The Effects of Sexual Dimorphism, Asymmetry, and Inter-trait Association on the Distribution of Thirteen Deciduous Dental Nonmetric Traits in a Sample of Pima Amerindians

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ABSTRACT One hundred dental casts of modern Pima Amerindian children, 50 male and 50 female, were examined for the presence and expression of thirteen deciduous nonmetric traits. The effects of sexual dimorphism, asymmetry, and inter-trait association on trait presence were examined to evaluate their utility in population distance studies. No statistically significant differences between the sexes were observed. The majority of examined variants displayed a strong trend toward bilateral expression and no statistically significant differences between antimeres occurred. These data support the hypothesis that strong genetic components coupled with negligible environmental influences are involved in deciduous trait presence. Five statistically significant associations between variants were detected. Four of these involved a combination of incisor and canine shoveling within and between jaws. This indicates that their combined use in biological distance studies violates the mathematical assumption of independence. The lack of significant sexual dimorphism and asymmetry in the deciduous discrete traits examined herein supports their use in population distance analyses if precautions are taken to use non-associated traits.

The number of studies dealing with nonmetric variation in human deciduous teeth pale in comparison with those of the permanent dentition (Scott and Turner, 1997). This discrepancy has been attributed to the paucity of deciduous dental remains at archaeological sites (Kitagawa, 2000; Sciulli, 1998), their shorter functional life span in comparison with permanent teeth (Kitagawa, 2000), and the difficulty in obtaining a set of Hanihara's (1961) reference plaques (Mayhall, 1992). Several studies, however, indicate that deciduous nonmetric dental traits are useful tools in assessing the biological relationships of human populations (Goldstein, 1948; Grine, 1986, 1990; Hanihara, 1956, 1961, 1963, 1965, 1970; Hrdlicka, 1920; Johnse, 1947; Jorgensen, 1956; Lukacs and Walimbe, 1984; Sciulli, 1977, 1990, 1998; Smith, 1976, 1978).

A number of fundamental assumptions underpin the use of discrete dental traits in population analyses. These include the following:

1. genes strongly control trait presence and expression
2. environmental influences on trait presence and expression are negligible
3. the effects of sexual dimorphism on trait presence and expression are minimal
4. antimere asymmetry is the result of environmental rather than genetic influences
5. associations between traits are not biologically meaningful

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This paper tests the validity of the latter three assumptions as they relate to deciduous dental morphology. In turn, this sheds light on the first two assumptions. Establishing the utility of deciduous nonmetric traits in human population research is imperative if they are to be used successfully in biological distance analyses. While skeletal samples typically do not consist of a preponderance of juveniles, this is not always the case (Fairgrieve and Molto, 2000; Tocheri and Molto, in press). Therefore, deciduous nonmetric dental traits offer a valuable alternative source of biological data.

In this study, my first objective is to examine the effects of sexual dimorphism on deciduous trait presence and expression. Discrete dental traits rarely exhibit sexual dimorphism in the permanent teeth and when they do, it is primarily restricted to a few variants (Harris, 1980; Nichol, 1990; Scott, 1977; Turner et al., 1991). Theoretically, deciduous traits may be influenced by sex more than permanent traits since all deciduous teeth begin to form *in utero*. The presence of dihydrotestosterone and other androgens in male embryos act to differentiate them from females beginning around the seventh fetal week (Daly and Wilson, 1983; Mange and Mange, 1990). Dempsey et al. (1999) studied the permanent teeth of a large sample of twins and singletons (n = 448) and found that females which had a male twin "have consistently larger teeth (on average) than other females" (Dempsey et al., 1999: 577). They proposed that these differences were the result of "diffusion of sex hormones from male to female co-twins *in utero*" (Dempsey et al., 1999:577). How these naturally occurring steroids affect the development and expression of primary nonmetric variants is not well understood because few studies have examined sexual dimorphism in these traits. Hanihara (1965, 1970) reported that "no differences between sexes has been found" for several deciduous variants; however, he did not discuss any statistical methodology (Hanihara, 1965: 136, 1970). Grine (1990) examined a sample of Kalahari San children and found a lack of statistically significant sexual dimorphism in the deciduous traits he scored. Similarly, he found no sex differences in a sample of South African black children (Grine, 1986). Sex differences, however, may vary between populations in both dental (Harris, 1980) and skeletal traits (Ossenberg, 1976; Molto, 1985). Therefore, it is important to document the effects of sex on deciduous trait presence and expression in other human groups.

My second objective is to examine asymmetry in trait presence and expression on the anitmeres. Asymmetrical studies can reveal information pertaining to the environmental and functional influences on the presence of dental and skeletal discrete traits along with their underlying genotype (Mayhall and Saunders, 1986; Turner, 1985; Trinkaus, 1978). Several researchers have examined asymmetry in permanent (Bailey-Schmidt, 1995; Baume and Crawford, 1980; Biggerstaff, 1972; Harris, 1977; Meredith and Hixon, 1954; Nichol, 1990) and in primary dental traits (Townsend, 1981; Townsend and Brown, 1980, 1981) and have found it to be a random phenomenon influenced by the environment. A sample size greater than 100 is typically considered appropriate for statistical analyses of asymmetry (Garn et al., 1979; Smith et al., 1982), however, the documentation of observed trends in smaller samples can aid future research.

Understanding the associations among deciduous dental traits is necessary to increase their effectiveness in biological distance calculations. Associations between cranial nonmetric variables have been shown to adversely affect the calculation of C.A.B. Smith's Mean Measure of Divergence (MMD) (Molto, 1985). Similar results have been reported for distance analyses using permanent discrete traits (Hawkey, personal communication 2000; Nichol, 1990). Therefore, my final objective is to statistically examine the associations between these thirteen traits and critically evaluate their combined use in population distance studies.

MATERIALS AND METHODS

The sample consisted of 100 deciduous dental casts, 50 male and 50 female, of Pima Amerindians from southern Arizona. All casts were collected from living children by Albert A. and Thelma Dahlberg between 1949 and 1975 and are curated at the Dental Anthropology Laboratory at Arizona State University. The age and sex of each individual was recorded at the time of casting. The majority of casts examined in this study represent individuals between 5 and 10 years of age. Approximately 60% of their deciduous teeth were present for analysis.

Thirteen nonmetric traits were scored following the plaques (D series) and written descriptions of Hanihara (1961). Only teeth unaffected by wear or pathology were scored. A list of the examined traits and a description of how grades were dichotomized into present-absent categories is presented in Table 1. Hanihara's (1961) dichotomizing criteria were used for all traits. Throughout the text and tables the following abbreviations are used: l, lower; u, upper; i, incisor; c, canine; m, molar; 1, first in tooth series; 2, second in tooth series.

Twenty dentitions were randomly selected and re-scored on separate occasions. In order to analyze intra-observer reliability, an integral part of any discrete trait study (Molto, 1979; Nichol and Turner, 1986). Intra-observer reliability scores are reported by grade, presence/absence per tooth and presence/absence per individual in Table 2. Scoring consistency was lowest by grade (75%) and highest per individual (92%). I considered the observed scoring consistency by grade to be too low to analyze differences between degrees of expression. Therefore, only differences between trait presence and absence are reported herein. Per individual, seven out of 13 traits were scored reliably 100% of the time, two between 90-95%, and three between 80-85%. The Protostylid (lm2) was the least reliably scored trait (65% per individual).

The relative frequencies of each trait were calculated using the individual-count method. This assumes each trait is symmetrical and predominantly controlled by a single genotype; therefore, the strongest expression of the trait in an individual represents that genotype most accurately (Scott, 1980; Turner and Scott, 1977; Turner, 1985; Turner et al., 1991).

Differences in trait relative frequency between males and females and also between the right and left sides were analyzed. The Pearson chi-square test statistic was used to detect significance ($p < 0.05$). Inter-trait associations were measured using the phi coefficient with p values less than 0.01 considered significant following the recommendations of Molto (1985) and Sjøvold (1973). In all statistical analyses, if one or more cells had an expected count less than 5, Fisher's exact test was used to examine significance.

Asymmetry was investigated using the index of bilaterality (BI), calculated by dividing the frequency of bilateral presence by the sum of the frequencies of unilateral and bilateral presence, and multiplying by 100 (Molto, 1983). This index reveals the symmetrical

TABLE 1. The trait list and scoring procedure used in this study

Tooth	Trait	Grades Scored	Presence[1]
ui1	Shovel	0, 1, 2, 3	2, 3
ui2	Shovel	0, 1, 2, 3	2, 3
uc	Shovel	0, 1, 2, 3	2, 3
um1	Crown Pattern	2, 3H1, 3H2, 3M1, 3M2, 4-, 4	4-, 4
um2	Crown Pattern	3+A, 3+B, 4-, 4	4-, 4
um2	Carabelli's Cusp	0, 1, 2, 3, 4, 5, 6, 7	4 - 7
li1	Shovel	0, 1, 2, 3	2, 3
li2	Shovel	0, 1, 2, 3	2, 3
lc	Shovel	0, 1, 2, 3	2, 3
lm2	Protostylid	0, 1, 2, 3, 4, 5, 6	2 - 6
lm2	Cusp 7	0, 1, 2, 3	1 - 3
lm2	Central Ridge	0, 1	1
lm2	Distal Trigonid Crest	0, 1, 2	1, 2

[1]follows Hanihara's (1961) dichotomy

tendencies of a trait when it is present. In other words, individuals who exhibit bilateral absence of a trait are not included in the calculation of the index. An index value greater than 50 indicates the trait occurs more often bilaterally whereas a value less than 50 indicates it occurs more often unilaterally.

RESULTS

The relative frequencies of each trait by sex and by antimere are shown in Tables 3 and 4, respectively. No statistically significant difference between the sexes or between antimeres was observed ($p < 0.05$). All traits displayed a tendency toward bilateral expression (BI > 50) except for Crown Pattern (um1; BI = 0), Carabelli's cusp (um2; BI = 40) and Distal Trigonid Crest (lm2; BI = 50) as shown in Table 5.

Five statistically significant ($p < 0.01$) associations between traits occurred (Table 6). The significant association between Shoveling (ui1) and Crown Pattern (um2) is not likely to be biologically meaningful given that they develop in different developmental fields (Dahlberg, 1949). The remaining four associations, however, all involved combinations of incisor and canine shoveling within and between jaws. These significant associations strongly suggest a shared developmental pathway and strong genetic component for shoveling in the anterior teeth.

DISCUSSION

My first objective was to analyze the effects of sex on trait relative frequency. Of the 13 nonmetric traits examined in this study, none displayed statistically significant sexual dimorphism. This complements the results of Alvrus (2000) who found a "fairly low degree of sexual dimorphism" in deciduous metric traits in Pima children (Alvrus, 2000:12). Together, the results of these two studies suggest that, among the Pima, sex does not strongly affect the expression of metric or nonmetric deciduous traits. Grine (1986, 1990) also found a lack of statistically significant sex differences for Kalahari San and South African black children. Clearly, sexual dimorphism plays little role in the development of the examined deciduous crown traits within these population samples.

My second objective was to analyze trait asymmetry. None of the deciduous variants examined were expressed significantly more often on a particular side. Only one difference between antimeres approached statistical significance (Crown Pattern [um1], $p = 0.054$), and this is likely attributable to the overall low relative frequency of this trait (4.3%). Ten traits were expressed more often bilaterally (BI $\geq$ 60). The overwhelming tendency toward bilateral expression is consistent with the hypothesis that strong genetic components are involved in dental trait expression (Turner et al., 1991). Crown pattern (um1) and Carabelli's cusp (um2) were expressed more often unilaterally (BI $\leq$ 40) while Distal Trigonid Crest occurred bilaterally and unilaterally equally as often (lm2; BI = 50). The unilateral tendency of Crown pattern (um1) and Carabelli's cusp (um2) may be the result of their low relative frequency in the study sample ($\leq$ 5.1%). In sum, these data are consistent with the hypothesis that asymmetry is a random phenomenon representing environmental influences on the underlying genotype (Mayhall and Saunders, 1986; Nichol, 1990; Turner, 1985).

A fundamental assumption underlying the use of the MMD statistic is that the variables examined are not associated with one another (Sjøvold, 1973). Therefore, combining dental or skeletal nonmetric traits that are significantly associated violates the assumption of independence (Molto, 1985; Nichol, 1990). In this study, four statistically significant associations were detected

TABLE 2. Intra-observer reliability scores for this study

Tooth	Side	Trait	Grade[1]	Per Tooth %	P/A[2]	%	Per Individual P/A[3]	%
ui1	R	Shovel	15	75	19	95	20	100
	L		17	85	20	100		
ui2	R	Shovel	15	75	15	75	20	100
	L		19	95	20	100		
uc	R	Shovel	15	75	17	85	17	85
	L		16	80	17	85		
um1	R	Crown Pattern	17	85	20	100	20	100
	L		11	55	14	70		
um2	R	Crown Pattern	18	90	20	100	20	100
	L		17	85	20	100		
um2	R	Carabelli's Cusp	10	50	19	95	20	100
	L		12	60	20	100		
li1	R	Shovel	19	95	18	90	18	90
	L		18	90	18	90		
li2	R	Shovel	17	85	20	100	20	100
	L		15	75	20	100		
lc	R	Shovel	18	90	19	95	19	95
	L		16	80	19	95		
lm2	R	Protostylid	5	25	10	50	13	65
	L		8	40	13	65		
lm2	R	Cusp 7	11	55	15	75	17	85
	L		15	75	16	80		
lm2	R	Central Ridge	14	70	14	70	16	80
	L		15	75	14	70		
lm2	R	Distal Trigonid Crest	17	85	19	95	20	100
	L		18	90	19	95		
		Total	388	75	455	88	240	92

[1]identical grade was consistently scored per tooth examined (out of 20)
[2]presence/absence was consistently scored per tooth examined (out of 20)
[3]presence/absence was consistently scored per individual examined (out of 20)

that likely have biological meaning. All involved a combination of incisor and canine shoveling. This trait was associated between ui1-ui2, ui2-uc, ui2-lc, and uc-lc. Sciulli (1998) noted:

> For the total sample and in the Woodland and Pearson samples, shoveling shows strong associations between anterior teeth. The maxillary incisors are significantly associated with each other but independent of the canines, while the mandibular incisors are associated with each other, the maxillary incisors, and the mandibular canine. Shoveling of the maxillary canine is the only feature independent of shoveling in all other anterior teeth [Sciulli, 1998:196].

Clearly, shoveling in the anterior teeth is likely the result of a similar, if not identical genetic component. If this is true, the combined use of shoveling traits on different teeth in biological distance studies may adversely affect the results of the MMD statistic. Molto (1985) demonstrated that using six associated cranial variants ($p < 0.015$) in a battery of 27 significantly altered the MMD results. Nichol (1990) and Hawkey (personal communication, 2000) have found similar results using significantly associated permanent discrete traits. Molto (1985) aptly summarized:

> In closing, I would like to emphasize that the concept of distance is a theoretical mathematical concept that has been borrowed and applied to population biology. Debate continues as to the meaning and/or legitimacy of distances computed using biological data (Sjøvold, 1977). In view of this, the very least researchers can do, is to obey the assumptions outlined by mathematical theory. This means that biological distances should be computed using variates that, except for an acceptable number of chance associations, are statistically independent of each other [Molto, 1985:64].

TABLE 3. Relative frequencies of 13 deciduous dental traits and their distribution by sex in a Pima Amerindian sample[1-2]

Tooth	Trait	Total N	Total %	Males N	Males %	Females N	Females %	P
ui1	Shovel	53	50.9	27	51.9	26	50.0	0.893
ui2	Shovel	73	71.2	39	69.2	34	73.5	0.686
uc	Shovel	99	42.4	49	36.7	50	48.0	0.257
um1	Crown Pattern	94	4.3	46	4.3	48	4.2	1.000
um2	Crown Pattern	97	88.7	48	87.5	49	89.8	0.721
um2	Carabelli's Cusp	99	5.1	50	2.0	49	8.2	0.204
li1	Shovel	20	5.0	14	7.1	6	0.0	1.000
li2	Shovel	43	16.3	25	16.0	18	16.7	1.000
lc	Shovel	95	74.7	47	76.6	48	72.9	0.680
lm2	Protostylid	99	80.8	49	83.7	50	78.0	0.474
lm2	Cusp 7	96	70.8	49	77.6	47	63.8	0.139
lm2	Central Ridge	94	70.2	47	72.3	47	68.1	0.652
lm2	Distal Trigonid Crest	97	28.9	48	35.4	49	22.4	0.159

[1]N, # of individuals; %, relative frequency.
[2]P, significance level (Chi-square or Fisher's exact test).

Therefore, researchers should be extremely cautious when using a number of deciduous shoveling traits in biological distance analyses. The use of "key" teeth for deciduous variants, as is common practice in permanent discrete trait studies (Hawkey, 1998), is recommended.

CONCLUSIONS

The nonmetric traits of the deciduous dentition examined herein showed no statistically significant sex or side differences in trait relative frequency. The majority of the traits were expressed bilaterally. Together these data suggest the deciduous traits examined are primarily under genetic control with negligible environmental influences involved in their expression. Four statistically significant associations between shoveling traits on the anterior teeth were interpreted as representing a shared developmental pathway and genetic component. Therefore, using more than one deciduous shoveling trait as part of a trait battery measuring biological distance would violate the mathematical assumption of independence between variables. In sum, the observed lack of significant sexual dimorphism and asymmetry in this study supports the use of deciduous discrete traits

TABLE 4. Relative frequencies of 13 deciduous dental traits and their distribution by antimere in a Pima Amerindian sample[1-2]

Tooth	Trait	Total N	Total %	Right 2N	Right %	Left 2N	Left %	P
ui1	Shovel	53	50.9	53	50.9	50	44.0	0.481
ui2	Shovel	73	71.2	66	68.2	71	70.4	0.776
uc	Shovel	99	42.4	94	36.2	97	40.2	0.566
um1	Crown Pattern	94	4.3	86	4.7	91	0.0	0.054
um2	Crown Pattern	97	88.7	94	83.0	95	88.4	0.285
um2	Carabelli's Cusp	99	5.1	99	3.0	96	4.2	0.718
li1	Shovel	20	5.0	18	5.6	18	5.6	1.000
li2	Shovel	43	16.3	38	13.2	39	12.8	1.000
lc	Shovel	95	74.7	89	73.0	93	66.7	0.350
lm2	Protostylid	99	80.8	96	74.0	98	74.5	0.933
lm2	Cusp 7	96	70.8	91	65.9	94	61.7	0.549
lm2	Central Ridge	94	70.2	89	62.9	91	64.8	0.789
lm2	Distal Trigonid Crest	97	28.9	94	19.1	94	24.5	0.377

[1]2N, # of sides; %, relative frequency.
[2]P, significance level (Chi-square or Fisher's exact test).

TABLE 5. The symmetrical tendencies of 13 deciduous dental traits used in this study

Tooth	Trait	Trait Presence Bilateral	Unilateral	Index of Bilaterality	Symmetrical Tendency
ui1	Shovel	22	3	88.0	bilateral
ui2	Shovel	43	4	91.5	bilateral
uc	Shovel	31	7	81.6	bilateral
um1	Crown Pattern	0	2	0.0	unilateral
um2	Crown Pattern	76	6	92.7	bilateral
	Carabelli's Cusp	2	3	40.0	unilateral
li1	Shovel	1	0	100.0	bilateral
li2	Shovel	3	2	60.0	bilateral
lc	Shovel	56	8	87.5	bilateral
lm2	Protostylid	64	12	84.2	bilateral
	Cusp 7	50	14	78.1	bilateral
	Central Ridge	49	10	83.1	bilateral
	Distal Trigonid Crest	13	13	50.0	---

in population analyses if the necessary precautions are taken involving significant associations between variants.

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TABLE 6. Associations between the 13 deciduous dental traits used in this study[1-3]

Tooth	Tooth Trait	ui1 SH	ui2 SH	uc SH	um1 CP	um2 CP	um2 CC	li1 SH	li2 SH	lc SH	lm2 PR	lm2 C7	lm2 CR	lm2 DTC
ui1	SH	-	**0.36**	0.17	-0.21	**0.39**	0.00	-	-0.05	0.04	0.16	0.19	0.31	-0.06
ui2	SH	**0.01**	-	**0.41**	0.16	0.31	0.02	-	0.14	**0.42**	-0.04	0.28	0.03	-0.10
uc	SH	0.21	**0.00**	-	-0.07	0.04	0.17	0.25	0.26	**0.28**	-0.05	0.08	0.13	-0.09
um1	CP	0.23	0.31	0.64	-	0.08	-0.05	-	0.20	0.13	-0.02	-0.15	-0.02	0.03
um2	CP	**0.01**	0.02	0.76	1.00	-	0.08	0.12	0.19	0.24	-0.09	-0.09	0.05	-0.13
um2	CC	1.00	1.00	0.16	1.00	1.00	-	-	-0.10	-0.09	-0.12	-0.06	0.16	-0.15
li1	SH	-	-	0.45	-	1.00	-	-	1.00	-0.40	0.13	0.10	-0.39	-0.14
li2	SH	1.00	0.64	0.11	0.32	0.57	1.00	0.05	-	0.09	-0.04	0.12	-0.14	0.00
lc	SH	0.79	**0.00**	**0.01**	0.57	0.03	0.59	0.25	1.00	-	0.13	-0.03	-0.06	0.11
lm2	PR	0.29	1.00	0.66	1.00	0.68	0.25	1.00	1.00	0.24	-	0.16	-0.03	-0.03
lm2	C7	0.18	0.02	0.42	0.21	0.50	0.62	1.00	0.65	0.78	0.12	-	0.23	0.05
lm2	CR	0.02	0.81	0.21	1.00	0.73	0.32	0.26	0.39	0.61	0.81	0.02	-	0.05
lm2	DTC	0.68	0.42	0.37	1.00	0.29	0.32	1.00	1.00	0.29	0.80	0.63	0.60	-

[1]SH, shovel; CP, crown pattern; CC, Carabelli's cusp; PR, protostylid; C7, cusp 7; CR, central ridge; DTC, distal trigonid crest.

[2]phi coefficients are above the main diagonal; p values are below the main diagonal.

[3]**bolded values** are statistically significant at the 0.01 level.

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Skeletal Anthropology Program

Opening January 2003
Department of Anthropological Sciences
Universidad Autónoma de Yucatán, Mérida

The Department of Anthropological Sciences of the Universidad Autónoma de Yucatán, Mérida, offers a new Program in Skeletal Anthropology leading to a certificate or forming part of a M.S. in Anthropological Sciences. The program is oriented to graduate students, professors and other professionals interested in bioarchaeology (archaeology, physical anthropology, forensic sciences, and biology).

The program offers a firm background in the theory, methodology , fieldwork and laboratory research. It is designed to train qualified professionals and broaden their range of job opportunities, or open the door for students towards doctorate programs in anthropology.

The Program

The program encompasses three quarters. The curriculum revolves around theory, methodology and practical applications. Along with the department facilities, the program will benefit from a specialized lab and on-going research projects based on several skeletal collections of the region. The lab is fully equipped for up-to-date bone histomorphology in addition to standard osteological and dental analyses. Primary faculty are Dr. Vera Tiesler and Dr. Andrea Cucina

Admission

Applicants must apply directly to the Department. In addition to general graduate admission requirements of the UADY, applicants must:

- Hold a B.A. or B.S. degree with a major in anthropolgy, social, biological or medical sciences.
- Have obtained a minimum GPA of 3.0 or equivalent.
- Have competence in reading, writing and speaking Spanish.
- A letter of intent showing a clear study goal.

The Department will evaluate applications received by October 30, 2002. Courses will begin January of 2003.

More information:

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