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HUMAN ODONTOMETRIC VARIATION: AN EVOLUTIONARY AND TAXONOMIC ASSESSMENT

ABSTRACT. — An analysis of biological distances based on human dental size and shape was performed. Phenetic distances expressed by Penrose generalized distance, size, and shape coefficients were computed from permanent crown measurements (mesiodistal and buccolingual) from 42 samples which ranged from prehistoric to modern. A cluster analysis demonstrated that size coefficients basically reflect technocultural development (e.g. hunting/gathering versus agriculture) while shape coefficients bassically reflect known taxonomic, biohistoric associations.

KEY WORDS: Odontometric variation — Human Evolution — Taxonomy.

With the rapidly accumulating wealth of dental metric data, it is now possible to attempt a global synthesis. A synthesis should further our understanding of evolutionary trends. It is also now possible to examine the taxonomic value of dental metric variation. Indeed, the assessment and establishment of taxonomic associations are enduring traditions and concerns in physical anthropology. As a step toward synthesizing and better understanding human dental variation this paper offers a preliminary analysis and interpretation of the phenetic or biologic distances separating human populations.

MATERIALS AND METHODS

When data collected from the literature were combined with those of the author, 42 populations which ranged from prehistoric to modern were available for study (see Appendix for sources of data). Both the mesiodistal and buccolingual dimensions of the complete permanent dentition were used. Data for all populations were derived from both sexes; however, sex ratios did vary from sample to sample. In those cases where authors reported separate odontometric data for males and females, population means were estimated by averaging the male and female means. Since only means and standard deviations are conventionally reported, the choice of a distance statistic was restricted. For anthropometric studies Mahalanobis's D^2 has enjoyed popular use; however, it requires relatively complete records for each individual along with large sample sizes and homogeneity of covariance (Penrose 1954; Rightmire 1970; Corruccini 1975). Consequently, a simpler distance statistic, that of Penrose (1954), was selected. Of note, investigators report good correspondence between Penrose distances and the more elegant multivariate distances such as D^2. Furthermore, the Penrose mean square distance offers the important advantage that it can be partitioned into a size and a shape component.

A fortran computer program was written to compute Penrose size (C^2_Q), shape (C^2_Z), and generalized distance (C^2_H) coefficients. Following Harris and Nweeia (1980), standardization among the variables was obtained by dividing the group means by the standard deviation of the larger sample for all pairwise comparisons. Thereby, variables with large means would not overwhelm those with small means. Penrose distances were then computed for all possible pairs of populations. Each distance was based on 32 variables: the mesiodistal and buccolingual dimensions (means) for the eight permanent teeth in each half of the upper and lower jaws. The size, shape, and generalized distance coefficients were next introduced into a cluster analysis procedure where the amalgamation method was minimum distance (University of California at Los Angeles Computing Facility, Program BMDP1M, Cluster Analysis of Variables).

The possibility of inter-observer error is acknowledged. Techniques and instruments for dental crown measurements do vary. For the present study, data from 24 different sources including the author were assembled. It is assumed that, by using such heterogeneous sources of data, errors would be randomized rather than systematized.

RESULTS

In general, students of morphological variation observe that, as taxonomic criteria, size differences among groups are far less meaningful and trustworthy than shape differences (Corruccini 1973). When taxonomic units vary in size, such differences can greatly outweigh the effects of differences in shape when computing phenetic distances or constructing classifications. Results of the cluster analysis here performed on dental metric variation appear to support this contrast between size and shape as taxonomic indicators.

Figure 1 is a dendrogram based on the Penrose generalized distance which combines both size and shape. Of note is the lowest cluster which shares a common, highly distant separation from the other 38 groups. It is a cluster of four hunter/gatherer samples ranging from Europe to Australia and including the *Homo erectus* sample from Choukoutien. The populations in this cluster obviously differ microtaxonomically; thus, it could be suggested that size factors have apparently outweighed shape factors in isolating and clustering these four distantly related groups. The next major cluster starts with the Bronze Age Thailand sample, ends with the late prehistoric Indians from Missouri, and includes modern Filipinos, American Whites, and Aztecs. It is also quite genetically heterogeneous. In addition, this cluster is, for the most part, comprised of populations which are agriculturally based. Thus, it would again appear that size more than shape accounts for a cluster of unrelated populations. This latter cluster, in turn, joins another comprised of 19 populations, 17 of which are either East Asian or New World. The Bantu sample is clearly the most alienated in the cluster. In general, the cluster is

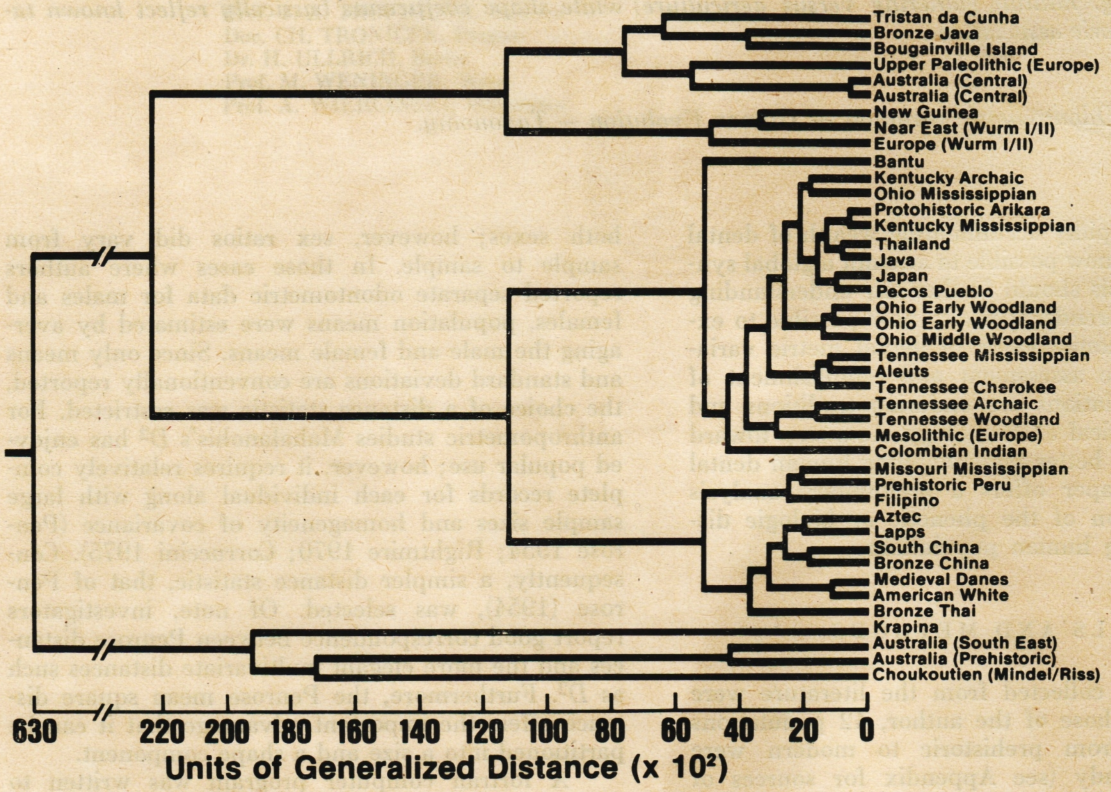


FIGURE 1. *Dendrogram based on Penrose generalized distance (C_H^2) coefficients computed from dental crown measurements.*

characterized by better geographic and biohistoric, i.e. racial, integrity than the previous two clusters. This would suggest a greater influence or expression of shape factors when compared to size factors. The uppermost major cluster of 9 populations reveals geographical as well as technocultural associations. In sum, the dendrogram based on generalized distance reveals the joint influences of size and shape with some indication of the former's influence perhaps exceeding that of the latter.

From the Penrose generalized distances in *Figure I* it is clear (1) that human populations do vary considerably in terms of dental metrics, (2) that the variation reveals some geographical/racial coherence, and (3) that the variation is also somehow related to subsistence and technology (e.g. hunting/gathering versus agriculture or prehistoric versus modern). Indeed, in the numerous studies that document trends in human dental evolution toward decreased tooth size and increased hypodontia, various cultural, technological and dietary changes are often considered significant if not causal (Brace and Mahler 1971; LeBlanc and Black 1974; Brace 1978; Hinton et al. 1980). It is frequently claimed that more recent and more technologically advanced groups possess smaller teeth than earlier pre-agricultural or less technologically advanced groups.

In *Figure II* the groups are clustered by Penrose size coefficients. The dendrogram provides strong confirmation that human tooth size is, in general, associated with technocultural factors. Do note the unorthodox scaling from right to left: 0.0001; 0.001; 0.01 etc. This procedure was elected in order to decompress the clusters for better visual appreciation of how similar various populations are to each other. The lowest cluster of 9 populations is phenotypically separated at a great distance from the other 33 populations. This cluster of early and/or less technologically advanced groups includes Australian aborigines, New Guinea highlanders, Neanderthals, and an *erectus* sample. Common technocultural properties more than racial affinities would seem to be reflected in this cluster. The next cluster above with 6 populations also suggests that variation in dental size is organized around technocultural factors. These spatially, temporally, and genetically varied groups are all agriculturally based. The next major cluster which includes Bronze Age Asians, modern Lapps, Aztecs, and prehistoric American Indians can be categorized as recent, and/or technologically advanced, and/or agriculturally based. The next cluster above which begins with Japan and ends with Tennessee Woodland testifies likewise to the association between tooth size and technocultural factors. With the exception of Pecos Pueblo, all of the New World groups have highly mixed economies where some hunting supplements agriculture. On a miscellaneous note, the marked extent of dental reduction in Europe from Paleolithic to Mesolithic times can be seen by the latter's position in the dendrogram as clustered with modern Java and with a partially agriculturally based New World population. Finally, one can also observe the Upper Paleolithic sample clustered with a megadontic Melanesian sample. In sum, technocultural status and subsistence practices appear to explain a major portion of the size associations depicted in *Figure II.*

Figure III is a dendrogram based on Penrose shape coefficients and allows an assessment of the taxonomic utility of dental shape. The Choukoutien *erectus* sample forms a distant, singular class apart from *sapiens.* Thus, the Penrose shape coefficient efficaciously differentiated one group which is phylogenetically removed from the others. Neanderthal groups from a distant cluster also quite far removed from the more recent populations. The largest major cluster of 21 populations (beginning with Kentucky Archaic and extending down to Colombian Indian) is dominated by New World groups and indicates a common morphological pattern among the populations. Of note, the clustering procedure not only isolated the New World group but also differentiated the more southern samples, i.e. Aztecs, Peruvians, and Colombians, from their more northern counterparts. The presence of Thailand, Japan, Java, and Filipino no doubt reflects the Asian origins of New World people. The grouping of twelve below the New World cluster is somewhat heterogeneous in terms of both time and space. Nonetheless, inspection again reveals the great sensitivity and discriminatory power of clustering procedures based on dental shape. For example, New Guinea and Bougainville Island converge as do Medieval Danes, Lapps, and American Whites. In sum, *Figure III* speaks well for the value of Penrose shape coefficients in determining human biological associations. One should always hesitate in any inference of genotype from phenotype, e.g. dental shape; yet, *Figure III* provides a strong temptation.

DISCUSSION AND CONCLUSION

The present paper is an attempt to distill and summarize much of the data bearing on human dental evolution and variation. Many authors motivated by Brace's leadership (1967) have labored to relate dental metric trends to cultural and technological evolution (Wolpoff 1971). It does appear from the global perspective offered in this paper *(Figure II)* that much of the dental size variation among contemporaneous groups and through time can, indeed, be quite parsimoniously and neatly explained by common evolutionary forces which are somehow enmeshed in technocultural and dietary changes. No other explanation seems to account more conveniently for the close similarities between modern Bantu and Thailand or between American Whites and prehistoric Peruvian agriculturalists. The same conclusion is warranted in accounting for the phenotypic similarities between modern New Guinea highlanders and European Neanderthals or between central Australian and Near Eastern Neanderthals.

The cluster alaysis based on Penrose shape coefficients *(Figure III)* accorded very well with known taxonomic, biohistoric associations and supports the claim (Palomino et al. 1977) that tooth

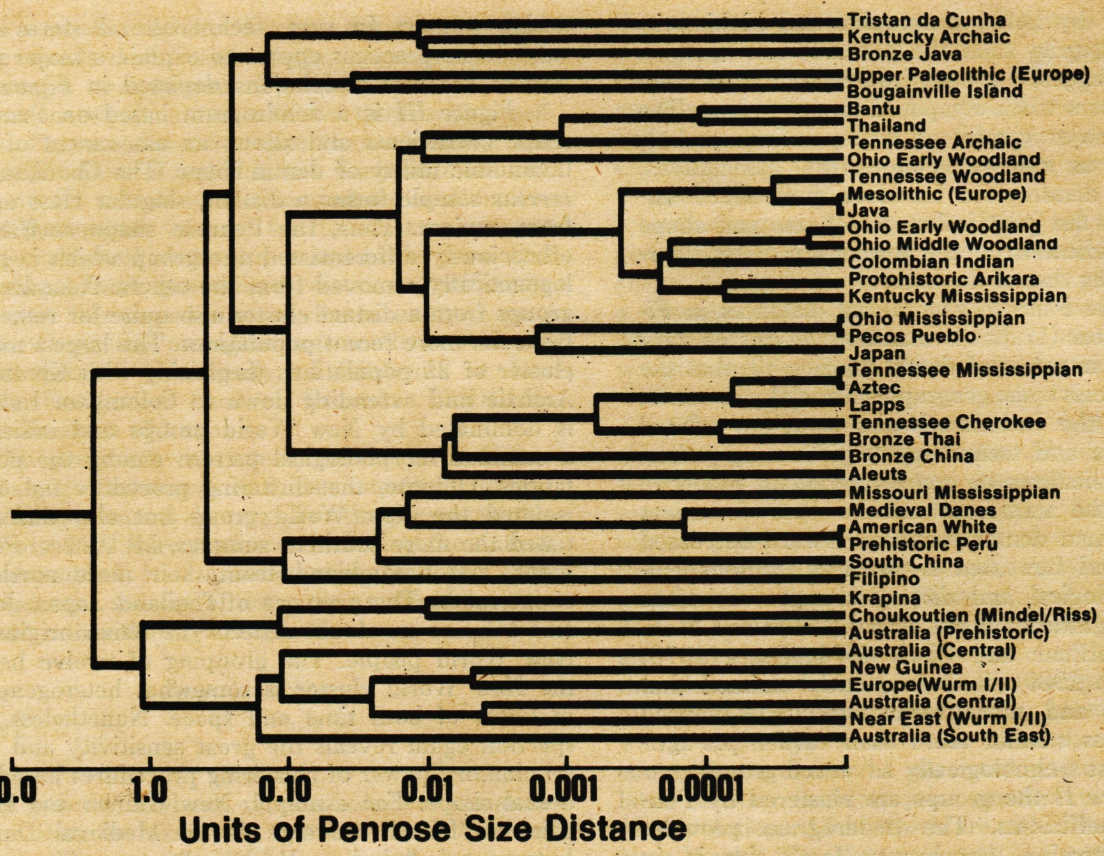
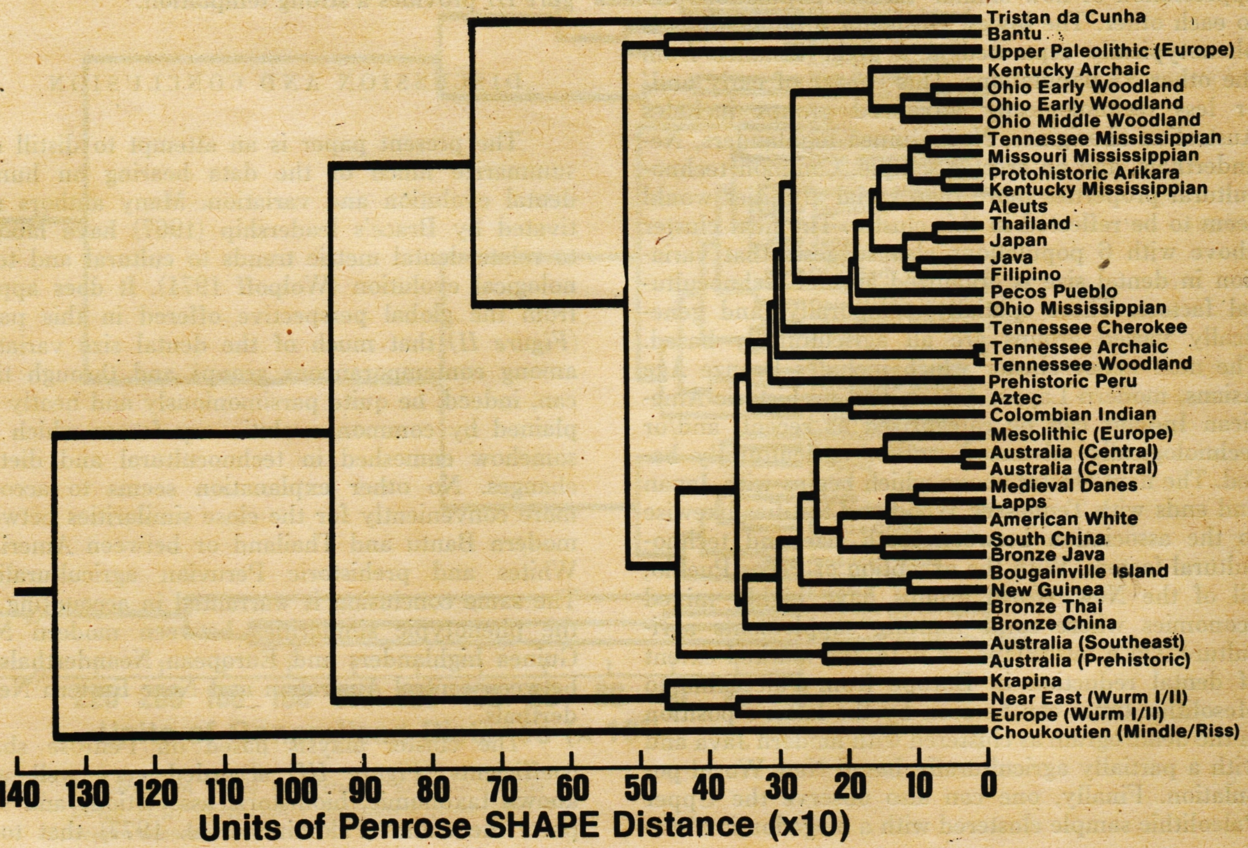


FIGURE II. *Dendrogram based on Penrose size (C_Q^2) coefficients computed from dental crown measurements.*

FIGURE III. *Dendrogram based on Penrose shape (C_Z^2) coefficients computed from dental crown measurements.*



morphology can be a useful indicator of biological distance between human populations. The cluster analysis demonstrated that, after size differences have been partitioned out, geographically, i.e. racially, related groups are morphologically quite distinctive and distinguishable. The strong inference is permitted that the similarity in shape among groups within geographic regions reflects an underlying genetic similarity. Hence, throughout the ubiquitous phylogenetic decrease in tooth size, basic shape distinctions were preserved and remain taxonomically informative. The preferability of shape criteria over size criteria in taxonomic studies is again properly underscored.

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APPENDIX

Sources of Odontometric Data *(Figures I, II, and III).*

Tristan da Cunha —

THOMSEN S., 1955: *Dental Morphology and Occlusion in the People of Tristan da Cunha.* Results of the Norwegian Scientific Expedition to Tristan da Cunha 1937—1938, No. 25. Det Norske Videnskaps-Akademi I Oslo.

Bronze Java, Thailand, Java, South China, Bronze China, Bronze Thailand —

BRACE C. L., 1978: Tooth reduction in the Orient. *Asian Perspectives* 19: 203—219.

Bougainville Island (Nasioi) —

BAILIT H. L., DEWITT S. J., LEIGH R. A., 1968: The size and morphology of the Nasioi dentition. *American Journal of Physical Anthropology* 28: 271—288.

Early Upper Paleolithic and Mesolithic (Europe) —

FRAYER D. W., 1977: Metric dental change in the European Upper Paleolithic and Mesolithic. *American Journal of Physical Anthropology* 46: 109—120.

Australia (Central), Australia (South East), Australia (Prehistoric) —

SMITH P., BROWN T., WOOD W. B., 1981: Tooth size and morphology in a recent Australian Aboriginal population from Broadbeach, south east Queensland. *American Journal of Physical Anthropology* 55: 423—432.

Australia (Central) —

BARRETT M. J., BROWN T., MACDONALD M. R., 1963: Dental observations on Australian aborigines: mesiodistal crown diameters of permanent teeth. *Australian Dental Journal* 8: 150—155.

BARRETT M. J., BROWN T., ARATO G., OZOLS I. V., 1964: Dental observations on Australian aborigines: buccolingual crown diameters of deciduous and permanent teeth. *Australian Dental Journal* 9: 280—285.

New Guinea (Goroka) —

DORAN G. A., FREEDMAN L., 1974: Metrical features of the dentition and arches of populations from Goroka and Lufa, Papua New Guinea. *Human Biology* 46: 583—594.

Near East (Wurm I/II), Europe (Wurm I/II), Choukoutien (Mindel/Riss) —

SMITH P., Regional variation in tooth size and pathology in fossil hominids. *American Journal of Physical Anthropology* 47: 459—466.

Bantu —

SHAW J. C. M., 1931: *The Teeth, the Bony Palate and the Mandible in Bantu Races of South Africa.* John Bale, Sons and Danielsson, Ltd., London.

Kentucky Archaic (North America Prehistoric) —

PERZIGIAN A. J., 1976: The dentition of the Indian Knoll skeletal population: odontometrics and cusp number. *American Journal of Physical Anthropology* 44: 113—122.

Ohio Mississippian (North American Prehistoric), Protohistoric Arikara (North America), Missouri Mississippian (North American Prehistoric), American Whites —

PERZIGIAN A. J., Unpublished Data.

Kentucky Mississippian (North American Prehistoric), Aztec —

RYAN A. S., 1977: Metric trends in the dentition of American Indian populations. Paper presented at annual meeting of Central States Anthropological Society (U.S.A.), Cincinnati, Ohio.

Japan —

GONDA K., 1959: On the sexual differences in the dimensions of human teeth. *Journal of the Anthropological Society Nippon* 67: 151—163.

Pecos Pueblo (North American Prehistoric) —

NELSON C. T., 1938: The teeth of the Indians of Pecos Pueblo. *American Journal of Physical Anthropology* 23: 261—293.

Ohio Early Woodland (two groups) and Ohio Middle Woodland (North American Prehistoric) —

SCIULLI P. W., 1979: Size and morphology of the permanent dentition in prehistoric Ohio Valley Amerindians. *American Journal of Physical Anthropology* 50: 615—628.

Tennessee Mississippian, Tennessee Archaic, Tennessee Woodland (North America Prehistoric) —

HINTON R. J., SMITH M. O., SMITH F. H., 1980: Tooth size changegs in prehistoric Tennessee Indians. *Human Biology* 52: 229—245.

Aleut —

MOORREES C. F. A., 1957: *The Aleut Den-*

tition. Harvard University Press, Cambridge. 196 pp.

Tennessee Cherokee (North American) —

BREITBURG E., (Personal Communication).

Colombian Indian —

HARRIS E. F., NWEEIA M. T., 1980: Tooth size of Ticuna Indians, Colombia, with phenetic comparisons to other Amerindians. *American Journal of Anthropology* 53: 81—91.

Prehistoric Peru —

SCOTT E. C., 1979: Increase of tooth size in prehistoric coastal Peru, 10,000 B. P.—1,000 B. P. *American Journal of Physical Anthropology* 50: 251—258.

Filipino —

POTTER R. H. Y., ALCAZAREN A. B., HERBOSA F. M., TOMANENG J., 1981: Dimensional characteristics of the Filipino dentition. *American Journal of Physical Anthropology* 55: 33—42.

Lapps —

KIRVESKARI P., HANSSON H., HEDEGARD B., KARLSSON U., 1978: Crown size and hypodontia in the permanent dentition of modern Skolt Lapps. *American Journal of Physical Anthropology* 48: 107—112.

Mediaeval Danes —

LUNT D. A., 1969: An odontometric study of Mediaeval Danes. *Acta Odontologica Scandinavica,* Supplement 55, 27: 1—173.

Krapina —

WOLPOFF M. H., 1979: The Krapina dental remains. *American Journal of Physical Anthropology* 50: 67—114.

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CORRUCCINI R. S., 1973: Size and shape in similarity coefficients based on metric characters. *American Journal of Physical Anthropology* 38: 743—754.

CORRUCCINI R. S., 1975: Multivariate analysis in biological anthropology: some considerations. *Journal of Human Evolution* 4: 1—19.

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HINTON R. J., SMITH M. O., SMITH F. H., 1980: Tooth size changes in prehistoric Tennessee Indians. *Human Biology* 52: 229—245.

LEBLANC S. A., BLACK B., 1974: A long term trend in tooth size in the Eastern Mediterranean. *American Journal of Physical Anthropology* 41: 417—422.

PALOMINO H., CHAKRABORTY R., ROTHHAMMER F., 1977: Dental morphology and population diversity. *Human Biology* 49: 61—70.

PENROSE L. S., 1954: Distance, size and shape. *Annals of Eugenics* 18: 337—343.

RIGHTMIRE G. P., 1970: Bushman, Hottentot and South African Negro crania studied by distance and discrimination. *American Journal of Physical Anthropology* 33: 169—196.

WOLPOFF M. H., 1971: *Metric Trends in Hominid Dental Evolution.* Case Western Reserve University Studies in Anthropology, No. 2, Cleveland, Ohio. 244 pp.

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