early-maturing children at the younger ages up to the average age, and then tapering down to the slower-maturing children who are the last to exhibit the grade before maturing into the next grade. The median age-at-occurrence is the vertical dashed line. Serial studies can be used to estimate the onset of a grade (the distribution to the left of the diagram), but onset and median occurrence are quite different events. The hypothesized distribution of one stage is shown. The curve for onset is drawn smaller, but its age range can rival that of the age-at-occurrence, depending on the variability of dental ages in the sample. Intra-individual variability is considerable, so when the average child's tooth is at one stage, slow maturing children of the same chronological age will have stayed in a prior stage, and fast maturing children will be in a more advanced stage.

MATERIALS AND METHODS

The best known and one of the most popular 'standards' of tooth formation are those of Moorrees, Fanning and Hunt (1963; Harris and Buck, 2002). This study combined data from jaw x-rays of children from A) Harold C Stuart's Longitudinal Study of Child Growth and Development (Stuart *et al.*, 1939; Stuart and Reed, 1959) and B) older children from the Fels Longitudinal Study (Yellow Springs, Ohio; Roche, 1992). The onset of World War II forced termination of the Stuart study because most of the medical personnel entered the Armed Forces, so Moorrees *et al.* collected their data on older children from the Fels Study. The x-rays were an oblique view of the jaws since the work predates the invention of panoramic x-ray machines (Graber, 1967).

Edward Hunt, the statistician on the project, used probit analysis to analyze the data (*e.g.*, Finney, 1971). This required plotting chronological age against the cumulative percentage of the children attaining the grade in question. In the early 1960s, this generally was determined visually

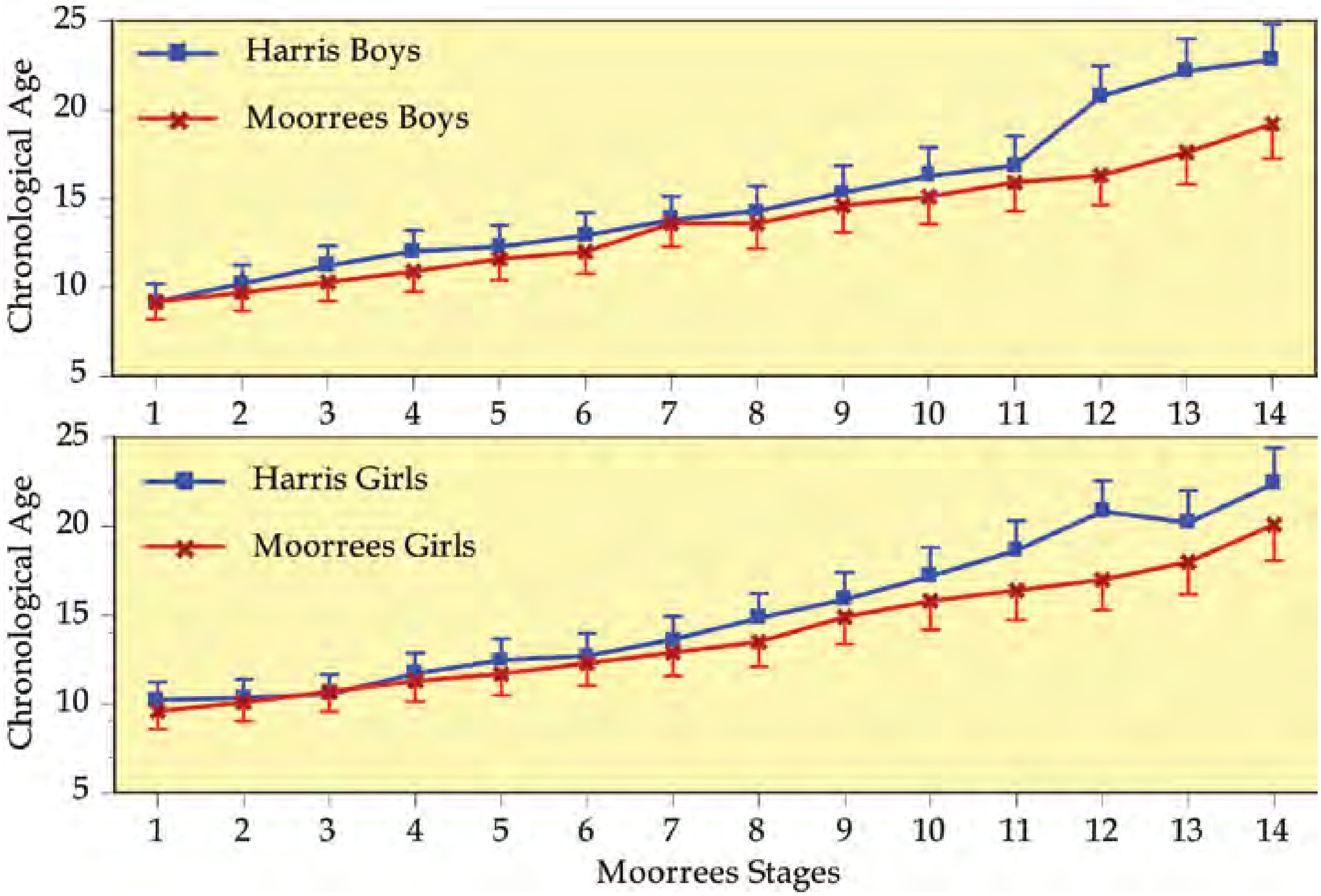

Fig. 2. Plots of the chronolological ages at each of Moorrees' 14 stages for the mandibular third molar as estimated by Moorrees *et al*. (1963) and from Mid-South whites (this study). The means differ by more than a year on average, and the apparent but incorrect interpretation is that the Moorrees sample developed faster. The real reason is that two different events are estimated; the Moorres values are for the *onset* of the grade, while the Harris estimates are for the *average occurrence* of the grade, which occur later.

from the graphed data. Unfortunately, how Moorrees' group actually performed the calculations is only described superficially. The data are provided separately by sex since Garn *et al.* (1958), among others, had documented sexual dimorphism in mineralization, which parallels that of tooth emergence (Cattell, 1928). Moorrees *et al.* (1963) chose to present their data graphically, so the actual values have to be interpolated from the diagrams (Harris and Buck, 2002).

The recent cohort described here consists of a cross-sectional study of adolescents and young adults collected by the author who were phenotypically normal and were routine dental patients receiving treatment at the College of Dentistry, University of Tennessee, Memphis. Sample size was 1,870 (1,070 ♂, 800 ♀). These data were analyzed using survival analysis (Cox and Oakes, 1984; Allison, 1995) to obtain the medians and standard errors for each of Moorrees' 14 stages by sex. These statistics are the average ages in a stage, not the onset of the stage.

RESULTS

The Moorrees standards, published in 1963, were based on children largely from the 1930s, so it is anticipated that more recent children (*i.e.*, the Harris data)—with better nutrition (CDC, 1999) and lessened morbidity—would be growing at faster tempos. Figure 2 shows the plots separately for boys and girls. The striking result is that the earlier, Moorrees group consistently formed their M3s faster from childhood (around 10 years of age) through completion of the root apices in the early 20s. The obvious question is why the results are so different? The mean difference is 1.6 years for boys and 1.4 years for girls. The facile (and incorrect) explanation is that these Mid-South children grew (and mineralized their LM3) much more slowly.

As alluded to, the main reason for the difference is that two different sorts of data are being compared, namely the *onset* of a stage (Moorrees) *versus* the average at which the stage occurs (Harris), which is Smith's "age of subjects in a stage." Of course, the onset predates the average occurrence, and the span of time for occurrence is greater than the onset. False interpretations stem from confusing these different events.

DISCUSSION

There is a long-term interest in how children grow, and, specifically, how the dentition forms (Krogman 1968; Demirjian (1986). Anthropologically, it is of interest whether some groups have a faster tempo of growth than others (perhaps the difference is adaptive). One well-known example is between blacks and whites. Using tooth eruption (gingival emergence), Suk (1919) was probably the first to show that sub-Saharan blacks grow faster than whites (sometimes strikingly so, see Swinburne, 2005). Boas (1933) disseminated Suk's findings in the literature. Independently, Steggerda and Hill (1942) showed that eruption occurred earlier in American blacks than whites, and this difference has been confirmed and elaborated on by Garn and coworkers (Garn *et al.*, 1972, 1973). Since tooth emergence is tied to the degree of tooth formation (Grøn, 1962), it follows that the two processes show the same ethnic differences. It seems most useful for such comparisons to use the median age-at-occurrence. This answers the question of whether the average-growing child from one group has a different rate of maturation than in a different group.

Clinically, a common use of dental age is to assess whether a child is growing at the "normal" rate: Is his/her degree of tooth formation consistent with the child's chronological age? This is the basis of numerous studies of children with growth problems.

Since Moorrees' published standards (1963) are commonly cited and commonly available (the *Journal of Dental Research* is an open-access journal), researchers are prone to use these 'standards' to evaluate the status of children of interest. Since onset of a stage necessarily predates average occurrence of a stage (Smith, 1991), a child's degree of dental delay will be exaggerated when the Moorrees ages at onset are used, and, if the child' dental age is above-normal (Midtbø and Halse, 1992; Hass *et al.*, 2001), dental age will be under-estimated when using these 'standards' because the comparison is between different events.

In sum, dental age is a practical method of gauging a child's degree of maturity. Because teeth form over a broad span of time—from the second trimester *in utero* through the onset of adulthood (Lunt and Law, 1974; McGettigan *et al.*, 2011)—and all children can be assessed using the same criteria, the method is broadly applicable. However, it behooves the researcher to understand how the normative standards being used were obtained so proper comparisons can be made.

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