Dental Asymmetry in a Late Archaic and Late Prehistoric Skeletal Sample of the Ohio Valley Area

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ABSTRACT. Dental asymmetry (directional, anti-symmetry, and fluctuating) is analyzed in samples from two prehistoric Native American populations: a terminal Late Archaic population (3200-2700 BP) and a Late Prehistoric population (ca. 750 BP). Both directional and fluctuating asymmetry were found in each sample. Directional asymmetry occurs in only four teeth in the Late Archaic sample and in two teeth in the Late Prehistoric sample. Neither sample exhibits the tendency for opposing arch dominance in directional asymmetry. Fluctuating asymmetry is significantly greater than measurement error for all teeth in each sample. However, contrary to expectations the Late Prehistoric maize agriculturists do not show an overall greater degree of fluctuating asymmetry compared to their forager ancestors. This result coupled with a survey of pathological conditions in these populations suggest that stress levels in Ohio Valley populations, at least that stress which affected dental developmental stability, were not drastically increased with the introduction of maize agriculture. Spearman correlations between relative tooth size variation (coefficient of variation), the magnitude of fluctuating dental asymmetry, and duration of time (per tooth) spent in soft tissue development were obtained for each sample. Coefficients of variation and fluctuating asymmetry are significantly correlated in both samples but fluctuating asymmetry is significantly correlated with duration of soft tissue development only in the Late Prehistoric population.

Developmental stability is the result of processes that act to insure that features of organisms differentiate, grow, and mature along their genetically predetermined pathways (Waddington, 1957). Two primary hypotheses have been offered to explain the genetic basis of developmental stability: the heterozygosity and the genomic coadaptation hypotheses. The heterozygosity hypothesis proposes that developmental stability is augmented by increasing heterozygosity. The mechanism for increased stability with increased heterozygosity may be greater biochemical efficiency (Mitton, 1994) or an increase in the range over which metabolic functions can be performed (Watt, 1983). The genomic coadaptation hypothesis proposes that developmental stability results from the action of natural selection which establishes and maintains complex genetic interactions, a genetic balance, over the evolutionary history of taxa (Dobzhansky, 1970; Mather, 1973). Recently it has been shown that heat-shock protein 90 (Hsp90), an essential and abundant protein at normal temperatures and induced by stress in all eukaryotes tested,buffers developmental stability against stochastic processes (Queitsch et al., 2002). Hsp90 normally acts to reduce the likelihood that stochastic events will alter the deterministic path of developmental programs by chaperoning metastable proteins and stabilizing them in conformations that allows them to be activated in the proper time and place (Queitsch et al., 2002).

Hybridization, according to the heterozygosity hypothesis, is expected to increase developmental stability while the genomic coadaptation hypothesis would predict reduced stability from hybridization. In some cases of hybridization between subspecies increased developmental stability for some features has been found (Ailbert et al., 1997; Freeman et al., 1995). Generally however developmental stability appears to decrease when coadapted gene complexes are disrupted (Graham, 1992) with the effect on developmental stability modified by the degree of divergence between the hybridizing taxa and the recency of hybridization (Markow and Ricker, 1991). Hsp90 may also be affected by increased polymorphism. While Hsp90 buffers the expression of genetic variation, extensive polymorphism in genomes may exceed Hsp90's ability to maintain functional developmental pathways resulting in reduced stability or altered features (Queitsch et al., 2002).

In addition to genetic causes environmental factors may affect developmental stability (Waddington, 1960; Siegel and Doyle, 1975a; 1975b; 1975c; Hurtado et al., 1997). Environmental stress is hypothesized to reduce developmental stability by decreasing the ability of organisms to buffer against developmental noise or by increasing developmental noise by increasing intracellular stress (Hochwender and Fritz, 1999; Queitsch et al., 2002).

Reduced developmental stability can be measured by the analysis of fluctuating asymmetry (Parsons, 1990; Clarke, 1992; Graham et al., 1993; Woods et al., 1998; Nosil and Reimchen, 2001). Fluctuating asymmetry (FA), the variance in random deviations from exact bilateral symmetry, is considered a

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measure of developmental stability because the sides of bilaterally symmetrical organisms share the same genotype and environmental differences between the sides, summed over development, are likely to be small. The differences between features from the sides of organisms can then be attributed primarily to random errors that accumulated in development (Klingenberg and Nijhout, 1999). A large accumulation of random errors in development will lead to greater magnitudes of FA and indicate reduced developmental stability.

Although there is substantial support for the hypothesis that increased environmental stress leads to increased FA (Parsons, 1990) some studies have found no association between FA and increased stress (see Palmer and Strobleck, 1986). This situation occurs particularly for studies of environmental stress in natural (non-experimental) populations. This inconsistency may arise because natural environmental perturbations were not severe enough (compared to experimental manipulations of environment) to affect FA and because not all features respond to stress in the same manner. Response to a given type of stress may be feature specific and some features may not be reliable indicators of increased environmental stress (Parsons, 1990; Woods et al., 1998).

While all features in organisms may not reflect increased stress by the analysis of FA, the human dentition does appear to be a reliable indicator if levels of stress are relatively high and sample sizes are adequate (Parsons, 1990). Variation in FA among both living and prehistoric human groups have provided indirect evidence of variation in developmental stability (Bailit et al., 1970; Doyle and Johnston, 1977; Perzigian, 1977; DiBernanardo and Bailit, 1978; Townsend and Brown, 1980; Harris and Nweeia, 1980; Townsend, 1981; Kieser et al., 1986; Mizoguchi, 1986; Kieser and Groeneveld, 1988).

The purpose of the present study is to compare levels of fluctuating dental asymmetry in samples of two prehistoric Native American populations from the Ohio Valley region. The populations represent an evolving lineage (Sciulli and Oberly, 2002) with one population extant during the Late Archaic period (ca. 3200-2700 BP) and the second extant during the Late Prehistoric period (950-300 BP). The earlier Late Archaic population subsisted primarily as hunter-gatherers while the Late Prehistoric population practiced maize agriculture. The transition to agriculture is associated with an inferred decline in general health status for many prehistoric populations (Cohen and Armelagos, 1984; Cook, 1984; Cohen, 1989; Larsen, 1995; Steckel and Rose, 2002). This inference is based on the general increase in prevalence of skeletal and dental lesions found in agricultural populations compared to their forager ancestors and is hypothesized to have resulted from an increase in physiological stress due to a reduction in the quality of the diet, an increased prevalence of infectious disease (due to crowding), and the synergistic effects of poor diet and diseases (Goodman and Armelagos, 1989; Larsen, 1995). Thus based on this hypothesis the Late Prehistoric maize agriculturalists are expected to show higher levels of FA compared to their Late Prehistoric forager ancestors.

The amount of FA as well as relative size variation have been found to be associated with the duration of the pre-calcification stage of tooth development (Mizoguchi, 1980; Farmer and Townsend, 1993; Townsend and Farmer, 1998). The present study will, in addition to the comparisons of FA, review the potential associations among these variables both within and between the samples.

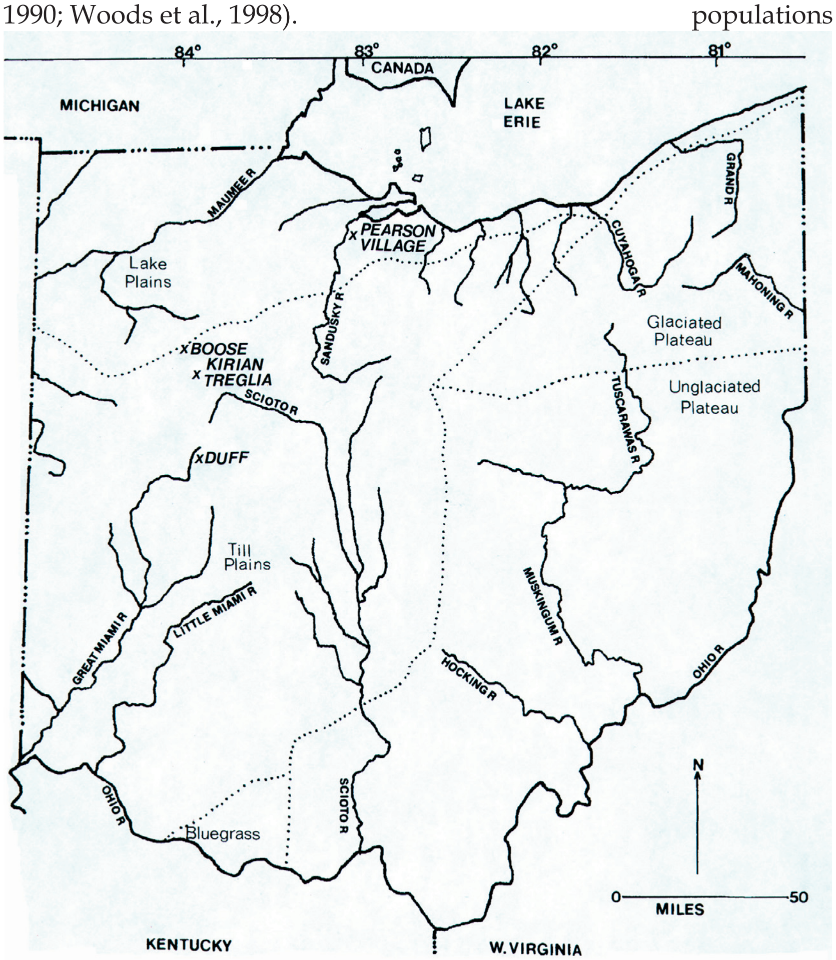

Fig. 1. Map of Ohio showing locations of Late Archaic (Boose, Kirian, Treglia, and Duff) and the Late Prehistoric Pearson Village sites.

MATERIAL AND METHODS

Samples

Two samples are used in the present study: Late Archaic and Late Prehistoric. The Late Archaic sample is derived from a population that was distributed in northwestern Ohio and composed of slightly differentiated subpopulations among which differentiation was related to the geographical dispersion of the subpopulations. The minimum F_{ST}, a measure of population divergence, for Late Archaic subpopulations is 0.039, similar in magnitude to F_{ST} values found for more recent Eastern Woodlands subpopulations (Jantz and Meadows, 1995; Rangdon, 1995; Tatarek and Sciulli, 2000).

Habitation sites of the Late Archaic subpopulations have yet to be discovered and archaeological data relating to subsistence-settlement patterns are thus lacking. Analysis of dental disease and stable carbon isotope ratios, however, have shown that Late Archaic subpopulations exhibited patterns of these diet indicators similar to hunting-gathering populations (Sciulli, 1997). Archaeological data from neighboring regions suggest that Late Archaic subpopulations subsisted by hunting-gathering with the probable inclusion of some native domesticated plants to the diet (Smith, 1989; 1995).

Three Late Archaic subpopulations are used in this study to represent the Late Archaic population: Boose (Sciulli and Schuck, 2001), Kirian Treglia (Sciulli et al., 1993), and Duff (Sciulli and Aument, 1987). These subpopulations are used because preservation was good, individuals were fairly complete, each sex was represented, and these were the largest subpopulations available. A total of 54 Late Archaic adults (18-35 years) comprise the sample with an equal number of males and females.

The Late Prehistoric sample studied here is from the Sandusky Tradition, Pearson Village. A total of 86 adults, 43 males and females, are sampled from the Middle cemetery (Sciulli et al., 1996). The Middle cemetery is associated with the North Pearson Village (ca. 750 BP) which was a late spring to early fall base camp at which maize agriculture was a primary subsistence activity (Bowen, 1978; Stothers and Abel, 1989). Faunal and floral analyses have shown that hunting, fishing, and gathering also contributed significantly to the subsistence of this population (Bowen, 1991). The settlement pattern of the Pearson Village population was characterized by spring to fall village occupation and winter dispersal to small extractive camps (Strothers and Abel, 1989).

Analysis of Late Prehistoric population structure in the Ohio Valley region has shown that subpopulations were somewhat more differentiated than in the Late Archaic (F_{ST} = 0.078) and that genetic differentiation was not related to the pattern of geographic dispersion of subpopulations. It has been hypothesized that the difference in population structure between the Late Archaic and Late Prehistoric populations was due to the increased pace of cultural change in the Late Prehistoric period related to the introduction of tropical domesticates (maize, beans) and increased population growth (Tatarek and Sciulli, 2000).

Procedures for estimating age and sex for the Late Archaic and Pearson Village samples can be found in Sciulli and Aument (1987) and Sciulli et al. (1996) respectively.

Measurement

The bucco-lingual (BL) diameters of permanent antimetric teeth present in each individual were measured except for the third molars. The BL diameters are the distances between points of maximum curvature of the buccal and lingual surfaces of a tooth. Each tooth was measured twice with time intervals between measures ranging from three weeks to four months. Teeth with excessive wear or lesions which affected the BL diameter were not used. Measurement of the Late Archaic sample was done with a Helios dial caliper (instrument accuracy $\pm$ 0.05 mm) and measurement of the Pearson Village sample was done with a Mitutoyo Digimatic caliper (instrument accuracy $\pm$ 0.02 mm).

Statistical Analyses

Preliminary analyses of the data consisted of obtaining descriptive statistics (mean, coefficient of variation, and a normality measure) and a measurement error determination for each tooth measure in both samples. Measurement error is determined as $\Sigma|R_i-L_i|/n$, where R and L are the diameters of the right and left sides, i is the measure (1 or 2), and n is the sample size.

The distributions of (R_i–L_i) were tested for size dependence, anti-symmetry, and directional asymmetry. To test for size dependence plots of (R_i–L_i) against a size measure (R_i–L_i)/2, were obtained. Although there was no evidence of size dependence for (R_i–L_i) all measures were transformed by dividing the (R_i–L_i) by the size measure for the analysis of variance (see below).

Anti-symmetry occurs when a structure in a groups of organisms is normally asymmetric but the side which has a greater development is variable (Van Valen, 1962). In extreme cases this will yield a bimodal distribution of the signed differences between the sides. In less extreme cases the distribution of signed differences will tend toward platykurtosis or possibly leptokurtosis if there is anti-symmetry only for larger deviations from equality (Van Valen, 1962). Although anti-symmetry has not been reported for the human dentition the distributions of (R_i – L_i) in the present samples were tested for departures from normality both graphically and numerically.

Directional asymmetry occurs when there is a greater development of a feature on one side of an organism than the other side (Van Valen, 1962). The distribution of signed differences about the mean is generally normal but the mean is significantly greater or less than zero depending on which side shows the greater development. Recently directional asymmetry has been noted in both the deciduous (Townsend and Farmer, 1998) and permanent (Harris, 1992) dentitions of human populations. For the present samples the means of the distributions of sized differences between the sides are tested for differences from zero. In addition, directional asymmetry is tested in the analysis of variance (see below).

The analysis of fluctuating dental asymmetry employed a two-way, mixed model analysis of variance (sides fixed, individuals random) with repeated measurements for each side (Palmer and Strobeck, 1986). The model is presented in Table 1, where S is the number of sides (S = 2), J is the number of individuals, and M is the number of measures per side (M = 2). This analysis cannot partition out anti-symmetry (the variance components of fluctuating asymmetry and anti-symmetry are contained in the non-directional variance component). However, the presence of anti-symmetry is tested in the evaluation of the (R_i – L_i) distributions. Non-directional asymmetry (MS_{SJ}) is tested over measurement error and directional asymmetry is tested over non-directional asymmetry. Size or shape variation is not tested in this study as the size correction transformation employed resulted in MS_J=0 for all measures. In the absence of anti-symmetry, FA can be quantified for a BL measure for a tooth as:

$$s^2_i = (MS_{SJ} - MS_M)/2$$

Comparisons of FA between the Late Archaic and Pearson Village samples used an F-test (ratio of s^2_i's) with degrees of freedom for each s^2_i given by:

$$(MS_{SJ} - MS_M)^2/((MS_{SJ})^2/J\text{-}1) + ((MS_M)^2/SJ).$$

Associations between relative duration of the precalicification stage of tooth development (Mizoguchi, 1980), relative tooth size variation (coefficient of variation), and FA (s^2_i) were tested using Spearman's rank correlation coefficient (Sokal and Rohlf, 1981). Associations were obtained within each sample as well as between samples. All analyses were performed using NCSS (Hintze, 1992).

RESULTS

Tables 2 and 3 contain the descriptive statistics and a measurement error estimate for the first and second BL measure in the maxillary and mandibular teeth of the Late Archaic and the Pearson samples. Overall relative variation of the BL diameters as measured by the coefficient of variation averages 2.6% higher in the Pearson Village sample. However, no variances are significantly different in the two samples (F-test; Sokal and Rohlf, 1981). Mean BL diameters are consistently smaller in the Pearson sample (3.4% overall) with the maxillary teeth (3.7%) somewhat smaller than the mandibular teeth (3.1%). Tests of the differences in the means of the BL diameters (t-test; Sokal and Rohlf, 1981) revealed that the Pearson Village sample exhibited significantly smaller BL diameters for all teeth except the maxillary first molar and the lower canine, which showed no differences between the samples.

The BL diameters are for the most part normally distributed in both samples. In the Late Archaic sample only the upper anterior premolar (both measures, right and left), upper lateral incisor (both measures, left side), and upper posterior premolar (both measures, right side) show departures from normality. In the Pearson Village sample only the upper second molar (both measures, right side) and lower lateral incisor (first measure, right side) show departures from normality.

Measurement error in the Late Archaic sample (0.06-0.09 mm) is in all cases greater than in the Pearson Village sample (0.03-0.04 mm) although the 95% confidence intervals overlap in most cases. The difference in measurement error is due primarily to the differences in the instrument accuracy (see Measurement).

Table 4 contains the results of the analyses of the distributions of (R_i – L_i) for the first and second measures in both samples. The Late Archaic sample exhibited some departures from normal (R_i – L_i) distributions for four measures: the upper canine showed a slight (p=0.04) right skewness (measure 1), the lower lateral incisor showed a slight leptokurtosis (p = 0.02) for measurement 2, the upper first molar was leptokurtotic (p = 0.06) for the second measure only, and the lower second molar showed a slight leptokurtosis (p = 0.04) for the first measure and slight skewness (p = 0.005) and leptokurtosis (p = 0.01) for the second measure.

In the Pearson Village sample, six teeth exhibited some departure from normality: the upper central incisor (p = 0.04) and the lower second molar (p = 0.03) showed slightly left skewed distributions for one of the two measures, the lower first molar showed a left skewness for both the first (p = 0.02) and second (p =

TABLE 1. Anova model; see text for discussion

Source of Variation	df	Mean Square	Expected Mean Square	Interpretation
Sides (S)	(S-1)	MS_s	$\sigma^2_m + M(\sigma^2_i + (^J/_{S\text{-}1})\Sigma\alpha^2$	Directional asymmetry
Individuals (J)	(J-1)	MS_J	$\sigma^2_m + M(\sigma^2_i + S\,\sigma_J^2)$	Shape or size variation
Remainder	(S-1)(J-1)	MS_{SJ}	$\sigma^2_m + M\,\sigma^2_i$	Non directional asymmetry
Measurement (M)	SJ(M-1)	MS_M	σ^2_m	Measurement error

TABLE 2. Descriptive statistics and measurement error for the buccolingual diameters of the maxillary teeth in the Archaic and Pearson samples

		ARCHAIC				PEARSON				
Tooth	Measure	mean[1]	CV	K^2	Measurement Error (limits)		mean[1]	CV	K^2	Measurement Error (Limits)
UI1										
(N=43)	R1	7.21	5.57	3.4	0.06 (0.05, 0.07)		6.97	6.26	0.6	0.04 (0.03, 0.05)
	R2	7.20	5.56	3.4		(n=53)	6.97	6.15	1.3	
	L1	7.27	5.60	1.6	0.07 (0.04,0.09)		7.00	6.71	0.4	0.04 (0.03, 0.05)
	L2	7.28	5.90	1.6			7.00	6.83	0.7	
UI2										
(N=44)	R1	6.54	8.20	3.4	0.06 (0.04,0.08)		6.33	7.13	1.0	0.05 (0.03,0.06)
	R2	6.55	8.46	5.0		(N=53)	6.32	7.25	1.8	
	L1	6.59	8.12	7.5[2]	0.07 (0.06,0.09)		6.30	7.95	6.5	0.04 (0.03,0.06)
	L2	6.61	8.13	8.6[2]			6.28	7.96	6.4	
UC										
(N=43)	R1	8.84	7.41	1.0	0.08 (0.06,0.10)		8.42	7.20	3.2	0.04 (0.03, 0.06)
	R2	8.82	7.52	0.8		(N=66)	8.43	7.29	2.6	
	L1	8.81	7.59	0.2	0.07 (0.05,0.10)		8.42	7.30	1.1	0.03 (0.02,0.04)
	L2	8.81	7.33	1.0			8.43	7.29	0.8	
UP3										
(N=45)	R1	9.87	6.19	9.4[2]	0.07 (0.05,0.09)		9.52	5.86	0.4	0.03 (0.02,0.04)
	R2	9.85	6.42	14.3[2]		(N=65)	9.52	5.97	0.2	
	L1	9.83	6.47	17.4[2]	0.06 (0.04,0.08)		9.48	6.03	0.9	0.04 (0.03,0.05)
	L2	9.83	6.61	17.8[2]			9.48	6.11	1.0	
UP4										
(N=37)	R1	9.82	6.06	8.0[2]	0.09 (0.06,0.11)		9.23	6.26	2.6	0.04 (0.03,0.05)
	R2	9.84	6.15	12.6[2]		(N=52)	9.23	6.29	2.3	
	L1	9.80	5.78	2.5	0.06 (0.05,0.08)		9.21	6.81	1.1	0.04 (0.03,0.05)
	L2	9.78	5.78	3.2			9.21	6.71	1.0	
UM1										
(N=45)	R1	11.94	4.40	0.4	0.07 (0.04,0.10)		11.86	4.18	0.2	0.04 (0.03,0.05)
	R2	11.94	4.46	0.6		(N=72)	11.85	4.15	0.0	
	L1	11.88	4.33	0.1	0.08 (0.04,0.10)		11.85	4.09	0.8	0.03 (0.02,0.04)
	L2	11.91	4.16	0.2			11.85	4.10	0.9	
UM2										
(N=44)	R1	12.08	4.95	0.9	0.09 (0.07,0.10)		11.60	5.64	9.42	0.06 (0.05,0.07)
	R2	12.09	4.94	1.4		(N=64)	11.60	5.65	8.82	
	L1	12.09	4.97	0.2	0.08 (0.06,0.10)		11.64	5.91	1.8	0.05 (0.04,0.06)
	L2	12.10	4.64	0.2			11.65	5.94	1.5	

[1]CV is coefficient of variation, K^2 is omnibus normality test (D'Agostino, 1990), error is $\Sigma|R-L|/n$, limits is 95% limits of error.
[2]$P < 0.05$.

0.002) measures, the upper first molar first measure (p = 0.03) and lower central incisor both measures (p = 0.03; p = 0.01) showed slightly leptokurtic distributions, and the lower lateral incisor showed a slight right skewness (p = 0.03) for both measures.

Because there is no indication of platykurtosis in any distribution of signed differences and since signed differences are not limited to larger deviations in the cases of leptokurtosis, overall anti-symmetry is judged to be absent in the present samples. Since most deviations from normality are relatively minor these data appear to be suitable for the analysis of FA.

TABLE 3. Descriptive statistics and measurement error for the buccolingual diameters of the mandibular teeth in the Archaic and Pearson samples

	ARCHAIC					PEARSON				
Tooth	Measure	mean[1]	CV	K[2]	Measurement Error (Limits)		mean[1]	CV	K[2]	Measurement Error (Limits)
LI1										
(N=39)	R1	5.72	5.04	0.9	0.06 (0.05,0.07)		5.58	5.39	1.0	0.03 (0.02,0.04)
	R2	5.70	5.15	1.7		(N=61)	5.58	5.41	0.6	
	L1	5.70	5.64	2.6	0.06 (0.05,0.07)		5.59	5.42	0.1	0.04 (0.03,0.06)
	L2	5.68	5.57	2.3			5.59	5.44	0.2	
LI2										
(N=44)	R1	6.19	5.19	2.6	0.07 (0.06,0.08)		6.00	5.18	6.5[2]	0.04 (0.03,0.05)
	R2	6.17	4.83	1.7		(N=60)	5.99	5.25	5.9	
	L1	6.18	4.63	1.7	0.07 (0.05,0.09)		5.97	5.12	0.3	0.04 (0.03,0.05)
	L2	6.14	4.75	0.2			5.96	5.09	0.8	
LC										
(N=50)	R1	7.86	7.01	0.3	0.06 (0.04,0.07)		7.72	7.16	3.4	0.03 (0.02,0.04)
	R2	7.85	7.10	1.0		(N=63)	7.73	7.15	4.0	
	L1	7.90	7.83	0.6	0.07 (0.04,0.09)		7.71	7.18	3.6	0.04 (0.03,0.04)
	L2	7.90	7.91	0.6			7.71	7.19	3.0	
LP3										
(N=45)	R1	8.28	5.66	0.7	0.06 (0.05,0.08)		7.86	6.61	0.7	0.04 (0.03,0.05)
	R2	8.29	5.57	0.2		(N=71)	7.86	6.62	0.6	
	L1	8.30	5.39	2.7	0.07 (0.05,0.08)		7.87	5.90	0.2	0.04 (0.03,0.05)
	L2	8.31	5.34	2.6			7.87	5.88	0.6	
LP4										
(N=47)	R1	8.65	5.32	5.2	0.07 (0.05,0.09)		8.30	5.91	0.6	0.04 (0.03,0.05)
	R2	8.66	5.50	3.9		(N=62)	8.29	5.85	1.2	
	L1	8.66	5.20	4.1	0.08 (0.06,0.09)		8.34	5.71	0.1	0.04 (0.03,0.05)
	L2	8.66	5.27	5.7			8.33	5.74	0.1	
LM1										
(N=53)	R1	10.81	4.63	0.4	0.09 (0.07,0.11)		10.63	4.65	1.1	0.04 (0.03,0.05)
	R2	10.83	4.76	0.7		(N=84)	10.62	4.55	1.0	
	L1	10.81	4.72	0.0	0.07 (0.05,0.09)		10.69	4.61	1.9	0.04 (0.03,0.05)
	L2	10.83	4.65	0.4			10.68	4.60	2.5	
LM2										
(N=45)	R1	10.79	5.80	3.9	0.07 (0.05,0.08)		10.35	4.93	1.0	0.04 (0.03,0.05)
	R2	10.80	5.87	3.5		(N=64)	10.35	5.00	1.0	
	L1	10.79	5.90	0.1	0.08 (0.06,0.10)		10.39	5.40	0.7	0.04 (0.03,0.05)
	L2	10.83	5.68	0.5			10.39	5.30	0.2	

[1]CV is coefficient of variation, K^2 is omnibus normality test (D'Agostino, 1990), error is $\Sigma|R\text{-}L|/n$, limits is 95% limits of error.
[2]$P < 0.05$.

The mean of the distribution of signed differences is significantly different than zero for three teeth (t-test): the upper central incisor and the upper first molar in the Archaic sample and lower first molar in the Pearson Village sample. In the Late Archaic sample the mean of the left upper central incisor is larger than the right ($p = 0.03$) while the right upper first molar is larger than the left ($p = 0.002$). For both of these teeth the differences are significant for the first measures only. In the Pearson Village sample the left lower first molar is larger than the right for both measures ($p = 0.002$; $p = 0.003$). Directional asymmetry appears to be present at least for the Pearson Village lower first molar.

Tables 5 and 6 contain the results of the analysis of

TABLE 4. Descriptive statistics for the distribution of (R_i-L_i) in the Late Archaic and Pearson Village samples

		Maxilla								Mandible							
		ARCHAIC				PEARSON				ARCHAIC				PEARSON			
	Measure	mean[1]	g_1	g_2	K^2	mean	g_1	g_2	K^2	mean	g_1	g_2	K^2	mean	g_1	g_2	K^2
I1	R-L(1)	-0.06	0.17	0.70	1.4	-0.03	-0.44	-0.17	1.9	0.02	0.31	1.24	3.1	-0.01	0.41	2.58[2]	9.0[2]
	R-L(2)	-0.07[2]	0.19	1.10	2.5	-0.03	-0.69[2]	-0.12	4.3	0.02	-0.24	1.59	3.7	-0.01	0.53	1.93[2]	8.2[2]
I2	R-L(1)	-0.06	-0.02	0.03	0.1	0.04	-0.21	0.65	3.8	0.01	-0.12	0.23	0.4	0.04	0.69[2]	1.07	7.3
	R-L(2)	-0.06	0.02	0.83	1.5	0.04	-0.42	0.99	1.7	0.04	0.33	2.31[2]	6.2[2]	0.03	0.67[2]	-0.15	4.5
C	R-L(1)	0.03	0.74[2]	1.26	6.6[2]	-0.01	-0.34	1.13	4.2	-0.04	-0.45	-0.16	1.8	0.01	0.07	0.90	2.1
	R-L(2)	0.01	0.25	0.85	2.1	0.01	0.01	0.09	0.1	-0.05	-0.59	-0.08	3.1	0.02	-0.03	0.04	0.1
P3	R-L(1)	0.04	-0.32	0.01	0.9	0.04	-0.09	-0.37	0.4	-0.02	-0.18	0.96	2.1	0.00	-0.06	-0.15	0.1
	R-L(2)	0.01	0.13	0.09	0.3	0.04	0.10	0.06	0.2	-0.02	-0.16	0.11	0.4	0.01	-0.03	-0.35	0.3
P4	R-L(1)	0.02	-0.37	-0.38	1.1	0.02	-0.07	1.42	3.3	-0.01	-0.51	0.73	3.5	-0.03	-0.56	0.97	5.6
	R-L(2)	0.06	-0.60	-0.39	2.6	0.02	0.13	1.12	2.6	-0.01	0.45	1.40	4.7	-0.03	-0.50	0.20	3.0
M1	R-L(1)	0.06[2]	0.55	0.93	4.2	0.01	0.17	0.04	0.5	0.00	-0.04	0.44	6.7	-0.06[2]	-0.65[2]	0.83	7.9[2]
	R-L(2)	0.03	-0.60	3.15[2]	10.3[2]	0.00	-0.42	1.65[2]	7.1[2]	0.01	0.28	0.69	2.1	-0.06[2]	-0.88[2]	0.79	11.6[2]
M2	R-L(1)	-0.01	0.37	-0.34	1.3	-0.04	-0.43	0.70	3.6	0.00	0.40	1.90[2]	5.7	-0.04	-0.66[2]	0.96	7.0[2]
	R-L(2)	-0.01	0.20	0.30	0.8	-0.04	-0.28	0.72	2.5	-0.03	1.08[2]	3.11[2]	15.2[2]	-0.04	-0.56	0.66	4.8

[1]g_1 is skewness, g_2 is kurtosis, and K^2 is omnibus normality test
[2]$P < 0.05$

variance (anova) for the maxillary and mandibular BL diameters respectively. The size correction transformation resulted in all cases in eliminating the size-shape (individual) source of variation (MS_J = 0). Thus three sources of variation remain: sides, fluctuating asymmetry (= non-directional asymmetry as anti-symmetry is not present), and measurement error.

Directional asymmetry (sides) as measured by the anovas is significant in four Late Archaic teeth and two Pearson Village teeth. In the Late Archaic sample the right upper first molar is larger than the left, while for the upper lateral and central incisors and lower canines, the left sides are larger than the right (these four teeth also show the greatest (R_i – L_i) differences in Table 4 although all are not significant). In the Pearson sample the lower left first molar is larger than the right while the lower right lateral incisor is larger than the left.

FA is significantly greater than measurement error for all teeth in both samples. The Late Archaic sample exhibits significantly greater variance components (s_i^2) for the upper canine and lower lateral incisor while the Pearson Village sample exhibits greater variance components for the upper lateral incisor and first molar.

Measurement error (s_m^2) as a percentage of (s_i^2 + s_m^2) ranges between 5.2 and 39.2% for the Late Archaic sample with most values in the 5-15% range. In the Pearson Village sample, in which measurement error was lower, the corresponding values range between 2.7 and 12.1% with most values in the 3-10% range.

Spearman rank correlation coefficients between the coefficients of variation (cv), variance components of FA (s_i^2) and the relative time a tooth spends in soft tissue stages of crown development (Mizoguchi, 1980) are contained in Table 7. In the Archaic sample FA is significantly correlated with CV (positive) while in the Pearson Village sample FA is significantly correlated with CV (positive) and time spent in soft tissue development (positive). Late Archaic FA is positively correlated with Pearson Village FA and CV but the Pearson Village FA is positively associated only with Late Archaic FA.

DISCUSSION

The Late Archaic and Pearson Village samples each exhibit directional and fluctuating asymmetry. While FA is present in all teeth in both samples, directional asymmetry is limited to four teeth in the Late Archaic sample (upper first molar, central and lateral incisors, and lower canine) and only two teeth in the Pearson Village sample (lower first molar and lateral incisor). Harris (1992) and Townsend and Farmer (1998) have found directional asymmetry in the permanent and deciduous teeth respectively and have noted that there appears to be a tendency for right side dominance in one arch to be associated with left side dominance in the opposing

TABLE 5. Analysis of variance for maxillay teeth in the Late Archaic and Pearson Village

		ARCHAIC						PEARSON					
Tooth	Source	df	SSQ[4]	MSQ	F	s_i^2	df	df	SSQ[4]	MSQ	F	s_i^2	df
UI1	Sides	1	33.67	33.67	4.11[2]			1	7.45	7.45	1.29		
	Individuals	42	0	0	0			52	0	0	0		
	Remainder	42	343.4	8.18	28.85*	3.95	39	52	299.2	5.75	43.20*	2.81	50
	Error	86	24.38	0.28				106	14.11	0.13			
UI2	Sides	1	37.58	37.58	4.04[2]			1	25.23	25.23	1.50		
	Individuals	43	0	0	0			52	0	0	0		
	Remainder	43	399.6	9.29	21.45*	4.43	40	52	874.0	16.81	57.37*	8.263	50
	Error	88	38.13	0.43				106	31.01	0.29			
UC	Sides	1	2.17	2.17	0.24			1	0.01	0.01	0		
	Individuals	42	0	0	0			65	0	0	0		
	Remainder	42	375.9	8.95	23.08*	4.28[2]	39	65	273.5	4.21	38.27*	2.05	62
	Error	86	33.36	0.39				132	14.68	0.11			
UP3	Sides	1	3.43	3.43	0.71			1	11.24	11.24	3.41		
	Individuals	44	0	0	0			64	0	0	0		
	Remainder	44	213.2	4.85	37.30*	2.36	37	64	211.0	3.30	47.14*	1.62	61
	Error	90	11.83	0.13				130	8.76	0.07			
UP4	Sides	1	5.31	5.31	0.72			1	3.24	3.24	0.44		
	Individuals	36	0	0	0			51	0	0	0		
	Remainder	36	266.7	7.41	28.50*	3.58	34	51	376.8	7.39	70.9*	3.64	50
	Error	74	18.95	0.26				104	10.84	0.10			
UM1	Sides	1	5.38	5.38	5.03[2]			1	0.18	0.18	0.11		
	Individuals	44	0	0	0			71	0	0	0		
	Remainder	44	46.98	1.07	4.13*	0.40	25	71	109.0	1.53	24.50*	0.74[2]	65
	Error	90	22.34	0.26				144	9.02	0.06			
UM2	Sides	1	0.19	0.19	0.04			1	9.05	9.05	1.87		
	Individuals	43	0	0	0			63	0	0	0		
	Remainder	43	182.7	4.25	19.31*	2.02	39	63	303.6	4.82	43.81*	2.36	60
	Error	88	19.15	0.22				128	13.52	0.11			

* $P < 0.001$
[1] $P \sim 0.05$
[2] $0.05 > P > 0.025$
[3] Pearson $s_i^2 >$ Archaic s_i^2 F=1.56, P~0.025
[4] Archaic $s_i^2 >$ Pearson s_i^2 F=2.09, P~0.005
[5] Pearson $s_i^2 >$ Archaic s_i^2 F=1.85, P~0.025
[6] SSQ, MSQ, and $s_i^2 \times 10^4$

arch. This tendency for opposing arch dominance is not exhibited by either the Late Archaic or the Pearson Village sample. In the Pearson Village sample only mandibular teeth exhibited directional asymmetry (one right and one left dominant) while in the Late Archaic sample only one mandibular tooth (canine, L > R) and three maxillary teeth (first molar, R > L; central incisor, L > R; lateral incisor, L > R) exhibited directional asymmetry. One possible pattern exhibited by the Late Archaic and Pearson Village samples is all teeth that exhibit directional asymmetry are relatively early developing permanent teeth. Harris (1992) proposed that the degree of directional asymmetry may be related to the level of developmental stress in a population and may result from differences in developmental timing between antimeres. Sharma et al. (1986) suggested that environmental or genetic stress could lead to unilateral acceleration of mitotic activity in developing enamel organs yielding directional asymmetry. While early development was likely a stressful period for children in the Late Archaic and Pearson Village populations an association between increased stress (as measured by FA) and directional asymmetry is absent. Of the six teeth that show directional asymmetry three (upper first molar and lateral incisor and lower lateral incisor) exhibit directional asymmetry in the sample that shows significantly less FA for that tooth. In the other three cases of directional asymmetry the samples

TABLE 6. Analysis of variance for mandibular teeth in the Late Archaic and Pearson Village

		ARCHAIC						PEARSON					
Tooth	Source	df	SSQ[4]	MSQ	F	s_i^2	df	df	SSQ[4]	MSQ	F	s_i^2	df
LI1	Sides	1	6.35	6.35	0.80			1	2.14	2.14	0.44		
	Individuals	38	0	0	0			60	0	0	0		
	Remainder	38	192.9	5.08	17.39	2.40	34	60	291.8	4.86	19.45	2.30	54
	Error	78	22.70	0.29					122	30.08	0.25		
LI2	Sides	1	5.53	5.53	0.88			1	15.75	15.75	5.96[1]		
	Individuals	43	0	0	0			59	0	0	0		
	Remainder	43	267.7	6.26	13.60	2.90[2]	37	59	156.0	2.64	15.62	1.24	51
	Error	88	40.90	0.46					120	20.27	0.17		
LC	Sides	1	13.76	13.76	3.60			1	2.13	2.13	0.62		
	Individuals	49	0	0	0			62	0	0	0		
	Remainder	49	187.3	3.82	11.31	1.74	40	62	211.2	3.41	28.49	1.76	57
	Error	100	33.77	0.34				126	15.08	0.12			
LP3	Sides	1	2.96	2.96	0.57			1	1.24	1.24	0.20		
	Individuals	44	0	0	0			70	0	0	0		
	Remainder	44	230.2	5.23	24.91	2.72	41	70	430.5	6.15	43.93	3.01	67
	Error	90	18.50	0.21				142	19.44	0.14			
LP4	Sides	1	0.39	0.39	0.09			1	7.44	7.44	1.54		
	Individuals	46	0	0	0			61	0	0	0		
	Remainder	46	208.9	4.54	15.66	2.12	40	61	293.9	4.82	41.76	2.47	58
	Error	94	27.16	0.29					124	14.31	0.12		
LM1	Sides	1	0.01	0.01	0.0			1	25.32	25.32	10.51[3]		
	Individuals	52	0	0	0			83	0	0	0		
	Remainder	52	149.1	2.87	13.04	1.32	44	83	199.7	2.41	26.78	1.16	77
	Error	106	23.76	0.22				168	14.42	0.09			
LM2	Sides	1	0.80	0.80	0.14			1	10.47	10.47	2.08		
	Individuals	44	0	0	0			63	0	0	0		
	Remainder	44	260.0	5.91	29.55	2.86	41	63	316.8	5.03	62.88	2.47	60
	Error	90	18.17	0.20				128	10.61	0.08			

[1] $0.025 > P > 0.025$
[2] Archaic s_i^2 > Pearson s_i^2
[3] $P > 0.05$
[4] SSQ, MSQ, and $s_i^2 \times 10^4$

show no differences in FA. Although scenarios could be proposed to explain these data on directional asymmetry, for example that the presence of increased FA masks the presence of directional asymmetry, I think Townsend and Farmer (1998:253) summarized the current situation very well when they stated:

> Although it would seem that directional dental asymmetry is not merely a statistical artifact, its exact nature and causes remain to be solved. So too does the question of whether there is any relationship between fluctuating and directional forms of dental asymmetry.

Fluctuating asymmetry is present for all teeth in both samples. However, contrary to expectations concerning the differences in environmental stress levels between foragers and agriculturalists, the Pearson Village agriculturalists do not show a greater level of FA compared to the Late Archaic foragers. The average FA (s_i^2) for all 14 teeth in the Late Archaic sample is virtually identical to that in the Pearson Village sample, 2.65 and 2.56 (x 10^{-4}) respectively. Only four teeth show significant differences between the samples with the Late Archaic sample showing greater FA for two teeth (upper canine and lower lateral incisor) and the Pearson sample showing greater FA also for two teeth (upper first molar and lateral incisor). The lack of an indication of increased developmental stress in the Pearson Village agriculturalists is likely due to the fact that maize

TABLE 7. Spearman rank correlation coefficients between FA, cv (relative variability) and duration spent in soft tissue development

		CV	FA	SOFT
(A)	CV	---	0.62[2]	0.47
	FA	0.60[1]	---	0.65[3]
	SOFT	0.46	0.24	---
			Pearson Village	
			CV	FA
(B) ARCHAIC		CV	0.88[4]	0.50
		FA	0.61[5]	0.64[6]

(A): Pearson Village above diagonal, Archaic below diagonal
1. $P = 0.024$
2. $P = 0.018$
3. $P = 0.012$
4. $P < 0.0001$
5. $P = 0.020$
6. $P = 0.014$

agriculture was adopted late in prehistory (ca. 1000 BP) by Ohio Valley and lower Great Lakes populations and a heavy reliance on hunting and gathering as well as agriculture characterized the entire Late Prehistoric period (ca. 1000-350 BP). The transition to a full agricultural subsistence was probably never completely realized in this region. A survey of skeletal and dental stress indicators in Late Archaic and Late Prehistoric populations of the region suggests that while stress is indicated to some degree for all populations the relatively low prevalence of pathological conditions indicates that stress levels were not elevated. Aside from dental lesions which increase dramatically in the Late Prehistoric period, other pathological conditions as well as indicators such as growth rates and adult stature show only minor differences among the populations. These results in toto suggest that general life-style patterns did not vary greatly in the region over this time span and even after the introduction of maize agriculture, overall environmental stress was not elevated to the degree that would result in increased fluctuating dental asymmetry (Sciulli and Oberly, 2002).

The similarity between the Late Archaic and Pearson Village samples also extends to the relationship of FA, relative variation (CV) and time spent in soft tissue development. In both the Late Archaic and Pearson Village samples FA (s_i^2) is significantly correlated at about the same magnitude with relative variation, teeth displaying greater crown size variability also tend to show greater FA. Relative variation is strongly correlated between the two samples and FA is significantly correlated as well.

The observation that teeth with greater relative variation also tend to have greater FA has been suggested to be associated with the duration of soft tissue development. It is proposed that teeth that spend longer periods in soft tissue development during which they can be affected by environmental disturbances show greater relative variation and FA (Mizoguchi, 1983). In the Pearson Village sample FA is significantly associated with the duration of soft tissue development (Mizoguchi, 1983) but Archaic FA, Archaic CV and Pearson CV are not significantly correlated with the duration of soft tissue development. All of the statistically insignificant rank correlations with duration of soft tissue development except for Archaic FA are relatively large in magnitude and the insignificant correlations may be the result of using durations of soft tissue development that are only approximate for the prehistoric populations.

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Sex Differences in Oral Pathologies at the Late Classic Maya Site of Xcambó, Yucatán[1]

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ABSTRACT The present study compares the frequency of oral pathologies—namely caries, antemortem tooth loss and periapical defects—between sexes in the Maya site of Xcambó, Yucatán, during the Late Classic Period (AD 600-900). There are marked differences in the occurrence of oral pathological conditions between the sexes in two of three major areas of the sites, despite evidence of archaeological and funerary homogeneity within the site. In these two compounds, females are significantly more affected by oral pathologies than males. In contrast, the third area of the site shows slightly higher frequencies in males, but with no significant sex difference. The results have been interpreted according to the site's location, size and economic role within a larger trade network in the Yucatán peninsula. The higher frequency of oral pathologies in females is interpreted as the result of sex differences in dietary and behavioral patterns. Females likely had more maize in their diet and, because of their role in food preparation, may have ingested food more frequently during the day. At the same time, the lack of difference between sexes in the third area of the site contradicts the archaeological evidence of intrasite homogeneity, and it raises questions on the cultural complexity of this population.

Oral pathologies are tightly related to subsistence patterns and they are utilized in anthropological studies as a means to assess diet and food preparation techniques (Powell, 1985; Lukacs, 1989; Larsen et al., 1991; Larsen, 1997; Hillson, 2000).

In ancient Maya society, diet has been investigated in several ways and under various perspectives, related to the "Maya Collapse" and to the shift from the Preclassic to the Classic and Postclassic periods (Whittington and Reed, 1997a; White, 1999). Studies of oral pathologies and of stable isotopes have indicated dietary heterogeneity between sites (Sanders and Price, 1968; Gerry and Krueger, 1997) although a common pattern shared by the whole Maya society was its strong reliance on maize (Landa, 1566; Lentz, 1991; Gerry and Krueger, 1997; White, 1997). Sex differences have been taken into account in the assessment of diet, though often without analyzing and interpreting the data within a more complex socioeconomic and cultural framework. At Copán for example, only the commoner portion of the society was investigated. Females showed higher frequency of caries than males, and this was explained as the result of a higher intake of carbohydrates and a less diversified diet in the formers (Whittington and Reed, 1997b; Whittington, 1999).

The present study reports preliminary findings on differences in the occurrence of oral pathologies by sex and compounds in the Classic Maya site of Xcambó (AD 300-900) from Northern Yucatán peninsula (México) (Fig. 1). The site was a center for salt production and trade (Sierra Sosa, 1999), strategically located next to the coast on a natural small mound surrounded by marshlands, not far from the town of Dzibilchaltún. The site's economical and geographical characteristics and the provenience of the remains from different areas (i.e., compounds) within the site made the sample interesting to with respect to the analysis of social and sexual aspects of the occurrence of oral pathologies in males and females within and between compounds. This paper aims at answering research questions in terms of social structure and the population's internal composition.

This study is part of a broader project on population relationships and lifestyles of this population as a unit and as part of a larger social and economic regional network. The network orbited around Dzibilchaltún but expanded as far as Guatemala to the south and Veracruz to the west because of its role in salt production and trade (Sierra Sosa and Martínez Lizarraga, 2001).

MATERIALS AND METHODS

The human skeletal remains currently available for analysis consists of a sample of 200 individuals, of which only 150 possess permanent dentition and/or dental bony support. Most individuals (N = 129) belong to the Late Classic period (AD 600-900), the others are from to the Early Classic period (AD 300-600). The remains were grouped

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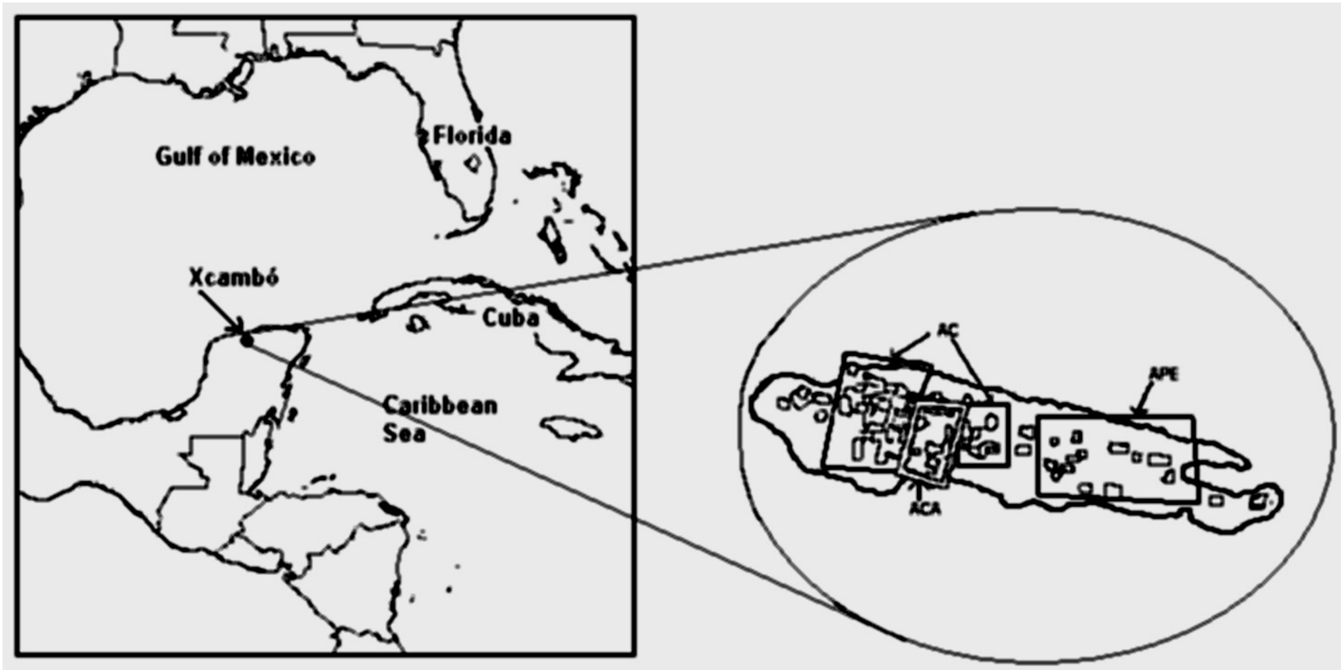

Fig. 1. Geographical location of the site and close up of the site and compounds.

and analyzed according to sex and burial placement. Three major compounds where distinguished: the Central Compound (Asentamiento Central; AC), the Central-Administrative Compound (Asentamiento Central Administrativo; ACA) and the patio groups to its east (Asentamiento Periférico Este; APE) (Fig. 1). In all, the sample totals 2676 permanent teeth. Since this investigation focuses on oral pathologies between sexes, only the adult, sexed individuals and their teeth have been used, and the numbers are listed in Table 1. For obvious reasons, these values are lower than the total ones. All permanent teeth and tooth sockets of the adult sexed individuals were evaluated for oral pathologies according to the methods of Metress and Conway (1975) and Marafon (1976), and following the discussion in Buikstra and Ubelaker (1994).

Caries were scored on each permanent tooth and registered as present when the cavity had reached the dentine and could be clearly detected both visually and with a dental probe. The number of teeth affected and the total available for analysis are listed in Table 2.

Antemortem tooth loss (AMTL) was calculated only on the basis of remodeled tooth sockets in comparison with non-remodeled ones to reduce the bias introduced by poor bone preservation and the associated underestimation of teeth lost during life. Their values and frequencies are reported in Table 3.

Periapical defects appear as round enlargements due to inflammatory processes and bone remodeling. The defects are characterized by smooth homogeneous surfaces on the apical part of the alveolar socket (Marafon, 1976; Lukacs, 1989). These defects were registered as "present" when they could be detected at the apical extremity either because the inflammation had destroyed the external bony tissue or because it was possible to remove the tooth from the jaw and investigate the socket. All the other cases were recorded as "absent". Lukacs (1989) reported that this procedure may underestimate the actual frequency of defects, but in the case of Xcambó the few teeth that could not be removed were not associated with caries and were not affected by heavy occlusal wear, which makes them likely to represent "healthy" sockets. The final values and frequencies for this type of pathological condition are listed in Table 4.

The site

The occupational sequence at Xcambó starts in the Preclassic period (AD 100-250). During the Early (AD 300-600) and Late (AD 600-900) Classic, Xcambó became a thriving center of salt production and trade (Sierra Sosa, 1999). The site, which is 700 meters long and 150 wide, was constructed on top of an artificially elevated, single large platform emerging from the swampy marshland. Canals and trails connected Xcambó with both the coastal strip and the inland areas. The small size of the site and the characteristics of the natural

TABLE 1. Number of individuals analyzed for caries, AMTL and periapical defects according to sex

	Caries	AMTL	Periapical Defects
Males	62	63	62
Females	37	39	34

TABLE 2. Number of teeth affected by caries, total number of scorable teeth available and percent affected

	Anterior[1]			Posterior[2]			Anterior +Posterior		
				ACA					
Males	3	87	3.4	19	158	12.0	22	245	9.0
Females	13	42	31.0	25	62	40.3	38	104	36.5
				AC					
Males	14	276	5.1	88	457	*19.3*	102	733	13.9
Females	31	99	24.0	58	177	32.8	89	276	32.2
				APE					
Males	6	47	12.8	20	101	19.8	26	148	17.6
Females	2	40	5.0	11	76	14.5	13	116	11.2
Total	69	591	11.7	221	1,031	21.4	290	1,622	17.9

[1]Anterior teeth are incisors and canines
[2]Posterior teeth are premolars and molars

mound limited the expansion of its monumental religious and administrative center and the associated domestic areas (Sierra Sosa, 1999; Sierra Sosa and Martínez Lizarraga, 2001).

Extensive and intensive archaeological surveys at the site were performed between 1996 and 2000 by the National Institute of Anthropology and History (INAH). In the course of the excavations more than 600 burials were retrieved from both the residential compounds and the central structures. Findings indicate a relative abundance and homogeneity in the distribution of funerary objects associated with the skeletons compared to other sites in the area. This, along with architectural homogeneity, points towards limited internal social differentiation at Xcambó (Sierra Sosa and Martínez Lizarraga, 2001).

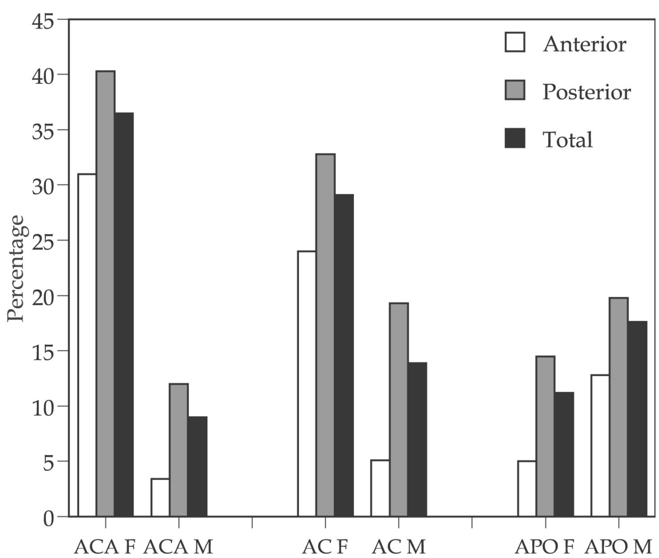

Fig. 2. Frequency of caries according to sex and compounds of the site

RESULTS

Tables 2 through 4 list the sample sizes and the frequencies of caries, AMTL and periapical defects divided by sex and compounds of Xcambó. The same values are graphically represented in Figures 2 through 4. Some from the three compounds belonged to the early Classic period, but the majority were from the Late Classic. Individuals were not differentiated according to chronological horizon because of the small number of individuals from the Early Classic period, and because any chi-square analysis run between the subsamples did not indicate statistically significant differences between the periods. The only case where a difference was significant significantly was the frequency of AMTL in the males from the AC compound (p values from chi-square test with one degree of freedom were 0.011 anterior dentition, 0.011 posterior dentition, and 0.000 total). In this case, as in Table 3 and Figure 3, the two periods have been considered separately.

The age distribution within each subgroup was similar and differences were not statistically significant among compounds. For this reason, we could rule out age at death as a factor influencing the rate of oral pathologies in the between-groups analysis.

Sex differences were evident for all the pathological conditions. Females showed much higher frequencies of oral pathologies than males, with the one exception of the APE compound. In this case, males surpass females. Chi-square P values for all the possible pair-wise comparisons are listed in Table 5. Differences between sexes were significant for the three pathological conditions in ACA and AC but not significant in APE. Within-sex comparison shows that the major changes in frequency are encountered between APE and the two other groups. Females at APE are constantly and significantly less affected than their counterparts in the two other compounds. In turn, no difference

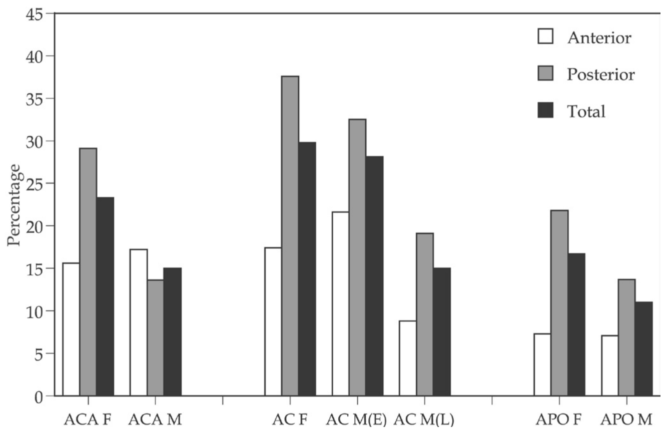

Fig. 3. Frequency of antemortem tooth loss by sex and compounds (Males have been sorted by period: M(E) Early Classic, M(L) Late Classic.)

was encountered in males from the later period among compounds. Caries differences are significant only between ACA and APE. The most noteworthy, significant differences occur when the AC early males are compared for AMTL with the other later males. In this case differences are always significant both in comparison with the other compounds and within AC.

DISCUSSION

Data on the distribution of oral pathologies by sex at Xcambó reveal some interesting tendencies. The first is that females in general were much more often affected by oral pathologies than males, and the second is that this pattern is common throughout the whole site with the exception of one particular area, the Asentamiento Periferico Este (APE), which shows the opposite tendency.

Several researchers suggest that females are often affected by a higher frequency for oral pathologies than males (Larsen et al., 1991; Larsen, 1997; Whittington and Reed, 1997b; Storey, 1999; Whittington, 1999). The interpretations encompass a large range of hypothesized causes: differences in diet between males and females, increased susceptibility in the latter, ad a longer time for pathologies to occur in females (given their earlier age of dental eruption and longer life span). A specific cause alone is not sufficient, and every situation is unique in terms of reasons underlying the frequency of oral pathologies (Powell, 1985).

Larsen et al. (1991) noted that major differences between periods in the archaeological samples from the Georgia coast area occurred after the shift in diet from hunting and gathering to agriculture and were not related to age at death. In the sample from Xcambó, age at death does not differ among compounds or between males and females, which rules out the possibility that higher frequencies might be related to longer exposure to cariogenic agents. Moreover, the archaeological evidence indicates that the population of Xcambó was socially homogeneous (Sierra Sosa and Martinez Lizarraga, 2001). Differences are mainly between sexes and not between compounds. This homogeneity excludes marked social stratification as one possible cause for different frequencies of oral pathologies, in contrast with what suggested for the Maya site of Calakmul (Cucina and Tiesler, 2002). Thus, the causes of the differences encountered between sexes should be sought in the kind of diet and/or behavioral and cultural patterns. Indeed, we think that the sex differences are multifactorial in nature and are likely to be related to the characteristics of the site. The site of Xcambó was small in size but an economically important center of salt production and trade (Sierra Sosa, 1999). The site's limited boundaries forced those committed to salt production to work outside the residential area. In most societies, males are those who do the manual labor and females are responsible for the household and food preparation. A model where men and women experience different types of nutrition, where males receive more protein in their diet because of the heavy-duty labor, explains their lower rate of cavities (Lee and DeVore, 1968; Larsen et al., 1991). Females might have been exposed to oral pathologies because of a diet where carbohydrates prevailed and because of a more frequent ingestion of food during the day. Larsen and colleagues (1991) pointed that the higher frequency of oral pathologies in females could be attributed to their engagement in food preparation, resulting in more frequent ingestion of food during the day, in comparison to males who may have eaten the same kind food but at specific hours during the day.

The individuals from the APE compounds show a different pattern. Cultural differences may be at the base of such discrepancy, in particular with respect to females' activities, even though the archaeological record does not reveal evidence that would support

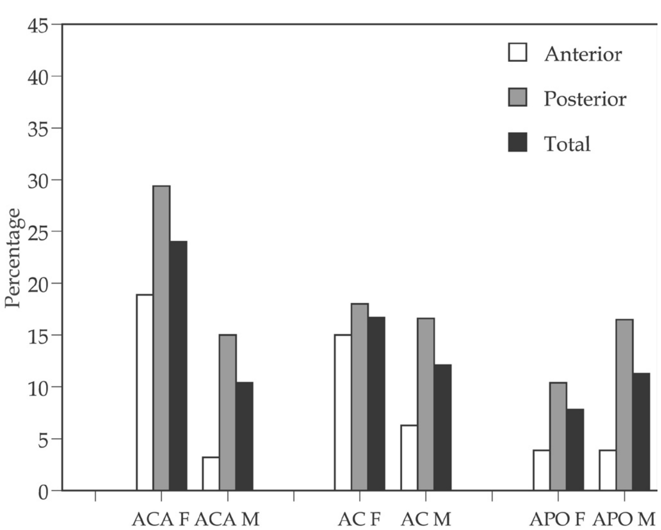

Fig. 4. Frequency of periapical defects by sex and compounds of the site.

TABLE 3. Number of sockets indicating AMTL, number of total sockets and frequency of AMTL

	Anterior			Posterior			Total		
	AMTL	n	%	AMTL	n	%	AMTL	n	%
				ACA					
Males	20	116	17.2	25	184	13.6	45	300	15.0
Females	10	64	15.6	25	86	29.1	35	150	23.3
				AC					
Males E	11	51	21.6	25	77	32.5	36	128	28.1
Males L	30	342	8.8	100	523	19.1	130	865	15.0
Females	35	201	17.4	120	319	37.6	155	520	29.8
				APE					
Males	6	85	7.1	17	124	13.7	23	209	11.0
Females	4	55	7.3	22	101	21.8	26	156	16.7
Total	116	914	12.7	334	1414	23.6	450	2328	19.3

the difference between APE females from the others. Nonetheless, the small size of the APE sample does not allow us to draw clear conclusions, and the data may result from sampling bias. A more thorough assessment will be possible when all the remains are studied. Similarly, a chronological interpretation of the differences encountered in the frequency of AMTL in the males from the AC group is not conclusive at this time because of the small size of the early Classic sample.

CONCLUSIONS

In conclusion, this preliminary analysis of oral pathologies from the site of Xcambó reveals interesting evidence that may link cultural and dietary factors to the geographical location and physical structure of the site as a unit, and as part of a wider, more complex economic and trade network. The different results obtained from the various compounds seem to contradict the homogeneity encountered at the archaeological level. Although this can be due to the small sample size of APE, it will stimulate further analyses addressing the biological and cultural complexity of the dynamic Maya population in Yucatán.

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TABLE 4. Number of sockets showing periapical defects, total number of scorable sockets, and the frequency of these defect

	Anterior			Posterior			Total		
	Present	n	%	Present	n	%	Present	n	%
				ACA					
Males	3	93	3.2	22	147	15.0	25	240	10.4
Females	10	53	18.9	15	51	29.4	25	104	24.0
				AC					
Males	22	350	6.3	77	465	16.6	99	815	12.1
Females	26	173	15.0	37	205	18.0	63	378	16.7
				APE					
Males	3	77	3.9	18	109	16.5	21	186	11.3
Females	2	51	3.9	8	77	10.4	10	128	7.8
Total	66	797	8.3	177	1,054	16.8	243	1,851	13.1

TABLE 5. P values from the chi-square analyses between sexes and between compounds[1]

	Caries			AMTL			Periapical defects		
	Anterior	Posterior	Total	Anterior	Posterior	Total	Anterior	Posterior	Total
Analysis within compounds[2]									
ACA									
M *vs* F	**	**	**	n.s.	**	*	**	*	**
AC									
M(E) *vs* M(L)				*	*	**			
M(E) *vs* F				n.s.	n.s.	n.s.			
M(L) *vs* F				**	**	**			
M *vs* F	**	**	**				**	n.s.	*
APE									
M *vs* F	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Analysis within sex[2]									
Males									
ACA *vs* AC(E)				n.s.	**	**			
ACA *vs* AC(L)				n.s.	n.s.	n.s.			
APE *vs* AC(E)				*	*	**			
APE *vs* AC(L)				n.s.	n.s.	n.s.			
ACA *vs* APE	*	*	*	*	n.s.	n.s.	n.s.	n.s.	n.s.
ACA *vs* AC	n.s.	n.s.	n.s.				n.s.	n.s.	n.s.
APE *vs* AC	n.s.	n.s.	n.s.				n.s.	n.s.	n.s.
Females									
ACA *vs* AC	n.s.	n.s.	n.s.				n.s.	n.s.	n.s.
ACA *vs* APE	**	**	**				**	**	**
APE *vs* AC	**	**	**				**	**	**

[1] The AC compound is the only one where males were kept separate according to chronology: M(E) stands for males Early period, M(L) for males Late period. Females were all pooled together.
[2] n.s. = $P > 0.05$; * = $0.05 \geq P > 0.01$; ** = $P \leq 0.01$ (1 df).

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Dental Anthropology at the University of Geneva

Suzanne Eades* and Jocelyne Desideri

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ABSTRACT This article presents research currently being conducted in the field of dental anthropology at the Department of Anthropology and Ecology of the University of Geneva, Switzerland. The first author, S. Eades, is carrying out a doctoral thesis on the familiality of dental morphological traits and their use as "familial" indicators in the case of multivariate and univariate analyses of interindividual distances. Her methods are based on the modern collection of Burlington (Ontario), and her results shall be applied to the Protohistorical necropolis of Kerma (Sudan) and the Neolithic multiple graves of Chamblandes (Switzerland). The second author, J. Desideri, began her graduate work on an interpopulational comparison of Swiss Neolithic populations based on their dental morphology. She is currently undertaking a doctoral thesis on the same problem, but tackling the whole of Europe.

Non-metric traits have been studied at our Department since the beginning of the 1990's,[1] when two studies were carried out concerning intra- and interpopulational analysis of cranial non-metric traits, under the direction of Dr. Christian Simon (Gemmerich, 1999; Eades, 1996; Eades and Simon, 1996). In 1997, S. Eades became interested in dental non-metric traits during her preparation of a Master's degree at the University of Bradford, England (Eades, 1997). On her return to the University of Geneva in 1998, she undertook a doctoral thesis[2] on these traits, bearing on their familial determination (or familiality) and the calculation of interindividual distances. At the same time, J. Desideri began her graduate work on an interpopulational comparison of Swiss Neolithic populations based on their dental morphology (Desideri, 2001).[3] She is currently undertaking a doctoral thesis[4] on the same problematic, but on a wider, European scale.

The traits recorded at our Laboratory of Paleoanthropology include those of the ASU system (using the reference casts; Turner, Nichol and Scott, 1991), those of Freiburg University (Alt, 1997; Alt, Pichler and Vach, unpublished data), when they did not overlap with those of the American system, and a few traits defined by Moskona et al. (1997), Kraus and Furr (1953) and Ludwig (1957).

INTERPOPULATION ANALYSIS

The first author (S. Eades) is examining the dental non-metric traits of a recent skeletal sample, namely, the Burlington collection (Toronto, Canada). The dental casts making up this sample were taken from several hundred families living in Burlington between 1952 and 1971 (Popovich, 1956). The goal of her thesis is to identify the traits expressing the greatest familiality and to use these traits for univariate and multivariate interindividual comparisons.

Dental traits are studied by two fields of research: genetics (for the determination of their mode of inheritance and their heritability), and archeology (for the application of these results when comparing ancient populations or individuals).

The link between the genotype and the phenotype of dental traits appears stronger than for other possibly inherited morphological variants such as non-metric traits of the cranial and post-cranial skeleton. Different studies have shown that there is a strong genetic component in the distribution of at least some dental characters, since there is a higher concordance between monozygotic twins than between dizygotic twins (Biggerstaff, 1973, 1979; Berry, 1978; Scott and Potter, 1984; Kaul et al., 1985; Townsend et al., 1988, 1992). Given this strong genetic determination, two types of studies have been carried out: the search for the mode of inheritance of these traits, and the calculation of their heritability. We shall see that these approaches did not give forth the results that were hoped for initially.

At first, researchers looked for a simple, Mendelian, mode of inheritance (see for instance Kraus, 1951). Deviations from this model were explained by incomplete penetrance and/or variable expressivity. During a second phase, a multifactorial, or polygenic inheritance was proposed (Sofaer, 1970; Goose and Lee, 1971; Lee and Goose, 1972), based on the model of quasi-continuous variation developed by Falconer (1960, 1965). Finally, the advent of computers led to the development of new techniques named complex segregation analyses, which test for the presence of major genes within polygenic systems. These were applied to dental non-metric traits by Kolakowski et al. (1980) on Carabelli's trait, and by Nichol (1989, 1990) on a number of dental traits. In many cases,

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inheritance was found to be polygenic, but influenced by a major gene. As the mode of inheritance could not be established with certainty for several traits, the necessity for more advanced methods of segregation was perceived.

As for the calculation of heritabilities, a wide range of figures has been obtained on different traits (see Scott and Turner, 1997, for a summary). The degree of heritability of a trait is the portion of total variance that is due to genetic variance, as opposed to environmental variance. It does not tell us what portion of an individual's phenotype can be associated with its heredity or its environment (Falconer, 1960, 1965). Furthermore, it is chrono-specific, population-specific, and requires a polygenic mode of inheritance, which, as we have seen, is not always the case for dental traits.

All these studies have demonstrated that dental traits are genetically determined, whatever the degree of this determination or the mode of inheritance, making them appropriate for infra-population analyses in an archaeological context. These analyses (which are also often based on other types of non-metric traits) are of three types:

- The study of residence patterns (see for instance Lane, 1977; Lane and Sublett, 1972; Spence, 1974a,b),
- The development of microchronologies in an archeological context (see Konigsberg, 1986, 1987, 1990; Crubézy, 1991),
- The identification of related individuals or lineages.

The last type of study is the subject of S. Eades' doctoral thesis. Although such studies have been carried out before (see for instance Alt, 1997, Alt et al., 1995, 1997; Crubézy, 1991; Howell et al., 1996; Corrucini and Shimada, 2002), they have rarely been based on individuals of known parentage (but see Eades, 1997 and Gemmerich, 1999). Based on data recorded on the Burlington collection (parents and children), S. Eades has estimated the familiality of 107 dental traits derived from concordance analysis (Ludwig, 1957). Those traits which were the most concordant in their expression within families, as well as their most useful format for such purposes (dichotomous, graded or dichotomized), were identified. Different univariate and multivariate analyses were carried out on these traits and on a selection of families with well-preserved dentitions. The multivariate analyses in particular gave forth some very encouraging results, which she would like to publish by next year. Their application in the field of skeletal archeology seems possible; obviously, dental morphological traits are not as powerful as DNA analysis, but it seems that in the case of clear groupings of graves or individuals (that is, when the presence of family units is suspected) over a restricted timespan, it is possible to indicate whether specific individuals are related or not.

S. Eades is currently applying these methods to the Neolithic necropolis of Kerma (Sudan, Bonnet, 1990, 2000), where it is suspected that the multiple burials with sacrificed individuals represent genetically linked family members. She shall also study multiple burials in stone cists from the Swiss Neolithic necropolis of Chamblandes (Moinat and Simon, 1986).

INTRAPOPULATION ANALYSIS

The second author (J. Desideri) is studying the Bell Beaker phenomenon. This period is primarily known as a pottery style found over most of Europe at the end of the Neolithic. This entity differs from previous archaeological cultures by its material culture, its funerary rituals and its diffusion processes. The Bell Beaker Culture has been studied extensively,[5] and research based on its associated artifacts has indicated either continuity or rupture in the peopling. However, there have been very few studies of the physical anthropology of the individuals making up this civilization.

The biometrician R. Menk (1979, 1981) proposed a synthesis of the Bell Beaker complex on an European scale, based on multivariate craniometric methods. He tried to isolate the morphological characteristics of these individuals in order to demonstrate the existence of a Bell Beaker "humanity" associated with its various cultural expressions and to deduce its origins and impact in different regions of Europe. According to Menk, this Bell Beaker "humanity" possessed a very different morphology to that of the local substrate. In the nuclear zone (central Germany, Moravia, Bohemia and Poland), the morphology is homogeneous; however, in peripheral areas, the Bell Beaker physical type becomes minoritarian and decreases as a function of the distance from the central zone.

J. Desideri's interest during her graduate work (Desideri, 2001) was to clarify the biological relationships between the local, Middle and Late Neolithic populations, and the later, culturally dissimilar Bell Beaker populations in Western Switzerland, by studying dental non-metric traits. She studied ten samples dating from the Middle Neolithic to the Early Bronze Age (Table 1). Craniometric analyses (Menk, 1979, 1981) and the evolution of funerary rituals (Bocksberger, 1976, 1978; Gallay, 1978, 1998) both pointed to a major event taking place around 2600 BC with the arrival of the Bell Beaker Culture in Western Switzerland. At this time, Late Neolithic dolmens were emptied and Bell Beaker remains were deposited in their place (M VI dolmen), furthermore, a new type of cist inhumation appeared (M XI dolmen). Dental traits were particularly appropriate to this purpose, as the crania recovered in the different dolmens are particularly fragmented, making for low sample numbers and insufficient population representation. In total, only five skulls could be measured; they were very different in their morphology from those preceding and following them chronologically, giving credence to population

TABLE 1. Presentation of the ten samples studied by J. Desideri for her graduate work (Desideri, 2001)

Dating	Site	Type of inhumation	Number of burials	References
Middle Neolithic : 4500-3200 BC	Barmaz I (canton of Valais)	Chamblandes-type cist, mostly single burials	41 graves, 49 subjects	Sauter, 1949, 1950, 1951; Honegger, 1996
	Barmaz II (canton of Valais)		21 graves, 22 subjects	Sauter, 1949, 1950, 1951
	Chamblandes (canton of Vaud)	Chamblandes-type cist, mostly collective burials	70 graves, 116 subjects	Moinat and Simon, 1986
	Corseaux (canton of Vaud)		27 graves, 60 subjects	Kramar et al., 1978; Baudais and Kramar, 1990
Late Neolithic : 3200-2600 BC	Dolmen M XII Sion Petit-Chasseur (canton of Valais)	Triangular-based dolmens	About 80 subjects	Favre and Mottet, 1990, 1995; Eades, 1996
	Dolmen M VI Sion Petit-Chasseur (canton of Valais)		About 40 subjects	Kramar, 1977; Gallay, 1986; Gallay and Chaix, 1984; Bocksberger, 1976, 1978
Bell Beaker Culture : 2600-2200 BC	Dolmen M VI Sion Petit-Chasseur (canton of Valais)	Triangular-based dolmens	About 10 subjects	Kramar, 1977; Gallay, 1986; Gallay and Chaix, 1984; Bocksberger, 1976, 1978
	Dolmen M XI Sion Petit-Chasseur (canton of Valais)	Lateral-entry dolmens	About 10 subjects	Gallay, 1986; Gallay and Chaix, 1984; Bocksberger, 1976, 1978; Claivaz-Caruzzo, 1975
Early Bronze Age : 2200-1550 BC	Sion Petit-Chasseur (canton of Valais)	Peripheral cists and graves	About 10 subjects	Bocksberger, 1976, 1978
	Barmaz I (canton of Valais)	Single graves	About 15 subjects	Honegger, 1996

movement theories.

The analyses, based on 61 uncorrelated traits after preliminary standard manipulations,[6] made it possible to draw a picture of the different populations, and particularly the circumstances which led to the emergence of the Bell Beaker Culture in Western Switzerland.

During the Neolithic, the populations are homogeneous and morphologically similar, without major external influences. This is not the case for the Bell Beaker Culture, as these populations are not only very different from the preceding populations, but also from one another. As for the Bronze Age, two situations co-exist: some groups possess a Neolithic morphology, whereas others are clearly different from the anterior groups.

The analyses (multidimensional scaling and hierarchical cluster analysis) based on the Late Neolithic and Bell Beaker groups made it possible to propose three interpretative models which could explain the differences encountered during the Bell Beaker Culture (Fig. 1). The models are based on the fact that the Bell Beaker dental remains were very different from those of preceding populations.

- The arrival of individuals from another population in Western Switzerland is possible. They may have completely replaced the preceding populations or, on the other hand, have been integrated into the local communities. These individuals may have belonged to two different groups, as the two Bell Beaker dolmens are quite distant from one another on these figures.
- It is possible that the new funerary rituals practiced by the members of this group may have played a major role, as Bell Beaker burials inside dolmens were restricted to a dozen individuals, whereas earlier necropoli (cist graves or similar dolmens) contained between 40 and 100 individuals. We may be looking at frequencies of a subset of the total population at this time (such as members of a single family or a social elite), and not population frequencies sensu stricto.
- The two preceding models are not exclusive. It is possible that these remains represent a subset of the

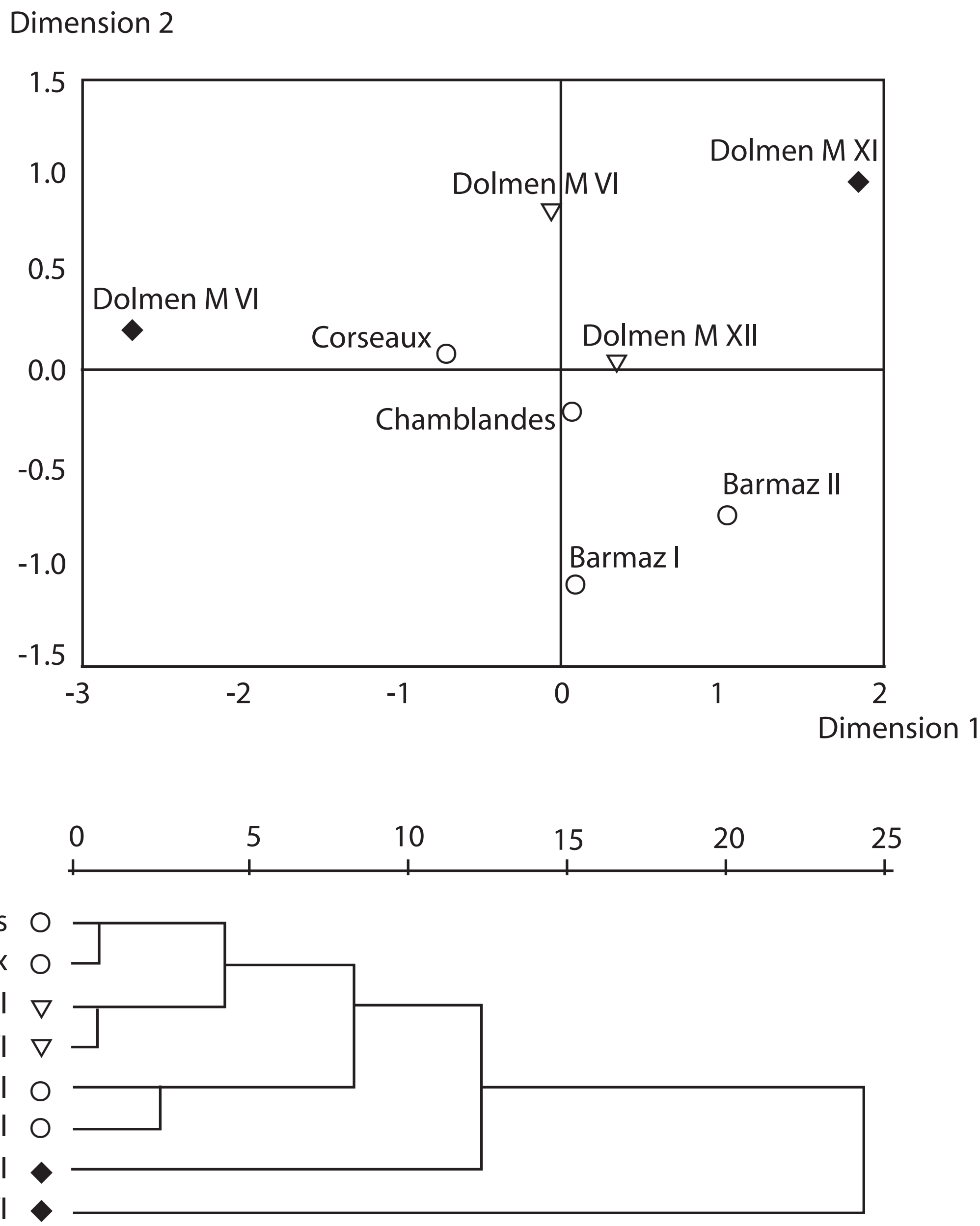

Fig. 1. Cluster analysis (Euclidean distance, UPGMA method), above, and multidimensional scaling (with a stress value of 5%), below, representing the position of different Middle Neolithic (symbolised by a circle), Late Neolithic (triangles) and Bell Beaker (lozenges) populations in Western Switzerland, based on the observation of 61 dental non-metric traits.

total population, including some individuals of foreign extraction, having arrived in Western Switzerland for trade or as specialized craftworkers, and having been integrated into the community. This would explain the extent of the morphological differences as well as the re-use of the Late Neolithic dolmens during the Bell Beaker period and the adoption of a new material culture around this time.

In summary, clear-cut differences were detected between Middle Neolithic and Bell Beaker dental remains. The reasons behind these differences are, however, difficult to explain fully. For the moment, an adequate way of describing the appearance of the Bell Beaker Culture in western Switzerland is not "rupture", nor "continuity", but simply "difference".

These results led J. Desideri to extend her research to the rest of Europe for her doctoral thesis. She shall base her research on the different geographical domains (Fig. 2) defined by M. Besse's (2001) study of Bell Beaker common ware,[7] by compiling a corpus including pre-Bell Beaker (Late Neolithic), Bell Beaker and post-Bell Beaker (Bronze age) individuals. The eastern domain shall be represented by a series of subjects from sites located mostly in the Czech Republic, but also from Hungary, Austria and Poland. The southern domain will cover funerary assemblages from Switzerland, Northern Italy and France. Finally, the northern domain shall include individuals from Belgium, the Netherlands, and part of Germany.

J. Desideri shall try to answer certain questions that should make it possible to reconstruct the history of these populations before, during, and after the Bell Beaker culture. She shall more specifically try to determine whether this culture is characterized by a rupture or a continuity of the local population, and whether it is responsible for the emergence of the Early Bronze age. By confronting her results with data from other archaeological and anthropological studies, she hopes to understand the modalities which made possible the emergence of such a widespread phenomenon.

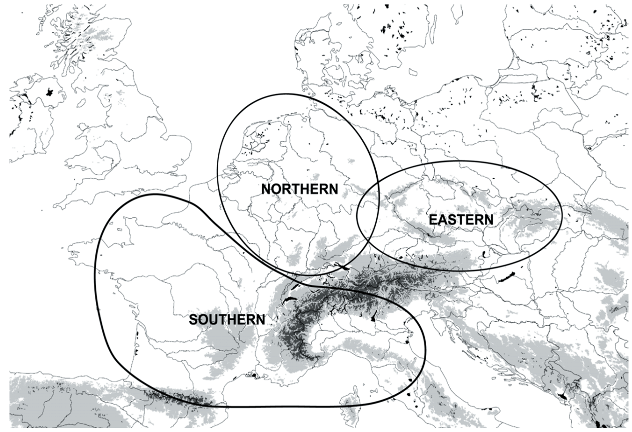

Fig. 2. The three geographic areas defined by Bell Beaker common ware in continental Europe (after Besse 2001;Fig. 238).

CONCLUSION

So far, work on dental non-metric traits carried out at the Department of Anthropology and Ecology of Geneva University has proved promising. Hypotheses concerning the population of Western Switzerland during the Late Neolithic have been arrived at, and data collected on individuals of known family relationships is currently being exploited. At the moment, little work is being carried out in Europe on dental non-metric traits, and the two authors have few opportunities to confront their results and methods with fellow researchers in this domain. We hope that this brief presentation in the papers of the DAA will be of interest to dental anthropologists working in America or elsewhere; any comments or suggestions concerning these two research subjects will be highly appreciated.The authors would like to thank Dr. Christiane Kramar for her help in writing this article.

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FOOTNOTES

[1] With the exception of a pioneering work by H. Muller in 1977.

[2] Under the direction of Profs. André Langaney and Alain Gallay from this Department.

[3] Under the direction of Dr. Christian Simon, Lecturer at the Department of Anthropology, who unfortunately passed away at the beginning of 2000, and Prof. Alain Gallay.

[4] Under the direction of Prof. André Langaney, Director, and Marie Besse, assistant professor, both at the Department of Anthropology of Geneva University.

[5] Sangmeister, 1963; Gimbutas, 1970; Lanting and Van der Waals, 1976; Gallay, 1978; 1998; Guilaine, 1998; Besse, 2001.

[6] Elimination of invariant expressions, of sexually dimorphic traits, fusion of bilaterally expressed traits, estimation of trait population incidences on mesial teeth by Turner's (1985) expression count.

[7] Besse defined three geographic areas in continental Europe based on the study of cultural differences according to the Bell Beaker common ware (Besse 2001): a northern, a southern and an eastern domain.

PRIMATE DENTITION: AN INTRODUCTION TO THE TEETH OF NON-HUMAN PRIMATES. By Daris R. Swindler. United Kingdom: Cambridge University Press (hardback), 2002. 294 pp. ISBN 0-521-65289-8. $80.00

Daris Swindler's update to his 1976 publication, *Dentition of Non-human Primates*, presents a comprehensive database of the dentition of 85 living primate species. The book includes morphological and metrical descriptions as well as an overview of basic concepts in tooth anatomy, morphology, and histology. Throughout the text, Swindler provides comparative analyses and techniques for age estimation and stresses the value of dentition for understanding phylogeny and ontogeny. The text begins with background on dentition and includes a chapter on deciduous dentition. The core of the book features dental measurements and descriptions organized taxonomically. This excellent resource offers not only an introduction to non-human primate dentition but also acts as starting point for further research.

Chapter one reviews basic information on the order Primates and the methods of odontometry used throughout the text. All measurements were taken from museum specimens, and Swindler focuses on the normal range of variation in the dentition. The first chapter introduces the reader to the terms of position and the Cope-Osborn cusp terminology both visually and in the text. The diagrams are particularly useful for those unfamiliar with tooth terminology. Swindler also includes a table of synonyms for the Cope-Osborn nomenclature.

In chapter two, Swindler discusses dental anatomy and devotes sections to enamel, dentine, cementum, the tooth root, and pulp. Within each topic, Swindler outlines the composition, histology, and formation of each component while also integrating topics of current research. The enamel section features a discussion of the study of enamel microstructure, enamel hypoplasias, and cross-striations and their ontogenetic and phylogenetic implications. Swindler also highlights often neglected areas of inquiry including the microanatomy of dentine and cementum lines.

Chapter three provides a brief overview of dental development. Swindler discusses two theories for the development of heterodont tooth morphology—the morphogenetic field theory and the clone model. The text covers odontogenesis, ontogeny of crown patterns, and stages of permanent tooth formation. Drawings and photographs clarify and supplement the discussion. In the section on age estimation, Swindler emphasizes the idea that tooth formation may give a better indication of age than tooth emergence.

An exceptionally noteworthy contribution is the chapter four discussion of deciduous dentition, a topic widely covered for human dentition but not for non-human primates. Swindler provides measurements and comparative analyses of the few specimens available for study. Within each section, Swindler provides written descriptions and detailed drawings and uncovers intriguing trends in dental development. For example, Swindler detects the presence of an underbite in the deciduous dentition of leaf-eating primates, *Alouatta* and *Colobus*. The condition occurs into adulthood, which suggests a genetic component for its presence.

The remainder of the text covers the morphological and metrical descriptions. Brief discussions of distribution and habitat, general dental information, and diet precede the morphological observations in each chapter. The general dental section features comparative analyses and identifies evolutionary trends for each group of non-human primates. Swindler also discusses the degree of sexual dimorphism in the dentition. The text includes detailed drawings of a majority of the species measured and illuminates the variations in dental features.

Swindler devotes chapter five to the suborder *Prosimii* with separate sections for each family. He incorporates such issues as the debate over the function of the dental comb into the morphological descriptions. Chapter six covers the superfamily *Ceboidea*. A diagram of canine-incisor relations in the marmoset and the tamarin clearly illustrates the differences in canine size and the variations between species. Chapter seven focuses on *Cercopithecidae* and includes a discussion on enamel thickness in relation to diet and the origin of the bilophodont molar. A short chapter on *Hylobatidae* follows. The discussion features a definition of the Y-5 molar pattern and its variations. The coverage of the Y-5 pattern continues in chapter nine, which is devoted to *Pongidae*. The chapter includes a table of the mandibular groove patterns and cusp number showing slight deviations from the standard configuration. Swindler also discusses the variable appearance of the deflecting wrinkle and two extra cusps, the tuberculum sextum and tuberculum intermedium, in hominoid mandibular molars.

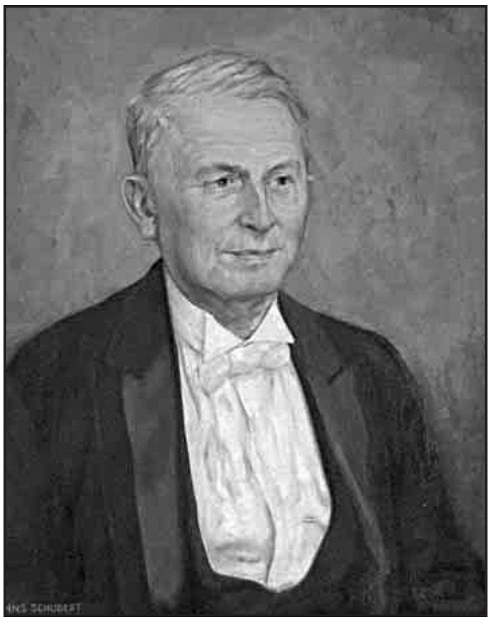
The appendices at the end of the book provide further reference resources. Appendix 1 features the odontometric information for the permanent and deciduous teeth (when available) of each species studied in the text. For each species, a table for the maxillary and mandibular teeth is presented with the number of specimens, the mesiodistal and buccolingual measurements for each tooth, t-test results for sexual dimorphism, and the range of measurements. Additionally, the tables include the presence/absence of a hypoconulid and the corresponding information. Appendix 2 provides the dental eruption sequences of the mandibular and maxillary teeth for all the species discussed in the book. When available, Swindler includes data for both sexes. The information is useful not only for aging individuals but also for ascertaining life history patterns. The text also features a glossary at its conclusion.

Primate Dentition serves as an essential resource for students and professionals in dental anthropology, primatology, and comparative anatomy. The diagrams and definitions prevent the text from becoming overwhelming for students but also not too rudimentary for more advanced readers. Swindler provides a valuable summary of current knowledge in non-human primate dentition and prompts further investigation in the field.

CATHY COOKE
The Ohio State University

First International Workshop on Evolutionary Changes in the Craniofacial Morphology of Primates September 18 to 20, 2003, Greifswald, Germany

To commemorate the life of Richard N. Wegner, a conference on primate craniofacial morphology will be held in the Institute of Anatomy, were Wegner served as the head of the department from 1948 to 1958. Researchers from around the world will converge on Greifswald, to discuss cutting edge work on many aspects of cranial evolution of primates, including humans. Students are especially encouraged to submit abstracts for poster and oral presentations.



Professor Wegner, 1881-1967.

The scientific program of the workshop will include keynote lectures, plenary lectures, single oral and poster sessions on the following topics: Functional morphology, Skull pneumatization, Growth and development, Dentition, and Primate collection. Other relevant topics are also welcome.

Professor Wegner, born in 1884 in Gelsenkirchen, studied medicine and natural sciences in Breslau, Munich, Grenoble, Lyon, Paris, and London. He served as an Associate Professor at the Anatomical Institutes of Rostock and Frankfurt and became full professor in 1923. In Nazi Germany, he was not allowed to leave the country nor to teach at German universities. Wegner survived the War as a physician in Dresden. During his time in Greifswald he was able to amass a large collection of primate skulls. His scientific work includes studies on comparative anatomy, paleontology, anthropology, ethnology, and medical history. Professor Wegner died in 1967 in Greifswald.

Participants will have the opportunity to utilize the extensive primate collection in the institute. This primate collections covers most extant groups, including lemurs, lorises, New World monkeys, Old World monkeys, and apes. In addition to crania, there are mounted specimens with complete skeletons. There is also a small but wide-range collection of comparative material of other mammals, birds, reptiles, and fishes.

For further information, contact one of the organizers or consult the congress webpage:

http://www.dur.ac.uk/t.c.rae/CT/Wegner/

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Geoffrey Sperber Honored by German University

Prof. Dr. Dr. h.c. Geoffrey H. Sperber has received the degree of an honorary doctor, bestowed upon him by the University of Witten-Herdecke, May 22, 2002. With this honor the university expresses its gratitude for the particular and outstanding efforts which Dr. Sperber has expended for the development of the Science of Embryology. In addition, the most fruitful and long lasting cooperation between Prof. Sperber and Prof. W. Arnold, Director of the Dept. of Anatomy at Witten-Herdecke Dental School was honored.

Fig. 1. Prof. Dr. R.J. Radlanski, Prof. Dr. W. Arnold, Prof. Dr. Dr. h.c. G. H. Sperber in Witten-Herdecke, May 22, 2002.

There was a ceremony at Witten-Herdecke Dental School during which the honorary doctorate was bestowed upon Geoffry Sperber, framed by music performed by students soloists and by speeches given by Prof. Dr. Wolfgang Arnold, and by Prof. Dr. Ralf J. Radlanski (invited speaker from Freie Universität Berlin). Geoffry Sperber, being well aware of the rarity of this honor, thanked the dean, Prof. Dr. W. Gaengler and he addressed a serious speech to the audience emphasizing the necessity and the obligation of the scientist to teach against ignorance where it is dangerous.

During Sept. 19-20, 2002, Prof. Sperber was hosted by Prof. Radlanski, Director of the Dept. of Experimental Dentistry at University Clinic Benjamin Franklin at Freie Universität Berlin. There he gave a seminar on prenatal craniofacial morphogenesis and the graduate students, working there on 3D reconstructions of the prental facial development appreciated the most knowledgeable and literate ingenuousness of Prof. Dr. Dr. h.c. Sperber.

Fig. 2. Dr. H. Renz, Dr. C. Knabe, Prof. Dr. Dr. h.c. G. H. Sperber and Prof. Dr. R.J. Radlanski, Berlin, Sept 20, 2002.

Dr. Sperber, a native of South Africa who immigrated to Canada many years ago by way of Great Britain, is the author of five books. He generally is best known for his very successful text on *Craniofacial Embryology*, that is now in its fifth edition. Geoff also has authored *Morphology of Cheeck Teeth of Early South African Hominids* (which served as his doctoral dissertaton under the supervision of Phillip Tobias and Raymond Dart), *Atlas of Radiographs of Fossil Man*, and *From Apes to Angels*, which is a festschrift for Phillip V. Tobias, and *Craniofacial Development*. Geoff also is well known for his numerous book chapters and science articles.

Geoff, a long-time member of the Dental Anthropology Association, also is a member of the International Association for Dental Research, The American Association of Anatomists, the Canadian Association of Physical Anthropologists, the American Academy of the History of Dentistry, the Cleft Palate-Craniofacial Association (Section Editor), and many others. He currently is Emeritus Professor of Dentistry, University of Alberta, Canada.

Ralf J. Radlanski, Berlin

More Teeth than You Can Shake a Stick at: Dental Anthropology Symposium to be Held at 2003 AAPA Meetings

For the first time in three years, the Dental Anthropology Association and the American Association of Physical Anthropologists are co-sponsoring a symposium on dental anthropology. A poster symposium entitled "Morphometric Variation in the Dentition of Modern Homo sapiens" is scheduled for the 2003 meetings of the AAPA in Tempe, Arizona, April 23-26.

International experts on contemporary dental variation will gather for this symposium. Emphasizing interpopulation comparisons, the primary intent of the symposium is to highlight several recent advances in the anthropological use of dental data. Additionally, contributors will assess and characterize the state of dental anthropology with regard to the types of data and analytical methods available. It is our hope to foster communication not only between the two organizations, but between members with varying perspectives, interests and experience.

The dozen posters to be presented are:

Dental morphometric variation and human sex chromosome complement. Author: Lassi Alvesalo

Worldwide variation in tooth formation and eruption. Author: Author: Helen Liversidge

Ancestry determination using mesiodistal measure-ments of deciduous teeth. Author: Loren R. Lease

A comparison of morphological traits in deciduous and permanent dentitions. Author: Jaime Ullinger

A dental morphological investigation of post-Neolithic incursions into the Indian sub-continent: Human migrations or mere movement of morphemes? Author: Brian E. Hemphill

Dental Morphometrics of Early Holocene India: A Comparison Indus and Ganga Valley Samples. Author: John R. Lukacs

Dental anthropology perspectives on the prehistory and colonisation of the Canary Islands. Author: Lawrence S. Owens

Dental morphometry and indicators of developmental stress in precontact and contact Maya populations from Yucatan. Author: Andrea Cucina and Vera Tiesler

Where's the variance? Odontometric variance components in American Blacks and Whites. Author: Edward F. Harris

Prediction of social race category using characteristics of dental morphology. Author: *Heather J. H. Edgar*

Additional dental evidence for an African origin of modern humans. Authors: Joel D. Irish and Debbie Guatelli-Steinberg

Metric and nonmetric dental variation of major human populations in the world. Author: Tsunehiko Hanihara, Hajime Ishida, and Takako Higa

Discussion will be led by G. Richard Scott and Simon Hillson. Unlike past years, all poster sessions will have their own rooms and will not have to share space with other components of the meeting. This should allow us to have a lively and informative discussion. Please be sure to come. Let's talk teeth!

Contributed by
Heather Edgar and Loren Lease

Erratum

The minutes of the 2002 meeting of the *Dental Anthropology Association* contained the erroneous information that one of our members, Dr. Michael Pietrusewsky (University of Hawaii), had passed away. This gaffe was due to misinformation to the Editor. Michael assures us that reports of his demise have been exaggerated. In fact, he reports that he recently completed the Honolulu Marathon (26.2 miles; 42.2 km) in 3 hours, 48 minutes, and 55 seconds. The Editor apologizes for this misinformation and wishes Michael continued good health.