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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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 (*).

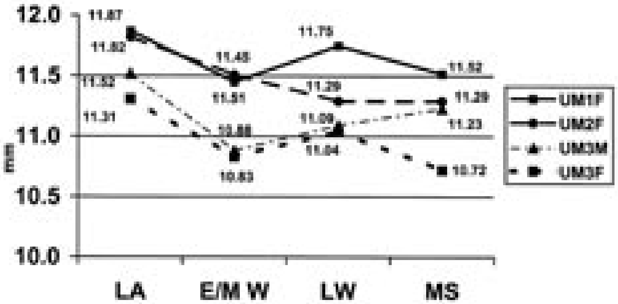

Fig. 2. Display of significant changes in female (F) maxillary first through third molars and male (M) maxillary third molar through time.

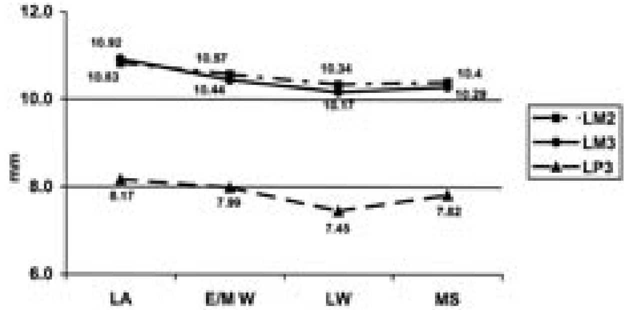

Fig. 3. Display of significant changes in female mandibular teeth through time.

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

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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