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From the President's Desk

Dear Colleagues:

Changes in leadership and productive discussions of exciting plans for the Dental Anthropology Association took place at the DAA's business meeting this past April, held during the 73rd Annual Meeting of the American Association of Physical Anthropologists in Tampa Bay. Joel Irish's (University of Alaska Fairbanks) two-year term as President came to a close, while mine began, and Simon Hillson (University College London) was voted President-Elect for 2006-2008. As a member of the DAA since 1986, the year during which the Association was founded, Joel brought historical depth and the founders' original vision to his presidency, a perspective he will continue to contribute in his new position as Executive Board Member. The Association also welcomed Greg Nelson (University of Oregon) to his new post as Book Reviewer Editor for *Dental Anthropology*, the DAA's official publication.

Of the plans for the DAA discussed at the business meeting, that with the highest priority is the creation of a DAA Web site, the purpose of which is to centralize the Association's multiple activities and make them accessible to current and potential members. Alma Adler (Arizona State University) presented a template she designed for the Web site and volunteered to serve as Web master. The finished Web site will feature news and announcements for the Association, a link to past editions of *Dental Anthropology* through which full articles can be accessed, dental anthropology research updates, and past President Phillip Walker's (University of Santa Barbara) 3-D images of the human dentition.

Other important topics discussed at the meeting were changes in *Dental Anthropology* and plans for a 2005 Dental Anthropology Symposium at next year's AAPA meeting. Edward Harris (University of Tennessee), current *Dental Anthropology* Editor and former DAA President, announced that the journal will go on-line in the near future, and DAA members can opt for either an on-line subscription, or a subscription which includes both the on-line and print versions. In addition, if article submission rates remain high, it will be possible to go from three to four issues per year. Edward has served as editor since 2002, continuing the high quality, peer-reviewed publication standards developed by A.M. (Sue) Haeussler (Arizona State University), past Editor and founder of *Dental Anthropology*. The 2005 Dental Anthropology Symposium, currently being organized by Joel Irish and Greg Nelson, will commemorate the 20th AAPA meeting of the Dental Anthropology Association by highlighting dental anthropology research frontiers. Joel and Greg are inviting speakers whose work represents the wide spectrum of dental anthropology research interests: from the teeth of fossil species to those of the living, from microstructure to macrostructure, and from genotype to phenotype.

In my two-year term as President, I plan to maintain the pattern of high productivity established by my eminent predecessors, including Yasar Iscan, C. Loring Brace, Daris Swindler, Stephen Molnar, John Lukacs, Phillip Walker, John Mayhall, Edward Harris and Joel Irish. Promoting the Association and facilitating communication among dental anthropology researchers worldwide are my two central goals, which I will pursue by working with Alma on the Web site, Edward on the journal, and Heather Edgar, Secretary-Treasurer of the Association, on membership. As members, you can help the Association achieve these important goals by continuing to submit your research articles to *Dental Anthropology*, attending DAA business meetings and symposia, and making use of our new Web site when it becomes available. With your participation in these endeavors, we can make the Association an even more dynamic forum for sharing research findings and ideas. Finally, with energetic participation in these DAA activities, our members will demonstrate to those in other sub-disciplines how insights gained by studying the dentition can illuminate questions of fundamental anthropological significance. I am looking forward to working together to help make the next two years an exciting time for dental anthropology.

Debbie Guatelli-Steinberg
President 2004-2006

Debbie Guatelli-Steinberg shown making dental impressions of *A. afarensis* teeth during a recent trip to Addis Ababa, Ethiopia.

Dental Reduction and Diet in the Prehistoric Ohio River Valley

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ABSTRACT Post-Pleistocene dental reduction has been documented around the globe. Dietary change is a common factor in many of the selectionist models explaining this reduction. The current study examines tooth size in the prehistoric Ohio River Valley of Indiana and Kentucky to determine if a dental reduction occurred from the Late Archaic to the Mississippian periods and, if so, to see if dietary shifts are associated with dental reduction. Data from 282 individuals are compiled from 21 sites that span from 5000 BC to AD 1400. These sites represent Late Archaic foragers, Early/Middle Woodland early horticulturalists, Late Woodland mixed-economy horticulturalists, and Mississippian agriculturalists. Previous studies have indicated that the diet became less abrasive through time in this region but became harder from the Late Archaic to the Early/Middle Woodland just to became softer again thereafter. Buccolingual diameters were taken for all suitable permanent teeth. Standard descriptive statistics, ANOVA, percent differences, and rate of change were calculated for each dental measurement to determine the degree of change between the various temporal groups. It was found that a dental reduction occurred in the Ohio River Valley that was more pronounced in females and in the maxillary molars. The general reduction in tooth size mirrors the reduction in dietary abrasiveness. By contrast, it does not seem to follow the course of dietary hardness. *Dental Anthropology 2004;17(2):34-44.*

Human teeth have reduced in size worldwide since the Pleistocene (Kieser, 1990). Dental reduction has been documented for males and females in Asia, Africa, Australia, Europe, North and South America (Asia: Brace, 1978; Brace and Hinton, 1981; Brace and Nagai, 1982; Brace et al., 1984; and Lukacs, 1985; Africa: Calcagno, 1989; Kieser et al.,1985; Australia: Brace and Hinton, 1981; North America: Nelson, 1938; Moorrees, 1957; Dahlberg, 1963; Wolpoff, 1971; Potter, 1972; Perzigian, 1976; Sciulli, 1979; Hinton et al., 1980, and Calcagno, 1989; South America: Kieser, Groeneveld, Preston, 1985). The cause or causes of this reduction are not entirely clear. Thus, it seems prudent to document dental size in as many time periods and localities around the globe as possible in order to fully understand the factors that contributed to changes in dental size.

Various mechanisms have been proposed to explain dental reduction (*e.g.*, Anderson and Popovich, 1977; Brace, 1963; Calcagno, 1989; Frayer, 1978; Machiarelli and Bondioloi, 1986), including the accumulation of mutations, decreased gene flow, genetic drift, and selection. The Probable Mutation Effect model (PME), proposed by Brace (1963, 1964), states that teeth became smaller through time as a result of reduced selection for large teeth. However, many researchers have argued that the accumulation of random mutations would occur too slowly and it is unlikely that a directional change such as reduction would result from a random process (*e.g.*, Prout, 1964; Wright, 1964; Bailit and Friedlaender,

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Editor's note: Ms. Hill's paper was awarded First Prize for 2004 in the Albert A. Dahlberg student research competition sponsored by the Dental Anthropology Association.

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1966; Holloway, 1966; Brues, 1968; Byles, 1972; Frayer, 1978; Williams, 1978; Calcagno, 1989).

Falconer (1967) suggests that inbreeding could result in the reduction of a phenotypic trait. However, many studies have shown that inbreeding is uncommon in modern humans (Bailit, 1966; Wobst, 1976; Frayer, 1978). It is also unlikely that genetic drift is solely responsible for dental reduction (Sciulli and Mahaney, 1991). Genetic drift more frequently eliminates those traits (*i.e.*, alleles) that are least common in a population. Therefore, it is improbable that small teeth could have evolved from populations with predominantly larger teeth by genetic drift alone (Calcagno, 1989). However, genetic drift cannot be ignored when comparing small, geographically isolated populations where interpopulation gene flow might have been significantly reduced.

Other models for dental reduction suggest that directional selection for smaller teeth resulted as masticatory stress declined and dietary pathogenesis increased (Calcagno, 1989; Frayer, 1978; see also Anderson and Popovich, 1977; Bailit and Friedlander, 1966; Brues, 1966; Goodman, 1991; Holloway, 1966; Jolly, 1971; LeBlanc and Black, 1974; Prout, 1964; Sciulli and Mahaney, 1991). Another theory, the "somatic budget effect," suggests that smaller teeth are less costly to form and thus conserve energy in nutrient-poor conditions (Jolly, 1971).

Human dental reduction has been documented in Africa, Asia, Europe, and North America and all reductions were accompanied by changes in subsistence. Specifically, many studies have reported that the largest teeth can be found in the older hunter/gatherer populations. Tooth size decreases

Fig. 1. Indiana and Kentucky sites used in this study. LA = Late Archaic, E/MW = Early/Middle Woodland, LW = Late Woodland, MS = Mississippian. Sample sizes are indicated in parentheses with the first number corresponding to the number of males and the second to the number of females.

through time as populations adopted more processed, horticultural diets, and ultimately, agriculture. The story of dental reduction, however, is still unclear. In some places dental reduction seems to be specifically associated with changes in diet, while in other places it appears that teeth change with the adoption of specific technologies like pottery.

A common denominator between the different selectionist models for dental reduction is diet, because all models suggest that what people eat can eventually affect tooth size. Studies that examine how changes in dental size co-occur with changes in subsistence and diet may therefore help to clarify the specific nature of the forces that were at play in human prehistory. The current study investigates the association between diet and tooth size by comparing dental metrics among four Ohio River Valley populations that date from 5,000 to 500 years ago, each with its own well-documented subsistence strategy. The study populations include representative foraging, horticultural, and agricultural groups from Indiana and Kentucky. The initial goal is to determine if dental reduction occurred from Late Archaic to the Mississippian periods. If a temporal reduction is found, the second goal will be to determine which dietary shift is associated with the most pronounced change.

MATERIALS AND METHODS

Samples

The 21 sites from which human remains were studied span approximately 6500 years from 5000 BC (the Late Archaic Indian Knoll site) to AD 1400 (the Mississippian Angel site). These sites cluster in southern Indiana and northern Kentucky near or within the Ohio River Valley (including the Green and White River Valleys) (Fig. 1). It is believed that these sites are culturally distinct entities that displayed spatial continuity and shared biological and some cultural influences throughout time (Griffin, 1983; Schroedl, Boyd, and Davis; 1990; Muller, 1986).

Data from 282 individuals were compiled for this study. Refer to Figure 1 for sample sizes and site locations. A portion of the study sample is comprised of unpublished dental metric data that were collected by Schmidt in 1998. The remainder and majority of the sample are data that were collected by Hill. Inter-observer error between Schmidt and Hill was found to be insignificant in a previous odontometrics study (Schmidt and Hill, 2001).

Subsistence in the Prehistoric Ohio River Valley. The Ohio River Valley is broadly defined as the areas adjacent to the Ohio River in Illinois, Indiana, Ohio, Kentucky, and Pennsylvania. Evidence suggests that this area was continuously occupied in prehistory from between about 10,000 and 12,000 years (Cassidy, 1984), and the subsistence strategies for the prehistoric populations that occupied this region have been adequately documented.

The archeological record of the Ohio River Valley suggests that the area's first inhabitants were foragers. Foraging was the primary subsistence strategy for over 5,000 years when eventually some of the Late Archaic people adopted horticulture around 3,000 and 4,000 years ago. The horticultural Early/Middle Woodland followed the Late Archaic, which was in turn followed by the Late Woodland around 1,400 years ago. People from these time periods had a mixed economy of horticulture with some maize agriculture. By the Mississippian, about 700 years ago, maize agriculture was the predominant subsistence strategy (Scarry, 1993).

Diet and Food Preparation. For the most part, there is a trend toward a softer/less abrasive and more cariogenic diet in the Midwest (Smith, 1984; Schmidt, 1998; Schmidt, 2001). Specifically, the transition from the Late Archaic to the Early/Middle Woodland saw the diet changing in both sexes from extremely abrasive to less abrasive (decreased microwear scratch widths) and very hard (increase in frequency of microwear pits) (Schmidt, 1998, 2001). The Late Archaic diet probably consisted of wild plants and riverine resources contaminated by sand (hence the abrasiveness). The Early/Middle Woodland diet relied very heavily on nuts. Both diets were based on wild foods, probably required significant masticatory processing that was stressful to the teeth and jaws, and neither diet was particularly cariogenic. However, the Early/Middle Woodland diet was facilitated with pottery, whereby this increase in food processing technology removed much of the abrasiveness from the diet.

The hard and less abrasive Early/Middle Woodland diet was replaced by the mixed diet of the Late Woodland, which had the hardness in both males and females of the Middle Woodland diet but was far more cariogenic. The microwear data do not change much between the Early/Middle and Late Woodland periods and the macrowear evidence groups the Early/Middle Woodland and Late Woodland periods together as well (Schmidt, 1998). These types of data indicate that although the introduction of maize in the Late Woodland period is very important archeologically, initially it does not create a significant dietary transition. The Mississippian diet was almost certainly based on maize agriculture (Schmidt, 1998), and was considerably softer, somewhat less abrasive, and far more cariogenic than all other time periods.

From what is known of the these time period in North America, and from the sites used in this study specifically (Schmidt, 1998, 2001), the significant changes in dietary abrasiveness occurred between the Late Archaic and Early/Middle Woodland periods. The diet became significantly softer and less abrasive (to a smaller degree) between the Late Woodland and Mississippian periods (agricultural transition). However, in the present study, the Late Woodland to the Mississippian transition could not be examined because the Late Woodland sample was deficient. Although maize was introduced during the Late Woodland period, the transition from the Early/Middle Woodland to the Late Woodland was not marked by any significant differences in microwear or macrowear nor with much change in dental caries (Schmidt, 1998). Therefore, examining the Early/Middle Woodland to Mississippian transition in place of the Late Woodland to Mississippian transition may not be all that problematic.

Tooth Size

Standard buccolingual (BL) diameters were taken from all available permanent teeth on the left side of the jaws. Teeth from the right side were substituted in cases where teeth from the left side were unavailable or inadequate, *i.e.*, if they were too heavily worn, fractured, or deciduous. Incisors were not suitable for measurements due to heavy wear. The resulting sample was thus limited to canines, premolars, and first through third molars of the maxilla and mandible. Buccolingual diameters were measured using Mitutoyo fine point digital calipers, with an accuracy of 0.01 mm, according to methods outlined in Buikstra and Ubelaker (1994) and Kieser (1990). The BL diameter was taken as the greatest distance perpendicular to the mesiodistal diameter.

Sex

The majority of the metric data were collected from individuals for whom sex could be determined. Sex was determined by analyzing skull and pelvis morphology following standards outlined by Buikstra and Ubelaker (1994). In a few instances sex determination was augmented by information from previous osteology reports in which sex was established by earlier researchers. Sex determinations for the majority of the individuals studied by the author were consistent with the published data.

The original sample included 56 individuals for whom sex was not determined. A series of 16 multivariate dental sexing formulae were applied to the individuals for whom sex was established to determine their efficacy. Five formula yielded percent correct values higher than 70 percent for the current study sample. These five formulae were derived from two studies. One formula was derived from the analysis of prehistoric remains from the Dickson Mound site in Illinois (Ditch and Rose, 1972). The remaining four formulae were derived from a study of a prehistoric population from the eastern Tennessee valley (Scott and Parham, 1979). Sex was then estimated for each of the 56 undetermined individuals using the five formulae. The results from the different formulae were in agreement for 17 of the 56 individuals, and so for these 17, the estimated sex was entered into the dataset. Therefore, the final dataset includes 152 males and 130 females and no unsexed individuals.

Statistical Analysis

Standard descriptive statistics were computed for each population including means, standard deviations, and variances. The means were compared among the four temporal groups while controlling for sex. The percent difference and rate of change were calculated to determine the degree of change between the four temporal groups in order to determine where the greatest changes occurred. The percent difference between the means was calculated by subtracting the mean tooth size from the more recent group from that of the older group, and dividing the difference by the

TABLE 1. Mean BL diameters ($\bar{x}$), sample size (n), and standard deviation (sd) for males through time

	Late Archaic			E/M Woodland			Late Woodland			Mississippian		
	$\bar{x}$	n	sd	$\bar{x}$	n	sd	$\bar{x}$	n	sd	$\bar{x}$	n	sd
UC	8.69	37	0.526	8.68	23	0.475	8.91	17	0.522	8.78	15	0.531
LC	7.90	40	0.530	7.95	24	0.465	8.26	20	0.529	8.12	20	0.518
UP3	9.66	28	0.725	9.66	22	0.609	9.29	14	1.133	9.79	13	0.649
LP3	8.38	32	0.428	8.29	28	0.456	8.28	21	0.538	8.25	18	0.632
UP4	9.53	28	0.720	9.53	22	0.524	9.44	14	0.860	9.74	13	0.606
LP4	8.48	30	0.445	8.59	27	0.443	8.72	24	0.471	8.63	21	0.522
UM1	12.05	28	0.495	12.12	16	0.529	12.11	16	0.613	11.78	18	0.396
UM2	12.05	31	0.614	11.74	17	0.723	11.81	18	0.680	11.86	19	0.823
UM3	11.52	30	0.755	10.88	25	0.758	11.09	13	0.750	11.23	17	0.620
LM1	11.29	35	0.467	11.21	24	0.430	11.30	22	0.566	10.97	19	0.460
LM2	10.90	35	0.551	10.76	24	0.507	10.70	21	0.620	10.63	24	0.534
LM3	10.91	32	0.752	10.70	28	0.702	10.69	14	0.456	10.59	21	1.00

TABLE 2. Mean BL diameters ($\bar{x}$), sample size (n), and standard deviation (sd) for females through time

	Late Archaic			E/M Woodland			Late Woodland			Mississippian		
Tooth	$\bar{x}$	n	sd	$\bar{x}$	n	sd	$\bar{x}$	n	sd	$\bar{x}$	n	sd
UC	8.44	34	0.436	8.63	21	0.473	8.39	16	0.599	8.34	20	0.500
LC	7.44	31	0.435	7.47	15	0.341	7.40	15	0.344	7.29	25	0.520
UP3	9.66	32	0.767	9.57	21	0.478	9.27	15	0.702	9.32	18	0.419
LP3	8.17	33	0.470	7.99	18	0.366	7.45	13	0.906	7.82	21	0.552
UP4	9.45	30	0.565	9.19	20	0.435	9.13	16	1.380	9.42	18	0.441
LP4	8.54	33	0.565	8.33	18	0.392	7.96	13	1.099	8.31	23	0.563
UM1	11.87	30	0.470	11.45	15	0.517	11.75	19	0.678	11.52	22	0.539
UM2	11.82	31	0.447	11.51	20	0.397	11.29	18	1.150	11.29	17	0.477
UM3	11.31	26	0.559	10.83	20	0.624	11.04	15	0.713	10.72	15	0.784
LM1	11.01	33	0.402	10.91	15	0.431	10.78	18	0.543	10.76	22	0.562
LM2	10.83	34	0.392	10.57	17	0.403	10.34	16	0.569	10.40	27	0.511
LM3	10.92	26	0.519	10.44	16	0.603	10.17	14	0.576	10.29	23	0.651

mean of the older group and multiplying the quotient by 100 (Calcagno, 1989):

$$\frac{\left(\bar{x}_1 - \bar{x}_2\right)}{\bar{x}_1}100$$

$\bar{x}_1$ = mean tooth size for older group

$\bar{x}_2$ = mean tooth size for more recent group

The extent or rate of change was calculated by the following formula, which controls for time differences between groups. The resulting rate is in terms of change per one million years.

$$\frac{\log \bar{x}_1 - \log \bar{x}_2}{\text{time}}$$

$\bar{x}_1$ = mean tooth size in sample 1

$\bar{x}_2$ = mean tooth size in sample 2

time = interval separating the two samples in millions of years.

TABLE 3. ANOVA results for measurements that significantly changed through time†

Sex	Tooth	n	d.f.	P	F-Ratio
M	UM3	85	3	0.018	3.528
F	LP3	85	3	0.002	5.398
F	UM1	86	3	0.044	2.821
F	UM2	86	3	0.018	3.563
F	UM3	76	3	0.025	3.307
F	LM2	94	3	0.001	6.122
F	LM3	79	3	0.000	6.964

†n = sample size, d.f. = degrees of freedom, P = probability value.

This formula allows for the visualization of the amount of change between temporally-adjacent populations. Rate was calculated between the Late Archaic and Early/Middle Woodland periods (separated by approximately 3,639 years), the Early/ Middle Woodland and the Mississippian periods (separated by approximately 1,485 years), and the Late Archaic and Mississippian periods (separated by approximately 5,124). These three transitions were compared because they represent important dietary transitions, and are divided by comparable spans of time.

Tests for normality and homoscedasticity were

TABLE 4. ANOVA results measurements that did NOT significantly change through time†

Sex	Tooth	n	d.f.	P	F-Ratio
M	UC	92	3	0.469	0.853
M	LC	104	3	0.059	2.567
M	UP3	77	3	0.356	1.097
M	UP4	77	3	0.696	0.482
M	LP3	99	3	0.804	0.330
M	LP4	102	3	0.284	1.285
M	UM1	78	3	0.172	1.711
M	UM2	85	3	0.447	0.897
M	LM1	100	3	0.091	2.220
M	LM2	104	3	0.274	1.313
M	LM3	95	3	0.476	0.839
F	UC	91	3	0.273	1.321
F	LC	86	3	0.510	0.777
F	UP3	86	3	0.140	1.878
F	UP4	84	3	0.421	0.950
F	LP4	87	3	0.078	2.352
F	LM2	87	3	0.213	1.530

†n = sample size, d.f. = degrees of freedom, P = probability value.

TABLE 5. Post hoc results for significant measurements

Sex	Tooth	Significant Difference
F	LP3	LA – LW (reduction) LA – MS (reduction)
F	UM1	LA – E/MW (reduction) LA – MS (reduction)
F	UM2	LA – LW (reduction) LA – MS (reduction)
F	UM3	LA – E/MW (reduction) LA – MS (reduction)
F	LM2	LA – LW (reduction) LA – MS (reduction)
F	LM3	LA – E/MW (reduction) LA – LW (reduction) LA – MS (reduction)
M	UM3	LA – E/MW (reduction)

conducted on the samples to determine if they met the assumptions of analysis of variance (ANOVA). A total of 24 Kolmogorov-Smirnov tests run on each BL diameter and for each sex revealed that all samples were normally distributed (for every tooth type and sex and measurement therein). Levene's test for homoscedasticity did not reject equal variances among any of the samples.

ANOVAs were conducted on the BL diameters for each sex independently, for a total of 24 ANOVAs. A protected t-test, Fisher's least significant difference (LSD), was then conducted as a sensitive *post hoc* test in order to determine where significant differences existed. All tests used an alpha value of 0.05 as the criterion for significance.

RESULTS

The descriptive statistics are listed in Tables 1 and 2. Time was significant in seven of these 24 ANOVAs (Tables 3 and 4). The majority of significant tests (n = 6) involved the molar measurements, with two tests being significant for lower molars (Fig. 3) and four tests being significant for upper molars (Fig. 2). The

TABLE 6. Rate of change and percent difference for the transitions from the Late Archaic to the Early/Middle Woodland, the Early/Middle (EM) Woodland to the Mississippian, and the Late Archaic to Mississippian periods (Total)†

		Late Archaic–EM Woodland		EM Woodland–Mississippian		Total	
Sex	Tooth	Rate	% Difference	Rate	% Difference	Rate	% Difference
M	UC	-0.14	-0.12	+3.35	+1.15	+0.87	+1.04
M	LC	+0.75	+0.63	+6.19	+2.14	+2.33	+2.78
M	UP3	0.00	0.00	+3.91	+1.35	+1.13	+1.35
M	LP3	-1.29	-1.07	-1.41	-0.48	-1.33	-1.55
M	UP4	0.00	0.00	+6.37	+2.20	+1.85	+2.20
M	LP4	+1.54	+1.30	+1.36	+0.47	+1.49	+1.77
M	UM1	+0.69	+0.58	-8.32	-2.81	-1.92	-2.24
M	UM2	-3.11	-2.57	+2.97	+1.02	-1.35	-1.58
M	UM3*	-6.82	-5.56	+5.59	+1.93	-3.22	-3.73
M	LM1	-0.85	-0.71	+2.34	+0.80	+0.08	+0.09
M	LM2	-1.54	-1.28	-3.55	-1.21	-2.13	-2.48
M	LM3	-2.32	-1.92	-3.02	-1.03	-2.52	-2.93
F	UC	+2.66	+2.25	-10.00	-3.36	-1.01	-1.18
F	LC	+0.48	+0.40	-7.13	-2.41	-1.73	-2.02
F	UP3	-1.12	-0.93	-7.74	-2.61	-3.04	-3.52
F	LP3*	-2.66	-2.20	-6.29	-2.13	-3.71	-4.28
F	UP4	-3.33	-2.75	+7.23	+2.50	-0.27	-0.32
F	LP4	-2.97	-2.46	-0.70	-0.24	-2.31	-2.69
F	UM1*	-4.30	-3.54	+1.78	+0.61	-2.54	-2.95
F	UM2*	-3.17	-2.62	-5.64	-1.91	-3.89	-4.48
F	UM3*	-5.18	-4.24	-2.99	-1.02	-4.54	-5.22
F	LM1	-1.09	-0.91	-4.05	-1.37	-1.95	-2.27
F	LM2*	-2.90	-2.40	-4.74	-1.61	-3.43	-3.97
F	LM3*	-5.36	-4.40	-4.23	-1.44	-5.04	-5.77

†Rate of change calculated in mm/million years. Percent difference calculated in mm/years separating two groups. A reduction in tooth size is indicated by (-) and an increase by (+). Teeth that changed significantly through time are indicated by (*).

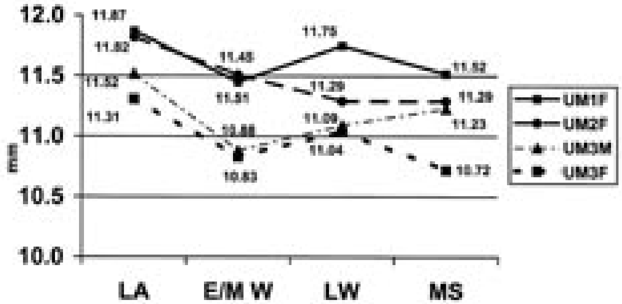

Fig. 2. Display of significant changes in female (F) maxillary first through third molars and male (M) maxillary third molar through time.

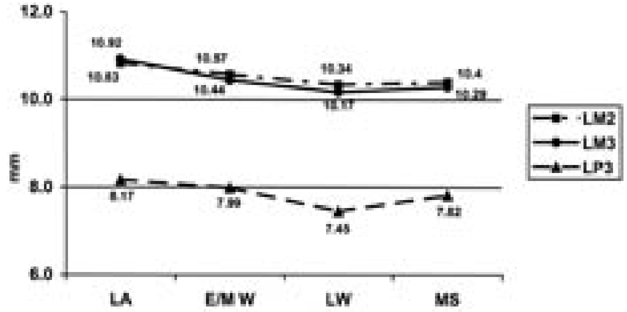

Fig. 3. Display of significant changes in female mandibular teeth through time.

only other significant difference was observed in lower third premolars (Fig. 3) and no significant differences were observed for canines. Only one of the 12 ANOVAs conducted for males were significant for Time, and 6 of the 12 ANOVAs conducted for females were significant for Time (Tables 3 and 4).

Rate of change and percent differences

The rate of change and percent differences were calculated in order to better understand the patterning of change across the different time periods (Table 6). The discussion of rates and percent change is limited to those teeth that changed significantly through time. Only two of the significant transitions were represented by an increase in tooth size. The male UM3 showed a 1.93% increase between the Early/Middle Woodland and Mississippian periods. Furthermore, the female UM1 showed a 0.61% increase during the same transition. The remaining significant teeth display reductions during all three transitions. The percent change is most often largest between the Early/Middle Woodland and Mississippian periods (five comparisons). The rate of change, however, is very similar between the two transitions. It is fastest between the Late Archaic and Early/Middle Woodland periods in four comparisons and between the Early/Middle Woodland and Mississippian three times.

DISCUSSION AND CONCLUSION

The purpose of this study was to determine if a dental reduction occurred through time and to determine if specific dietary shifts are associated with specific patterns or rates of change. It is apparent that a reduction in tooth size did occur between 4,000 BC and AD 1,400 in this prehistoric Ohio River Valley sample. A number of specific points merit further discussion: several of the significant tests were for maxillary molars; no canine measurements changed significantly through time; the majority of the significant results were for females.

Maxillary molars

Time is significant for more maxillary molar measurements than for any other measurement analyzed in this study, and their mean values clearly decrease from the Late Archaic to Mississippian time periods. These results suggest that maxillary reduction exceeds that of the mandible, which is consistent with other dental reduction studies (*e.g.*, Wolpoff, 1971; Perzigian, 1976; LeBlanc and Black, 1974; Sofaer *et al*., 1971; Sofaer, 1973; Lukacs, 1985). In fact, Lukacs (1985) observed a reduction in maxillary second molars and none in mandibular third molars, suggesting that even later-erupting lower molars do not change to the extent of earlier-erupting upper molars. Therefore, although other studies have shown that later-erupting third molars are more variable in morphology and size (*e.g*., Sofaer *et. al.,* 1971), Lukacs' study implies that the maxillary teeth are still changing more despite the fact that they are earlier-erupting teeth. Since the end of the Pleistocene (after 10,000 BP), the rate of maxillary reduction has consistently surpassed that of the mandible (Brace, Rosenberg, and Hunt, 1987). Frayer (1978) suggests that an increase in the rate of change implies an increase in the severity of the force behind the change. According to this logic, the force behind the change in the maxillary dentition would have been greater than that behind the mandible.

It is possible that the maxillary teeth are reducing in accordance with an overall reduction of the maxillofacial complex (Larsen, 2002). The maxillofacial complex consists of the maxilla, surrounding facial bones, and teeth. Studies have shown that the reduction in the face has occurred at a much faster pace than that of the teeth alone, although strong correlations between tooth size and the overall reduction of this complex have been documented (see summaries in Kieser, 1990). As the maxillofacial complex reduced, the available space for developing teeth also reduced. Since the mandible is more flexible in its development (Kieser, 1990), it seems plausible that it may have been able to accommodate the slower reducing, large teeth, whereas the maxilla would not.

Canines

Canines did not change significantly through time in this study. It would benefit the interpretation of these results if other anterior teeth were available for comparison, as the majority of Holocene dental reduction studies agree that posterior dental reduction is more marked than that of the anterior teeth (Sofaer *et al*., 1971; Sofaer, 1973). For example, Calcagno (1989) observed a reduction only in molars between agricultural and intensive agricultural groups. Sciulli (1979) reported a reduction in both molars and incisors, but not for canines. In this study only one premolar significantly reduced through time, the LP3 of females. Therefore its seems, at least in part, that the reduction observed in this study is more marked as one proceeds posteriorly through the jaw, which is consistent with the previously-mentioned studies.

Females vs. males

In the overwhelming majority of ANOVAS in this study, time was significant only for females. Sciulli (1979), Larsen (1981), and Calcagno (1989) also reported more significant changes in females through time. In Sciulli's (1979) study, the patterns of sexual dimorphism and variability did not change through time, although females were often larger than males in the earlier Glacial Kame group (3 anterior teeth and 3 posterior teeth), seldom larger in the Adena group (3 anterior teeth and 1 posterior tooth), and rarely larger in the Hopewell group (1 anterior tooth). This indirectly suggests that through time the females are reducing more markedly (and especially in the posterior dentition) than the males. Larsen (1981) found a reduction only in females between pre-agricultural (2,200 BC – AD 1,150) and mixed economy (AD 1,150) groups from the Georgia coast. Calcagno (1989) noted a greater reduction in females. Although 30 of the 32 measurements were significant for males in his study, and only 26 of the 32 were significant for females, the percent reduction was much greater for females through time.

A few explanations have been proposed to clarify why females changed more markedly over the time span observed here. The majority of the explanations suggest a differential environmental impact on each sex. For example, Garn and associates (1972) suggest that because males trail females in permanent tooth eruption, their dentition might be more plastic to the effects of a selection event. Although, this reasoning seems logical, it is also plausible that males and females do not differ in eruption by enough time to make a considerable impact. Dental caries and wear have also been documented to vary by sex and therefore dental measurements may reflect this (Perzigian, 1976; Hinton *et al*., 1980; Schmidt 1998). These two variables, caries and wear, are strongly linked to health and diet. One thought is that females react to stressors differently than males, resulting in higher incidences of dental caries. In many populations the frequency of certain pathological conditions (such as caries) is relatively high in females (Cohen and Armelagos, 1984).

Another explanation implies a long-term selection event that may have affected females differently. Larsen (1981) suggests that reduction is only found in females because it is only the females whose diet and subsistence dramatically changed from pre-agriculture to a mixed economy. He explains that females were burdened by the responsibilities of agriculture while the male subsistence strategy did not change (males continued to hunt). However, Schmidt found no significant difference between male and female microwear and macrowear for the majority of samples used in this study (1998, 2001).

Diet and Dental Reduction

The second goal of this study was to address the role of diet in dental reduction. The premise is that reduction is most significant between those populations where dietary change is most marked, *i.e*., became noticeably less abrasive, softer and/or more cariogenic.

When comparing the two transitions by looking at the *post hoc* test results (Late Archaic to Early/Middle Woodland and Early/Middle Woodland to Mississippian) it seems as if the first transition is the more significant. The mean measurements of the UM1, UM3, and LM3 for females and UM2 for males are significantly different between the Late Archaic and Early/Middle Woodland periods, whereas no measurements are significant in the later transition. These results are very similar to those of Sciulli and Mahaney (1991), who found a significant reduction only between Late Archaic and Middle Woodland Ohioans. The authors conclude that the advent of pottery at the end of the Late Archaic is the most significant change that led to dental reduction. Their conclusion is not without support, as Brace consistently argued that the incorporation of pottery and more processed foods was the reason that dental reduction accelerated at the end of the Pleistocene (*e.g*., Brace, Rosenberg and Hunt, 1987).

The percent difference and rates of change show very comparable results. These values are often used in odontometric studies of this kind, but it must be stressed that these values are not being compared here with any statistical methods. In other words, it is obvious by observing the percentages that the differences are more often greater during the second transition; however, the significance of those values has not been demonstrated here. Despite this, the results listed in Table 6 do provide a descriptive display of the amount and rate of the significant and non-significant changes.

In the current study the average maxillary reduction (as averaged from the significant teeth in Table 6 is 0.799%/1,000 years, and the mandibular rate is 0.911%/1,000 years. These results indicate a minimal amount of reduction, especially compared to those observed by LeBlanc and Black (1974) who observed a rate of 2.0 percent every 1,000 years, since the end of the Pleistocene, with the maxillary rate exceeding that of the mandible (LeBlanc and Black, 1974). The rates observed here may be artificially low since the author took a very conservative approach to calculating rate (only for those teeth that changed significantly through time in the ANOVA). Furthermore, the rates calculated in this study represent one "population" in the world that lived during the Holocene period, and it is likely that these rates fit well within the range of other dental reduction rates gathered from various other parts of the world, including North America. Finally, there is no direct way of knowing whether the rate of dental reduction increased in North America at this time, for material from earlier time periods is not yet available for study.

While these results are consistent with other studies that interpreted reduction as a certain selection event, these results do have certain implications for how one interprets the force behind the selection. During the Early/Middle Woodland the diet is very hard, yet it has become less abrasive because of processing techniques that removed much of the sand from the food. Processing techniques changed somewhat from the Early/Middle Woodland to the Mississippian periods, but it is the food that changed dramatically. Studies have shown that agricultural diets are markedly softer and somewhat less abrasive than those of previous time periods (*e.g.*, Schmidt, 1998). Therefore the reduction shown in this study and many others may be more associated with a reduction in dietary abrasiveness rather than hardness.

Dietary Abrasiveness in a Dental Reduction Context. Earlier experimental studies tended to focus on dietary hardness/softness as a variable that controlled jaw and tooth size. For example, animals that were fed softer diets in laboratory experiments tended to have craniofacial shortening and smaller jaws in general and narrower maxillary arches in particular (Corruccini, 1991; see also Larsen, 1997). While studies like this have concluded that the reduction in masticatory apparatus is associated with a transition to softer foods (*e.g.*, Frayer, 1978; Hinton *et al.*, 1980; Larsen, 1981; Sciulli, 1979; Sciulli and Mahaney, 1991) it is important to note that considering dietary abrasiveness as a factor in dental reduction is a relatively new approach. Moreover, the results herein that state dietary abrasiveness is associated with human dental reduction do not obviate conclusions stating that dietary hardness/softness can affect other components of the masticatory complex.

CONCLUSION

A previously undocumented reduction in tooth size was found among populations dating from the Late Archaic to the Mississippian periods from the Ohio River Valley in Indiana and Kentucky. These results are consistent with numerous other studies that have found dental reduction in comparable populations around the world. The reduction was most pronounced in females and in maxillary teeth. Both the number of significant maxillary reductions and the rate of maxillary reduction were greater than those of the mandible.

Dental reduction seems to be associated with a significant reduction in dietary abrasiveness. As the advent of pottery and more efficient food processing techniques removed sand from much of the same types of foods between the Late Archaic and Early/Middle Woodland periods, teeth reduced at a steady, yet comparatively slow pace.

ACKNOWLEDGEMENTS

I would like to thank the Indiana University Department of Anthropology, the Glenn Black Laboratory at Indiana University, and the Webb Museum of Anthropology at the University of Kentucky for the opportunity to study the remains housed at their institutions. Special thanks, also, to Chris Schmidt for his advising and assistance during this project. In addition, I would like to thank Stephen Nawrocki and Paul Sciulli for their assistance and editing. Funding provided by a grant from the Indiana Academy of Science.

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Minutes of the 19th Annual Dental Anthropology Association Business Meeting: April 15th, 2004, Tampa, Florida

Call to Order:

The meeting was called to order at 7:50 P.M., by President Joel Irish.

Old Business:

DAA website: Alma Adler reported that the new improved website was almost ready to be made available to the public. The site will be hosted by University of Tennessee, Health Science Center, Memphis, TN.

New Business:

1. **Retirement of officers:** Joel Irish ended his term as President.
2. Instatement of new officer. Debbie Guatelli-Steinberg ended her term as President-Elect and began her term as President.
3. **Election of new officer:** Simon Hillson was elected by unanimous vote to the position of President-Elect.
4. **A. A. Dahlberg Student Prize**: The winner of the 2004 competition was Molly K. Hill, at Ohio State University, for her paper entitled "Dental reduction and diet in the prehistoric Ohio River Valley." She received $200, a certificate of award, a year's free membership in the DAA, and will have her article published in the journal [*Editor's note*: This article starts on page 34]. Celeste Marie Gagnon, University of North Carolina, was named first runner up for her paper entitled "Food and the state: Bioarchaeological investigations of diet in the Moche Valley of Perú." Celeste received $50, a certificate of award, a year's free membership in the DAA, and will have her article published in the journal [see page 45, this issue].
5. **Editor's Report:** Edward Harris reported that the next issue of the journal was ready for publication. He also urged faculty and students to submit articles for consideration to the journal.
6. **Secretary-Treasurer's Report**. Heather Edgar reported that as of April 11th, 2004, the DAA has $3,891.91 in operations funds, and $1,843.91 in the AA Dahlberg prize fund. There are 161 members in the association who are current with their dues, and 126 who are delinquent from between one and three years. An e-mail message is going to be sent to all members (63) who are two and three years behind in their membership dues.
7. **Additional topics:** Joel Irish issued for ideas for a dental anthropology symposium for next year's meetings. Greg Nelson was named new Book Review Editor for *Dental Anthropology*

Adjournment:

Joel Irish adjourned the meeting at 8:40 P.M. The meeting was followed by a period of socializing around the DAA cash bar.

Submitted by: Heather J.H. Edgar
DAA Secretary-Treasurer

Food and the State: Bioarchaeological Investigations of Diet in the Moche Valley of Perú

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ABSTRACT The Moche of north coastal Perú were among the earliest New World societies to develop state socio-political organization. The Moche State (AD 200-800) was a centralized hierarchical society that controlled the Moche Valley as well as valleys to the north and south. Prior to the establishment of the state, a series of less hierarchical organizations were present in the valley. Irrigation agriculture has often been cited as central to development of the Moche State. To test this assertion I examined 750 individuals recovered from the largest cemetery at the site of Cerro Oreja. Although the most important occupation of Cerro Oreja was during the Gallinazo phase (AD 1-200), many individuals were interred here during the earlier Salinar period (400 -1 BC). Consequently, the Cerro Oreja collection holds a key to understanding the development of one of the earliest and most extensive states in the Americas. The teeth and/or alveoli of each individual were examined for the presence of dental caries, periodontal disease, abscesses, and antemortem tooth loss. My analysis suggests women and children did increasingly focus their diet on agricultural products. These findings seem to support the hypothesis that increased irrigation and reliance on agricultural production was fundamental to the development of the Moche state. However, men's diets remained consistent through time. Status seems to have been of little import in determining diet before and during early periods of state development, in dramatic contrast to what we know of its importance during the zenith of the state's power. I suggest that increasing differentiation of gender roles was important to the development of the state, and that gender differences may have been the most salient force in the transition to political hierarchy and social stratification in the Moche valley. *Dental Anthropology* 2004;17(2):45-54.

The Moche of north coastal Perú were among the earliest New World societies to develop a bureaucratic state organization (Moseley, 1992; Bawden, 1996). The Moche State (AD 200–800) was a centralized hierarchical society that controlled the entire Moche Valley and perhaps valleys to the north and south (Fig. 1). The Moche elite marshaled their economic resources to build large public works, such as roads and monumental ceremonial structures (Hastings and Moseley, 1975; Moseley, 1975), and to dramatically increase arable land through canal construction (Moseley and Deeds, 1982). The elite also amassed great personal wealth, as indicated by archaeological excavations of wealthy tombs (Donnan and Castillo, 1992; Alva and Donnan, 1993). To exert their influence, the elite used ideological power manifested in public rituals held at large monuments, and iconography that supported state ideologies. Physical power, in the form of warfare, conquest, and sacrifice, was also central to elite control (Shimada, 1978; Bawden, 1996; Billman, 1996; Bourget, 1996. 2001; Verano, 2001).

Prior to the establishment of the state, societies in

Celeste Marie Gagnon

Editor's note: Ms. Gagnon's paper was awarded 'First Runner Up' for 2004 in the Albert A. Dahlberg student research competition sponsored by the Dental Anthropology association.

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Table 1. Moche Valley cultural periods and work projects

Phase	Estimated Dates	Cultural Horizon[1]	New Canals Excavated	Ceremonial Architecture
Middle Moche	AD 400–700	Early Intermediate Period	312,000 m^3	416,000 m^3
Gallinazo–Early Moche	AD 1–400	Early Intermediate Period	0 m^3	15,000 m^3
Salinar	400–1 BC	Early Intermediate Period	60,000 m^3	67,000 m^3
Cupisnique	1800–400 BC	Initial Period–Early Horizon	42,000 m^3	1,291,000 m^3

[1]Following Moseley (1992) and Billman (2002).

the valley were organized in less hierarchical political structures (Topic and Topic, 1978; Brennan, 1980; Topic, 1982; Billman, 1997, 1999). It was the people of these societies who first opened the desert lands of the Moche valley to agriculture (Table 1). Construction of the valley-wide canal system that enabled agriculture production began during the Cupisnique phase (1800–400 BC), when approximately 4200m^3 of canals were built, irrigating 4100 hectares. This system was expanded by approximately 60,000 m^3 during the Salinar phase (400–1 BC), allowing for the cultivation of 6750 to 7300 hectares. During the Gallinazo and Early Moche phases (AD 1–400) no new land appears to have been brought under cultivation. Later, the Moche State doubled agricultural production through the irrigation of 12,550–13,200 hectares (Billman, 2002). This dramatic increase in agricultural production has led researchers to suggest that in Perú, as elsewhere, irrigation played a central role in state development (Steward, 1949; Rowe, 1963; Moseley, 1974; Haas, 1987). This is because staple crops could be produced on a grand scale in irrigated fields creating storable surpluses. By controlling these stores, elites financed their state building activities (D'Altroy and Earle, 1985; Earle, 1997). Because increased agricultural production is reflected in an increase in the consumption of agricultural products, the link between irrigation and state development can be tested by tracking prehistoric changes in diet. To this end, I examined individuals who lived during the Salinar and Gallinazo phases, just prior to and during the beginnings of state formation, for evidence of increased prevalence of dental pathological conditions indicative of the increased consumption of starchy and/or sugary agricultural products. An advantage of using biological rather then ethnobotanical data to chart consumption is that these data are linked to specific individuals for whom sex, age-at-death, and status information is known. This allowed me to examine not only changes in agricultural production, but who these changes affected, and thus link changes in social roles, particularly gender roles, to changes in political organization.

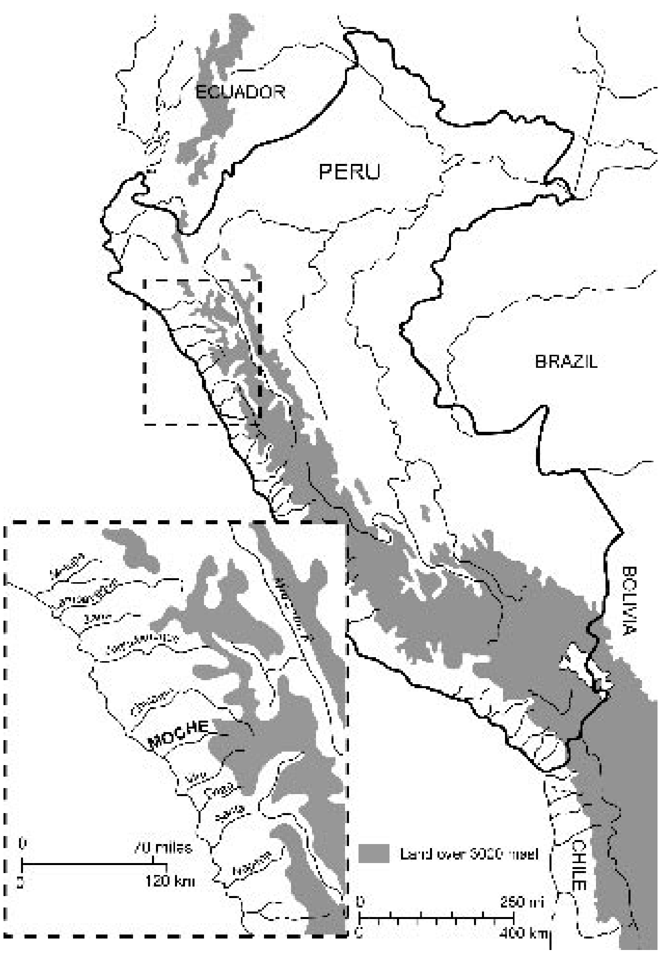

Fig. 1. Perú with north coast inset, from Moseley 1992.

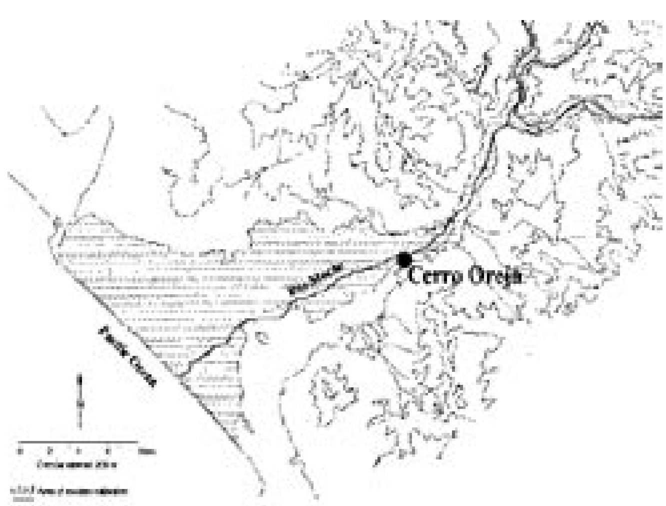

Fig. 2. Map of the lower and middle Moche valley locating Cerro Oreja, from Billman 1999.

Table 2. Study sample

Age in years	Salinar	Early Gallinazo	Middle Gallinazo	Late Gallinazo
fetal	0	5	8	0
birth - 4.9	24	110	90	49
5 - 9.9	11	21	12	9
10 - 14.9	3	12	4	3
15 - 19.9	5	10	11	7
20 - 24.9	2	9	4	5
25 - 29.9	0	9	7	11
30 - 34.9	6	6	10	7
35 - 39.9	8	10	10	3
40 - 44.9	5	10	8	4
45 - 49.9	4	5	5	2
50 - 54.9	0	0	2	0
55 - 59.9	1	0	0	0
> 18	2	5	1	5
> 20	3	20	28	26
> 30	2	11	10	13
> 40	0	2	5	1
50 +	0	0	0	1

THE SAMPLE

The remains I examined in this study were excavated by the Instituto Nacional de Cultura (INC) from the site of Cerro Oreja (Fig. 2). Cerro Oreja, located at the neck of the Moche valley, was the largest urban center in the valley during the Gallinazo phase (Billman, 1999). Downstream from this location the Moche valley widens as the river drains into the Pacific. At the neck and upstream, the Río Moche cuts into the Andean foothills. Here bottom land is limited and valley slopes rise steeply. It is in this area that people, both in the past and present, have built irrigation canal intakes. Although the most important prehistoric occupation of Cerro Oreja was during the Gallinazo phase, many individuals were also interred here during the Salinar phase.

Of the 909 burials excavated from Cerro Oreja by the INC, I examined 681. Several burials contained the remains of more than one individual, and as a result the study sample represents 750 individuals. The INC made phase designations based on burial goods and stratigraphic location. The sample I analyzed for this study included the remains of 61 Salinar, 142 Early Gallinazo, 109 Middle Gallinazo and 69 Late Gallinazo individuals (Table 2). Although the mortuary analysis of the Cerro Oreja cemetery is in its preliminary stages, information about the presence of grave goods is available. Using these data, I divided individuals into two status categories, those with goods and those without.

Age-at-death and sex identifications were made as a joint effort by the members of the Cerro Oreja Bioarchaeology Project, which is co-directed by Dr. Patricia Lambert of Utah State University and Dr. Brian Billman of the University of North Carolina at Chapel Hill. During the summer field seasons of 1999, 2000, and 2001, I worked with Dr. Lambert and Bonnie Yoshida, a graduate student at the University of California at Santa Barbara, to make age-at-death and sex estimations for 243 individuals. During an extended research season, Yoshida identified the age-at-death and sex of an additional 183 individuals. In 2003, I examined these individuals as well as the remains of 324 additional individuals.

Our age-at-death and sex identifications were made following *Standards* (Buikstra and Ubelaker, 1994). We based subadult age estimates primarily on tooth formation and eruption (White, 1991). Skeletal development and fusion (Johnston, 1962; Fazekas and Kósa, 1978; Buikstra and Ubelaker, 1994) were used in estimating the age-at-death of fetuses and infants, as well as of individuals for whom the dentition was not preserved. Adult ages were estimated based on combined morphological changes at the pubic symphysis and auricular surface, and also on cranial suture closure (as presented in Buikstra and Ubelaker, 1994). Occasionally sternal rib ends were well-enough preserved to be included in our age assessments (see Bass, 1987). We assigned individuals a mean age and an error estimate. Errors ranged from several months for well-preserved children to as much as 15 years for fragmentary adults. For this analysis, I grouped individuals in five-year categories based on their mean age. Adult remains too fragmentary to be assigned a mean age were not included.

Sex identification of adults was established using the Phenice Method and qualitative observations of pelvic morphology, such as relative size of greater sciatic notch, length of the pubic ramus and width of the subpubic angle. We also considered cranial morphology and robusticity when sexing adults (White, 1991; Buikstra and Ubelaker, 1994). If the os pubis was extremely fragmentary or absent, we used metric data from the femora, tibiae, and humeri to support cranial sex identifications (Iscan and Miller-Shaivitz, 1984; Dittrick and Suchey, 1986). Not all individuals could be assigned a sex with the same degree of certainty. To incorporate our varying error, we employed a four-tier system to rank our identifications: female/male, probable female/male, possible female/male, and unidentified. Individuals in the last two categories were excluded from this analysis.

Approximately 56% of the individuals in this study had preserved teeth and/or alveoli that I could examine for the presence of the following dental pathological conditions: caries, periodontal disease, abscesses, and antemortem tooth loss.

METHODOLOGICAL CONSIDERATIONS

Biological anthropologists have effectively used the frequency of dental pathological conditions to chart changes in diet, particularly with regard to the consumption of agricultural products (see Kelley and Larsen, 1991; Hillson, 1996; Larsen, 1997). Because of the nature of human dentitions and the vagaries of skeletal preservation, researchers have struggled with several sampling issues. The primary issue is scalar: Should individuals or teeth be the unit of analysis? In an analysis at the individual level, individuals are diagnosed as having or not having a particular condition. Such an analysis can provide researchers with useful information; but it can also obscure variation. At this level, an individual with 32 observable teeth, only one of which is carious, cannot be distinguished from an individual with 32 carious teeth, though these two individuals certainly had different diets. Characterizing individuals by the percentage of affected teeth addresses this issue, but raises questions about sample comparability. An individual with 32 observable teeth, all of which are carious, and an individual with only two teeth, also carious, would both be classified as 100% affected. To mitigate the effects of individual preservation differences, researchers often exclude individuals who do not have some minimum number of observable teeth.

In addition to these issues of comparability, substantial data loss occurs when each individual is characterized by only one datum point. In the comparison described above, 32 teeth were observed. However, when these data are analyzed at the individual level, there is only one datum point—the presence (or absence) of carious lesions, or the percentage of affected teeth. This loss can result in sample sizes that are insufficient to address research questions.

To maximize data and address comparability difficulties, many researchers analyze their data at a higher scale (following Turner, 1979). All the teeth of many individuals are pooled into groups, the boundaries of which are defined by the questions to be addressed. These types of studies yield some interesting information about diet. However, statistical analyses of data grouped in this way assume that each tooth in the group is independent of all others. This assumption does not hold, as the teeth of an individual are affected by her/his diet and are therefore more likely to resemble each other than the teeth of other individuals. Additionally, the pooling of samples can increase group heterogeneity, leading to spurious results. To test for diet change over time, all individuals from each period can be grouped to create a lesion rate for each. Statistical analysis of these rates may not identify significant differences among groups because the differences that do exist may average out. Summary measures of a bimodal distribution (*e.g.*, female teeth are always affected while male teeth are not) can be very similar to those of a standard distribution (*e.g.*, both female and male teeth are often affected). To address this issue, groups can be more narrowly defined, creating a larger number of groups each of which includes fewer individuals. Doing so, however, decreases sample size and the power of statistical tests to identify differences among the groups.

Two other factors complicate both individual and group level analysis: the differing susceptibility of different tooth types to dental pathological conditions, and the varying ages-at-death of sample individuals. Teeth vary in their overall size and the complexity of their shape. Both of these factors affect a tooth's probability of developing pathological lesions. At the individual level of analysis for example, a person with eight observable anterior teeth is much less likely to display carious lesions than someone with eight observable molars. At the group level, samples pooled for comparison might contain substantially different distributions of tooth types. Dental pathological conditions are also age-dependent. For this reason, researchers segregate subadults and adults in both individual and group level analyses. In some cases the adult sample is further divided into young, middle, and old categories. As with other attempts to mitigate sample heterogeneity, the level of error must to be balanced against decreasing the sample size.

To address these persistent problems, I analyzed these data using logistic regression. A log-linear model simultaneously explores the complex relationships between a categorical independent variable, in this case the presence or absence of a dental condition, and any number of numeric and/or categorical dependent variables (*e.g*, age-at-death, sex). Secondly, it solves the dilemma of analytical scale. Model estimates of population parameters are calculated using individual teeth, allowing the largest possible sample size. However, the teeth of an individual remained linked, preserving individual-level information. This nesting sampling strategy adjusts for sample-effects by weighting the value of the independent variable for each tooth according to how much additional information it provides about the individual. Finally, interactions among dependent variables can be examined for significance. If two dependent variables vary simultaneously their interaction will be more significantly associated with the independent variable than either would when independently analyzed.

The model I used in this analysis was programmed in SAS with the help of Chris Wiesen, staff statistician for the Odum Institute at the University of North Carolina at Chapel Hill. In this model age-at-death was the only numeric, dependent variable. We treated this variable as numeric because it behaved linearly, even when described in 5-year intervals. The categorical variables we included were period, status, sex, and tooth-type. Period, status, and sex identifications have been discussed above. I defined several tooth-types based on differing susceptibility of each type to various dental conditions. All teeth were assigned to either one of four permanent types (anterior, premolar, first or second molar, third molar), or to one of three deciduous types (anterior, first molar, second molar). This classification allowed us to modify the model so that it accounted for variation in the number of teeth from each type that were observable in each individual. Additionally, tooth-types were weighted based on their expected occurrence in the population (0.375, 0.25, 0.25, and 0.125, 0.6, 0.2, 0.2, respectively). The inclusion of these dependent variables in the model controlled for variation in the analysis without breaking the sample down into multiple subgroups, thus preserving sample size.

RESULTS

Permanent and deciduous teeth were considered separately in all analyses. The first analytical step was to calculate rates of dental pathological conditions at both individual and tooth levels. I grouped all individuals who had at least one observable tooth by their status, and compared the percentage of people affected by each condition across periods. No significant status differences were identified (Table 3). Similarly, no significant status differences were found when teeth were grouped by status and compared across time (Table 4). Differing patterns were found when adult individuals, and the teeth of adults, were divided into female and male samples and compared across periods (Table 5 and 6). Therefore, a sex-by-period interaction was included in the log-linear model, and individuals of unknown sex were excluded from further analyses.

As part of the logistic regression, the Wald statistic was calculated to test the null hypothesis that groups are characterized by similar rates of dental pathological conditions. To create a visual representation of these data, rates of dental conditions, adjusted for sample variations in size, age-at-death, and tooth-type, were plotted.

Deciduous teeth affected by carious lesions generally increased through time (Fig. 3), although this pattern is not statistically significant ($P < 0.2680$). Female adult carious lesions rates show a similar trend (Fig. 4), which is significant ($P < 0.0077$). Temporal variation in male carious lesion rates are not significant ($P = 0.4903$), and shows no pattern (Fig. 4). Significant differences were identified between female and males in the Middle and Late Gallinazo phases ($P = 0.0051$ and 0.0286,

Table 3. Individuals affected by dental pathological conditions

Period / Status	Deciduous Carious Lesions n	%	Permanent Carious Lesions n	%	Permanent Periodontal Disease n	%	Permanent Abscesses n	%	Permanent Tooth Loss n	%
Salinar										
high	28	25	31	74	14	86	17	47	19	68
low	1	0	5	100	3	100	3	67	3	33
Early Gallinazo										
high	27	37	36	64	6	83	21	43	22	59
low	35	29	42	50	7	71	15	47	16	69
Middle Gallinazo										
high	10	30	21	71	7	86	15	53	16	63
low	32	44	36	61	12	67	20	35	24	58
Late Gallinazo										
high	4	25	11	73	4	100	6	17	6	67
low	21	29	18	67	7	43	11	45	11	55

Table 4. Teeth affected by dental pathological conditions

Period Status	Deciduous Carious Lesions n	Deciduous Carious Lesions %	Permanent Carious Lesions n	Permanent Carious Lesions %	Permanent Periodontal Disease n	Permanent Periodontal Disease %	Permanent Abscesses n	Permanent Abscesses %	Permanent Tooth Loss n	Permanent Tooth Loss %
Salinar										
high	263	20	350	18	236	39	360	7	616	13
low	15	0	81	12	69	30	113	7	159	3
Early Gallinazo										
high	153	16	287	21	62	24	281	12	683	11
low	217	10	293	19	116	45	310	13	717	12
Middle Gallinazo										
high	62	13	159	30	92	20	170	12	409	11
low	262	15	323	21	47	45	260	7	627	7
Late Gallinazo										
high	98	11	69	35	54	41	75	7	196	23
low	29	10	154	23	22	73	217	8	478	7

respectively).

Adult periodontal disease rates show changes over time for both females (P = 0.2383) and males (P = 0.0871), but the pattern of change is different than that seen in carious lesion rates (Fig. 5). Among both females and males periodontal disease rates increased from the Salinar to the Early Gallinazo phase and then fell from the Early to the Middle Gallinazo. Throughout these periods, female rates were higher than males, but these differences are only marginally significant during the Early Gallinazo phase (P = 0.0961). The female and male patterns dramatically change in the Late Gallinazo phase, when there is a significant increase in periodontal disease among males (P = 0.0286), but female rates continue to fall.

Dental abscessing and antemortem tooth loss among females and males display no clear temporal patterns. Females are more often affected by these conditions than males (Figs. 6 and 7). Differences in the rates of abscessing are only statistically significant during the Middle Gallinazo phase (P = 0.0536). Antemortem tooth loss differences between females and males are significant during the Salinar (P = 0.0257) and Middle Gallinazo (P = 0.0286).

DISCUSSION

What do the various measure of dental pathological conditions tell us about agricultural consumption at the site of Cerro Oreja during the periods preceding the development of the state? Carious lesion rates suggest that adult females, and to a lesser extent children, carbohydrate consumption steadily increase through time (Figs. 3 and 4). This seems to support the hypothesis that an intensification of agricultural

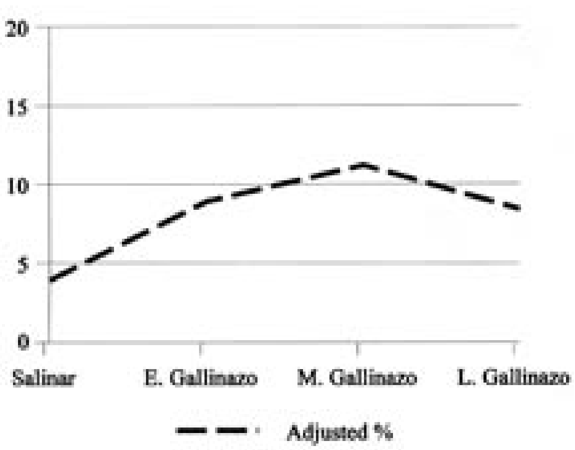

Fig. 3. Deciduous carious lesion rates by period.

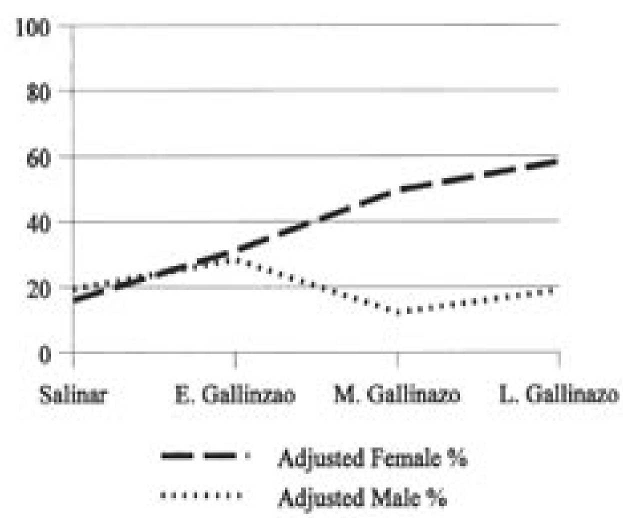

Fig. 4. Carious lesion rates for females and males by period.

Table 5. Individuals affected by dental pathological conditions

Period Sex	Carious Lesions n	Carious Lesions %	Periodontal Disease n	Periodontal Disease %	Permanent Abscesses n	Permanent Abscesses %	Permanent Tooth Loss n	Permanent Tooth Loss %
Salinar								
female	9	87	7	86	9	56	9	89
male	7	86	7	86	7	29	7	43
Early Gallinazo								
female	12	83	6	100	14	43	14	86
male	16	63	7	86	19	58	20	65
Middle Gallinazo								
female	15	93	10	80	17	53	20	75
male	7	57	7	86	10	30	11	64
Late Gallinazo								
female	7	86	8	75	10	40	10	70
male	4	50	3	67	6	17	6	50

production, and a correlated increased in staple consumption, was central to the development of the Moche state. However, adult male consumption does not follow this pattern (Fig. 4). Rather, it appears that males consumed fewer starchy and/or sugary staple agricultural products than did children and females, in amounts that did not change over time. An increasingly different diet among males, compared to females and children suggests increasingly differentiated gender roles in society.

What kinds of changes in gender roles might have resulted in such different diets? As a point of comparison I offer the Inka state's policy of mit'a labor, in which men were required to work on large-scale, state-sponsored projects. While taking part in such work parties laborers were supplied with specialized food-stuffs (D'Altroy and Earle, 1985; Hastorf, 1990, 1991, 1993). Similarly, the substantial investment in public construction in the Moche valley throughout the study period would certainly have required elites to marshal and supply a sizable work force (Table 1). Therefore, I suggest that the men of Cerro Oreja were being increasingly drafted by the elite into similar work parties where they were provisioned with, or offered as an enticement, meat and/or marine resources, while women and children continued to tend agricultural fields and consume the staple crops they produced.

Periodontal disease rates do not follow the same pattern as carious lesion rates, for either females or males (Fig. 5). This suggests that periodontal disease in the Cerro Oreja sample is not as closely linked to consumption as carious lesion rates. To understand this pattern I examined how non-food items that people put into their mouths can affect the oral environment.

Table 6. Teeth affected by dental pathological conditions

Period Sex	Carious Lesions n	Carious Lesions %	Periodontal Disease n	Periodontal Disease %	Permanent Abscesses n	Permanent Abscesses %	Permanent Tooth Loss n	Permanent Tooth Loss %
Salinar								
female	107	17	82	54	150	1	233	13
male	111	22	90	46	130	6	199	7
Early Gallinazo								
female	109	32	45	76	148	14	284	18
male	123	28	45	64	161	23	367	17
Middle Gallinazo								
female	126	43	45	44	152	13	351	15
male	54	15	31	42	83	6	176	10
Late Gallinazo								
female	59	53	32	34	85	8	184	17
male	54	13	13	77	44	2	96	6

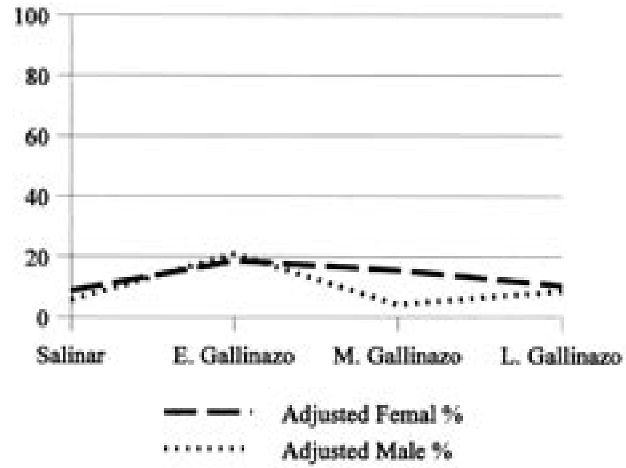

Fig. 5. Periodontal disease lesion rates for females and males by period.

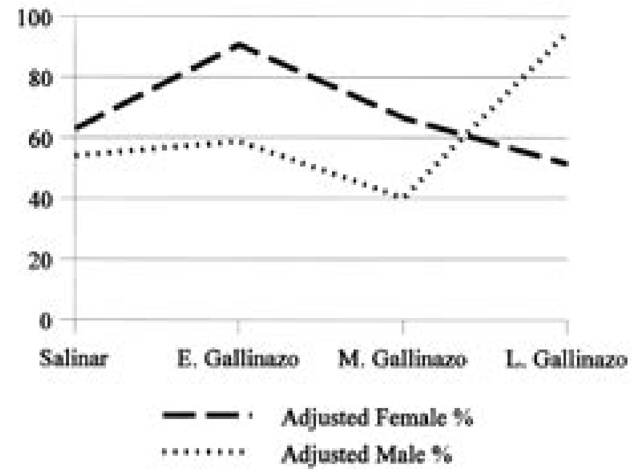

Fig. 6. Abscess rates for females and males by period.

Coca leaf chewing is a common activity in the Andes with a very long history (Rostworoski, 1988; Plowman, 1985; Allen, 1985, 1988). Because of the stimulant qualities of coca and the corrosive nature of the lime with which coca leaves are chewed, this activity is associated with alveolar resorption, periodontal disease, and the development of carious lesions in the subsequently exposed tooth roots (Langsjoen, 1996; Indriati, 1997; Indriati and Buikstra, 2001). Unfortunately, the poor curation of the Cerro Oreja skeletal collection resulted in the fragmentation of many tooth roots, thus the rate of root lesions could not be compared to that of crown lesions. Such a comparison could have provided support for my interpretation.

Archaeological investigations in the Moche valley provide information relevant to the question of coca use at Cerro Oreja. Billman (1996, 1997) has identified an in-migration of highland people into the Moche valley during the beginning of the Gallinazo phase, based on the appearance of sites dominated by highland ceramics. Of particular interest is the highlander occupation of the limited coca growing areas located in the upper portion of the middle valley. The occupation of these areas by highlanders may have resulted in a reduced access to and use of coca by local residents, as indicated by the decrease in periodontal disease from the Early to the Middle Gallinazo period. Billman proposed that these distinctive highland sites were abandoned as highlanders were displaced, absorbed, and/or eliminated by the end of the Gallinazo phase. In the Late Gallinazo coca may again have been available to valley residents, but increasing gender role differentiation resulted in its use by men, not women. Since coca chewing increases work capacity (Allen, 1985; Plowman, 1985), this may again be an example of elites provisioning men as they labor on irrigation and ceremonial construction projects.

Beyond coca's dramatic biological effects, it has, and has had, important religious and social significance to Andeans (Isbell, 1978; Allen, 1985, 1988; Weismantel, 1988). Thus I would suggest, that its effects on work capacity is only part of the story. The Moche valley elite may have offered coca as payment to common men for their labor, and in this way engaged them as willing participants in their state-building projects.

Female and male rates of dental abscesses and antemortem tooth loss show little difference and no patterned change over time (Figs. 6 and 7). Because these are not primary conditions, but are the result of untreated dental caries (crown or root), periodontal disease and/or dental wear, this lack of temporally patterned variation may be the result of an "averaging"

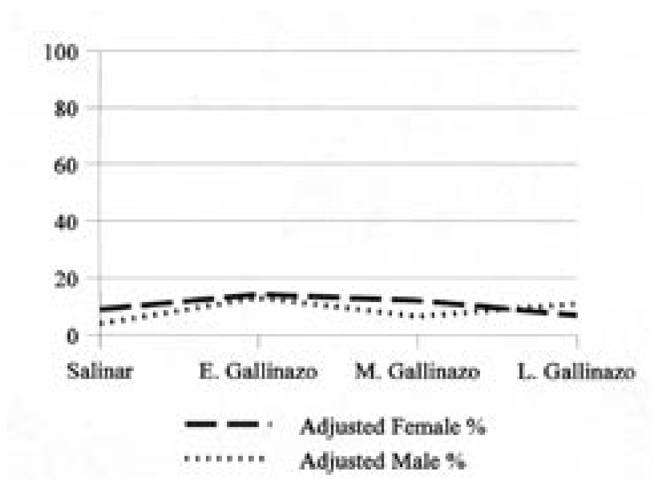

Fig. 7. Antemortem tooth loss rates for females and males by period.

of the effects of these primary pathological conditions.

CONCLUSION

In this analysis I tested the hypothesis that the development of the Moche state (AD 200–800), one of the earliest and most hierarchical in the Americas, was based on intensification of irrigation agriculture. This hypothesis is based on the dramatic increase of arable land in the Moche Valley during the Salinar and Gallinazo phases, prior to the development of the state and during the early period of state development (Table 1). As people increased agricultural production, they would also have increased their consumption of starchy and/or sugary agricultural products. My analysis suggests women and children did increasingly focus their diet on agricultural products (Figs. 3 and 4). These findings seem to confirm the hypothesis that increased irrigation and reliance on agricultural production was fundamental to the development of the Moche state. However, the story is more complex. Men's diets remained consistent through time (Fig. 4). Additionally the data suggest that women and men's use of coca varied temporally, in significantly different ways (Fig. 5). Status seems to have been of little import in determining diet before and during early periods of the state, in dramatic contrast to what we know of its importance during the zenith of the state's power. Together these data suggest that increasing differentiation of gender roles was important to the development of the state. Gender differences may have been the most salient force in the transition to political hierarchy and social stratification in the Moche valley.

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Dentitions, Distance, and Difficulty: A Comparison of Two Statistical Techniques for Dental Morphological Data

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ABSTRACT One of the main uses of dental morphological data is to study patterns of affinities among populations. Many different approaches to this purpose are available, each one having its own strengths and weaknesses. For this study, observations were made of the morphology of 614 African American and 327 European American dentitions (n = 941). Each of these samples was divided into three groups based on the time in which they lived. Affinities among the resulting six groups were estimated based on the frequencies of dental morphological characteristics, by the use of both the Mean Measure of Divergence and a Pseudo-Mahalanobis' D^2. The results of these analyses are compared using a Procrustes transformation that rotates and scales coordinates derived from distances until achieving the best fit. The two statistics produce similar, although not identical results. The appropriate use and relative value of each approach is discussed. *Dental Anthropology* 2004;17(2):55-62.

The Mean Measure of Divergence (MMD) has become the standard statistical technique for assessing biological affinities when using frequencies of dental morphological characteristics (Scott and Turner, 1997). There are several advantages in using this statistic: It is appropriate for nominal data, it is relatively easy to compute, and it is comparable among researchers. There is however, a drawback to using the MMD; it is only appropriately used when the traits being studied are independent. The assumption of independence is weak for several dental characteristics, so inter-trait correlations must be tested, and traits that are correlated must be removed from of a MMD analysis.

An alternative to MMD is the Mahalanobis' D^2 statistic, which allows correlated features to be used in affinity measures (Mahalanobis, 1936). However, as originally formulated, this statistic is useful only for metric, not nominal, data. Konigsberg (1990) used a pseudo-Mahalanobis' D^2 to determine biological affinity using non-metric data. This statistic has the potential to allow distance measures to be based on a greater variety and number of dental characteristics than the MMD. Of course, like MMD, the D^2 statistic has its drawbacks. The primary problems with the application of this statistic are its limited applicability when analyzing a number of traits with little or no correlation, the need for multiple observations per individual, and its relatively more difficult computation. Because every trait must be compared to every other for each sample being studied, comparing more than a few traits at a time can become quite arduous, even with a computer. Additionally, the inclusion of a new sample for analysis requires the recalculation of all measures of affinity among groups, not simply the measures of affinity of the new sample with the original groups, as with the MMD.

This study presents the results of a comparison of MMD and pseudo-D^2 methods for determining biological affinity among several samples. The goals are to investigate whether the two types of analysis result in similar findings, and if not, to consider why.

MATERIAL

The data for this study comes from the dentitions of 941 African Americans and European Americans, analyzed as part of a larger study of the microevolution of African American dental morphology. Samples come from collections temporarily or permanently housed at the National Museum of Natural History, National Museum of Health and Medicine, Cleveland Museum of Natural History, University of Tennessee Health Sciences Center, Ohio State University, and Arizona State University. The samples were divided into six groups, based on ancestry and time period. The samples sizes and time periods are listed in Table

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Table 1. Sample compositions

	Early born circa 1650-1850	Middle born circa 1825-1910	Late born circa 1920-1960	total
African American	35	414	165	614
European American	33	139	155	327
total	68	553	320	941

1.

For this study, a maximum of 136 observations of 32 morphological characteristics was possible per dentition. Observation procedures were based on the Arizona State University dental anthropology system (Turner *et al*., 1991). No significant directional asymmetry of expression or sexual dimorphism was found, so rights and lefts were combined (with the greatest trait expression being represented), as were observations from males and females. Observations were then dichotomized with guidance from Haeussler *et al*. (1989), Irish (1993), Irish and Turner (1990), Scott and Turner (1997), and Turner (1987).

All statistics were performed using the SAS statistical package (SAS Institute Inc., 1990). Associations between traits were determined using the likelihood ratio statistic. The list of traits that was used for each analysis can be found in Table 2. Traits used in the MMD analysis are independent from each other. To invert the matrix of correlations, the D^2 analysis requires that most variables have some tetrachoric correlation with all other variables. Several variables were eliminated from D^2 analyses because they were found to have little or no correlation with other variables, and thus the tetrachoric correlation matrix was singular. Different variable combinations were used in each analysis because of the requirements of each statistics; traits should be uncorrelated for the MMD and correlated for the D^2.

Table 2. Dental characters used in each analysis

Max MMD	Mand MMD	Max D^2	Mand D^2
DIAS	LI2SS	UI2SS	LI1SS
UCSS	LCDR	UCSS	LI2SS
UI1LC	LP3LC	UI1LC	LP4LC
UI2DS	LP4LC	UI2TD	LM2MT
UI2IG	LM1AF	UCTD	LM1PS
UM3CA	LM2GP	UCDR	LM2PS
UCTD	LM1DW	UP3MD	LM2C5
UCDR	LM1MT	UP4MD	LM1C6
UP3MD	LM2PS	UM1MC	
UP4MD	LM2C5	UM2MC	
UM2MC	LM1C6	UM1HC	
UM1HC	LM2C7	UM1C5	
UM2C5		UM2C5	
UM2CB		UM1CB	
		UM2CB	

STATISTICAL METHODS

Mean Measure of Divergence

The MMD statistic was developed by C. A. B. Smith, and was first used to look at changes due to inbreeding in mice (Grewal, 1962; Berry *et al*., 1967). Berry and Berry (1967) first applied it to the study of biological affinities or distance in humans. The MMD estimates biological distance between samples based on the degree of phenetic similarity (Irish, 1997). The statistic requires an assumption of independence of traits. Like D^2, it is useful if trait expression varies in a population, when frequencies are 5-95% (de Souza and Houghton, 1977). Some major benefits of its use are its ability to work with incomplete data and its applicability to samples as small as 10-20 observations. MMD is defined as:

$$MMD=(\sum(\Theta_1 - \Theta_2)^2 - (1/n_1 + 1/n_2))/c$$

where Θ_1 and Θ_2 are the arc sin ($\sin^{-1}$) transformations of the observed frequencies in the two samples being compared, n_1 and n_2 are the sample sizes, and c is the number of characters employed (Freeman and Tukey, 1950).

Pseudo-Mahalanobis' D²

The Pseudo-Mahalanobis' D^2 is defined as the sum of squares of differences between corresponding mean values of two sets of measurements, weighted by the variance/covariance matrix (Burnaby, 1966):

$$D^2=\left(\chi_{ik}-\chi_{jk}\right)'\sum\left(\chi_{ik}-\chi_{jk}\right)$$

where χ_{ik} is the mean of expression for sample i for k traits, and χ_{jk} is the same for sample j. The middle term ($\sum$) is the pooled covariance matrix between the k traits (Manly, 1994). In this study, the means of trait expressions are the threshold values corresponding to the trait frequencies in the samples (Falconer, 1981), and the middle term is a pooled matrix of tetrachoric correlations between the traits (Brown, 1977). These transformations account for correlations between characteristics being used (Konigsburg, 1990; Mizoguchi, 1977) and the threshold nature of dental morphological traits (Scott and Turner, 1997).

Table 3. MMD distances, maxillary traits

	Late AA	Late EA	Middle AA	Middle EA	Early AA	Early EA
Late AA	0	0.113	0.074	0.443	0.244	0.402
Late EA	0.113	0	0.113	0.231	0.395	0.239
Middle AA	0.074	0.113	0	0.222	0.187	0.247
Middle EA	0.443	0.231	0.222	0	0.292	0
Early AA	0.244	0.395	0.187	0.292	0	0.218
Early EA	0.402	0.239	0.247	0.000	0.218	0

Procrustes' transformation

The purpose of this statistic is to rotate and scale two sets of coordinates so as to achieve the best fit between them (Gower, 1971, 1975). For this study, the coordinates come from principal coordinates analysis of four distance matrices, and represent the first two axes of each matrix. The better the fit between two sets of coordinates, the smaller the summed deviations should be. Gower (1971) refers to the statistic as R^2 (for residual), but it can also be found as S^2 (for sum of squares) (Goodall, 1991) and M^2 (for minimum)(Jackson, 1995). R^2 is defined as:

$$R^2 = \sum \Delta^2(P_i P_i^*),$$

where P_i and P_i^* represent the corresponding points in two different sets of coordinates. The R^2 statistic is the sum of squared differences after rotation and scaling. The smaller the R^2, the smaller the difference is between the two sets of coordinates. For this study, a small R^2 will indicate good agreement between the MMD and D^2 statistics.

RESULTS

Before discussing the direct comparison of statistical methods, an examination of the pictures presented by each analysis is in order. Due to the difficulty in performing pseudo-Mahalanobis' D^2 with a large quantity of traits, maxillary and mandibular traits were considered separately.

Measures of affinity

Results for MMD analyses based on maxillary and mandibular traits can be seen in Tables 3 and 4, respectively. The maxillary traits show a separation between African Americans (AA) and European Americans (EA) at all time periods. There is a closer relationship between early and middle EA than either to late EA. Early AA is different from all groups, with middle and late AA being most like late EA. Analysis of the mandibular traits emphasizes the split between EA and AA and minimizes other details.

Results for the D^2 analyses are summarized in Tables 5 (maxillary traits) and 6 (mandibular traits). The results for the maxillary traits seem to emphasize the time difference between groups rather than differences in ancestry. Late and middle AA and EA cluster most closely, with early AA and EA being very distant from each other and all other groups. The results based on the mandibular trait D^2 are the most difficult to characterize. There is a large difference between early and middle AA, and a relatively small difference between middle and late AA. While the indication that change in the African American gene pool slowed down after the Civil War reflects known historical patterns of admixture (Davis, 1991), it does not explain the apparent similarity of early EA and middle AA, the smallest distance in the matrix. This information is graphically presented in Figure 1, which shows the principal coordinates of the relationships among the six groups resulting from MMD analyses,

Table 4. MMD distances, mandibular traits

	Late AA	Late EA	Middle AA	Middle EA	Early AA	Early EA
Late AA	0	0.507	0.094	0.471	0.122	0.488
Late EA	0.507	0	0.525	0.119	0.601	0.148
Middle AA	0.094	0.525	0	0.401	0.122	0.374
Middle EA	0.471	0.119	0.401	0	0.449	0.000
Early AA	0.122	0.601	0.122	0.449	0	0.410
Early EA	0.488	0.148	0.374	0	0.410	0

Table 5. D^2 distances, maxillary traits

	Late AA	Late EA	Middle AA	Middle EA	Early AA	Early EA
Late AA	0	4.175	7.692	7.755	6.676	17.243
Late EA	4.175	0	4.472	4.563	10.015	10.769
Middle AA	7.692	4.472	0	3.184	7.982	8.698
Middle EA	7.755	4.563	3.184	0	8.303	6.499
Early AA	6.676	10.015	7.982	8.303	0	10.295
Early EA	17.243	10.763	8.698	6.499	10.295	0

Table 6. D^2 distances, mandibular traits

	Late AA	Late EA	Middle AA	Middle EA	Early AA	Early EA
Late AA	0	1.473	8.630	3.593	8.725	8.302
Late EA	1.473	0	4.598	4.714	6.300	5.243
Middle AA	8.630	4.598	0	8.442	7.281	2.442
Middle EA	3.593	4.714	8.442	0	5.040	7.459
Early AA	8.725	6.300	7.281	5.040	0	8.800
Early EA	8.302	5.243	2.448	7.459	8.800	0

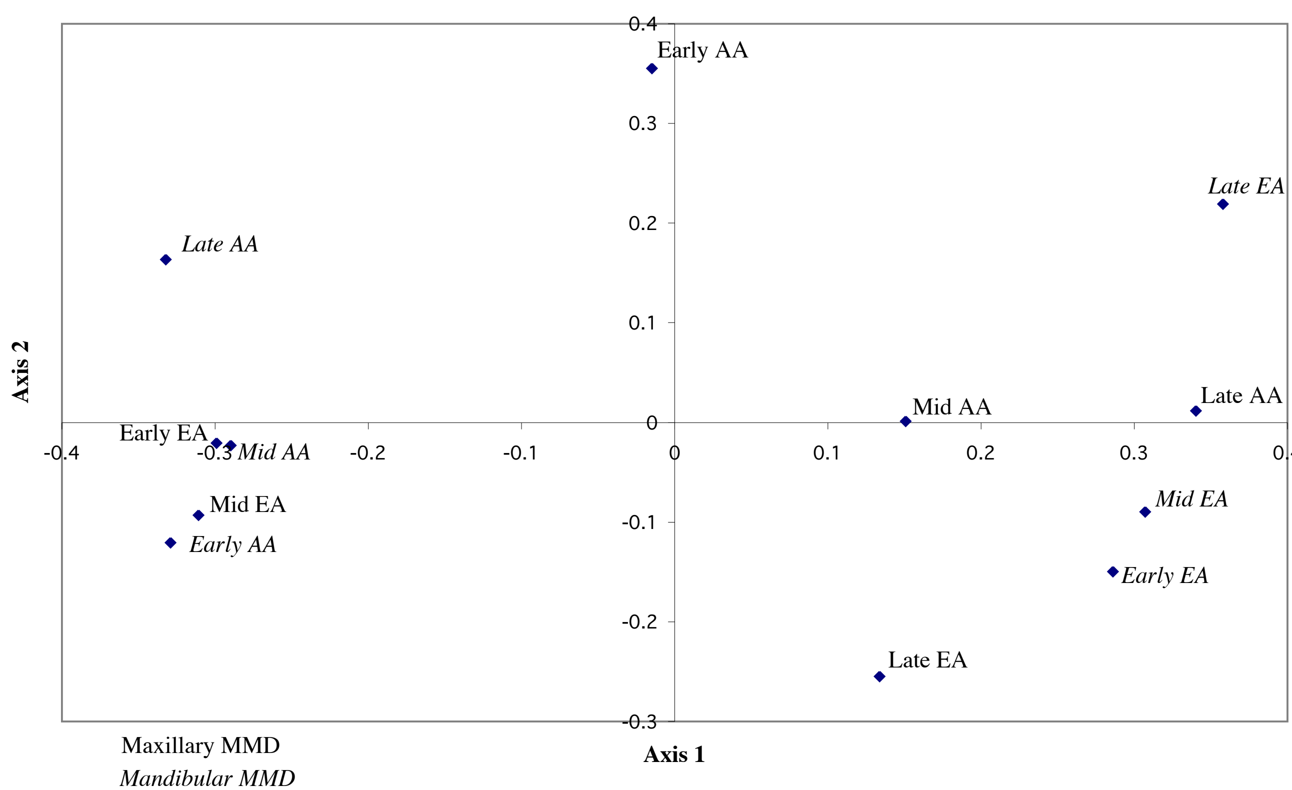

Fig. 1. Principal coordinates for MMD analyses.

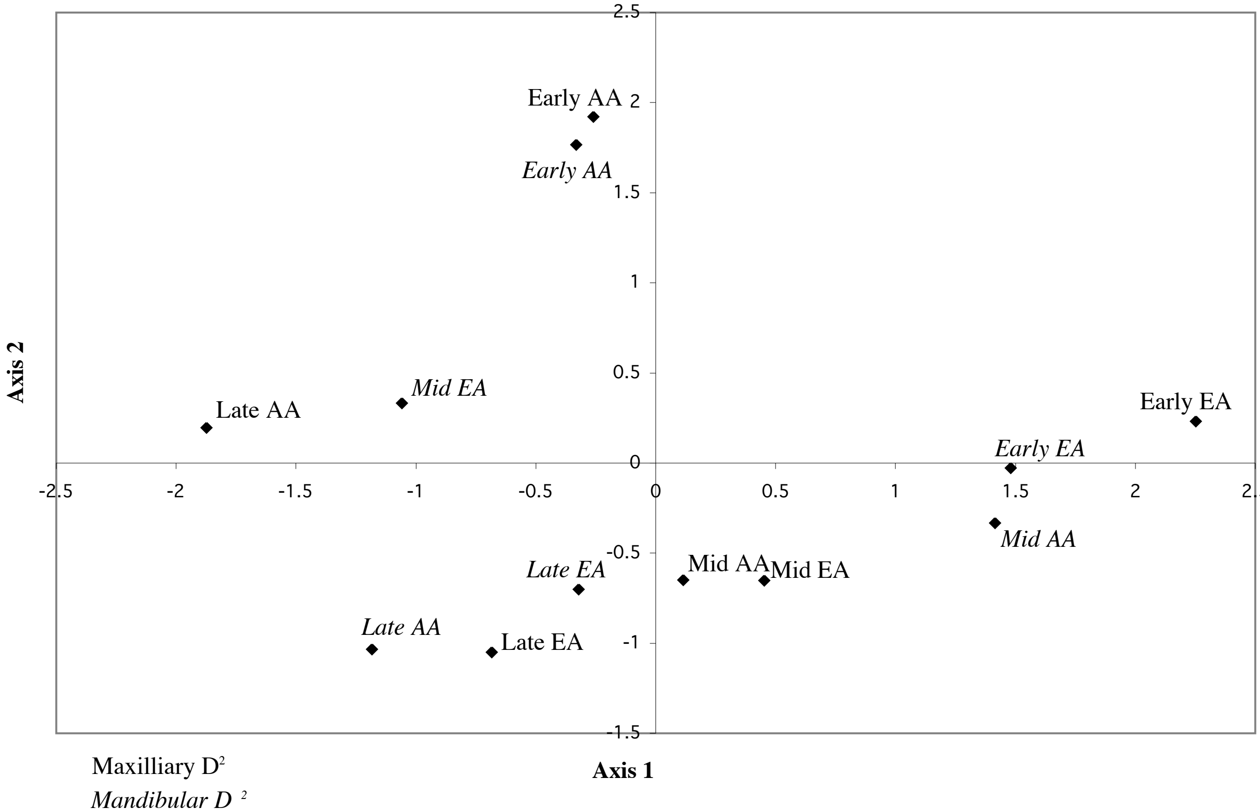

Fig. 2. Principal coordinates for D^2 analyses.

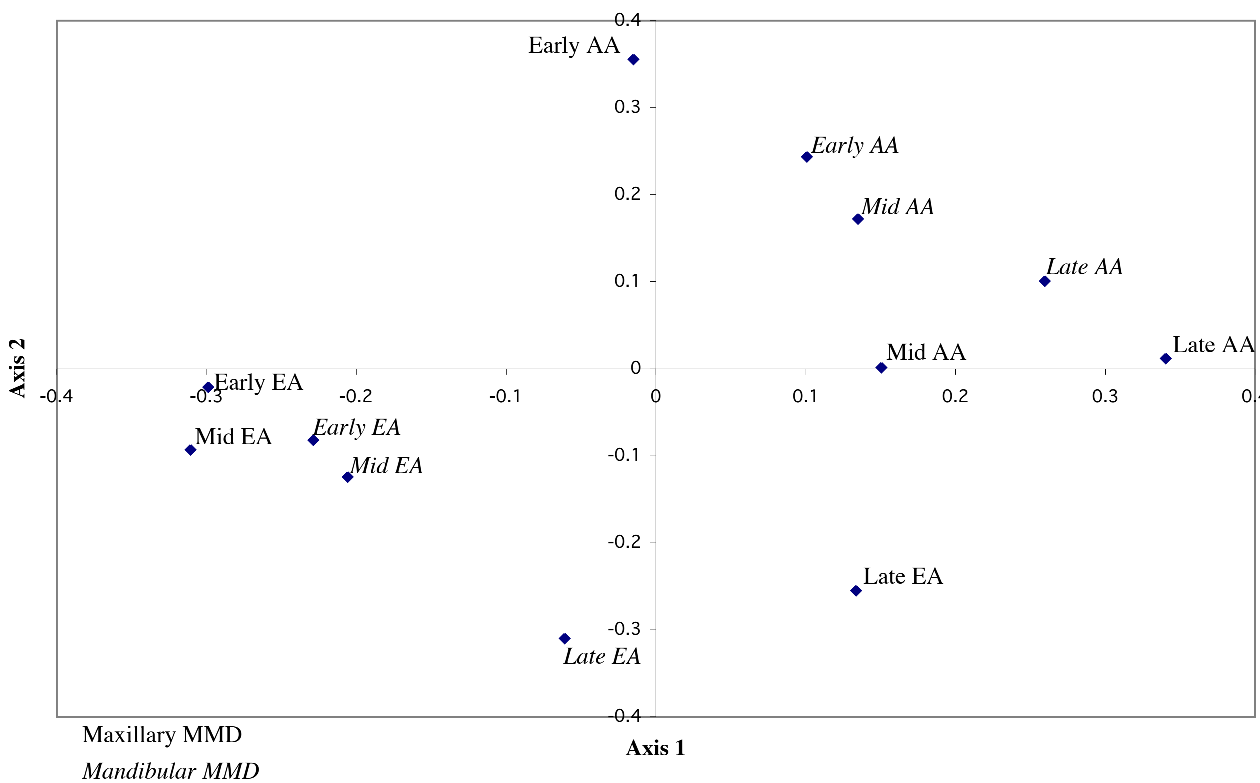

Fig. 3. MMD Principal coordinates after procrustes transformation.

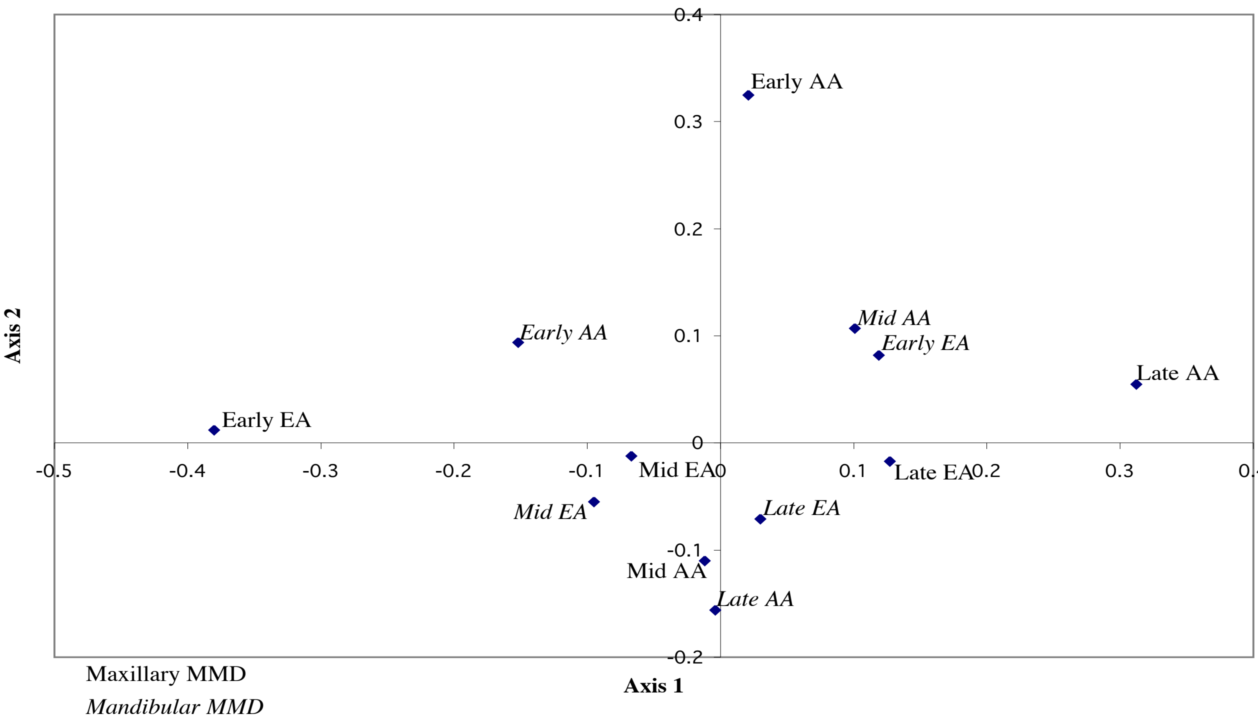

Fig. 4. D^2 Principal coordinates after procrustes transformation.

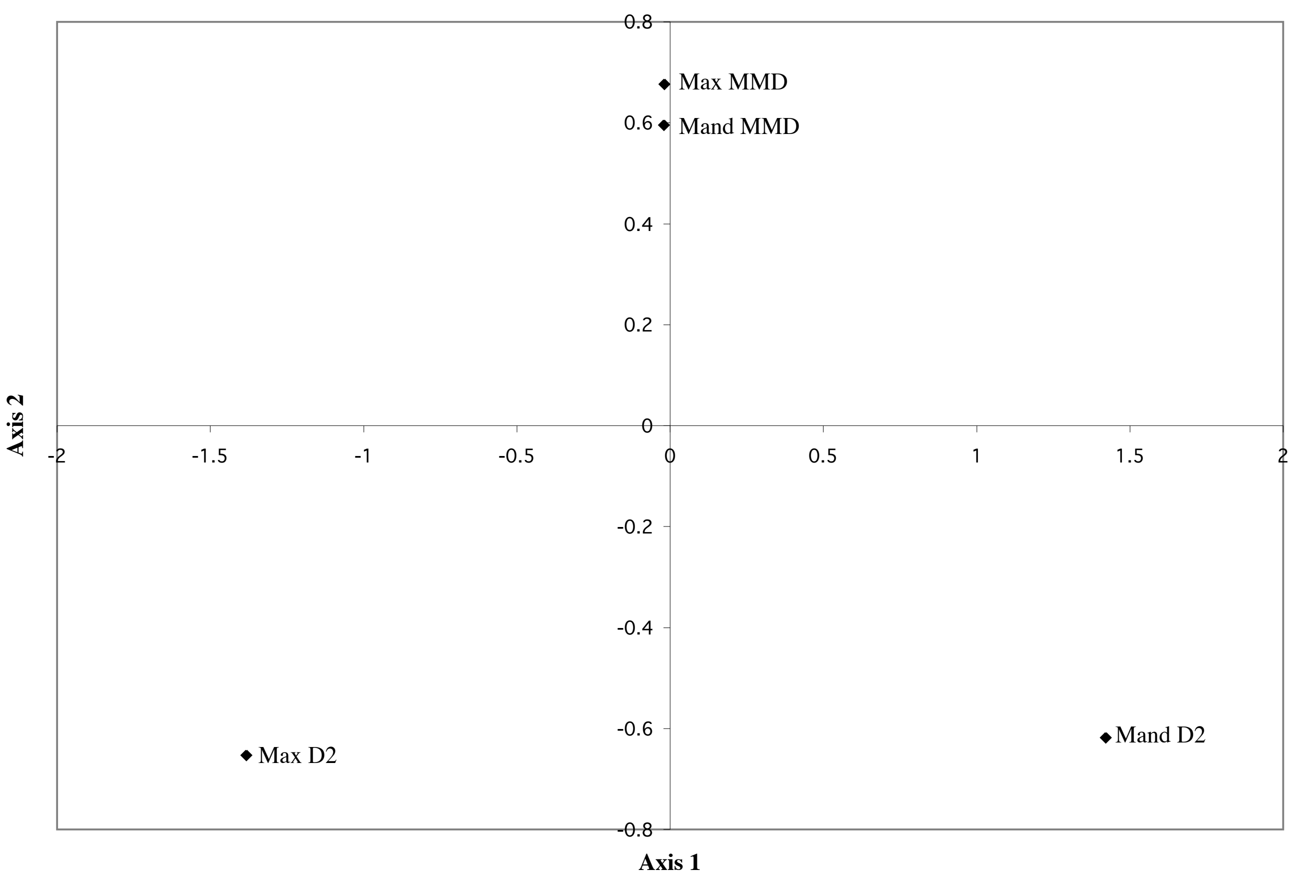

Fig. 5. Principal coordinates of residuals.

and Figure 2, which shows the same relationships for D^2 analyses.

Procrustes analysis

Figures 3 and 4 show the relationships between the six samples after rotation and scaling of the principal coordinates for MMD and D^2, respectively. The coordinates for maxillary MMD results acting as a baseline for both tables. Each of the other groups has been redrawn to its best fit, meaning the one that yields the smallest residual. The residuals between all the groups are summarized in Table 7. There is no test of significance for R^2, but it can be seen that all the values are relatively small except for between the D^2 for maxillary and mandibular characteristics. It is possible to simplify this table by performing a principal coordinates analysis for this R^2 matrix and display the relationships in the simplest geometric space. A graph of these coordinates shows relationship between the four methods of determining affinity. Figure 5 shows that the two MMD matrices are in nearly perfect agreement. The two D^2 matrices are quite different from each other, but neither is more different from the MMD matrices than the other.

It remains to be explained why the D^2 matrices are so different from each other. One possible explanation is a lack of differences between the samples being studied in these particular traits. In fact, among the traits used for the mandibular D^2 analysis, there is half the average difference in expression between groups as there is in the maxillary D^2 and MMD, and one quarter as much difference as in mandibular MMD.

CONCLUSIONS

Overall, there is very good agreement between the biological distance matrices generated using MMD and pseudo-Mahalanobis' D^2 statistics. Both statistics have their place in the analysis of biological distance, especially when utilizing characteristics of dental morphology. As with all statistics, the MMD and D^2 are limited by the data they analyze. If there is little difference between samples for the characteristics in question, the results will show small distances; if the differences are large for those particular characteristics, the distances will be large as well. A careful evaluation of the data should be made before attempting any measure of affinity.

When there are many traits available for analysis and they have little inter-trait correlation, MMD is appropriate. When the data consist of a relatively few, correlated traits, a pseudo-Mahalanobis' D^2 is more accurately applied, as it makes no assumption about a lack of correlation between traits. In a large study, the use of both statistics may allow analysis of more of the collected data. If all things are equal and either statistic is applicable, MMD is simpler to use and more widely comparable.

ACKNOWLEDGEMENTS

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13th International Symposium on Dental Morphology

First Announcement

The 13th International Symposium on Dental Morphology is taking place from Wednesday 24 to Saturday 27 August 2005, hosted by the University of Lódz, Poland. The conference web-site is at: http://www.biol.uni.lodz.pl/antropolog/conference/index.html

Files can be downloaded from the web-site for 1) Symposium Registration, 2) Presenter's Information, and 3) Guideline for manuscript preparation with presenter's instructions. Documents should be completed and return by the 28th February 2005.

Scientific Program: The Scientific Programme will be held in the conference facilities at the University of Lódz and will follow the general pattern of previous meetings, with single oral and poster sessions.

Abstracts: We welcome abstract submission, with the deadline of 28th February 2005. An abstract submission form and a presenter's form is available from the organizers, with the choice of preferred option of poster or oral communication.

Symposium Proceedings: The Symposium proceedings will consist of the presentations as short papers. Our proposed deadline for manuscripts will be 31th May 2005. See information on the web-site for submission formats. The Symposium and the accommodation are organized in the University Conference Centrum. The Centrum is set in the University District in very pleasant grounds, close to the city center (Piotrkowska street). We will be using all the conference facilities on site. The accommodation includes single and double rooms. Travel from this venue to our social events and return is included in the fee.

Symposium Costs:

Participant	130 Euro by 28.02.2005	180 Euro by 31.05.2005
Accompanying person	50 Euro by 28.02.2005	80 Euro by 31.05.2005

Please note: We regret that any cancellation after 01.07.2005 will not be refundable.

Conference Fee covers: book of abstracts, the Symposium Proceedings, attendance to all sessions, refreshments during the meeting, conference facilities, the Welcome Reception, sightseeing of Lódz, grill party and the Gala Dinner. Much more information is available on the website.

Editor's Note: This information is abstracted from a detailed e-mail sent in early October. Be certain to refer to the web-site for specifics.

Brief report:

Tooth Shape Deviations of Mandibular Premolars

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In the last issue of *Dental Anthropology*, Edgar and Sciulli (2004) highlighted an interesting abnormality of human mandibular premolar (MnP) shape in their report, "Elongated mandibular premolar: a new morphological variant." They noted that the affected premolar is characterized by "either compressed… buccolingual dimension or longer … mesiodistal dimension."

We show here that these observations have greater depth in the literature. For example. we identified and illustrated the same morphological crown anomaly in 1975 (Peck and Peck) in two North American white orthodontic patients, describing the occurrence as a tooth shape deviation (TSD) of MnP. One case was a female with bilateral MnP1-TSD (Fig. 1) and the other was a case of a male with bilateral MnP2-TSD (Fig. 2). In fact, this variation had previously been recognized by Dahlberg (1951) in a white female (bilateral MnP2) and by Suzuki and Sakai (1960) in a Japanese male (bilateral MnP2), each referring to the condition as "buccolingually compressed" mandibular premolars. To our knowledge, occurrences of this anomaly have not been demonstrated for the maxillary premolars.

We applied an MD/FL crown index ([mesiodistal diameter in mm ÷ faciolingual diameter in mm] X 100) to quantify the extent of this tooth shape anomaly in our two subjects: deviant MnP1 teeth, with widened mesiodistal dimension and narrowed faciolingal dimension, had an MD/FL index of 122; deviant MnP2 teeth showed an MD/FL index of 120-127. This compares with MD/FL indices for unaffected MnP1 in whites of 90 ± 5 and for unaffected MnP2, 85 ± 5.

Fig 1. Tooth shape deviations of both mandibular first premolars (MnP1-TSD) in a white female (reproduced courtesy of *The Angle Orthodontist*).

Fig 2. Tooth shape deviations of both mandibular second premolars (MnP2-TSD) in a white male (reproduced courtesy of *The Angle Orthodontist*).

We also found an association between MnP-TSD and a similar TSD of the mandibular incisors, commonly associated with the tendency for dental crowding (Peck and Peck, 1972a,b).

Here I report another case, a European white female showing unilateral expression of MnP1-TSD (Fig. 3).

From these several reported cases, I conclude that these peculiar deviations in mandibular premolar shape may derive from a developmental pinching of the faciolingual tooth mass with an associated enlargement of the mesiodistal tooth diameter. MnP-TSD is usually the product of reduced FL and increased

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Fig 3. Tooth shape deviation of the mandibular left first premolar (MnP1-TSD) in a white female.

MD dimensions. All elements of occlusal morphology of the affected teeth seem to be intact, just dimensionally shifted and distorted. The anomaly occurs in either sex, in either the first or second mandibular premolars independently, expressed mostly bilaterally and occasionally unilaterally. The MnP-TSD anomaly is found occurring in whites, blacks and Asians.

My co-workers and I are undertaking further studies of various phenotypes of this unusual dento-morphological condition.

ACKNOWLEDGMENT

The author thanks Dr. Daniela Garib for her contributions to this report.

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