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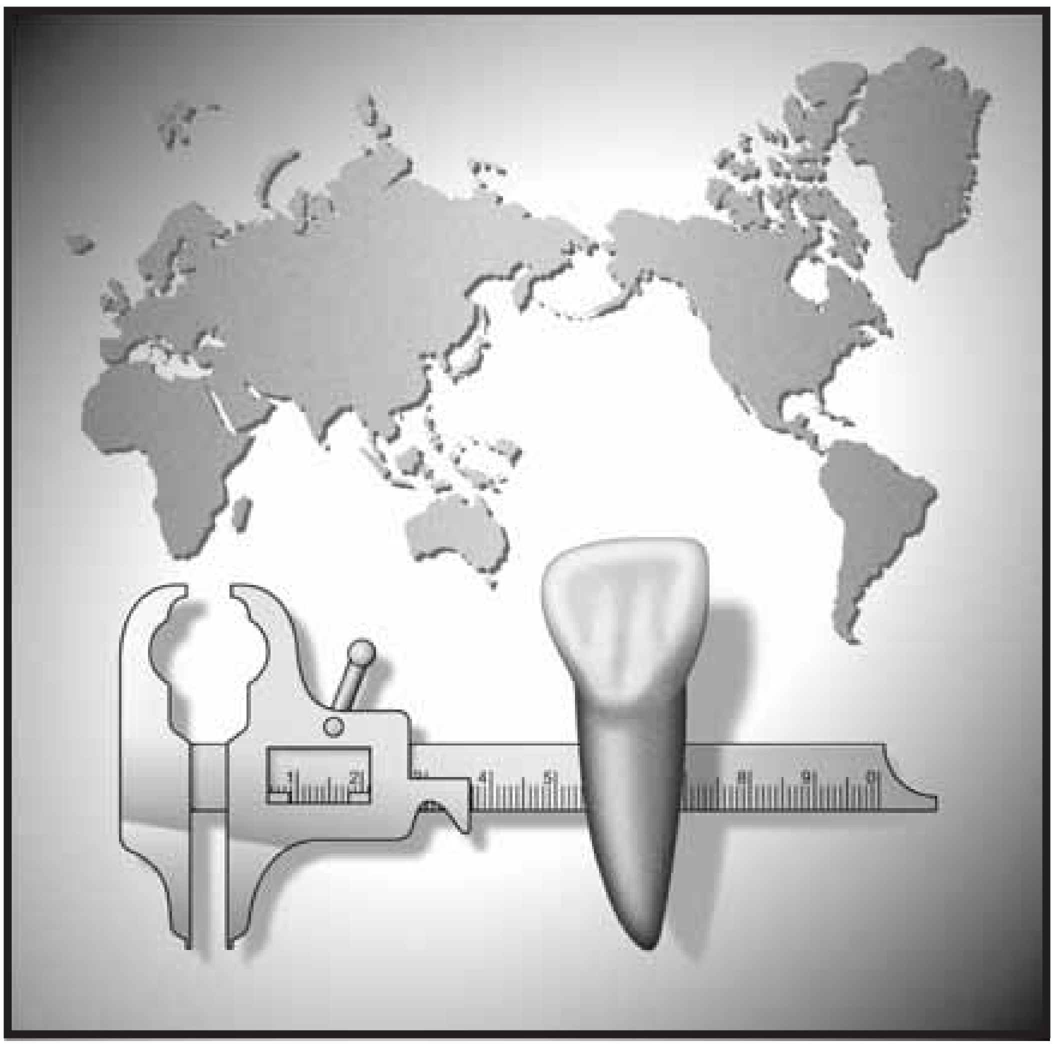

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Dental Anthropology is the Official Publication of the Dental Anthropology Association.

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From the President's Desk

Dear fellow Dental Anthropology Association members: The 2002 DAA business meeting, which took place in conjunction with the 71st Annual Meeting of the American Association of Physical Anthropologists in Buffalo, NY, was the setting for two major changes in Association leadership. First and foremost, after an unprecedented 12 years, Dr. A. M. (Sue) Haeussler (Arizona State University) stepped down as Editor of our official publication, *Dental Anthropology*. During her tenure, the publication, which began as a simple newsletter, expanded in size and improved in quality to become the journal we are familiar with today. For her remarkable, and long-standing efforts, Sue was presented with a plaque of appreciation from the DAA. Congratulations, Sue! Dr. Edward Harris (University of Tennessee), the new Editor and former President (see below), promises to maintain the quality of *Dental Anthropology* that was achieved by Sue and her colleagues over the years. He will also create and maintain a new DAA website to keep members updated on the latest news and views. There are more details on all of this elsewhere in this volume.

The second major change to take place involved the office of President. That is, Edward's two-year term ended, mine began, and Dr. Debbie Guatelli-Steinberg (Ohio State University) was voted in as our new President Elect. Over the past two years, DAA membership has increased, and our association continues– its momentum toward rivaling other AAPA-affiliated groups in size and importance, including: the Human Biology Association, Paleopathology Association, Primate Biology and Behavior Interest Group, American Dermatoglyphics Association, and American Association of Anthropological Genetics.

At this time, during the DAA's 16th year of existence, I see no reason for this momentum to end. The study of human and primate teeth continues to grow and expand in all sub-fields of biological anthropology. A quick review of the 2002 AAPA Annual Meeting Issue supports this view. Dental presentations at the Buffalo meeting were subsumed under every subfield—from genetics to paleoanthropology, and covered every conceivable topic—from dental histology to pathology, and everything in between. One of my favorite experiences during the AAPA meeting concerned a paleoanthropologist who, after years of avoiding them, conceded that teeth yield the most useful data regarding species/genus affiliation. That comment made my day.

To conclude, I would like to thank the members for electing me as the new DAA President. It is an honor to follow such a long line of distinguished past presidents, including Yasar Iscan, C. Loring Brace, Daris Swindler, Stephen Molnar, John Lukacs, Phillip Walker, John Mayhall, and Edward Harris. To me, this post represents the pinnacle of an affiliation with the Association that began in 1986, its founding year. Over the next two years of my term, I see a bright future for the DAA. Our journal will continue to provide the latest news of our association and all things dental, our new website will pick up where the old one left off (and then some), and, most importantly, our international and national membership will continue to grow—as biological anthropologists and other interested folks learn the merits of dental study. Finally, I would like to encourage you, the members, to take a more active role in the Association. You can help expand and improve the DAA by: (1) sending your articles or dental anthropology news to the journal for consideration of publication, (2) accessing and supporting the new website when it is up and running, (3) attending the yearly business meetings and AAPA dental symposia/sessions, (4) updating your membership, and (5) continuing your interest/research in the subfield that bonds us all together, dental anthropology.

Joel D. Irish
President

Editor's Comments

It's a pleasure and an honor to have been elected as the Editor of *Dental Anthropology*. This journal, that began as a casual newsletter has grown under the direction of Dr. Sue Hauessler to become a respected peer-reviewed journal. My commitment is to further strengthen the quality of *Dental Anthropology*. We will continue the peer review process for all manuscripts and will seek to continually attract high-quality papers that reflect all aspcts of dental anthropology. In part, of course, this depends on you the readers submitting quality articles for review. *DA* will be published three time a year, and, within budgetary limits, we intend to published a total of about 100 pages per volume. News of interest to the Association, including ongoing research and news of interest to the readership will be included. I encourage you to submit articles describing your current research and that of your department. *DA* originally provided a forum for dialogue and for sharing idea; I hope that we can continue to do this instead of becoming too formal.

I have revised the *Guide to Authors* (inside of back cover) to reflect everyone's greater access and facility with computers and the internet. In most respects the Guide mirrors the format required by the *American Journal of Physical Anthropology*. Most of the publishing process now can be conducted electronically.

DA offers a forum for rapid publication, and the author can be assured of a receptive, targeted audience. Please encourage your colleagues and students to consider sending relevant manuscripts to this journal.

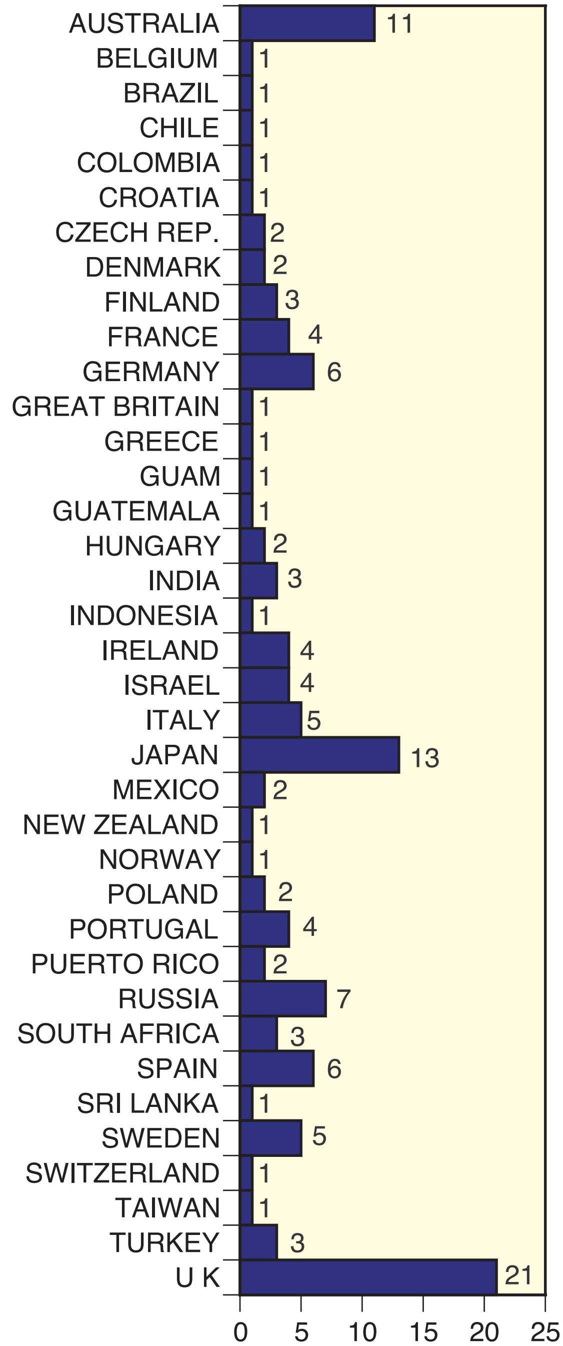

Fig. *Dental Anthropology* reaches subscribers throughout the world. A total of 37 countries outside of North America currently are represented.

A measure of the Association and the journal's growth is its ecumenical membership. In addition to the 200-plus members in North America, we have members in 37 other countries (Fig.).

In sum, I will make every effort to be accessible and helpful to you as authors of our invigorated, relevant journal.

Edward F. Harris
Editor

Form, Symmetry and Asymmetry of the Dental Arch: Orthogonal Analysis Revisited

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ABSTRACT There have been numerous attempts to quantify the shape of the dental arch mathematically, with orthogonal polynomial curves providing a robust and versatile method for quantifying variation in both shape and asymmetry. Lu (1966) first presented the theoretical basis for fitting orthogonal polynomials to arch shape data. Whilst theoretically sound, Lu's original paper contained several arithmetic errors and a number of incorrect assumptions. In this paper we present corrections for these errors and extrapolate the theory to unequally-spaced arch shape data using a simple recursive procedure first developed by Robson (1959).

The shape of the dental arches has held the attention of physical anthroplogists and dentists since the beginning of the last century. Many methods have been developed to describe dental arch morphology, ranging from simple geometric classifications (Hrdlička, 1916), through combinations of linear dimensions (Moorrees, 1959) to various complex curve-fitting procedures (Lu, 1966; Jones and Richmond, 1989; Kasai et al., 1995; Battagel, 1996). The application of fourth-order polynomials of the form:

$$y = a + bx + cx^2 + dx^3 + ex^4$$

provides a number of advantages, the most significant being that the coefficients can be easily interpreted (Richards et al., 1990). The second (x^2 or quadratic) and fourth (x^4 or quartic) terms describe the arch shape while the first (x^1 or linear) and third (x^3 or cubic) terms describe asymmetry.

Lu (1966) drew attention to the inter-dependence of coefficients of simple polynomials. The sum of squares associated with the *k* coefficients cannot be partitioned into *k* parts, each attributable to a single degree of freedom. Consequently, it is not possible to assign accurate values to the relative contributions of symmetry and asymmetry to overall arch shape. The partition can be achieved, however, by using orthogonal polynomials (Kendall, 1959). Lu (1966) presented the first detailed account of fitting orthogonal polynomials to arch data. Unfortunately, although the theory for equally-spaced x-coordinates was sound, Lu's worked example contained some mathematical errors. Furthermore, the extrapolation to non-equally spaced data was flawed. Kendall (1959) provided the correct general parameterization for unequally-spaced data, and this was further simplified to a recursive method by Robson (1959). The aim of the current paper is to address the errors within Lu's orginal paper, and to present a valid extrapolation of his work to unequally-spaced arch data for use in quantitative assessments of arch form.

Editor's Note: Lu's paper (1966) has been cited many times in the dental literature, but researchers have been confused by the nature of the analysis (orthogonal regression is not the same as conventional regression analysis) and most biologists and clinicians have been unable to "break-through" Lu's mathematics, particularly since there are several key errors in the paper. Toby Hughes and his colleagues were invited to submit this paper to facilitate the understanding and application of this useful analytic method.

RESULTS AND DISCUSSION

The theoretical workings presented on pages 1058-1062 of Lu's original paper are substantially correct, with one small exception, and it would be inappropriate to reproduce this section in great detail. We urge those readers who are interested in Lu's adaptation of orthogonal theory that produces a partition of arch shape variance for equally-spaced data to examine the original paper, noting that the calculation for the sums of squares for the intercept of the orthogonal regression on page 1059 reads:

$$SS(b_0\xi_0)=\frac{\sum Y^2}{n}$$

when it should instead read:

$$SS(b_0\xi_0)=\frac{\left(\sum Y\right)^2}{n}$$

Theoretically, Lu's concept cannot be faulted. However, the application of the theory was flawed, particularly in the use of published orthogonal polynomial tables for equally-spaced data (Fisher and Yates, 1957), leading to biased estimates of orthogonal coefficients. In the next section of this paper we reproduce verbatim the worked example from Lu's original paper

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AN ILLUSTRATIVE EXAMPLE

Although the curve-fitting technique is well known in statistical circles, it is thought that the intended audience of this paper might not be as familiar, and for this reason the sample is explained in considerable detail.

The arch width is divided into 14 equidistant intervals defined by 15 points. We have the following observed data:

X (arch base): -7, -6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7

Y (arch height): 27.7, 20.1, 13.9, 9.4, 6.1, 3.4, 1.4, 0, 0.3, 1.3, 3.2, 6.3, 11.0, 18.2, 29.0

The computations are illustrated in Table 1.

$\sum Y\xi_1$ **= 43.2** [c]	$\sum \xi_1^2 = 280$
$\sum Y\xi_2$ **= 6932.2** [a]	$\sum \xi_2^2$ **= 37,128** [a]
$\sum Y\xi_3$ **= -684.4** [a]	$\sum \xi_3^2$ **= 39,780** [a]
$\sum Y\xi_4$ **= -105,958.6** [ab]	$\sum \xi_4^2$ **= 6,466,460** [ab]

Explanatory notes

From observed data, we compute $\sum Y^2$ and $\sum Y$.

2. Column 1 is obtained by adding the *Y* values pairwised from the centre, e.g. 1.4 + 0.3 = 1.7; 3.4 + 1.3 = 4.7, etc.[c]
3. Column 2 is obtained by subtracting the *Y* value corresponding to *X* from the *Y* value corresponding to –*X*, e.g. 1.4 – 0.3 = 1.1; 3.4 – 1.3 = 2.1, etc.[c]
4. Columns 3, 4, 5 and 6 are obtained from the **orthogonal polynomial tables**[a] (Fisher and Yates, 1957) with n = 15. The $\sum \xi_i^2$ are also obtainable from this table. These values are only listed for the upper half of the entire polynomial.[c] For even-powered ξ the omitted half are duplicates of the exhibited half; for odd-powered ξ the omitted half are numerically the same values as the exhibited half, except with the signs reversed.
5. To obtain $\sum Y\xi_1$ and $\sum Y\xi_3$ we obtain the sum of cross products of the differences (Column 2) with Column 3 and Column 5 respectively.[c]
6. To obtain $\sum Y\xi_2$ and $\sum \xi_4$, we obtain the sum of cross products of the sum (Column 1) with Column 4 and Column 6, respectively.[c]

for equally-spaced arch shape data (boxed text, page 4) from Lu's page 1062 onwards, important errors are shown in **bold**, and footnotes (listed below) to the text contain explanations and appropriate corrections.

- **a** ξi represents a polynomial of degree *i* in *x* (i.e. $\xi i = \varphi_i(x_j)$). The original table from Fisher and Yates (1957) specifies a series of pre-multipliers (λ_{in}) for ξ_1-ξ_4 in footnotes beneath the table. Following Fisher (1921), these arbitrary constants are determined conveniently so that ξ_i is an integer for all *j* = 1, 2, ..., *n*. They were not referenced in Lu's paper, and his failure to apply them in subsequent calculations resulted in substantial errors throughout the remainder of the worked example.
- **b** This value was incorrectly signed as negative (-) in Lu's paper resulting in incorrect values for $\sum Y\xi_4$ and $\sum \xi_4^2$.
- **c** Whilst Lu's use of sums and differences is arithmetically correct, we feel it adds unneccesary complexity to the calculations. Indeed, in the one series of calculations where the pre-multiplier was 1 and in which Lu's figures should have been correct, the sign of $\sum Y\xi_1$ was incorrectly reported as positive (+), presumably due to the incorrect summing of the cross-products of the differences. It is preferable to simply list the full table and obtain the cross-products directly. Correct values for $\sum Y\xi_i$ and $\sum \xi_i^2$ are as follows:

$$\sum Y\xi_1 = -43.2$$

$$\sum \xi_1^2 = 280$$

$$\sum Y\xi_2 = 2{,}310.7$$

$$\sum \xi_2^2 = 4{,}125$$

$$\sum Y\xi_3 = 821.3$$

$$\sum \xi_3^2 = 57{,}283$$

$$\sum Y\xi_4 = 2{,}590.2$$

$$\sum \xi_4^2 = 760{,}139$$

Due to the calculational errors noted above plus a number of subsequent arithmetic and typographical errors, the remainder of the worked example was substantially incorrect. The correct parameterization with the associated partition of variation (Table 2) is presented below:

$\sum Y^2 = 2848.55$	$\sum Y = 151.3$	n = 15
$\sum Y\xi_1 = -43.2$	$\sum Y\xi_2 = 2{,}310.7$	
$\sum Y\xi_3 = 821.3$	$\sum Y\xi_4 = 2{,}590.2$	

TABLE 1. Computational table for fitting a fourth order orthodongal polynomial to 15 points

Sum	Difference	ξ_1 [a]	ξ_2 [a]	ξ_3 [a]	ξ_4 [a]
0.0	0.0	0	-56	0	756
1.7	1.1	1	-53	-27	621
4.7	2.1	2	-44	-49	251
9.3	2.9	3	-29	-61	-249
15.7	3.1	4	-8	-58	-704
24.9	2.9	5	19	-35	-869
38.3	1.9	6	52	13	-429
56.7	-1.3	7	91	91	**-1001**[b]

$$b_0 = \frac{\sum Y}{n} = \frac{151.3}{15} = 10.0867$$

$$b_1 = \frac{\sum Y\xi_1}{\sum \xi_1^2} = \frac{-43.2}{280} = -0.1543$$

$$b_2 = \frac{\sum Y\xi_2}{\sum \xi_2^2} = \frac{2310.7}{4125} = 0.5602$$

$$b_3 = \frac{\sum Y\xi_3}{\sum \xi_3^2} = \frac{821.3}{57283} = 0.143$$

$$b_4 = \frac{\sum Y\xi_4}{\sum \xi_4^2} = \frac{2590.2}{760139} = 0.0034$$

SS ($b_1\xi_1$) $= b_1\sum Y\xi_1$ = (-0.1543)(-43.2)
= 6.67

SS ($b_2\xi_2$) $= b_2\sum Y\xi_2$ = (0.5602)(2310.7)
= 1294.45

SS ($b_3\xi_3$) $= b_3\sum Y\xi_3$ = (0.0143)(821.3)
= 11.74

SS ($b_4\xi_4$) $= b_4\sum Y\xi_4$ = (0.0034)(2590.2)
= 8.81

SS ($b_0\xi_0$) $= b_0\sum Y$ = (10.0867)(151.3)
= 1526.12

SS (total) $= \sum Y^2 - SS(b_0)$ = 2848.55 – 1526.12 = 1322.43

TABLE 2. Partition of variation

Source	d.f.	Sum of Squares
Total	14	1322.43
Symmetry ($b_2 + b_4$)	2	1303.26
Quadratic (b_2)	1	1294.45 . . . V_2
Quartic (b_4)	1	8.81 . . . V_4
Asymmetry ($b_1 + b_3$)	2	18.41
Linear (b_1)	1	6.67 . . . V_1
Cubic (b_3)	1	11.74 . . . V_3
Remainder	10	0.76

Total SS explainable by regression:

$$R^2 = \frac{1322.43 - 0.76}{1322.43} = 0.9997$$

Index of total symmetry:

$$A = \frac{V_2 + V_4}{V_1 + V_2 + V_3 + V_4} \times 100$$

$$= \frac{1303.26}{132167} \times 100 = 98.31\%$$

Index of total asymmetry:

$B = 100 - A = 1.69\%$

Index of taperedness:

$$A_2 = \frac{V_2}{V_2 + V_4} \times 100$$

$$= \frac{1294.45}{1303.26} \times 100 = 99.32\%$$

Index of squaredness:

$A_4 = 100 - A_2 = 0.68\%$

Index of lopsidedness:

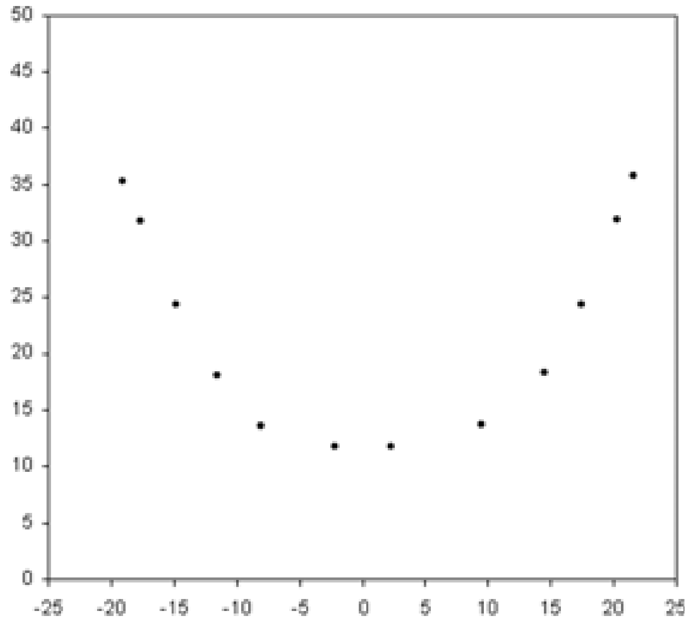

Fig. 1. Graphical representation of cusp tip spacings used to define arch shape.

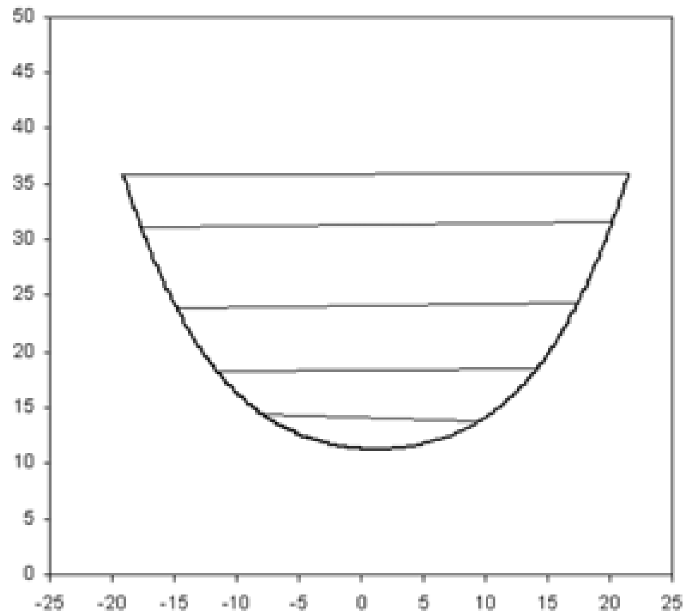

Fig. 2. Arch shape described by an orthogonal fourth order polynomial, with antimeric points joined to illustrate the degree of asymmetry.

$$B_1 = \frac{V_1}{V_1+V_3} \times 100 = \frac{6.67}{18.41} = 36.26\%$$

Index of tiltedness:

$B_3 = 100 - B_1 = 63.77\%$

The procedure outlined above is suitable for data obtained at equidistant increments of X. However, on most occasions, investigators wish to define the dental arch in terms of specific anatomical landmarks. In such cases, the width distances of the arch may increase unequally and the use of tabulated orthogonal coefficients is invalid. Lu's (1966) analytical extension to unequally-spaced data was flawed, irrespective of the numerous typographical errors that were present in the derivation. Lu noted that in computing the following simple polynomial regressions:

$Y = a + b_1x$

$Y = a' + b'_1x + b_2x^2$

$Y = a'' + b''_1x + b'_2x^2 + b_3x^3$

$Y = a''' + b'''_1x + b''_2x^2 + b'_3x^3 + b_4x^4$

it can be shown that:

$$Y = a - b_1\varphi + b_2\varphi^2 + b_3\varphi^3 + b_4\varphi^4$$

where φ_1, φ_2, φ_3, and φ_4 are orthogonal polynomials and their coefficients are the last unprimed coefficients of each of the four equations respectively. However, this is only true in the case of equally-spaced data, a fact overlooked in the original paper. Even were it appropriate for use on unequally-spaced data, the subsequent partition of variance that was presented (cited from Ostle, 1958) was also incorrect, a fact which can be easily verified by application to the equally-spaced data from the same paper.

Kendall (1959) presented the analysis of equally-spaced *x*-values as a special case of the more general usage of orthogonal polynomials for all data-types. Robson (1959) extended the analysis of non-equally spaced *x*-values by presenting a simple recursive procedure to estimate appropriate orthogonal polynomial equations. An alternative construction procedure, also recursive but requiring the solution of *r* linear equations for the construction of $\int_r(x_i)$ was described by Grandage (1958). Robson's (1959) methodology is robust and efficient and remains the method of choice for both equally- and unequally-spaced arch data. For the full methodology, a detailed examination of the original paper is recommended.

A simplified protocol appropriate for fitting a fourth-

TABLE 4. X and Y values for the dental arch used in the illustrative example

X (arch base):	-19.12,	-17.68,	-14.81,	-11.63,	-8.03,	-2.20,	2.22,	9.41,	14.46,	17.38,	20.19,	21.54
Y (arch height):	35.18,	31.78,	24.41,	18.28,	13.61,	11.80,	11.79,	13.77,	18.42,	24.43,	31.84,	35.75

TABLE 3. Partition of variation

Source	d.f.	Sum of Squares	
Total11	935.87		
Symmetry (b_2+b_4)	2	932.19	
Quadratic (b_2)	1	918.21	...V_2
Quartic (b_4)	1	13.98	...V_4
Asymmetry (b_1+b_3)	2	1.00	
Linear (b_1)	1	1.00	...V_1
Cubic (b_3)	1	0.00	...V_3
Residual	7	2.68	

order orthogonal polynomial to arch shape data, and the subsequent partition of variance (Table 3) and derivation of shape-indices is presented below. The worked example uses data from a single arch (Hughes et al., 2001) for illustrative purposes (Fig. 1). The data are listed in Table 4.

$$\xi_0 = \frac{1}{\sqrt{n}}$$

$$\xi_1 = \frac{x-\xi_0\sum x\xi_0}{\sqrt{\sum\left(x-\xi_0\sum x\xi_0\right)^2}}$$

$$\xi_2 = \frac{x-\xi_0\sum x^2\xi_0-\xi_1\sum x^2\xi_1}{\sqrt{\sum\left(x-\xi_0\sum x^2\xi_0-\xi_1\sum x^2\xi_1\right)^2}}$$

$$\xi_3 = \frac{x-\xi_0\sum x^3\xi_0-\xi_1\sum x^3\xi_1-\xi_2\sum x^3\xi_2}{\sqrt{\sum\left(x-\xi_0\sum x^3\xi_0-\xi_1\sum x^3\xi_1-\xi_2\sum x^3\xi_2\right)^2}}$$

$$\xi_4 = \frac{x-\xi_0\sum x^4\xi_0-\xi_1\sum x^4\xi_1-\xi_2\sum x^4\xi_2-\xi_3\sum x^4\xi_4}{\sqrt{\sum\left(x-\xi_0\sum x^4\xi_0-\xi_1\sum x^4\xi_1-\xi_2\sum x^4\xi_2-\xi_3\sum x^4\xi_4\right)^2}}$$

$b_1 = \sum y\xi_1 = 1.00$ $SS_1 = b_1^2$

$b_2 = \sum y\xi_2 = 30.30$ $SS_2 = b_1^2$

$b_3 = \sum y\xi_3 = 0.04$ $SS_3 = b_3^2$

$b_4 = \sum y\xi_4 = 3.74$ $SS_4 = b_4^2$

$$\text{Total SS} = \frac{\sum y^2 - \left(\sum y\right)^2}{n} = 935.87$$

Total *SS* explainable by regression:

$$R^2 = \frac{935.87 - 2.68}{935.87} = 1.00$$

Shape indices can be calculated as outlined earlier. Total symmetry = 99.89% is composed of taperedness (98.50%) plus squaredness (1.5%). Total asymmetry = 0.11% is composed of lopsidedness (100.00%) plus tiltedness (0.00%). The relative magnitudes of these indices are illustrated in Figure 2, which shows the fitted curve with connected antimeres.

CONCLUSION

Lu's original 1966 paper remains of value for illustrating the utility of orthogonal polynomials in the analysis of arch shape data, and clearly the original theoretical considerations were of merit. Unfortunately, the numerous mathematical errors contained within the paper make its application to real-world data misleading and inaccurate. The corrections outlined in the present paper should now enable researchers to carry out more accurate and reliable quantitative assessments of dental arch form using the orthogonal polynomial approach.

ACKNOWLEDGEMENTS

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Dental and mtDNA Relatedness Among Thousand-Year-Old Remains from Huaca Loro, Peru

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ABSTRACT Within and between tombs at the site of Huaca Loro (ca. A.D. 1000) on north coastal Peru, biological relatedness based on 23 dental characters follows statistically significant patterns. mtDNA groupings that are based on lineages inferred from inherited derived D-loop bp sequences have also been traced among the individuals. The present study finds a significant, although rather poorly predictive, relation between mtDNA and dental interindividual linkages. When analyzing the individual dental traits for correspondence to mtDNA "lineages", several significant relations are found and one trait in particular, buccal expansion of the maxillary distal premolar, corresponds highly to mtDNA patterning.

Huaca Loro (ca. A.D. 1000) is a monumental adobe platform mound with a series of deep shaft tombs under and around its base. This mound with a temple at the top is situated in the Poma National Historical Sanctuary on the north coast of Peru. The Sicán Archaeological Project has conducted fieldwork in and around Poma for more than 2 decades (Shimada, 1981, 1990, 1995, 2000). Since 1990, excavations have included recovery of 34 individuals from the East Tomb, West Tomb and North Trench (Shimada et al., 1998, 2000; Shimada and Merkel, 1993).

Comparative odontological (Corruccini and Shimada, 2002) and other analyses (Shimada et al., 1998, 2001; Farnum et al., 1998) pertain to these remains. Corruccini (1998) cites other studies concurring that dental variables are informative for establishing genetic and familial affinities between samples. With the recent addition of mtDNA analysis of the teeth (Shimada et al., 2001), it is possible to examine the dental traits for overall (multivariate) and trait-specific (univariate) concordance with a known genetic variant.

Dental indications of biological relatedness were sought within and between the following nine partitions of the total sample: the Principal West Tomb burial at the center of the Central Chamber, a juvenile male "looking" at him from the Antechamber higher up, two accompanying (possibly sacrificial) females in south and north niches of the Central Chamber, eight scorable females to the south, eight scorable females from the grouping to the north, five inferred "commoners" from the North Trench, and the Principal (adult male) interment and three other individuals (two adult females and a juvenile) from the East Tomb. See Figure 1.

From silicon molds taken by R. Benfer and I. Shimada of maxillary and mandibular arches and dental stone casts made by W. Duncan, 23 dental traits scored by R. Corruccini yielded size-equalized Euclidian distance coefficients between those 29 adequately preserved individuals. The traits were scored for the most part according to Turner et al. (1991) and Corruccini and Potter (1981) on the best preserved side. Considerably more descriptive detail is in the publication by Corruccini and Shimada (2002):

1. Maxillary central incisor labial convexity.
2. Maxillary incisor shoveling.
3. Maxillary double shoveling.
4. Mandibular incisor shoveling.
5. Canine accessory ridge and basal tubercle.
6. Maxillary distal premolar buccal cusp (paracone) diameter.
7. Mandibular distal premolar lingual component mesiodistal diameter.

8-9. Hypocone development on maxillary M1 and M2.
10. Maxillary M3 metacone.
11-13. Cusp number for mandibular M1-3.
14-15. Chord from mesial fovea to central fovea for mandibular M1-2.
16-17. Chord from central fovea to distal fovea (or distal marginal ridge) for mandibular M1-2.
18-19. Chord from central to distal fovea on maxillary M1-2.
20. M_1 bilaterally lost in the presence of M_2 (not an appeal to congenital but rather pathological genetic tendencies).
21. M_2 bilaterally lost in the presence of M_1.
22. Central incisor winging.
23. Third cusp ("entoconid") lingual development on the distal mandibular premolar.

Random resampling of the resultant distances yielded p = 0.006 for the null hypothesis of random odontological intracemetery patterning. Among salient aspects of the statistically significant result (Corruccini and Shimada, 2002) were three particular patterns: the

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morphological cohesiveness of the South females, the heterogeneity among North females, and high similarity among the inferred high-status males of East and West Tombs.

Teeth are useful for ancient mtDNA analysis, and an unrelated earlier study was successful in correlating biokinship measured from both mtDNA and odontometry (Shinoda et al., 1998). A well-preserved tooth was extracted by KS from each individual. Whole teeth were soaked in DNA contaminant removal solution, rinsed in distilled water and dried. mtDNA was extracted from ground tooth powder (Shimada et al., 2001) following a modified protocol (GENRCLEAN kit; BIO 101 Co.). Eluted DNA was amplified by PCR.

RESULTS

Several probably derived mtDNA sequences are identifiable among the interments. Most New World indigenous mtDNA polymorphisms are at the mitochondrial "D-loop" (Gonzalez-Oliver et al., 2001). A combination of RFLP haplotype and D-loop sequence analysis determined variants successfully for 18 West Tomb, 3 East Tomb and 2 North Trench individuals. Sequences encompassing 192 bp were determined in which mutations were found at 25 sites. At 24 sites transition mutations alone occurred, C to T transition observed 16 times and A to G 8 times. In studies involving DNA of ancient samples the original sequences may easily have changed. This potential limitation (implying differential degradation particularly involving A/G versus C/T transitions) may apply also to the celebrated Neandertal studies (Krings et al., 1997).

Among the individuals included in the dental analysis, the pertinent "lineages" implying shared maternal ancestry (of uncertain remoteness) are indicated in Table 1 and Figure 1. These include haplotypes uniting the North niche female and 3 other of the North females, and two distinct haplotypes occurring in 5 of the South females. Thus various women within but not between North and South groupings are related. In addition the East and West Tomb male principal interments (plus one other, North Trench burial) are more tenuously linked. Although the initial finding of relatedness between East and West Tomb principal individuals could not be replicated a second time owing to problems with extracting and reproducing the West individual's DNA, there was no negation of a genetic link between these two.

In comparing the dental distances within these genetically inferred matrilineages versus distance between them, an overall mean of 1.40 is found within the 13 interindividual d's (3+6+3+1) that are intralineage, and d=1.41 for all the remaining interlineage pairs admittedly not arguing for much difference. However, the time depth of the postulated shared maternal ancestry remains unknown, and could vary according to the different haplotypes, whereas the dental variants would be inherited through nuclear DNA recombined from both parents with a generational diluting effect on the matrilineage from ongoing male input.

Furthermore, the North females have an undue influence on results, constituting 46.2% of the intra-lineage d's in Table 1 (6/13) but only accounting for 7.6% of interlineage d's. Since these North females have consistently very large dental d's, they disproportionately inflate the intralineage distance. Accordingly a matched comparison can be designed as indicated in Table 1, contrasting the dental affinities of the 13 DNA-linked pairs with their spatially closest corresponding groups that are unlinked. Those individuals linked by mtDNA pattern are quite consistently (but very slightly) closer in dental pattern than the "unrelated" individuals (paired $t = 3.12$, 12 d.f., one-tailed $p < 0.005$). The p remains < 0.01 (11 df) when the one pair of distances involving East and West Tomb principal individuals, the most tenuous mtDNA linkage, is removed.

TABLE 1. Average linear Euclidian distances over 23 dental traits (converted to normalized shape variables) among individuals belonging to distinct mtDNA types compared to distances among the remainder of their archaeologically positioned group[1]

Lineage	d within	Compared to	d within
First* (3)	1.284	Other East Tomb, North Trench occupants	1.482
Second**(3)	1.566	North Niche to unrelated North females	1.694
Second**(3)	1.552	All other North females	1.573
Third***(3)	1.268	Other South females	1.250
Fourth****(1)	1.219	Other South females	1.250

[1]The number in parentheses is the number of comparisons within a mtDNA "lineage" that can be contrasted with matching average d within the appropriate comparison group.

*East Tomb principal interment, West Tomb principal, and burial 3 from North trench

**North Niche (sacrificial) Central Chamber female d to the other 3 North females of same mtDNA type, compared to her d from unrelated North females. Then the d within the seemingly related 3 North females is compared to the d among all other North females

***South female burials 10, 13 and 14

****South female burials 6 and 8

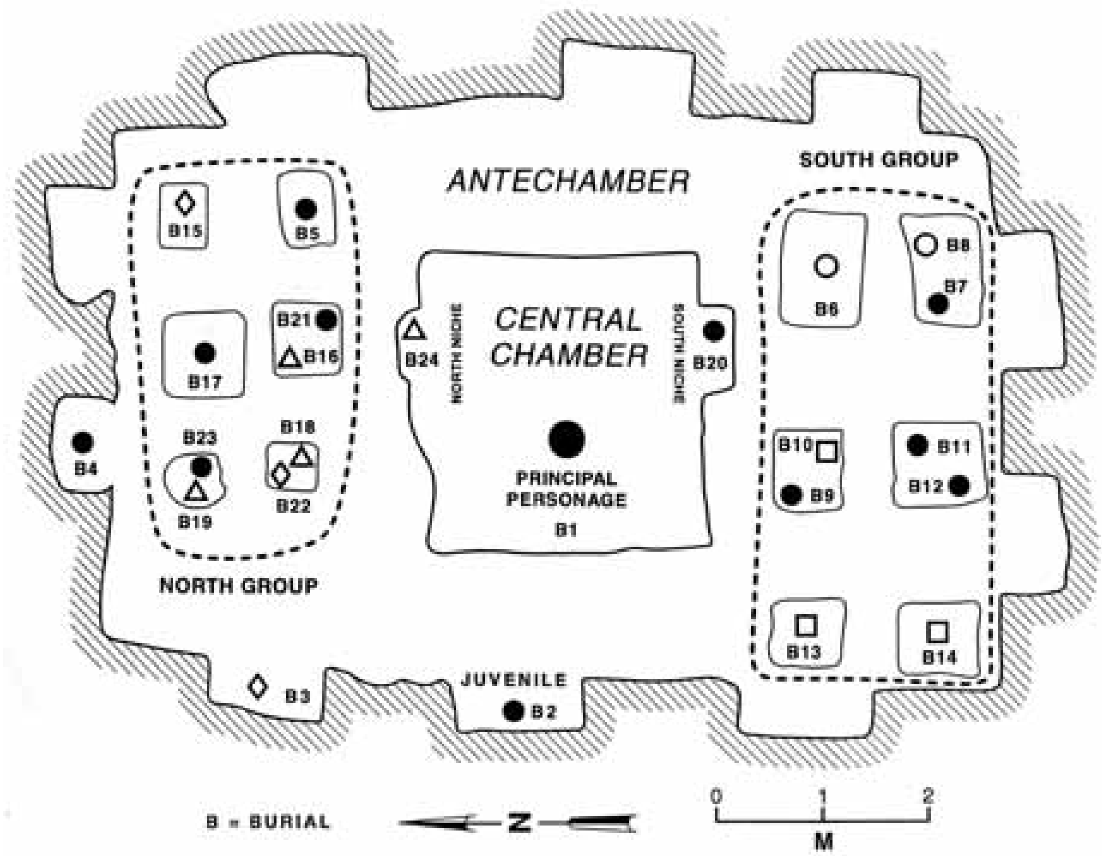

Fig. 1. Spatial distribution of individuals with matching haplotypes within the West Tomb indicated by outlined symbols (i.e., circle, triangle, square, and diamond). The solid black circles represent individuals who are not maternally related to anyone else within the tomb. Only one of the three females represented by diamonds preserved adequate teeth, so there is no intra-group contribution from that haplotype.

Having detected an admittedly subtle yet significant parallel between dental discordance and mtDNA unrelatedness, it is of interest to see which traits correspond most closely within these "matrilineages". This is attempted in Table 2, where the pairwise squared interindividual variance is contrasted within the linked groups and between remaining unlinked individuals. The F-ratio can be used to test the one-tailed proposition that variances shall be smaller among pairs of individuals within mtDNA types, but some consideration of the degrees of freedom is warranted. Only 29 total individuals have yielded (29 X 28)/2 = 406 pairwise differences. The F statistic will be subject to Type I error when read with an inflated 392 and 12 degrees of freedom (406-13-1 d's between and 13-1 d's within haplotypes). At the other extreme, reducing this to a minimalist 16 (17 unlinked individuals minus 1) and 11 (12 individuals involved in mtDNA matches minus 1) degrees of freedom will substantially overcorrect and bring about Type II error.

Furthermore, there is concern over the redundancy effect of testing multiple (23) separate null hypotheses using the same sample of individuals repeatedly. This is the Bonferroni effect (Sokal and Rohlf, 1987:17-18) and can be corrected (probably too harshly, as there would only be partial redundancy) by adjusting the critical probability from the usual p = 0.05 to 0.05/23 = 0.0022. Table 2 shows the two extremes, i.e., maximized d.f. that will be very sensitive, and minimized d.f. with Bonferroni's correction included. The latter sets rather high standards for a significant result. The reality about the null probability is presumably somewhere between those estimates.

Six of the 23 traits indicate significant partition of variance according to mtDNA homogeneity, quite a bit more than the random expectation of 23 X 0.05 = 1.15 results expected to be due to Type I error when the critical p is 0.05. Thus there does seem to be familial resemblance affecting the teeth, although this might be thought unlikely to be detectable unless the shared maternal ancestry is fairly recent or the trait is sex-linked. Looked at another way, the directional F-ratios have a geometric mean well over 1.0, again suggesting overall segregation of dental variance according to mtDNA affinity. That one of the traits, the distal maxillary premolar paracone inflation, clears the Bonferroni hurdle suggests not only that this particular variable is confidently rejecting the null hypothesis,

TABLE 2. mtDNA "lineage" segregation (variance among non-lineage individual pairs divided by variance within mtDNA lineage pairs) over the 23 dental traits for 29 individuals

Trait Number	Among	Within	F-ratio
1	0.349	0.174	2.09
2	0.954	0.634	1.51
3	0.752	1.406	0.53
4	0.848	0.350	2.42*
5	0.585	0.814	0.72
6	72.022	8.094	8.90**
7	54.925	16.000	3.43*
8	2.303	4.111	0.56
9	21.258	14.778	1.44
10	0.188	0.136	1.38
11	1.559	4.400	0.35
12	11.824	26.818	0.44
13	35.154	48.714	0.72
14	17.962	26.400	0.68
15	23.747	19.900	1.19
16	27.527	8.050	3.42*
17	29.201	16.500	1.77
18	16.109	28.889	0.56
19	36.314	48.875	0.74
20	0.118	0.231	0.51
21	0.221	0.154	1.43
22	0.168	0.038	4.37*
23	0.355	0.066	5.36*

*Broadly significant, F for 392 and 12 d.f. yields $p < 0.05$
**Narrowly significant, F for 16 and 11 d.f. yields $p < 0.05/23 = 0.0022$

but clears the way for the conclusion of a significant "treatment effect" among the variables in general.

In addition to the strongly significant paracone diameter, two other of the traits indicating significant similarity among relatives (according to the broader interpretation of d.f.) are metric, the second mandibular molar's mesial occlusal diameter (trait 15) and the mandibular distal premolar's lingual mesiodistal diameter; the latter (trait 7) measures somewhat the same thing as P4 third cusp presence (trait 23) which is also significant. The other non-mensurational traits with significant F in Table 2 are mandibular incisor shoveling and incisor winging.

DISCUSSION

Molar traits figure less than premolar traits in the list of significant results in Table 2, but this may signify little for genetic interpretations of odontological variants. Correspondence to mtDNA affinity may be haphazard for dental traits, although of some interest in analyses of prehistoric samples in regard to the matrilocal/ patrilocal question (Corruccini, 1998).

Comparison to Nichol (1989:Table 4) yields perspective from a vaguely related (Amerind: Pima) sample, for which segregation analysis of individual dental variables estimates the heritable tendencies among families. Nichol does not detect unusually strong genetic segregation for winging or shoveling, although both probably have significant transmissibility (the former fitting a polygenic and the latter a dominant or major gene model best). The distal mandibular premolar lingual extra cusp may fit a dominant or polygenic model with higher transmissibility than winging and shoveling, but not higher than other traits.

The possibility of sex-linked heritability is particularly interesting here due to maternal mode of transmission of mtDNA. However Nichol does not examine sex-linked tendencies. Other studies send mixed signals (Garn et al., 1965; Townsend and Brown, 1978) regarding sex-linkage of overall tooth size. One crown variant, Carabelli's cusp, has been examined thoroughly and does not appear sex-linked in its heritability (Townsend and Martin, 1992; Garn et al., 1966).

Some confidence is gained here for the widely accepted procedure of treating dental variables as genetic indicators. Speculation regarding specific family affinity of individuals, and sex-linked inheritance of variables that correspond to mtDNA "lineages", is just that. One outstanding biological dilemma is provided by the relatively widespread mtDNA connection among North females who are relatively dentally disparate.

Models incorporating incremental generational change in polygenic dental variables, contrasting with the unadmixed maternal mtDNA transmission, could be contemplated. Perhaps the South females, dentally similar, are closely related by way of males such as would come about through, say, a sororal polygynous background, while the North females (who are also distinct in terms of archaeological indicators) might be distantly related through female ancestors such as could result from matrilocal background.

Thus familial resemblance affecting the highly heritable dental traits reverberates somewhat through the mtDNA linkages, but, as is quite expectable, the correspondence is imperfect and susceptible to speculations about matrilocal versus patrilocal biological transmission.

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Tooth Mineralization: A Technical Note on the Moorrees-Fanning-Hunt Standards

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ABSTRACT One of the largest, longitudinal studies of tooth mineralization is that described by Moorrees, Fanning and Hunt (J Dent Res, 1963) based on children growing up in Boston, Massachusetts, and Yellow Springs, Ohio. This short communication provides tables of the means and standard deviations, by sex, in order to make the data more accessible and usable than the graphic form of the information in the original article. Characteristics of the study and applications are discussed.

Tooth formation proceeds in a highly regimented fashion, and the developmental status of formative teeth can be used to assess a child's dental age, which is one measure of his degree of biological maturity. Tanner et al. (1975) comment that, "Maturity differs in an important way from a measurement such as stature, in that the normal growth process takes every individual from one common condition of being wholly immature to another of being wholly mature." Various tissue systems have been used to determine biological age; the most common techniques depend either on formation of the teeth (so-called *dental age*), the morphological development of a set of bones, notably those in the hand and wrist (*bone age*), and the onset of secondary sexual characteristics (*pubertal age*; Marshall et al., 1969, 1970). Dental and bone ages have the advantage that their applicability extends over much of a person's growth span from fetal life through late adolescence.

Formation of the teeth is useful for a variety of reasons. The degree of crown-root formation can be viewed directly on skeletal material (both recent and archeological; Owsley and Jantz, 1983; Conroy and Vannier, 1987; Liversidge, 2000) and analogously on living subjects (e.g., Crossner and Mansfield, 1983. Tooth formation spans almost two decades when the primary and permanent teeth are combined along with the variable third molars (Harris, 2002). Additionally, tooth formation appears to be under substantial genetic control (Pelsmaekers et al., 1997; Merwin and Harris, 1998)—more so than bone age (e.g., Garn et al., 1965; Keller et al., 1970).

Moorrees, Fanning and Hunt (MFH) published the first standards for tooth formation derived from a large series of children followed longitudinally. Longitudinal data are requisite to identify the timing of *onset* of a stage (Smith, 1991). The MFH standards have been applied broadly and still are commonly cited despite their narrow ethnic base (Americans of western European extraction) and the possibility of secular effects speeding up the tempo of tooth formation since the MFH data were collected beginning in the 1930s (Nadler, 1998). Moreover, the long absence of comparable data from other groups of Caucasians has led to a de facto assumption of homogeneity in the growth tempo of contemporary humans. That is, since only the MFH data were available for decades, it was presumed that these standards were applicable globally. More recent studies of other groups has disclosed important systematic differences in the tempos of growth among populations (e.g., Fanning and Moorrees, 1969; Haavikko, 1970; Anderson et al., 1976; Harris and McKee, 1990; Liversidge and Molleson, 1999) as well as in the sequencing of tooth formation (Tompkins, 1996).

A technical difficulty in using the MFH data is that the information was only published in graphical format; there was no supporting table of descriptive statistics. This obliged users to plot each of their cases on a graph, which is tedious, impractical if sample sizes are large, and still required interpolation of the graph to a numerical value of "dental age." Also, the graphs cannot be used to computerize the methodology (cf. Demirjian et al., 1973).

The two-fold purpose of the present note is to supply tables of descriptive statistics for the MFH data and to comment on the nature and limitations of these classic data.

MATERIALS AND METHODS

Moorrees, Fanning and Hunt (1963) scored the formation of 10 teeth from oblique jaw radiographs. These were the maxillary incisors (I1, I2) and all eight mandibular tooth types (I1 through M3). The other maxillary teeth were excluded because superimposition of the complex bony structures of the midface interfered with their consistent visualization on the radiographs.

MFH combined two collections of growth data for their study. Children with chronological ages prior to about 10 years were obtained from headfilms that had

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TABLE 1. Age at attainment (years) of stages of crown-root formation of permanent incisors[1]

Grade	UI1 $\bar{x}$	UI1 sd	UI2 $\bar{x}$	UI2 sd	LI1 $\bar{x}$	LI1 sd	LI2 $\bar{x}$	LI2 sd
Girls								
Ci	•	•	•	•	•	•	•	•
Cco	•	•	•	•	•	•	•	•
Coc	•	•	•	•	•	•	•	•
Cr 1/2	•	•	•	•	•	•	•	•
Cr 2/3	•	•	4.6	0.51	•	•	•	•
Cr 3/4	•	•	•	•	•	•	•	•
Cr c	4.9	0.54	5.7	0.62	•	•	•	•
R 1/4	6.0	0.66	6.6	0.71	4.5	0.51	4.7	0.53
R 1/3	•	•	•	•	•	•	5.2	0.57
R 1/2	6.6	0.71	7.2	0.76	5.1	0.57	5.9	0.65
R 2/3	7.1	0.76	7.7	0.82	5.6	0.62	6.3	0.68
R 3/4	7.6	0.81	8.3	0.87	6.1	0.66	6.7	0.72
R c	8.2	0.86	9.1	0.95	6.6	0.72	7.6	0.80
A 1/2	8.9	0.93	9.6	0.99	7.4	0.79	8.1	0.86
A c	•	•	•	•	7.7	0.82	8.5	0.89
Boys								
C i	•	•	•	•	•	•	•	•
C co	•	•	•	•	•	•	•	•
C oc	•	•	•	•	•	•	•	•
Cr 1/2	•	•	•	•	•	•	•	•
Cr 3/4	•	•	•	•	•	•	•	•
Cr c	5.3	0.59	5.9	0.64	•	•	•	•
R 1/4	6.3	0.68	6.9	0.75	•	•	5.3	0.60
R 1/3	•	•	•	•	•	•	5.6	0.62
R 1/2	6.9	0.74	7.6	0.80	5.2	0.59	6.2	0.68
R 2/3	7.6	0.80	8.1	0.86	5.8	0.64	6.8	0.74
R 3/4	8.1	0.85	8.7	0.91	6.4	0.70	7.4	0.78
R c	8.6	0.90	9.6	1.01	7.0	0.75	8.0	0.84
A 1/2	•	•	•	•	7.7	0.81	8.5	0.90
A c	•	•	•	•	8.1	0.85	9.3	0.98

[1]Codes: cusp (C), crown (Cr), root (R), apex (A). Stages: initiation (i), coalescence (co), cusp outline complete (co), complete (c), interradicular root cleft (cl).

been collected at Harvard University by Harold C. Stuart (e.g., Stuart et al., 1939). World War II interrupted Stuart's collecting, so data also were obtained from the Fels Longitudinal Study in Yellow Springs, Ohio (Roche, 1992). The resulting set of data is somewhat confounded because information on younger and older children were obtained from different populations of "North American White children," and the Fels children had a faster tempo of growth (S. M. Garn, pers. comm.).

Both the Harvard and Fels data were collected in a longitudinal manner (Moorrees, 1959; Roche, 1992), which makes it curious that MFH used a graphical method of probit analysis (e.g., Finney, 1971) to calculate average ages at attainment of each tooth's stage of formation. This wastes the value of the longitudinal data because the *onset* of a stage can be identified directly from successive films, and it treats the data cross-sectionally if the ages of all children *exhibiting* a stage are averaged (Smith, 1991)

Besides the foldout graphs published in the *Journal of Dental Research* (MFH, 1963), these authors made copies available to the interested public in an oversize 11" x 17" format. It was intended that a sheet be used once for a child then filed or discarded. We have used these oversize sheets to "reverse engineer" the process of obtaining numerical values from the graphs. Positions of the means and lengths of the error bars were obtained with drafting instruments and sliding calipers. Some researchers have estimated the means (but not the SD) from the MFH graphs (see, e.g., Ubelaker, 1999; Smith, 1991; Scheuer and Black, 2000), but inconsistencies in their data suggest that they used the smaller graphs in the *Journal of Dental Research*. We were able to base the data in our tables on more precise measurements.

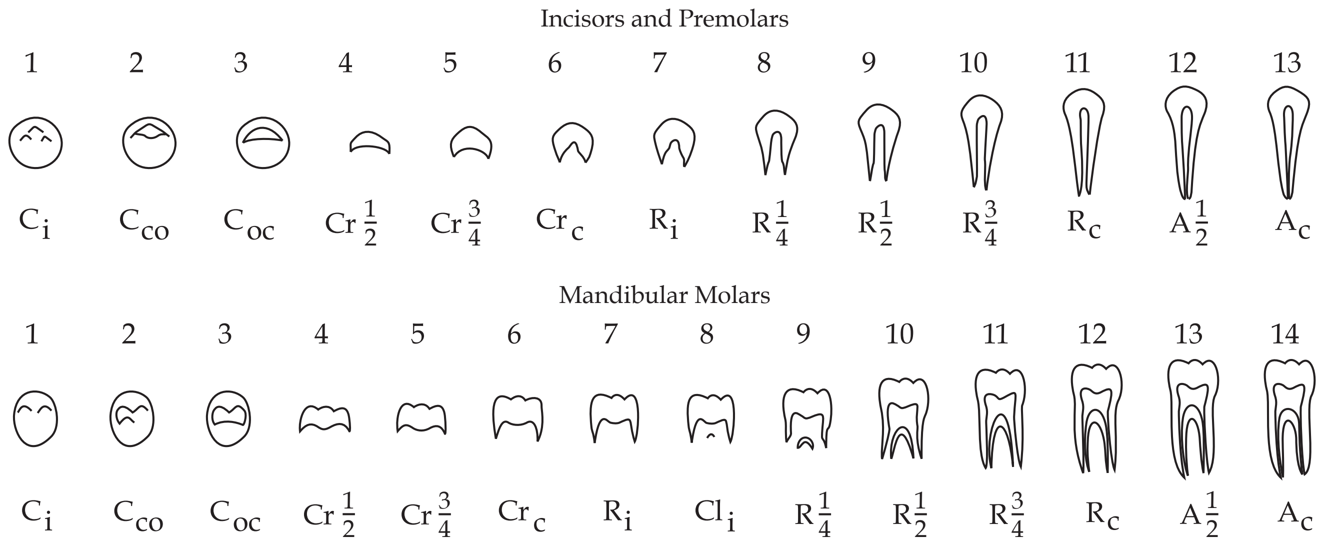

Fig. 1. Diagrammatic illustrations of the morphological grading system for crown-root mineralization of the single-rooted (top) and multi-rooted teeth (bottom). (Modified from Moorrees et al., 1963).

RESULTS

Means and standard deviations by tooth, grade, and sex are listed in Tables 1 and 2. The sample sizes of scorable teeth at each examination were not reported, but they could not have exceeded the 99 Boston children available up to about age 10 (48 boys; 51 girls) nor the 246 Fels children at later ages (136 boys; 110 girls).

According to their text, MFH scored the stages of crown-root formation using a 13-stage (single rooted teeth) or a 14-stage (multi-rooted teeth) scheme. These stages are illustrated in Figure 1 and defined in Table 3. The difference is simply that the initial mineralization of the interradicular (bifurcation) area is an additional stage for molars. The ordinal scale used by MFH was effectively the brain child of Izaac Gleiser and Edward Hunt (1955), also at the Forsyth Dental Infirmary, who previously had created a 15-grade scale to characterize development of the lower first molar. Elizabeth Fanning (1958, 1960, 1961) elaborated this grading scheme to 20 stages for the molars (and 12 for incisors and 18 for premolars). These schemes, except for the incisors, proved to be too fine-grained, leading to confusion between nearly-identical adjacent grades, so MFH settled on a simpler system. The practical value of the resulting morphological criteria is reflected in its adoption in numerous subsequent studies (e.g., Haavikko, 1974; Demirjian et al., 1973; Anderson et al., 1976; Harris and McKee, 1990). Fanning actually scored the radiographs in the MFH study using more grades than illustrated in their article (see Fig. 1). This is obvious from the inclusion of "extra" grades in their diagrams (and see Table 1). For example, R 1/3 and R 2/3 are graphed for some teeth but not others and not included in the grades illustrated in their article. There also is the grade of Cr 2/3 that is graphed only for the upper lateral incisor and only for girls, not boys. It seems to us that these "extra" grades were included when there was an adequate sample for statistical analysis, while the illustrations of the grades were made uniform across all tooth types for consistency.

DISCUSSION

How is dental age figured for a child? The MFH approach—which still is broadly applied—uses their graphs to determine the normative chronological ages at which the formative stage of each scorable tooth has been achieved, then these tooth-specific ages are averaged as the person's dental age. As an example, if the archeological remains of a girl are examined and UI1 and UC both have their root half-formed and the crown of UM2 is three-fourths complete, then the normative tooth specific dental ages are 6.6, 7.1, and 6.2 years, respectively (Tables 1-2). The average dental age would be the arithmetic mean, 6.6 years.

The downside of this method is that the tempos of tooth formation are statistically interrelated (Moorrees and Kent, 1981; Anderson and Popovich, 1981), so there is some unknown redundancy in combining all teeth. This remains an ambiguous issue because the structure of tooth interrelationships has not been described in any detail, but it is evident that it varies among individuals and among populations (e.g., Tompkins, 1996). Some researchers have developed methods of dental aging based on fewer teeth (Haavikko, 1974; Bolanos et al., 2000), but these simplifications were driven by empirical assessments and on the ease of grading tooth stages—not on statistical criteria.

Demirjian and coworkers (1973, 1976) dealt with the issue of statistical interrelationships of formative rate among teeth by generating multiple linear regression equations that weighted each tooth's informational content. They also restricted the number of teeth since, again, intercorrelations are counter to the intuitive

TABLE 2. Age at attainment of stages of crown-root formation for the permanent mandibular buccal teeth

	C		P1		P2		M1		M2		M3	
Grade	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
Girls												
C i	0.5	0.12	1.7	0.24	2.9	0.35	0.1	0.05	3.5	0.41	9.6	1.00
C co	0.7	0.15	2.2	0.28	3.5	0.40	0.2	0.09	3.8	0.43	10.1	1.05
C oc	1.2	0.18	2.9	0.35	4.1	0.47	0.7	0.14	4.3	0.49	10.7	1.11
Cr 1/2	1.9	0.25	3.5	0.41	4.7	0.53	1.0	0.17	4.8	0.54	11.3	1.17
Cr 3/4	2.9	0.35	4.2	0.49	5.3	0.59	1.4	0.20	5.4	0.59	11.7	1.20
Cr c	3.9	0.45	5.0	0.56	6.2	0.66	2.2	0.28	6.2	0.68	12.3	1.27
R i	4.7	0.52	5.7	0.63	6.7	0.73	2.6	0.32	7.0	0.75	12.9	1.32
R cl	•		•	•	•	•	3.5	0.41	7.8	0.83	13.5	1.39
R 1/4	5.3	0.57	6.5	0.69	7.5	0.79	4.6	0.52	9.1	0.96	14.9	1.53
R 1/2	7.1	0.75	8.1	0.86	8.7	0.92	5.1	0.57	9.8	1.01	15.8	1.62
R 3/4	8.3	0.88	8.8	0.97	10.0	1.05	5.5	0.60	10.5	1.09	16.4	1.67
R c	8.8	0.93	9.9	1.03	10.6	1.12	5.9	0.63	11.0	1.13	17.0	1.71
A 1/2	9.9	1.03	11.0	1.15	12.0	1.24	6.5	0.71	12.0	1.23	18.0	1.82
A c	11.3	1.18	12.1	1.26	13.6	1.40	8.0	0.85	13.8	1.43	20.1	2.01
Boys												
C i	0.5	0.11	1.8	0.24	3.0	0.37	0.0	0.09	3.7	0.42	9.2	0.98
C co	0.8	0.15	2.3	0.31	3.5	0.42	0.2	0.11	4.0	0.44	9.7	1.01
C oc	1.2	0.19	2.9	0.36	4.2	0.48	0.5	0.11	4.8	0.52	10.3	1.07
Cr 1/2	2.1	0.27	3.6	0.43	4.7	0.53	1.0	0.17	5.1	0.56	10.9	1.14
Cr 3/4	2.9	0.35	4.4	0.52	5.3	0.59	1.5	0.21	5.7	0.61	11.6	1.20
Cr c	4.0	0.46	5.2	0.58	6.2	0.69	2.1	0.29	6.5	0.69	12.0	1.24
R i	4.8	0.55	5.8	0.64	6.9	0.74	2.7	0.34	7.1	0.76	12.7	1.32
R cl	•	•	•	•	•	•	3.5	0.41	8.1	0.84	13.6	1.41
R 1/4	5.7	0.63	6.8	0.74	7.8	0.83	4.7	0.53	9.3	0.98	14.6	1.50
R 1/2	8.0	0.86	8.5	0.91	9.4	0.99	5.1	0.57	10.1	1.04	15.1	1.54
R 3/4	9.6	1.00	9.9	1.04	10.8	1.13	5.4	0.61	10.8	1.12	15.9	1.62
R c	10.2	1.06	10.3	1.09	11.5	1.21	5.8	0.64	11.3	1.16	16.3	1.67
A 1/2	11.8	1.23	11.9	1.24	12.7	1.30	6.9	0.75	12.2	1.25	17.6	1.79
A c	13.0	1.35	13.3	1.38	14.2	1.46	8.5	0.91	14.2	1.46	19.2	1.95

approach that more teeth should yield more information about a person's biological age.

We are unaware of any study that has made use of the standard deviations in the MFH article, presumably because there is no way of applying these measures of variation in their graphical form unless the chronological age is known—which often is not the case in archeological, forensic and some ethnological settings (e.g, Voors and Metselaar, 1958; Voors, 1973). Now that these values are tabled, they can be used to test for statistical significance, for an individual compared to the group or between the MFH sample and another sample. This can be done on a tooth-specific basis (averaging over individuals) or using the individual as the unit of study (averaging over tooth types) as described by Harris et al. (1993).

In sum, we have reverse-engineered the often-used graphs published by Moorrees, Fanning and Hunt (1963) to provide normative data on American white children for crown-root development of 10 permanent tooth types. The intent is to make these data—means and standard deviations—more usable in terms of statistical applications and computerization of the dental aging method.

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TABLE 3. Definitions of the tooth formation stages[1]

Single-Rooted Teeth	Definitions	Multi-Rooted Teeth
1	Initial cusp formation: amelogenesis has begun on the individual cusp tips.	1
2	Coalescence of cusps: centers of mineralization are merged but the border is not everywhere radiodense	2
3	Cusp outline complete: the coronal outline of the tooth is mineralized.	3
4	Crown 1/2 formed: amelogenesis has proceeded half way to the crown-root as judged from morphology of the radiodense portion	4
5	Crown 1/2 complete	5
6	Crown complete: morphologically, all the crown has mineralized but root formation has not begun.	6
7	Initial root formation: there is a trace of root radiopacity below the crown outline.	7
--	Initial cleft formation: mineralization is evident in the interradicular area.	8
8	Root length 1/4: the radiographic morphology of the root is 1/4 its projected final size.	9
9	Root length 1/2 complete.	10
10	Root length 3/4 complete.	11
11	Root length complete.	12
12	Apex half closed: the lateral borders of the root tip become convex rather than tapered as earlier.	13
13	Apical closure complete: size of the apical foramen is reduced to its mature size.	14

[1]Modified from Harris and McKee (1990).

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Early Christian Pilgrimage to a Byzantine Monastery in Jerusalem—A Dental Perspective

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ABSTRACT The presence of 30 morphological traits was scored on over 1,500 teeth from a bone repository located at St. Stephen's, an urban Byzantine monastery in Jerusalem. The frequencies of dental traits found in the sample were compared with frequencies of the same traits in seven other groups (compiled from published data) in order to determine possible biological affinities of the monks. The Mean Measure of Divergence (MMD) statistic was used to statistically analyze the phenetic/genetic similarity among the groups. The genetic background of this group of monks is interesting because historical sources suggest that many foreigners may have been present in monasteries during this time period as pilgrims. Some argue that their presence is exaggerated, however, and that the majority of monks were from the surrounding region. The results suggest that many of the monks were most likely from the region, but that the presence of foreigners (particularly European foreigners) cannot be ruled out using dental evidence.

A multi-year research project led by Dr. Susan Sheridan of the University of Notre Dame has been focusing on the health and daily life of the inhabitants of a Byzantine monastery in Jerusalem. Over 15,000 bone fragments and 1,500 teeth have been recovered from the burial crypt at the monastery. The skeletal remains indicate that approximately 93% of the collection was male and that more than half of the individuals were over age 40 at the time of death (Sheridan, 2000). The present study is designed to determine the possible genetic affinities of the monks.

Empress Eudocia built the monastery of St. Stephen just north of the Jerusalem city walls in AD 428. The monastery was in use during the height of the Byzantine influence in the Near East, until the Islamic conquest in AD 614, at which time it is believed to have been destroyed. This period was a time of great growth and development in the region. Numerous historical records speak of travelers and pilgrims entering the "Holy Land" at this time (Binns, 1994; Chitty, 1966; Hirschfeld, 1992; Hunt, 1982; Wilkinson, 1976). Many people made pilgrimage, eventually returning home to tell others of their journeys. Others remained in the city once they arrived, as is evident by the population growth in the area at that time (Broshi, 1979).

The identity of those who inhabited the monasteries has recently been debated. Historical records suggest that these monks had been pilgrims coming together from all over Europe, Africa, and Asia (Binns, 1994; Hirschfeld, 1992). Israel Hershkovitz (1988:58) uses this idea to argue "the remains in the graves [around a Byzantine city in the Southern Levant] are those of the native population and not of intrusive monks". However, the monks may be members of the native population themselves, and not "intrusive", as often suggested.

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Scholars now question the validity of historical texts, arguing that the historical records may only reflect the lives of the elite; perhaps indigenous people made up the majority of inhabitants in a monastery (Binns, 1994; Hunt, 1982; Wilkinson, 1976). Although Binns (1994) argues that the monks from Asia Minor appear to be underrepresented historically, he also states, "The monks of the Palestinian desert had a double vocation. They were both pilgrims and monks" (Binns, 1994:

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TABLE 1. Morphological traits used in the study

Trait	Tooth Analyzed	Presence	Absence
Shoveling	Upper First Incisor	3-7	0-2
Double Shoveling	Upper First Incisor	2-6	0-1
Interruption Grooves	Upper Second Incisor	+	-
Tuberculum Dentale	Upper Second Incisor	1-6	0
Canine Mesial Ridge	Upper Canine	1-3	0
Carabelli's Cusp	Upper First Molar	5-7	0-4
Cusp 5	Upper First Molar	1-5	0
Enamel Extensions	Upper First Molar	2-3	0-1
Hypocone absence	Upper Second Molar	0-1	2-5
Parastyle	Upper Third Molar	1-5	0
Cusp 6	Lower First Molar	1-5	0
Cusp 7	Lower First Molar	1-5	0
4-cusp Lower Second Molar	Lower Second Molar	4	5,6
Y-groove Pattern	Lower Second Molar	Y	+, X
Deflecting Wrinkle	Lower First Molar	3	0-2
Distal Trigonid Crest	Lower First Molar	1	0
Protostylid	Lower First Molar	1-8	0

13). Despite numerous primary sources, the origins of monks during this period are not well known.

Dental morphological traits are used in the present study to assess the biological relationships among the monks and other groups. Dental morphological traits have been used in numerous studies to test the genetic relationships of groups (Scott and Turner, 1997; Turner, 1987; Irish, 1998; Scott et al., 1983). These traits are strongly controlled by genetics and their use is particularly important when studying a collection such as this one, where the remains are commingled, as the traits are not strongly influenced by sex or side.

MATERIALS AND METHODS

Using the Arizona State University Dental Anthropology System (ASUDAS), the author analyzed the morphological traits of more than 1,500 teeth from Byzantine St. Stephen's. The collection was scored for over 30 traits; however, for this study only 17 crown traits are analyzed because they are the traits that all eight samples have in common (Table 1). The data for the seven other samples are taken from published material.

The teeth from St. Stephen's were mostly loose teeth found in various layers of a collection of bones excavated from underneath a burial bench in the underground crypt of the monastery (Sheridan, 2000). Because most of the teeth were loose, and the identity of individuals impossible, all possible teeth were scored initially for all traits. Then, each tooth type was looked at to determine which side had the most teeth present. The side represented by the largest number of teeth was chosen to represent the group as a whole.

St. Stephen's was compared with seven other samples. The eight samples are labeled Byzantine St. Stephen's (BSS), Ein Gedi (EGD), Lejjun (LEJ), Early Egypt (EEG), North Africa (NAF), Early Near East (ENE), Historic Near East (HNE), and Historic North Europe (HNO). The Ein Gedi sample is taken from Lipschultz (1996). It represents a site occupied from the Late Hellenistic to the Early Byzantine period (200 BC-AD 640). Its location is less than 50 km from Jerusalem, and occupation was contemporaneous with St. Stephen's monastery. The sample from Lejjun, a modern-day site inhabited by Bedouin in Jordan, is taken from Roler (1992). The samples of Early Egypt (1943 BC-258 AD), and North Africa (19th-20th century) were collected by Irish (1993). The Early Near East (8200-1700 BC), Historic Near East (100BC-present), and Historic North Europe (AD 150-present) samples were taken from a variety of sources, as compiled by Hawkey (1998).

Each of the samples was compared with all other samples using the Mean Measure of Divergence (MMD) statistic. This statistic is a relative measure of biological affinity between the populations and assumes that the phenotype approximates the genotype (Irish, 1998). A lower number indicates similarities in phenetic/genetic affinity, while a higher number indicates a dissimilarity.

RESULTS

The MMD values for each sample comparison are presented in Table 2. The Byzantine collection was most closely related to the samples from Historic North Europe, Early Near East, and Early Egypt. The sample was most divergent from the Ein Gedi sample.

The relatively smaller MMDs found when comparing the site with larger, regional groups (comprised

TABLE 2. Mean Measure of Divergence (MMD) values among all groups taken pairwise

	BSS	HNO	ENE	EEG	NAF	HNE	LEJ	EGD
Byzantine St. Stephen's (BSS)		0.113*	0.129*	0.135*	0.148*	0.160*	0.198*	0.395*
Historic North Europe (HNO)	0.113*		0.223*	0.055*	0.101*	0.225*	0.264*	0.191*
Early Near East (ENE)	0.129*	0.223*		0.126*	0.159*	0.069*	0.047	0.301*
Early Egypt (EEG)	0.135*	0.055*	0.126*		0.022	0.127*	0.118*	0.131*
North Africa (NAF)	0.148*	0.101*	0.159*	0.022		0.267*	0.174*	0.108*
Historic Near East (HNE)	0.160*	0.225*	0.069*	0.127*	0.267*		0.059	0.381*
Lejjun (LEJ)	0.198*	0.264*	0.047	0.118*	0.174*	0.059		0.340*
Ein Gedi (EGD)	0.395*	0.191*	0.301*	0.131*	0.108*	0.381*	0.340*	

* indicates a statistically significant MMD value (P < 0.05).

of multiple sites), and larger MMDs found when comparing the site with smaller, single-site groups is to be expected. The larger, regional groups should show greater affinity with individual sites, while specific groups making up the regional groups will show less affinity for each other, as the larger groups are meant to represent all the smaller groups. The larger, regional groups will be discussed first, followed by the smaller, single-site groups. The MMD values are also illustrated in terms of these group divisions (see Tables 3 and 4).

DISCUSSION

The St. Stephen's monastery group was found to be dentally most similar to Historic North Europe (MMD = 0.113; SD = 0.024), followed by the Early Near East (MMD = 0.129; SD = 0.027) and Early Egypt (MMD = 0.135; SD = 0.027). The standard deviations for each place them well within range of each other. This indicates that the group from the monastery is fairly closely related to all three groups equally. The Historic North Europe group was not strongly related to the Early Near East group (MMD = 0.223), but was very closely related to the Early Egypt group (MMD = 0.055). This may reflect the large number of people from modern populations in this category (including "American whites"). This similarity presents several interesting questions beyond the scope of this paper; however, this interesting correlation should be noted.

The relation of the St. Stephen's group to both groups in the Near East and Europe suggests that the people inhabiting the monastery were perhaps composed of both indigenous and foreign populations. This result is somewhat difficult to determine, as the Near East is a major geographical crossroads. Nevertheless, the statistics suggest that the inhabitants buried at the monastery are strongly related to both Historic North Europeans and people from the Early Near East.

The comparison of the monastery with single-site samples is also interesting. The group from the monastery is more closely related to modern-day Bedouin from the site of Lejjun (MMD = 0.198) than they are to the Ein Gedi group (MMD = 0.395). The Ein Gedi group lived less than 50 km from the Jerusalem monastery during the same time period, yet are quite dentally dissimilar. However, the large MMD values for the Ein Gedi group compared with almost every other group suggests that the group may have been quite homogenous and endogamous (possibly for religious reasons). It is unclear as to why these two groups are so divergent.

TABLE 3. MMD values between St. Stephen's and multi-site samples

	BSS	HNO	ENE	EEG	NAF	HNE
BSS		0.113*	0.129*	0.135*	0.148*	0.160*
HNO	0.113*		0.223*	0.055*	0.101*	0.225*
ENE	0.129*	0.223*		0.126*	0.159*	0.069*
EEG	0.135*	0.055*	0.126*		0.022	0.127*
NAF	0.148*	0.101*	0.159*	0.022		0.267*
HNE	0.160*	0.225*	0.069*	0.127*	0.267*	

* indicates a statistically significant MMD value (P < 0.05).

TABLE 4. MMD values between St. Stephen's and single site samples

	BSS	LEJ	EGD
BSS		0.198*	0.395*
LEJ	0.198*		0.340*
EGD	0.395*	0.340*	

* indicates a statistically significant MMD value (P < 0.05)

CONCLUSIONS

The people living in the Byzantine monastery of St. Stephen's are dentally most similar to Historic North Europeans and other people from the Near East. It is quite possible that the teeth scored came from individuals both foreign and indigenous. There are very few contemporaneous samples to compare the Byzantine group to; the one sample available showed that the two groups were very divergent. Future research will compare the group to more samples and focus on gaining more information on groups similar to the monks, particularly those from the Byzantine period.

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Fourth Molars in the Anthropoidea

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ABSTRACT Fourth molars are not common in the anthropoidea. Orangutans possess the highest frequencies (7-13%) while many genera in the suborder lack the fourth molars. A review of the incidence of M4's in the Anthropoidea is presented and a description of the ontogeny of M4 in *Macaca nemestrina* is described and offered as an explanation of the development of M4's in this taxon.

Polydontia (extra teeth) are found in both extinct (Jungers and Gingerich, 1980) and extant primate taxa (Colyer 1936; Krapp and Lampel, 1973; Lavelle and Moore, 1973; Miles and Grigson, 1990; Schultz, 1935). But as Jungers and Gingerich (1980:1) mentioned in their investigation, "the developmental basis of extra teeth in a particular tooth category remains obscure." Several explanations have been proffered through the years regarding the development of fourth molars, e.g., distal growth of the dental lamina, duplication of the M3 tooth germ and atavism (see in particular Jungers and Gingerich, 1980; Miles and Grigson, 1990). The fourth molar is a rarity in the genus *Macaca*. In an ongoing longitudinal study of dental development in *Macaca nemestrina*, M_4 and M^4 were observed radiographically in a male specimen. Development of the M4 is discussed and the appearance and frequency of M4's in the Anthropoidea is reviewed.

MATERIALS AND METHODS

The parental generation was collected from free-ranging populations in Sumatra and transported to the National Primate Research Center at the University of Washington. These animals were the breeding colony of the animals in the longitudinal growth and development study (Sirianni and Swindler, 1985). After weaning, between 3 and 8 months, the animals were raised and housed separately with their age mates. Radiographs of the head in *norma lateralis* were taken on a regular schedule from about three months to seven years. There were a total of 140 animals in the study, 70 females and 70 males. Tables 1, 2 and 3 present the number of specimens with M4's except for the figures presented of Selenka (1898), Hrdli□ka (1907) and Hooijer (1948) in Table 2 that record the total number of M4's

RESULTS AND DISCUSSION

The M4 was observed in the radiograph of one male and was present in both the maxilla and mandible. Thus of a total sample of 140 *Macaca nemestrina* 0.7% showed this condition (Table 1). A slightly lower percentage has been reported for the presence of M4 for the genus *Macaca* by Miles and Grigson, 0.2% of 901 animals (1990), Lavelle and Moore (1973) recorded 0.3% for 350 *Macaca*

TABLE 1. Incidence of M4's in the Cercopithecidae

Genus	Number of Specimens	M4	Percent
Colobus[1]	1,485	22	4.00
Colobus[2]	140	0	0.00
Colobus[8]	155	5	3.23
Presbytis[1]*	289	1	0.30
Presbytis[2]	100	0	0.00
Presbytis[8]	321	1	0.31
Pygathrix[1]	16	0	0.00
Rhinopithecus[1]	17	0	0.00
Rhinopithecus[3]	11	1	9.10
Simias[1]	10	0	0.00
Nasalis[1]	83	0	0.00
Cercopithecus[1]	1,823	10	0.50
Cercopithecus[2]	350	4	1.10
Cercopithecus[8]	2,460	16	0.65
Erythropithecus[1]	95	3	3.20
Erythropithecus[8]	95	2	2.11
Cercocebus[1]	311	0	0.00
Papio[1]	410	2	0.50
Papio[2]	38	1	2.60
Papio[8]	541	6	1.11
Mandrillus[1]	56	0	0.00
Theropithecus[1]	7	0	0.00
Macaca[1]	901	2	0.20
Macaca[4]	140	1	0.70
Macaca[2]	350	1	0.30
Macaca[8]	2,379	9	0.38

[1]Miles and Grigson (1990) (M^4 and M_4)
[2]Lavelle and Moore (1973) (M^4 and M_4)
[3]Hooijer(1952) (M^4)
[4]This paper (M^4 and M_4)
[8]Krapp and Lampel (1973) (M^4 and M_4)
**P. entellus* and *vetulus* groups

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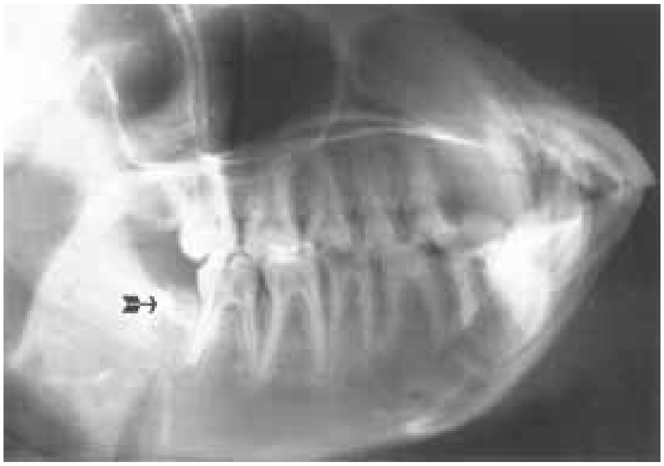

Fig. 1. *Macaca nemestrina* 6.2 years old. M_4 crown visible within its crypt distal to M_3. An interdental bony septum separates M_4 from M_3.

Fig. 2. *Macaca nemestrina* 7.0 years old. M_4 crown complete and initial emergence has begun. There appears to be initial mineralization of M^4 within a crypt.

as having total polygenesis but did not designate which teeth were involved. Krapp and Lampel (1973), in their comprehensive study of dental anomalies of living anthropoidea, found 0.38% of 2,379 macaque specimens with fourth molars.

The presence of extra teeth is low in all living cercopithecids irrespective of the tooth group, and it is interesting to note that most investigations have found a higher incidence of M4's in the subfamily Cercopithecinae than in the Colobinae, (Table 1). A notable exception to this finding is the 9.1% presence in *Rhinopithecus*; however, that figure represents one specimen out of a total of only eleven animals (Table 1). Of all the genera depicted in Tables 1, 2 and 3, *Pongo* has the highest frequency of M4 while colobines and New World monkeys generally have the lowest frequencies. Among living primates, *Pongo* is generally reported to have the highest percentage of M4's (Tables 1, 2 and 3). Gibbons appear to lack development of M4, a fact that has been known since the work of Bateson (1894) as reported in Miles and Grigson (1990). Also, several different genera of both New and Old World monkeys lack the 0ccurrence of M4. The taxonomic presence of M4's in the living Anthropoidea seems to lack any discernible correlation with body mass or facial prognathism since the M4 condition appears in primates ranging in size from gorillas to squirrel monkeys and in primates with both long and short snouts.

The aetiology of polydontia is uncertain. Earlier literature suggested that such occurrences were the result of atavism, although today the term has lost favor in most scientific circles. The heritability of the condition is not completely understood (Finn, 1967); however, there is evidence indicating that polydontia appears more often in isolated populations, and especially among some domesticates, which has suggested thethe involvement of genetic drift as a possible cause to Miles and Grigson (1990).

"Connate teeth" is an anomaly; that is, double teeth, incomplete dichotomy, or syndonty that should be reserved for teeth that are "developed or born together" (Miles and Grigson, 1990; Winkler and Swindler, 1993; Drusini and Swindler, 1994).

In the present case, both the upper and lower M4 would seem to represent the continued distal growth of the dental lamina in that M4 appears distally to the formation of M3. The development of M_4 will be discussed since it is more easily observed and it is assumed that M^4 passed through similar developmental stages. The dental follicle and M_4 appear between 5.5 and 6.2 years. At 6.2 years the crown is present, the cusps are connected but the crown is not complete and it is inclined obliquely at about 45^0 to the occlusal plane (Fig. 1). There is no root development and the cleft has not yet formed, and as seen in this radiograph, an interdental septum separates M_3 and M_4 (Fig.1). In Fig. 2, (7.0 years), the crown appears nearly formed with beginning root formation while the crown is still inclined relative to the occlusal plane. The mesiodistal length of the crown is 8.5 mm which is about 3 mm shorter that the average size of M_3 in male *M. nemestrina* (10.9 mm) and about equal in length to M_2 (8.6 mm) (Swindler, 2002). Thus, this M_4 is within the normal mesiodistal size range for molars of *M. nemestrina*. Unfortunately, this animal was not studied after 7 years of age so there is no information regarding the age of the animal when M_4 emerged.

CONCLUSION

The presence of M4's is rare among living primates, particularly in gibbons, New World monkeys and colobine genera. The orangutans possess the highest frequency of M4's (7 to 13%) of all living anthropoidea. The aetiology of M4's remains uncertain and may represent different developmental processes in different

TABLE 2. Incidence of M's in the Pongidae and Hylobatidae

Genus	Number of Specimens	M4	Percent
Gorilla[1]	546	22	4.00
Gorrila[2]	190	12	6.30
Gorilla[8]	1,409	56	4.00
Pan[1]	467	13	2.40
Pan[2]	100	2	2.00
Pan[8]	1,040	28	2.72
Pongo[1]	229	16	7.00
Pongo[2]	100	6	6.00
Pongo[5]	88	6	6.80
Pongo[6]	388	46	11.90
Pongo[7]	44	6	13.60
Pongo[8]	1,808	200	11.12
Hylobates[1] *	391	3	0.80
Hylobates[2]	150	0	0.00
Hylobates[8]	1,276	9	0.71

[1]Miles and Grigson (1990) (M^4 and M_4)
[2]Lavelle, and Moore (1973) (M^4 and M_4)
[5]Hooijer (1948) (M_4)
[6]Selenka (1898) (M_4)
[7]Hrdlička (1907) (M_4)
[8]Krapp and Lampel (1973) (M^4 and M_4)
**Hylobates* and *Symphalangus*

TABLE 3. Incidence of M's in the Cebidae

Genus	Number of Specimens	M4	Percent
Lagothrix[1]	94	0	0.00
Brachyteles[1]	25	0	0.00
Ateles[1]	232	7	3.00
Ateles[8]	612	6	0.98
Saimiri[1]	110	1	0.90
Saimiri[8]	100	1	0.10
Cebus[1]	651	4	0.60
Alouatta[1]	787	3	0.40
Alouatta[8]	956	3	0.31
Cacajao[1]	23	0	0.00
Pithecia[1]	155	0	0.00
Callicebus[1]	122	0	0.00
Aotus[1]	10	0	0.00

[1]Miles and Grigson (1990) (M^4 and M_4)
[8]Krapp and Lampel (1973) (M^4 and M_4)

species. On the basis of the present specimen, it seems clear that M_4 develops in a normal manner i.e., follicle, initial calcification, crown formation and root formation from a distal extension of the dental lamina, and that tooth formation takes place in a follicle distal to an interdental septum between it and M_3.

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Minutes of the 16th Annual Dental Anthropology Association Business Meeting, April 11, 2002, Buffalo, NY

CALL TO ORDER:
The meeting was called to order at 5:00 PM, by President Edward Harris.

OLD BUSINESS:
No old items were discussed.

NEW BUSINESS:
1. **Election of new officer**. One new officer was elected: Debbie Guatelli-Steinberg (President-Elect, for the term 2002-2004).

2. **Retirement of officers.** Sue Haeussler (past Editor of *Dental Anthropology*) was presented with a commemorative plaque by the Dental Anthropology Association in appreciation for her invaluable contribution for the past 12 years of the 16 years DAA has been in existence. Harris stepped down as President of DAA, and will take over the duties of Editor for the term 2002-2006.

3. **Albert A. Dahlberg Student Prize**. The winner of the 2002 AA Dahlberg Student Prize was awarded to Jaime Ullinger (Arizona State University) for her paper entitled *An Early Christian Pilgrimage to a Byzantine Monastery in Jerusalem: A Dental Perspective*. Jaime will receive $200.00, a certificate of award, a year's free membership in the DAA, and will have her article published in the *journal*.

4. **Albert A. Dahlberg Student Prize Contributions**. On behalf of DAA, Harris thanked the individuals responsible for generous contributions to the fund, including Thelma Dahlberg and Stephen Hershey.

Harris noted that the next mailing of *Dental Anthropology* will contain fliers announcing the Dahlberg prize and forms for membership in the DAA. Please post these fliers in your department and encourage students to compete for the Dahlberg Prize—and encourage membership in the association.

5. **Secretary-Treasurer's Report**. [Diane Hawkey was unable to attend the meeting to present the report, but sent the following information on the status of the DAA Treasury and Membership, read by Joel Irish.] As of April 6th, the DAA has a balance of $2,963.58. This amount consists of $2,187.74 in the AA Dahlberg Prize Fund and $777.84 from the 2001 operations budget. The operations budget does not yet include the 2002 dues which are payable by June 1st.

We have 382 members (142 of whom are members outside of the United States).

6. **Additional topics**. Harris suggested that the Association consider sponsoring a symposium at next year's AAPA meeting and called for topic suggestions. Heather Edgar and Loren Lease will be co-Chairs and co-Organizers of the DAA symposium for the next meeting in Tempe, 2003.

Harris noted with sadness the passing of two of our long-term members, Lucile St. Hoyme and Michael Pietrusewsky.

7. **New President.** At the end of the meeting, Harris passed the official DAA gavel to Joel Irish, who will be the new President (2002-2004).

ADJOURNMENT:
The meeting was adjourned at 5:25 PM by Irish, to allow members to attend the AAPA plenary session scheduled at 5:30.

Submitted by: Diane E. Hawkey
DAA Secretary-Treasurer

DEVELOPMENT, FUNCTION AND EVOLUTION OF TEETH. Edited by Mark F. Teaford, Moya Meredith Smith and Mark W.J. Ferguson. New York: Cambridge University Press. 2000. 314 pp. ISBN 0-521-57011-5. $100.00 (cloth).

With the advent of new technologies and new methods of analysis, there has been an exponential increase in the quantity of information resulting from scientific investigation. These advances have opened new perspectives in research, as well as facilitating new approaches to old questions. Such developments have led to the burgeoning of new fields of inquiry and areas of increased specialization. Unfortunately, with this expansion, it is ever easier as editor Teaford points out, to 'lose sight of the forest among the trees' and dental research is not exempt from this myopia. This ambitious volume, edited by Teaford, Smith and Ferguson, successfully counters this situation by broadening the channels of communication between diverse disciplines and clearly demonstrating the interrelatedness of the multiple perspectives addressing questions of dental morphology. Resulting from the symposium "Teeth: homeoboxes to function" at the 4th International Congress of Vertebrate Morphology at the University of Chicago, the editors have united the contributions of experts from a wide range of perspectives on the morphology of teeth. With chapters that provide overviews of "a wide range of dental topics, linking genes, molecules and developmental mechanisms within an evolutionary framework", this volume demonstrates the numerous approaches that the field of dental morphology now encompasses.

The book is divided into four parts, reflecting the study of increasing levels of organization; molecules and genes, tissues, teeth and dentition, and "macrostructure". In this way, each section provides a foundation for subsequent levels of analysis. Part one, "Genes, molecules and tooth initiation" contains four chapters that attempt to move beyond descriptions of developmental processes at the molecular level to discern the mechanisms involved in tooth formation. In the first chapter, Sharpe discusses the role that homeobox genes play in organogenesis and the potential function these genes and homeoproteins have in the development of the orofacial region, particularly the regulation of tooth position and shape. Chapter two furthers the discussion of developmental control in teeth. Jernvall and Thesleff focus on epithelial enamel knots and their function as mediators of cusp development. Though these structures have long been described, their role in the morphogenesis of single and multicusped teeth has only recently begun to be understood. In the third chapter, Ruch and Lesot discuss the molecular signaling involved in the terminal differentiation of odontoblasts and their role in the formation of dentine. This section concludes with a chapter by Fincham et al., in which the authors review the strides made to date in understanding the role of enamel genes in the assembly and disassembly of the organic extracellular matrix during enamel formation and maturation.

Part two addresses the evolution and development of dental tissues. Building on the third chapter, chapters five and six focus on dentine. Smith and Sansom begin with a synthetic presentation of the evolution of dentine, considering the possible functional advantages of this tissue in the dermal armor of early vertebrates. Chapter six, by Smith, examines the functional interdependence of dentine and pulp during reactionary dentinogenesis (initial tissue formation) and reparative dentinogenesis (repair after injury to the tissue). Sander's provides an overview of the diversity of enamel in reptiles and presents a model for the evolution of prismatic enamel in Mesozoic mammals. In chapter eight, von Koenigswald's paper continues the discussion of mammalian enamel, comparing the enamel microstructure of marsupials and placentals. He asserts that the enamel of both subclasses is formed by the same enamel types, reflecting their common heritage. However, the frequency of these types and the structural elements they form differ. This further differentiation of enamel types between Eutheria and Marsupiala is considered the result of convergent evolution. This section ends with Dean's chapter on the utility of incremental growth marks in enamel and dentine in both fossil and extant species. It is noted that the differential rates of enamel formation in humans and apes are identifiable, yet the rates of dentinogenesis do not vary.

Continuing the pattern of increasing organizational complexity, part three is entitled "Evolution of tooth shape and dentition." This section begins with Smith and Coates' argument that the previously established theories of tooth and jaw development as a functional unit are not supported by more recent data. Based on fossil evidence, they claim that the development of jaws and teeth were distinct events, with "jaws originating for suspension or suction feeding and teeth for food apprehension or sampling…." Zhao et al. provide an overview of the evolution of dentition patterns (number, location and arrangement of differently shaped teeth) and review various models (e.g., gradient, clone, homeobox genes) put forth to explain the developmental mechanisms behind these patterns. The authors find that none of the current models are established by "convincing experimental data", yet assert that ongoing genetic and molecular advances (such as those reported in part one of this volume) will continue to shed light on the mechanisms of dentition pattern formation. Gaengler focuses on the periodontal attachments that have been developed in vertebrates to contribute to an understanding of the phylogeny of dentition "in its broadest sense". In an examination of the polyphyodontic dentition of non-mammalian vertebrates, Berkovitz reports that patterns of replacement in these teeth are related to continuous growth in body size. The most common pattern involves waves of alternating teeth, preventing the organism from an extensive lack of teeth at any point in the process. In chapter 14, Butler presents a detailed review of the variation in primate tooth shape and discusses how these variations are functionally adaptive for an arboreal lifestyle. In the final chapter of the section, Smith reevaluates 'Schultz's Rule' ("the tendency for replacing teeth to come in relatively early in slow-growing, longer-lived species") in light of new data from primates. Additionally, she examines the applicability of this rule to the tooth emergence patterns of other mammals, specifically ungulates. According to her research, Schultz's rule is supported by recent primate data, as well as data from insectivores. However it cannot explain the variation present among the ungulates, particularly the more specialized species.

The focus of the final section is the "Macrostructure and function" of teeth. It begins with Huysseune's exploration of the environmentally induced variability of phenotypes in the dentition of African cichlids. In this case, phenotype varies in relation to the hardness of diet. Chapter 17, by Shellis and Dibdin, addresses the influence of enamel pores on the optical and mechanical properties of this tissue. Rensberger provides a review of the morphologies of mammalian enamel, examining the functional basis for this differentiation. He then examines how the attributes of abrasion and fracture resistance at the microscopic level create selection pressures at the macroscopic level. Jernvall et al. present a case in which they apply their method of classifying molars to the dental evolution of hooved mammals. Based on their analysis, the authors establish five patterns in this evolutionary history and suggest relationships between these trends and patterns of ungulate radiation. The function of postcanine teeth in mastication is the foundation of Lucas and Peters' chapter, in which they examine the advantages of certain tooth shapes in the mastication of particular foods. By comparing the material properties of food (strength, toughness and Young's modulus) and the shape of teeth, specifically the sharpness or bluntness of the occlusal surfaces, the authors highlight the selective advantages of both tooth shapes relative to diet. Teaford's final chapter in the book reintroduces many of the themes presented in the contributed papers of this volume. By reviewing the microscopic and macroscopic perspectives, the insights each has provided and the promise of future contributions, the editor again underscores the importance of the integrative approach to the study of *dental functional morphology*.

By design, this book is relevant to many with research interests in teeth, regardless of specialization. Though the contributing authors come from a wide range of disciplines, most of the papers do not require highly specialized knowledge of the particular field. Many papers begin with an introduction in which terminology is standardized or taxonomic relationships are indicated, making the paper accessible to those outside the author's immediate area of specialization. At the first scan of the book the direct relevance of some of the papers to a dental anthropologist may not be readily apparent. However, upon reading the text, one is continuously reminded of the necessity of being familiar with these many perspectives relating to tooth morphology. With the likelihood of continued advancements in these many related areas, such collaborative endeavors as the book are necessary to make best use of this new information and should be commended and emulated.

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Dental Symposium at 2003 AAPA Meeting

Heather Edgar and Loren Lease, from the University of Ohio, have organized a poster symposium through the auspices of the *Dental Anthropology Association* for the 2003 meeting of the American Association of Physical Anthropologists to be held in Tempe, Arizona, this coming April. Details will be printed in the next issue of *Dental Anthropology*. Please make plans to attend this official *DA* function.

Fig. John T. Mayhall (*above*), the receipt of insignia (*top*, right), and view of the auditorium during the ceremony (*right*).

John Mayhall Receives Honorary Doctorate from the University of Oulu

One of our own, Past-President of the Dental Anthropology Association Dr. John T. Mayhall was awarded an Honorary Doctorate from the University of Oulu this past May, 2002. John was promoted for this distinctive honor by his long-time friend and collaborator Dr. Lassi Alvesalo and Lassi's wife Sirkka, who also hosted John and his wife Melinda while in Finland. A member of the dental faculty at the University of Toronto for over 30 years, John was honored for his numerous publications, research, teaching, and administration. The festivities and ceremonies surrounding the award took three days, where John was among 22 honorary conferees—and one of just five North Americans.

The conferment committee awarded the doctorate based on the facts that:

> Professor ... Mayhall commenced in late sixties his internationally widely acknowledged dental-anthropological research. The research was first directed to original arctic Eskimo populations in the United States and Canada, aiming to explore morphology, prevalence and inheritance of dento-oral structures and health. The research collaboration in Finland has since 1987 consisted of studies on the effects of sex chromosomes on human oral growth, and has produced a number of joint publications. He has been lecturing at the universities of Oulu, Turku and Kuopio, and acted as a referee and opponent of doctoral dissertations at Oulu. A number of Finnish academics has enjoyed his hospitality and professional support at the University of Toronto.

The Finnish conferment committee described the festivities in grand terms: "The conferment ceremonies are alive with music, speeches and festive graciousness, but also jovial lightness and bountiful tables. At the conferment ceremony, the doctoral candidates will receive doctor's insignia—a hat and a sword—and a diploma. The doctor's hat is a symbol of freedom and simultaneously a sign that its carrier has achieved citizenship in the republic of science. The sword symbolizes a weapon of spirit. The doctor will need it in order to fight for what she or he has found to be true, right and just."

The DAA is happy to recognize John's distinctive honor. John is a founding member of the *DAA*, past-president of the Association, and an active and reliable supporter of our group. We wish him well and are pleased to be able to acknowledge his significant academic honor—though it is unlikely that we will get to see his sword at the annual meeting.

The Editor
(with much help from Lassi Alvesalo)

NOTICE TO CONTRIBUTORS

Dental Anthropology publishes research articles, book reviews, announcements and notes and comments relevant to the membership of the *Dental Anthropology Association*. Editorials, opinion articles, and research questions are invited for the purpose of stimulating discussion and the transfer of information. Address correspondence to the Editor, Dr. Edward F. Harris, Department of Orthodontics, University of Tennessee, Memphis, TN 38163 USA (e-mail: eharris@utmem.edu).

Research Articles. The manuscript should be in a uniform style (one font style, with the same 10- to 12-point font size throughout) and should consist of seven sections in this order:

Title page	Tables
Abstract	Figure Legends
Text	Figures
Literature Cited	

The manuscript should be double-spaced on one side of 8.5 x 11″ paper (or the approximate local equivalent) with adequate margins. All pages should be numbered consecutively, beginning with the title page. Submit three (3) copies—the original and two copies—to the Editor at the address above. Be certain to include the full address of the corresponding author, including an e-mail address. All research articles are peer reviewed; the author may be asked to revise the paper to the satisfaction of the reviewers and the Editor. All communications appear in English.

Title Page. This page contains (a) title of the paper, (b) authors' names as they are to appear in publication, (c) full institutional affiliation of each author, (d) number of manuscript pages (including text, references, tables, and figures), and (3) an abbreviated title for the header.

Abstract. The abstract does not contain subheadings, but should include succinct comments relating to these five areas: introduction, materials, methods, principal results, and conclusion. The abstract should not exceed 200 words. Use full sentences. The abstract has to stand alone without reference to the paper; avoid citations to the literature in the abstract.

Figures. One set of the original figures must be provided with the manuscript in publication-ready format. Drawings and graphics should be of high quality in black-and-white with strong contrast. Graphics on heavy-bodied paper or mounted on cardboard are encouraged; label each on the back with the author's name, figure number, and orientation. Generally it is preferable to also send graphs and figures as computer files that can be printed at high resolution (600 dpi or higher). Most common file formats (Windows or Macintosh) are acceptable; check with the Editor if there is a question. The journal does not support color illustrations. Print each table on a separate page. Each table consists of (a) a table legend (at top) explaining as briefly as possible the contents of the table, (b) the table proper, and (c) any footnotes (at the bottom) needed to clarify contents of the table. Whenever possible, provide the disk-version of each table as a tab-delimited document; do not use the "make table" feature available with most word-processing programs. Use as few horizontal lines as possible and do *not* use vertical lines in a table.

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