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The Ancient Inhabitants of Jebel Moya Redux: Measures of Population Affinity Based on Dental Morphology

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ABSTRACT This paper reexamines some of the methods and craniometric findings in the classic volume *The Ancient Inhabitants of Jebel Moya (Sudan)* (1955) by Mukherjee, Rao & Trevor, in light of recent archaeological data and relative to a new dental morphological study. Archaeological evidence characterises these inhabitants as having been heavily influenced by outside sources; yet they managed to establish and maintain their own distinctive culture as seen in the site features and surviving artefact collections. The dental study, modelled after the original craniometric-based investigation and using the same or similar comparative samples, detected complementary indications of outside biological influence. In the study, up to 36 dental traits were recorded in a total of 19 African samples. The most influential traits in driving inter-sample variation were then identified, and phenetic affinities were calculated using the Mahalanobis D^2 statistic for non-metric traits. If phenetic similarity provides an estimate of genetic relatedness, these affinities, like the original craniometric findings, suggest that the Jebel Moyans exhibited a mosaic of features that are reminiscent of, yet distinct from, both sub-Saharan and North African peoples. Together, these different lines of evidence correspond to portray the Jebel Moya populace as a uniform, although distinct, biocultural amalgam. Copyright © 2006 John Wiley & Sons, Ltd.

Key words: dental anthropology; trait variation; phenetic affinity; Sudan; Africa

Introduction

Fifty years ago R. Mukherjee, C.R. Rao and J.C. Trevor (1955) wrote *The Ancient Inhabitants of Jebel Moya (Sudan)*. The volume served as the official report on skeletal remains recovered by the Wellcome Expedition between 1911–1914 at the site—which was initially thought to date to 1000–400 BC (Addison, 1949). Originally entrusted to such luminaries as Sir Arthur Keith and G.M. Morant by the Trustees of the Estate of Sir Henry Wellcome, the long overdue report was finally delegated to the aforementioned authors after a series of setbacks and delays, including two world wars. Unfortunately, the 40-year hiatus between excavation and analysis proved to be catastrophic for the remains, which were poorly housed and moved repeatedly after shipment to England (Mukherjee *et al.*, 1955; Addison, 1956). As a result, of more than 3000 skeletons originally excavated, only 98 crania, 139 mandibles and a handful of post-cranial elements survived to allow study. Nevertheless, the three authors were initially optimistic that a serviceable report could still be produced, as field cards for 2903 skeletons

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had been saved; these cards contained osteological observations and measurements made by Expedition physical anthropologists in the field. The outlook turned negative, however, when over three-quarters of the cards were found to contain erroneous or useless data (Mukherjee *et al.*, 1955; Gerharz, 1994); thus, the mood of the authors at the time of writing can be summarised by the statement '... what at present survives of it [Jebel Moya skeletal sample] represents hardly a tithe of the original, and anthropological science has been denied a unique opportunity to deal with a substantial body of data, for which the field measurements are, alas, only too imperfect' (Mukherjee *et al.*, 1955: 31).

Despite these and other deficiencies, the report was notable for its groundbreaking use of advanced statistical analyses to understand the Jebel Moya population's make-up and affiliations. Although retaining terms and some methodology equated with racial typology of early physical anthropology (see Keita, 1990, 1992, 1996), Mukherjee and associates applied the now-common Mahalanobis D^2 distance to craniometric data for the first time; the result was a measure of group divergence between Jebel Moya and 19 other African samples (Mukherjee *et al.*, 1955). This fresh approach, directed away from typology and towards the concept of population affinity, would not otherwise become a focus of physical anthropologists until the 1970s and beyond (Berry & Berry, 1972, 1973; Greene, 1972; Howells, 1989; Konigsberg, 1990; Keita, 1990, 1992; Irish, 1993, 1998a,b,c,d, 2005; Brace *et al.*, 1993; Johnson & Lovell, 1994; Prowse & Lovell, 1996; Hemphill, 1998; Roseman & Weaver, 2003; Pietrusewsky, 2004; among many others).

Recent reappraisals of the long-neglected archaeological collections (e.g. Caneva, 1991; Gerharz, 1994) revealed that, although Jebel Moya 'has been a centre of controversy' (Adams, 1977: 718) and its 'reputation ... suffered' (Caneva, 1991: 263), important information can still be gleaned for both descriptive and comparative purposes. This positive outlook, together with new dating (Gerharz, 1994) prompted the current first author to find and study the site's skeletal remains while conducting other research; the intent was to see whether the old sample might yet be able to provide some new insights about the site inhabitants. Thus, using the now-classic Mukherjee *et al.* (1955) report as a model, the present study will contrast the remains with the same or similar African comparative samples originally used. However, in place of D^2 distances based on craniometrics, highly heritable dental variants are compared among samples using an analogous distance statistic for non-metric traits. The objectives are to: (1) compare results between studies; and (2) further explore the biological 'place' of Jebel Moyans in African prehistory—a subject that has received scant attention over the last half century. In the process, several peopling scenarios based on inter-region cultural parallels will be addressed.

The site

Jebel Moya is located 250 km south-southeast of Khartoum, Sudan, in the southern part of the Gezira plain between the White and Blue Niles (Figure 1) (Martin, 1921; Addison, 1949; Mukherjee *et al.*, 1955). According to Addison (1949), author of the official archaeological site report, 'Jebel Moya' refers to a massif that actually

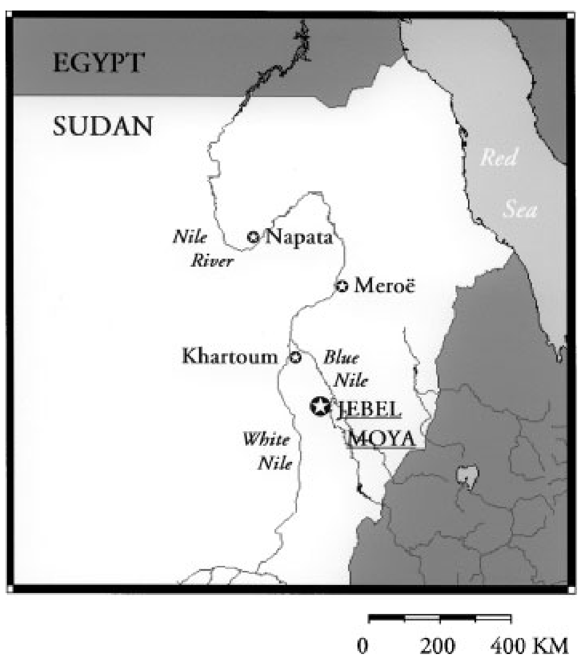

Figure 1. The location of Jebel Moya relative to some other landmarks mentioned in the text.

comprises a compact group of granite hills interconnected by ridges and valleys; however, the name later came to be associated with the archaeological site situated within the north-easternmost of these valleys.

The site is roughly 104,000 m^2 in area, of which about a fifth was excavated during the Wellcome Expedition's four field seasons (Addison, 1949; Mukherjee *et al.*, 1955). Because a permanent water source was present (Williams *et al.*, 1982), numerous habitation and grave sites were established to accommodate the nomadic pastoralists who occupied the valley (Addison, 1949; Gerharz, 1994). An enormous quantity of cultural material, much of which evidenced extra-regional influence in manufacture and design, was recovered from both types of sites; artefacts included thousands of lipstuds, beads and other ornaments, hundreds of stone tools, some imported objects (see below), and 'several tons of potsherds' (Addison, 1956: 4; see also Martin, 1921). Like the skeletal remains, only a fraction of these items survive today to allow study (e.g. Caneva, 1991). Regarding graves, nearly 2800 were cleared by excavators; some contained multiple inhumations, whereas others were empty or consisted of animal burials. The number of human skeletons recovered, many of which were fragmentary, was 3137. Both sexes and all age groups were represented (Addison, 1949; Mukherjee *et al.*, 1955). Addison (1949: 40) noted that the dead appeared to 'have been disposed of with scant ceremony'. Almost half of the individuals were buried without grave offerings. Most others received only a few offerings—often ornaments that may have been worn in life (Addison, 1949). Moreover, there was little evidence of a standard mortuary practice; tomb types differed in appearance, body position varied widely, and graves 'were oriented to every point of the compass' (Addison, 1949: 40; 1956: 4; also Gerharz, 1994).

As mentioned, the site was originally thought to date to 1000–400 BC, corresponding to much of the Napatan period of Upper Nubia, a region located along the Nile north of Khartoum. Addison (1949) based this dating on the presence of Napatan objects within some burials and, primarily, on four distinct strata observed during the course of excavation. He later modified his interpretations (Addison, 1956), placing the site occupation between 500 BC–AD 400. The new timing corresponds to the Meroitic period; objects from this later Nubian culture were also found in a number of burials (Hofmann, 1967; Gerharz, 1994). More recently, Gerharz (1994) found that both sets of dates are incorrect. Problems with stratigraphic information (Caneva, 1991; Gerharz, 1994) led to misinterpretations by Addison. The new dating is thought to comprise three main temporal phases between ca. 5000–100 BC. Phase I (ca. 5000–3000 BC) was identified by the presence of diagnostic dotted wavy line pottery; however, the original settlement horizon was said to have been destroyed by the later inhabitants (Gerharz, 1994). Surviving site features, including all graves, date to Phase II (ca. 3000–800 BC) and Phase III (800–100 BC). By comparing their horizontal distribution, Gerharz (1994) assigned individual graves to phases. When uncertain, the date could still be determined if Nubian and certain other grave goods that originated in Phase III were present. These determinations are corroborated by 3rd millennium BC radiocarbon dates from basal layers of the site (Clark & Stemler, 1975; Clark, 1984; Haaland, 1987).

Materials and methods

The report by Mukherjee *et al.* (1955) provided a relatively complete study of the remnant Jebel Moya sample, including inventory, ageing and sexing of the remains. They also attempted a 'racial' description and comparison of the crania (i.e. Negroid, non-Negroid) by stratum, using a number of obscure and more common non-metric characteristics. However, the primary analysis of interest involved the affinity study between Jebel Moya and 19 comparative samples using seven cranial measurements (e.g. maximum length, breadth, height, etc.) in the males only; refer to the report for a full list and descriptions. Use of additional measures was deemed impossible due to the large number of calculations required for the Mahalanobis statistic in pre-computer 1955. Comparative samples came from Egypt, Nubia, Ethiopia, Kenya, and several west African locales; they are listed on the left side of Table 1 in the

Table 1. Jebel Moya and comparative samples used in the craniometric and dental studies

Craniometric samples from Mukherjee *et al.* (1955)			Same, equivalent, or similar samples used in present dental study[a]				
Sample	Origin	Period	Sample	Origin	Cultural affiliation	Date	No.
Jebel Moya (JEM)[b]	Sudan	Prehistoric	Jebel Moya (JEM)[c]	Jebel Moya	Jebel Moya Complex	c. 3000–100 BC	58
Egyptian 'E' (EGE)	Egypt	26–30th Dynasty	Egyptian 'E' (EGE)	Giza	26–30th Dynasty	664–332 BC	62
Naqada (NAQ)	Egypt	Predynastic	Naqada (NAQ)	Naqada	Predynastic Egyptian	c. 4000–3200 BC	65
Badarian (BAD)	Egypt	Predynastic	Badarian (BAD)	Badari	Predynastic Egyptian	c. 4400–4000 BC	40
Sedment (SED)	Egypt	9th Dynasty	Saqqara (SAQ)	Saqqara	4th Dynasty Egyptian	2613–2494 BC	41
Egypt 'Negroes' (EGN)	Egypt	Dynastic	El Hesa (HES)	El Hesa	Roman Period Egyptian	AD 200–400	72
Kerma (KER)	Nubia	12–13th Egypt Dynasty	Kerma (KER)	Kerma	Kerma Classique Nubian	1750–1500 BC	63
A-Group (AGR)	Nubia	<4th Egypt Dynasty	A-Group (AGR)	Faras to Gamai	A-Group Nubian	3000 BC	52
B-Group (BGR)	Nubia	4–6th Egypt Dynasty	NA[d]				
C-Group (CGR)	Nubia	7–16th Egypt Dynasty	C-Group (CGR)	Faras to Gamai	C-Group Nubian	2000–1600 BC	62
D-Group (DGR)	Nubia	18th Egypt Dynasty+	D-Group (DGR)[e]	Faras to Gamai	Pharonic Nubian	1650–1350 BC	38
Meroitic (MER)	Nubia	1st–2nd cents AD	Meroitic (MER)	Semna; Faras/Gamai	Meroitic Nubian	100 BC–AD 350	94
X-Group (XGR)	Nubia	3rd–6th cents AD	X-Group (XGR)	Semna; Faras/Gamai	X-Group Nubian	AD 350–550	63
Taita (TAI)	Kenya	20th cent. AD	Kenya (KEN)	Kenya, Tanzania	Kikuyu, Swahili, Chaga, Pare	19–20th cent. AD	114
Cameroons (CAM)	Cameroon	19th cent. AD	Nigeria–Cameroon (NIC)	Nigeria, Cameroon	Efik, Ibibio, Boki, Anyang	19th cent. AD	57
Tigrean (TIG)	Ethiopia	19th cent. AD	Ethiopia (ETH)	Ethiopia, Eritrea	Tigre, Amhara, Danakil, etc.	19–20th cent. AD	40
Ashanti (ASH)	Ghana	19th cent. AD	Ghana (GHA)	Ghana	Ashanti, Fanti	19th cent. AD	47
Tetela (TET)	Congo, Gabon	19th–20th cents AD	Congo (CNG)	Congo, Gabon	Teke, Kongo, Binga, etc.	19–20th cent. AD	52
Fernand Vaz (FRV)	Gabon	19th cent. AD	Gabon (GAB)	Gabon	Fang, Nkomi, Lumbo, etc.	19–20th cent. AD	39
Ibo (IBO)	Nigeria	Recent	Togo–Dahomey (TOD)	Togo, Benin	Ewe, Fon	19th cent. AD	25

[a] See text for details of sample comparability between studies.
[b] Three-letter abbreviations of craniometric study samples used in Figures 4 and 5.
[c] Three-letter abbreviations of dental study samples used in Tables 2 and 4, and Figure 3.
[d] The 'B-Group' is no longer recognised as a distinct Nubian cultural period, so there is no equivalent sample used in the dental study.
[e] 'D-Group' is referred to today as Pharonic Nubians.

same order as described in Mukherjee *et al.* (1955). Considering the limited availability of such data at the time, these samples represent a decent cross-section of North and northern sub-Saharan African cultures.

The dental samples

The present investigation emulates the craniometric study in several ways, most notably by comparing the same or similar samples. Ideally, dental data would have been collected in all of the samples originally used by Mukherjee *et al.* (1955). Unfortunately, many are now dispersed, lost, possess an insufficient number of recordable dentitions, or are otherwise unavailable. An overview of the samples and their comparability to those in the craniometric study is presented below and in Table 1. In-depth information is available in Irish (1993, 1997, 1998a,b,c,d, 2005).

The Jebel Moya dental sample (abbreviated JEM in tables and subsequent figures) consists of 58 specimens with the most complete upper and lower dentitions of the 98 crania. The comparative Egyptian 'E' (EGE), Naqada (NAQ) and Badarian (BAD) samples are exactly the same as those used by Mukherjee and associates. Saqqara (SAQ) replaces the original Sedment sample; although the former is several hundred years more recent, both samples are from the same area in Lower Egypt. Likewise, El Hesa (HES) replaces the Egyptian 'Negroes' sample; El Hesa is younger but, again, both were recovered near Aswan in extreme southern Upper Egypt. Kerma (KER) is the same early Nubian sample used in the original study. The A-Group (AGR), C-Group (CGR), D-Group (DGR), Meroitic (MER) and X-Group (XGR) samples are not those used in the first study, but derive from the same Nubian populations, so may be considered equivalent. It should be noted that although the term 'D-Group' is retained to facilitate comparability to the original study, this culture is most commonly called Pharonic Nubians today (Nielsen, 1970; Adams, 1977; Calcagno, 1986). Moreover, the 'B-Group' (again see Table 1) is no longer considered a distinct Nubian cultural period; thus, there is no corresponding dental sample in this one case. Kenya (KEN) consists of Bantu-speakers from Kenya and Tanzania who are closely related biologically and linguistically to the original Taita (Kitson, 1931). Nigeria–Cameroon (NIC), Ethiopia (ETH), Ghana (GHA), Congo (CNG), and the Gabon (GAB) samples are also closely related to, or come from, the same population as Cameroons, Tigrean, Ashanti, Tetela and Fernand Vaz, respectively. Only Togo–Dahomey (TOD) is not directly equivalent to the original Ibo sample from Nigeria, although both derive from spatially proximate west African locations. In total, 1084 dentitions in these 19 samples were analysed for the present study.

Dental trait recording

The study is concerned with morphological variation of the permanent dentition. Thirty-six non-metric traits employed in previous African affinity studies (Irish, 1993, 1994, 1997, 1998a,b,c,d, 2000, 2005, 2006; Irish & Guatelli-Steinberg, 2003) were recorded in the 19 total samples (see list in Table 2). The rationale for selecting them has been previously detailed (Irish, 1993, 1998d, 2005); of critical importance, however, is the high genetic component reported for many of these traits (Scott, 1973; Larsen, 1997; Scott & Turner, 1997), which makes them ideal for biodistance analyses (Larsen, 1997).

Excluding midline diastema, each trait is part of the Arizona State University Dental Anthropology System (ASUDAS) (Turner *et al.*, 1991). The ASUDAS procedures have proven reliable in many studies (e.g. Scott, 1973, 1980; Turner, 1985a, 1987, 1990, 1992; Sakuma & Ogata, 1987; Haeussler *et al.*, 1988; Turner & Markowitz, 1990; Irish & Turner, 1990; Irish, 1993, 1994, 1997, 1998a,b,c,d, 2000, 2005; Jackes *et al.*, 2001). Using 23 rank-scale reference plaques to standardise scoring (Turner *et al.*, 1991), bilateral traits are recorded in both antimeres and the side with highest expression counted (Turner & Scott, 1977). This approach assumes scoring for the maximum genetic potential (Turner, 1985a). Due to minimum trait sexual dimorphism (Scott, 1973, 1980; Smith & Shegev, 1988; Bermudez de Castro, 1989; Turner *et al.*, 1991; Hanihara, 1992; Irish, 1993), it is also standard procedure to pool the sexes (Irish, 1997). The ASUDAS is described fully in Turner *et al.* (1991) and Scott & Turner (1997).

Quantitative analyses

Once recorded, frequencies of occurrence for the 36 traits were calculated for each sample, after having first been dichotomised, as necessary, into categories of present or absent based on their appraised morphological thresholds (Haeussler *et al.*, 1988). For the most part, dichotomisation was done according to standard procedure (Turner, 1985b, 1987; Irish, 1993). However, a small subset of traits was considered present at higher ranks (e.g. LM1 cusp 7 is considered present at ASU grades 2–4 compared to standard 1–4) to differentiate better between North African and sub-Saharan samples (for additional discussion see Irish, 1993). Trait dichotomisation is required (Sjøvold, 1977) before submitting the rank-scale data to most multivariate statistics (see below). The resulting frequency table contains information that is useful for identifying and qualitatively comparing the sample trait variation.

A more definitive way to assess this variation is to use a distance statistic, which provides a quantitative estimate of inter-sample biological divergence based on similarities among traits. Rightmire (1999: 2) related that '...it is all but certain that these phenotypic [dental] patterns reflect underlying genetic variation'; thus, it is assumed that phenetic similarity approximates or is an estimate of genetic relatedness (Scott *et al.*, 1983). Of many distance statistics previously used, the authors and others (e.g. Berry & Berry, 1972; Sjøvold, 1973, 1977; Greene, 1982; Scott *et al.*, 1983; Turner, 1984, 1985a; Konigsberg, 1990; Turner & Markowitz, 1990; Lukacs & Hemphill, 1991; Ishida & Dodo, 1997; Irish, 1997, 1998a,b,c,d, 2000, 2005; Donlon, 2000; Jackes *et al.*, 2001) have often employed two: the modified Mahalanobis D^2 statistic for non-metric traits derived by Konigsberg (1990), and the mean measure of divergence (MMD) which incorporates the Freeman and Tukey angular transformation to correct for low (≤ 0.05) or high (≥ 0.95) frequencies and small sample sizes ($n \geq 10$) (Berry & Berry, 1967; Sjøvold, 1973, 1977; Green & Suchey, 1976).

To emulate Mukherjee *et al.* (1955) most closely, the modified Mahalanobis statistic was used to compare Jebel Moya with the comparative samples. It extends the original Mahalanobis generalised distance by utilising a tetrachoric correlation matrix with the dichotomised dental data. Correlations are calculated within each sample and pooled using sample size for each trait pair to find the weighted average correlation. As such, this statistic is effective in correcting for the small sample sizes that characterise many archaeological skeletal collections. Furthermore, it provides an advantage over other methods (incl. MMD) by adjusting for phenotypic correlations between traits; this adjustment avoids any undue weight on groups of characteristics that co-occur. Additional methodological details and the formulae are listed in Konigsberg (1990), Konigsberg *et al.* (1993), Ishida & Dodo (1997) and Bedrick *et al.* (2000).

Prior to applying the D^2 statistic, several problematic dental traits were deleted, including those with many small sample sizes (e.g. <10 cases) and shared high (i.e. fixed at or close to 100%) or low frequencies (0%). Correspondence analysis (CA), using the SPSS Procedure Correspondence, was then used to quantify which remaining traits vary most among the samples. This technique has been used in many prior anthropological studies (Greenacre & Degos, 1977; Schneider, 1986; Sciulli, 1990; Gerharz, 1994; Kitagawa *et al.*, 1995; Coppa *et al.*, 1998; Irish, 2005, 2006). A variant of principal components analysis (PCA), CA factors non-metric data comprising columns and rows of a contingency table and displays them in reduced space to illustrate association. Among other output, a biplot is produced that combines column and row points to identify which traits are most influential relative to the samples: see Irish (2005) for a complete description of using CA with ASU dental data. Publications by Greenacre & Degos (1977), Clausen (1988), Benzécri (1992) and Phillips (1995) provide methodological details.

An additional step, employed here for the first time, was to quantify the amount of intra-sample trait variability affecting the Jebel Moya dentitions.

Evidence of cultural diversity in site features and artefacts prompted Addison (1949) and other researchers to suggest that the Jebel Moyans may have been biologically diverse as well. Among other approaches, Mukherjee *et al*. (1955) tested for intra-sample variability by calculating craniometric standard deviations and coefficients of variation to contrast with those in a 'racially homogeneous' comparative sample. Until now, no statistics were available to allow a corresponding comparison for ASUDAS rank-scale/ordinal data. However, in the following it is shown how the multiple threshold model that characterises ASUDAS trait variation (e.g. Scott, 1973) can be used to find relative variability in such data.

To provide some context for this method, a normal distribution is assumed in the multiple threshold model. As such, when examining one sample it is possible to estimate the threshold values by reading the standard normal cumulative backward from probabilities to quantiles. For example, with a trait that comprises five ordered states (i.e. grades of 0, 1, 2, 3, 4) of expression, the four thresholds can be located on this distribution for a large pooled sample where some grand mean and standard deviation are assumed. To find the relative mean and relative standard deviation for any subsample (i.e. relative to grand mean and standard deviation), the method of maximum likelihood (Eliason, 1993) can then be used to estimate these two parameters while keeping the threshold values fixed for the total sample. This approach is only relevant with traits scored on a rank scale, not those few initially recorded at a binomial/dichotomous level (see below). With binary traits there are two parameters to be estimated—the mean and standard deviation—but only one 'piece' of information: the trait frequency.

Calculations of rank-scale sample means and standard deviations were undertaken for each selected trait using a program written by the second author in R (http://cran.r-project.org/). This program (available upon request from the first author) uses areas under a normal curve between thresholds based on cumulative frequencies to fit such distributions using maximum likelihood. To illustrate, when LM1 cusp 7, a trait considered here to comprise five states, was compared among samples (refer to Table 2), the numbers of specimens exhibiting each grade were initially listed by sample in 19 rows. These frequencies were summed down each column to yield five grand sample totals which were then cumulatively summed across this row. Next, the first four of these cumulative sums were divided by the final sum to yield cumulative relative frequencies. A normal distribution with a mean of 5.0 and a standard deviation of 1.0 was then used to determine quantiles. These two values are arbitrary; alternative selections work just as well and would not impact on the relative variability comparisons (Thomas, pers. comm., 2005). In the ensuing step, the four quantiles are assumed to come from a normal distribution with mean and standard deviation values unknown; maximum likelihood was used to estimate these values. Finally, the 19 estimated standard deviations were compared to describe relative variability, and identify the sample(s) exhibiting most variability for LM1 cusp 7 expression. The process was repeated with additional traits to help quantify whether Jebel Moya is dentally diverse relative to the remaining samples.

Lastly, once the edited list of dental traits has been submitted to the Mahalanobis statistic, a matrix of D^2 values among samples is produced. However, a more intuitive manner in which to interpret the results is to present the patterning of inter-sample affinities visually using multi-dimensional scaling (MDS). Procedure Alscal in SPSS 12.0 was used here. MDS provides a spatial representation of 1 to n dimensions consisting of a geometric configuration of points (the dental samples) (Kruskal & Wish, 1978). Therefore, plotting of samples into groups indicates degrees of relationship. In the present case interval-level MDS was used, as the large number of traits causes the matrix of distance values to approximate continuous data.

Results

Dental trait frequencies

Table 2 lists the 36 dental traits for the 19 samples. Samples are listed in the same order as that on the right side of Table 1. The percentage of individuals exhibiting each trait and the total number of individuals scored are presented.

Table 2. Dental trait percentages (%) and number of individuals scored (n) for Jebel Moya and the 18 comparative samples[a]

Trait[b]		JEM	EGE	NAQ	BAD	SAQ	HES	KER	AGR	CGR	DGR	MER	XGR	KEN	NIC	ETH	GHA	CNG	GAB	TOD
Winging UI1	%	9.1	4.3	6.0	5.6	2.8	6.4	5.4	2.6	16.3	5.6	12.8	5.7	4.0	3.5	0.0	0.0	9.1	3.5	10.0
(+=ASU 1)	n	33	47	50	36	36	63	56	39	49	54	39	35	99	29	36	23	22	29	20
Labial Curvature UI1	%	39.3	17.7	12.5	50.0	9.1	65.0	38.5	43.5	57.9	46.2	24.4	38.9	37.5	60.0	36.4	53.9	40.0	75.0	64.3
(+=ASU 2–4)	n	28	17	8	20	11	20	13	23	19	13	41	18	16	5	11	13	5	8	14
Palatine Torus	%	0.0	0.0	0.0	5.6	0.0	0.0	1.8	0.0	0.0	5.2	10.7	10.2	0.9	0.0	10.8	2.2	3.9	8.1	0.0
(+=ASU 2–3)	n	31	47	50	36	39	68	55	24	42	58	84	49	108	55	37	46	52	37	25
Shoveling UI1	%	0.0	15.4	14.3	25.0	0.0	29.4	22.2	15.8	10.5	15.4	38.9	25.0	7.1	42.9	28.6	41.7	0.0	12.5	54.6
(+=ASU 2–6)	n	25	13	7	16	7	17	9	19	19	13	36	12	14	7	7	12	5	8	11
Double Shoveling UI1	%	0.0	0.0	0.0	0.0	0.0	15.8	0.0	0.0	0.0	0.0	4.6	6.7	6.7	0.0	0.0	0.0	0.0	0.0	0.0
(+=ASU 2–6)	n	27	16	7	16	8	19	7	21	17	11	44	15	15	7	7	13	5	8	11
Interruption Groove UI2	%	0.0	4.2	9.1	10.0	33.3	50.0	9.1	4.4	45.0	27.8	36.2	40.0	11.5	25.0	23.1	7.1	12.5	0.0	6.3
(+=ASU +)	n	35	24	11	20	9	22	11	23	20	18	47	15	26	8	13	14	8	6	16
Tuberculum Dentale UI2	%	5.9	25.0	27.3	36.4	66.7	61.9	8.3	13.0	35.0	23.5	40.5	42.9	36.0	25.0	41.7	20.0	42.9	66.7	37.5
(+=ASU 2–6)	n	34	24	11	22	6	21	12	23	20	17	42	14	25	8	12	15	7	6	16
Bushman Canine UC	%	10.0	6.3	0.0	0.0	0.0	6.5	16.7	11.5	0.0	0.0	19.6	10.0	13.0	22.2	5.6	7.7	8.7	6.3	35.3
(+=ASU 1–3)	n	40	32	22	22	10	31	18	26	26	19	51	20	46	27	18	26	23	16	17
Distal Acc. Ridge UC	%	11.5	7.1	15.0	12.5	0.0	13.6	18.2	33.3	12.5	18.2	31.0	21.4	36.6	57.9	27.3	62.5	64.7	58.3	61.5
(+=ASU 2–5)	n	26	28	20	16	6	22	11	18	16	11	42	14	41	19	11	16	17	12	13
Hypocone UM2	%	73.3	84.2	90.9	86.7	95.7	75.4	91.7	73.7	76.1	81.4	78.5	85.7	78.0	90.9	66.7	83.8	94.6	86.2	100
(+=ASU 3–5)	n	45	38	44	30	23	57	48	38	46	43	79	35	91	44	33	37	37	29	21
Cusp 5 UM1	%	5.3	5.7	17.5	10.0	0.0	8.7	24.1	12.0	40.0	15.8	10.9	21.2	14.8	25.8	7.4	38.1	18.2	18.8	30.8
(+=ASU 2–5)	n	38	35	40	20	9	46	29	25	25	19	64	33	81	31	27	21	11	16	13
Carabelli's Trait UM1	%	18.2	72.7	68.4	64.7	100	47.6	51.6	73.1	75.0	54.6	58.6	60.7	55.2	38.5	60.7	59.4	61.1	69.2	58.8
(+=ASU 2–7)	n	33	33	38	17	16	42	31	26	24	22	58	28	87	39	28	32	18	26	17
Parastyle UM3	%	0.0	0.0	0.0	0.0	0.0	2.7	5.4	0.0	2.5	2.6	0.0	4.0	2.7	0.0	0.0	0.0	3.0	4.0	4.6
(+=ASU 1–5)	n	38	26	28	23	15	37	37	40	40	38	58	25	73	40	24	31	33	25	22
Enamel Extension UM1	%	2.6	6.4	15.2	6.5	0.0	3.3	4.0	5.0	2.3	4.3	13.5	6.7	1.1	20.0	5.6	22.0	2.6	0.0	27.3
(+=ASU 1–3)	n	38	47	46	31	18	61	50	40	43	47	89	45	93	50	36	41	38	30	22
Root Number UP1	%	77.3	62.5	76.1	70.6	89.7	63.8	80.4	72.4	83.0	71.1	53.9	70.7	68.6	64.7	53.6	57.9	62.8	58.8	65.0
(+=ASU 2+)	n	22	32	46	17	29	47	51	29	47	38	78	41	102	51	28	38	43	34	20
Root Number UM2	%	96.3	72.7	73.5	80.0	82.6	62.2	90.2	77.8	86.7	86.7	81.7	90.3	90.6	76.7	85.0	91.7	76.9	84.0	95.0
(+=ASU 3+)	n	27	22	34	15	23	37	41	27	30	30	60	31	85	43	20	36	39	25	20
Peg-Reduced UI2	%	0.0	1.8	0.0	10.3	6.1	0.0	1.6	4.8	0.0	6.7	1.9	4.8	0.0	6.9	2.6	0.0	15.4	11.1	5.3
(+=ASU P or R)	n	49	57	60	39	33	24	63	42	56	60	54	42	30	29	38	37	13	9	19
Odontome P1–P2	%	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	5.3	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	3.6	0.0
(+=ASU +)	n	50	42	49	31	12	59	41	36	38	33	82	31	85	41	27	34	34	28	21

Congenital Absence UM3	%	2.0	15.4	3.7	8.6	20.0	30.8	16.7	4.4	7.1	6.8	7.3	17.8	3.0	1.9	12.8	2.4	0.0	0.0	4.2
(+=ASU −)	n	51	52	54	35	35	65	60	45	56	59	82	45	100	52	39	42	47	35	24
Midline Diastema UI1	%	2.9	0.0	0.0	5.3	0.0	3.0	3.3	5.9	0.0	1.7	8.7	3.6	15.3	9.1	10.3	2.8	17.4	16.7	10.5
(+ 0.5 mm)	n	34	52	52	38	33	66	60	34	52	58	23	28	72	44	39	36	23	30	19
Lingual Cusp LP2	%	48.7	61.9	95.7	79.2	66.7	61.5	86.4	80.0	72.4	58.8	86.0	100	40.0	69.0	37.5	86.2	66.7	72.7	83.3
(+=ASU 2–9)	n	39	21	23	24	12	52	22	35	29	17	50	18	15	29	8	29	15	11	18
Anterior Fovea LM1	%	64.0	17.4	18.8	9.1	14.3	32.0	43.8	20.0	100	28.6	40.0	57.9	69.2	85.0	57.1	85.7	71.4	61.5	91.7
(+=ASU 2–4)	n	25	23	16	11	7	25	16	15	16	7	35	19	13	20	7	21	7	13	12
Mandibular Torus	%	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+=ASU 2–3)	n	45	51	58	40	37	72	60	43	50	55	81	52	21	37	12	39	36	23	23
Groove Pattern LM2	%	48.9	29.6	45.8	35.3	22.7	18.2	41.3	63.4	50.0	39.4	10.5	29.0	83.3	58.3	66.7	39.4	75.0	68.4	55.0
(+=ASU Y)	n	45	44	48	34	22	66	46	41	46	33	76	38	18	36	12	33	28	19	20
Rocker Jaw	%	2.1	13.7	24.1	10.3	24.3	20.0	5.3	5.9	27.3	10.9	22.0	13.2	14.3	5.4	0.0	7.9	0.0	4.4	8.3
(+=ASU 1–2)	n	47	51	54	39	37	70	57	34	44	46	82	53	21	37	12	38	35	23	24
Cusp Number LM1	%	6.5	2.3	7.9	0.0	0.0	1.9	0.0	3.1	5.7	0.0	6.9	5.7	5.6	37.0	8.3	46.4	11.8	31.6	20.0
(+=ASU 6+)	n	46	43	38	24	10	53	28	32	35	17	72	35	18	27	12	28	17	19	15
Cusp Number LM2	%	50.0	25.0	27.8	19.1	25.0	31.0	41.2	32.1	56.3	25.8	33.3	33.3	52.9	82.9	37.5	81.3	81.0	66.7	73.7
(+=ASU 5+)	n	38	36	36	21	12	58	34	28	32	31	75	33	17	35	8	32	21	18	19
Deflecting Wrinkle LM1	%	18.9	5.7	15.2	9.5	0.0	4.6	11.1	12.0	36.4	30.0	7.0	11.1	33.3	24.0	18.2	40.0	33.3	42.9	40.0
(+=ASU 2–3)	n	37	35	33	21	8	44	27	25	22	10	57	27	12	25	11	20	6	7	10
C1-C2 Crest LM1	%	0.0	2.9	3.0	9.5	0.0	6.5	0.0	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+=ASU +)	n	41	34	33	21	5	46	27	26	26	12	61	28	12	27	12	26	7	13	14
Protostylid LM1	%	2.4	11.4	22.2	12.5	7.1	16.1	11.5	2.9	32.3	21.4	49.3	27.5	35.3	15.2	0.0	25.8	31.3	23.5	16.7
(+=ASU 1–6)	n	41	35	36	24	14	56	26	34	31	14	69	40	17	33	12	31	16	17	18
Cusp 7 LM1	%	19.6	4.3	10.9	13.3	0.0	6.7	17.1	7.1	11.6	0.0	3.5	14.6	11.1	31.3	16.7	26.5	34.8	5.3	28.6
(+=ASU 2–4)	n	51	47	46	30	20	60	35	42	43	29	85	48	18	32	12	34	23	19	21
Tome's Root LP1	%	14.3	0.0	10.7	5.6	6.7	11.1	25.0	15.4	19.6	9.5	6.0	2.9	25.0	13.9	0.0	28.6	27.6	15.8	50.0
(+=ASU 3–5)	n	21	47	56	18	30	45	52	26	46	42	50	35	20	36	5	28	29	19	16
Root Number LC	%	0.0	1.9	5.1	4.2	6.1	0.0	1.9	2.6	8.2	4.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+=ASU 2+)	n	24	52	59	24	33	31	52	38	49	42	65	43	18	33	6	21	30	20	10
Root Number LM1	%	0.0	0.0	5.1	0.0	0.0	2.2	2.0	2.7	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0
(+=ASU 3+)	n	26	34	39	19	26	46	49	37	39	31	45	29	18	37	11	37	31	21	23
Root Number LM2	%	100	82.4	86.1	75.0	86.7	86.7	94.0	84.6	91.2	84.4	89.6	92.0	100	94.3	88.9	94.7	100	100	95.7
(+=ASU 2+)	n	20	34	36	16	30	45	50	26	34	32	48	25	17	35	9	38	27	20	23
Torsomolar Angle LM3	%	2.4	2.9	2.2	5.9	0.0	17.0	15.7	4.9	4.8	2.6	16.7	16.7	12.5	13.5	0.0	20.6	7.7	5.9	13.6
(+=ASU +)	n	42	35	46	34	23	47	51	41	42	39	60	30	16	37	11	34	26	17	22

[a] JEM = Jebel Moya, EGE = Egyptian 'E', NAQ = Naqada, BAD = Badari, SAQ = Saqqarah, HES = El Hesa, KER = Kerma, AGR = A-Group, CGR = C-Group, DGR = D-Group, MER = Meroitic, XGR = X-Group, KEN = Kenya, NIC = Nigeria–Cameroon, ETH = Ethiopia, GHA = Ghana, CNG = Congo, GAB = Gabon, TOD = Togo–Dahomey.
[b] ASU rank-scale trait breakpoints from Irish (1993, 1997, 1998a,b) and Scott & Turner (1997).

ASUDAS presence/absence dichotomies are listed under each trait name. As can be seen, several traits suffer from small sample sizes, particularly those in anterior teeth that are commonly missing post-mortem. Such data should be guardedly interpreted because they may not be representative of the populations from which they derive.

Overall, Jebel Moya's trait percentages appear largely intermediate in occurrence relative to those of the remaining samples, although it does exhibit exceptionally low incidences of UI2 tuberculum dentale and, particularly, UM1 Carabelli's. Moreover, in moving down the columns it appears that none of the other samples closely parallel the Jebel Moyans for more than just a handful of trait occurrences.

Trait editing

Before applying the Mahalanobis statistic, six traits exhibiting four or more samples with <10 cases were dropped from the analysis (UI1 labial curvature, UI1 shoveling, UI1 double shoveling, UI2 interruption groove, UI2 tuberculum dentale, LM1 anterior fovea). Another nine traits characterised by shared low or high expression were also deleted (palatine torus, UM3 parastyle, peg-reduced UI2, premolar odontome, mandibular torus, LM1 C1-C2 crest, LC root number, LM1 root number, LM2 root number). This editing yielded 21 highly variable dental traits with adequate sample sizes for submission to CA. Correspondence analysis tabular output (omitted for brevity but available from the first author) and the biplot (Figure 2) then identified the most influential of these traits in driving inter-sample variation.

The biplot's enumerated white diamonds denote the 21 dental traits. The 19 samples are represented by black dots; although not labelled to facilitate plot legibility, they can be seen to form a Y-pattern. Sub-Saharan samples comprise the left and North Africans the right half of the 'Y'. This distribution is discussed further below.

Over 57% of the variance explained by the CA model is illustrated in Figure 2. Most of it (42.5%) is distributed along the first dimension or x-axis. Thus, for example, traits 15 (6-cusped LM1) and 3 (UC distal accessory ridge) distinguish the

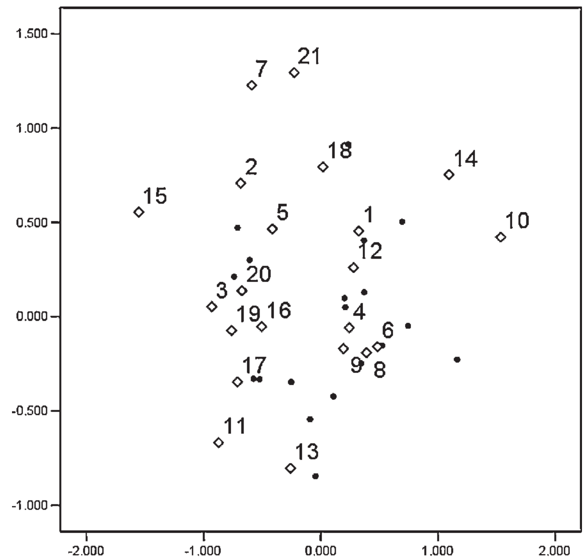

Figure 2. Two-dimensional correspondence analysis biplot illustrating relationships among the 19 samples and 21 dental traits. Samples are depicted by unlabelled black dots and traits with enumerated white diamonds. Numbers correspond to the following traits: (1) UI1 winging, (2) UC Bushman canine, (3) UC distal accessory ridge, (4) UM2 hypocone, (5) UM1 cusp 5, (6) UM1 Carabelli's trait, (7) UM1 enamel extension, (8) UP1 root number, (9) UM2 root number, (10) UM3 congenital absence, (11) UI1 midline diastema, (12) LP2 lingual cusp, (13) LM2 groove pattern, (14) rocker jaw, (15) LM1 cusp number, (16) LM2 cusp number, (17) LM1 deflecting wrinkle, (18) LM1 protostylid, (19) LM1 cusp 7, (20) LP1 tome's root, and (21) LM3 torsomolar angle.

sub-Saharan samples, whereas 14 (rocker jaw) and 10 (UM3 congenital absence) occur most frequently in North Africans. Because only 15% of the variation occurs on the second dimension (y-axis), trait/sample associations are less clear cut. Still, high frequencies of traits 7 (UM1 enamel extension) and 21 (LM3 torso-molar angle) are found in the topmost samples (from left to right, GHA, MER and HES), while 13 (LM2 Y-groove) characterises the bottom two (ETH and JEM), among others. Beyond this, a drop to <10% of the total variance on a third dimension indicates that sufficient information is provided in the two-dimensional biplot to identify the most influential traits. They include: UC Bushman canine, UC distal accessory ridge, UM1 cusp 5, UM1 enamel extension, UM3 congenital absence, UI1 midline diastema, LM2 groove pattern, rocker jaw, LM1 cusp number, LM1 deflecting wrinkle, LM1 protostylid, LM1 cusp 7, LP1 Tome's root, and

LM3 torsomolar angle. Standard PCA of trait percentages yields an analogous list.

Intra-sample variability

Of these 14 traits, UM3 congenital absence, UI1 midline diastema, LM2 groove pattern and LM3 torsomolar angle are initially recorded as dichotomous data. Thus, rank-scale standard deviations could only be determined for the ten remaining traits among samples. Jebel Moya was not found to exhibit the greatest variability for any of these traits; in fact, several of its standard deviations are lower than those in the majority of comparative samples—including several that were long assumed to be temporally and spatially homogeneous based on site reports and other information (e.g. X-Group, A-Group, Kenya, El Hesa, etc.).

The amount of tabular information required to present comparisons of 10 ASUDAS trait standard deviations in the 19 samples is considerable. Thus, only a representative example, i.e. results for the LM1 cusp 7 comparison, is presented here. The remaining nine tables may be requested from the first author. In Table 3 the numbers of individuals scored in each sample are listed, as are the means—which vary relative to the arbitrary mean of 5.0; the mean gives an indication of the number of individuals receiving each of five LM1 cusp 7 grades across the rows, but is otherwise not used to compare variability among samples. Lastly, the corresponding standard deviations and their ranks, which indicate the most to least variable samples, are presented. It can be seen that Jebel Moya has a lower standard deviation for this particular trait than 13 other samples (Table 3).

Table 3. LM1 cusp 7 rank-scale variation[a] among the samples

Sample	Trait N	Mean	SD	SD Rank
Jebel Moya	51	5.423	**0.832**	14
Egyptian ‘E’	47	3.933	**1.308**	6
Naqada	46	4.478	**1.289**	7
Badarian	30	4.563	**1.406**	5
Saqqara	21	5.720	**0.111**	19*
El Hesa	60	4.429	**1.070**	11
Kerma	35	4.742	**1.558**	4
A-Group	42	3.465	**1.670**	3
C-Group	43	4.529	**1.163**	10
D-Group	29	5.699	**0.113**	18
Meroitic	85	5.056	**0.677**	16
X-Group	48	4.184	**1.781**	1**
Kenya	18	4.720	**1.227**	9
Nigeria–Cameroon	32	5.327	**1.238**	8
Ethiopia	12	4.203	**1.762**	2
Ghana	34	6.020	**0.316**	17
Congo	23	5.786	**0.771**	15
Gabon	19	4.940	**0.945**	12
Togo–Dahomey	21	5.617	**0.938**	13

[a] See text for description of the method.
* Sample exhibiting lowest trait variation.
** Sample exhibiting greatest trait variation.

Dental affinities

The distance matrix generated from the suite of 14 traits is presented in Table 4. Values for Jebel Moya support the view implied by the qualitative comparison of frequencies; the range of 1.53–3.62 is roughly intermediate to those of the comparative samples. Likewise, its mean D^2 value of 2.59 (i.e. the sum of 18 pairwise comparisons divided by total) is less than that in seven, although greater than that in 11 samples; this mean suggests there is some degree of phenetic distinction. Lastly, looking at individual D^2 values, Jebel Moya is most akin to the sample from Ethiopia and least like Meroitic Nubians.

The output from two-dimensional MDS of distances among the 19 dental samples is seen in Figure 3. North African comparative samples are represented by black squares; those of sub-Saharan origin are identified by white triangles. Their overall distribution is similar to that in Figure 2. Two-dimensional MDS of a 21-trait MMD comparison (not shown), undertaken prior to write-up, is also equivalent. That is, Jebel Moya is intermediate to both groups on the x-axis, and distinct along the y-axis. Such methodological concordance implies that the dental affinities are real, and not an artefact of the statistic or illustrative method used.

Although there is not, of course, a direct 1:1 relationship between MDS diagram (Figure 3) and distance matrix, the former does provide a good representation; Kruskal's stress formula 1 value is 0.174 and the r^2 is 0.841. For the purposes of methodological comparison, two-dimensional MDS of the original craniometric-derived D^2

Table 4. Mahalanobis distance matrix for 14 non-metric dental traits among the 19 samples

Sample	jem	ege	naq	bad	saq	hes	ker	agr	cgr	dgr	mer	xgr	ken	nic	eth	gha	cng	gab	tod
Jebel Moya	0																		
Egyptian 'E'	2.65	0																	
Naqada	2.63	1.78	0																
Badarian	2.09	1.47	1.60	0															
Saqqara	2.64	1.20	1.84	1.71	0														
El Hesa	2.97	1.80	2.37	1.58	1.59	0													
Kerma	2.13	2.37	2.53	1.69	2.38	1.70	0												
A-Group	1.61	2.34	2.28	1.75	2.32	2.50	1.70	0											
C-Group	2.92	2.35	1.55	2.07	2.15	2.44	2.42	2.59	0										
D-Group	2.60	1.82	1.53	1.70	1.72	2.24	2.32	2.01	1.38	0									
Meroitic	3.62	2.51	2.59	2.38	2.58	2.04	2.73	3.03	3.04	2.63	0								
X-Group	2.82	1.64	2.06	1.45	2.03	1.44	1.77	2.33	2.24	2.09	1.73	0							
Kenya	2.64	3.28	2.93	2.59	3.21	3.00	2.38	2.13	2.56	2.49	3.11	2.67	0						
Nigeria–Cameroon	2.56	3.33	2.80	2.70	3.46	3.33	2.64	2.25	3.31	3.13	2.86	2.49	2.59	0					
Ethiopia	1.53	2.44	2.51	1.68	2.48	2.54	1.89	1.27	2.81	2.37	3.23	2.26	2.24	2.16	0				
Ghana	3.10	3.52	2.59	2.85	3.47	3.27	2.87	2.80	2.91	2.96	2.82	2.59	2.95	1.43	2.76	0			
Congo	2.58	3.97	3.46	2.96	4.03	3.71	2.76	2.50	3.50	3.33	3.62	3.17	1.93	2.06	2.26	2.57	0		
Gabon	2.78	3.55	3.06	2.92	3.39	3.55	3.07	2.35	2.96	2.58	3.24	2.97	1.81	2.14	2.31	2.37	1.93	0	
Togo–Dahomey	2.73	3.70	3.04	2.94	3.61	3.35	2.42	2.29	3.32	3.19	3.10	2.89	2.59	1.45	2.39	1.77	2.22	2.53	0

values among 20 samples from Mukherjee *et al.* (1955) is presented in Figure 4. It too displays a separation between the sub-Saharan and North African samples, with an intermediate, yet distinct position for Jebel Moya. The corresponding stress and r^2 values are 0.164 and 0.892. For both MDS figures, minimal improvement in these measures of fit did not warrant the use of more-difficult-to-interpret three-dimensional graphing.

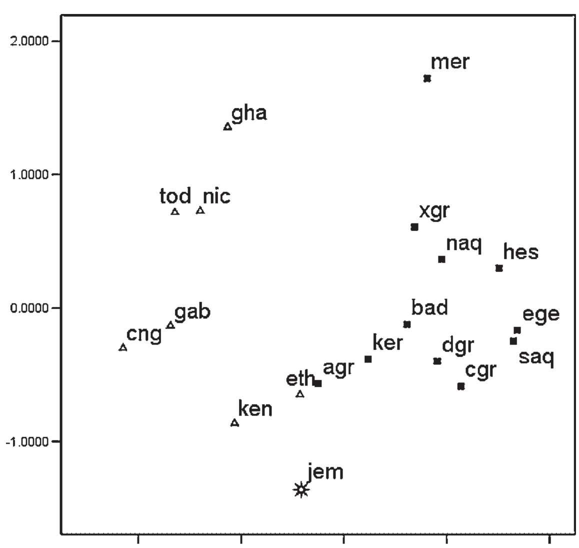

Figure 3. Two-dimensional MDS of 14-trait Mahalanobis D^2 dental distances between Jebel Moya and 18 comparative samples from the present study. North Africans are depicted with black squares and sub-Saharan Africans with white triangles. The three-letter sample abbreviations are defined in the text and Table 1.

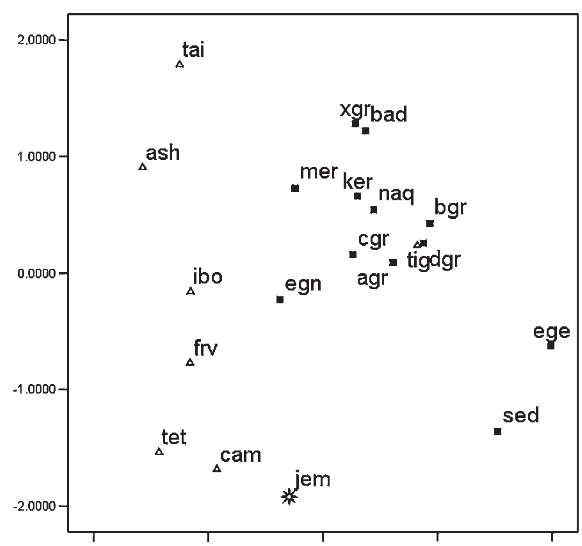

Figure 4. Two-dimensional MDS of Mahalanobis D^2 craniometric distances between Jebel Moya and 19 comparative samples: derived from distance matrix in Mukherjee *et al.* (1955). North Africans are depicted with black squares and sub-Saharan Africans with white triangles. The three-letter sample abbreviations are listed in Table 1.

Discussion

Inter-sample variation

The most obvious pattern among dental samples (Figure 3) is, as noted, the divergence between sub-Saharan and North Africans. It emulates those derived from numerous other biocultural data (among others, Murdock, 1959; Greenberg, 1966; Hiernaux, 1975; Mourant, 1983; Nurse *et al.*, 1985; Roychoudhury & Nei, 1988; Howells, 1989). And, not surprisingly, the present results are equivalent to those in prior dental affinity studies (Irish, 1993, 1997, 1998a,b,c); as before, sub-Saharan samples, especially those from west Africa, exhibit complex mass-additive traits, including: UC Bushman canine (i.e. 2 in Figure 2), UC distal accessory ridge (3), UI1 midline diastema (11), 6-cusped LM1 (15), LM1 cusp 7 (19), and LP1 Tome's root (20). Conversely, North Africans have been shown to possess simple mass-reduced morphology (Irish, 1998a, b), with low frequencies of the above, and a high incidence of UM3 absence (10) and rocker jaw (14). The present trait combinations correspond with the previously defined Sub-Saharan African- and North African Dental Trait Complexes, respectively (Irish, 1997, 1998a,b).

This divergence also carries over to the craniometric data, as evidenced by the MDS of D^2 values (Figure 4) that are provided in Mukherjee *et al.* (1955). Their Tigrean sample from Ethiopia is associated with North Africans cranially, and intra-regional sample affinities do differ, but the north–south dichotomy is otherwise maintained. By comparison, dental-based affinities (Figure 3) actually correspond to geographical provenance more closely than those based on craniometrics. As can be seen, the west (GHA, TOD, NIC), central (CNG, GAB), and east (KEN, ETH) sub-Saharan dental samples form separate subgroups. Egyptians (BAD, NAQ, HES, EGE, SAQ) also cluster together, although the Nubian samples are somewhat dispersed.

Before proceeding, an interesting side note is worth mentioning. Although not specified, the original two-dimensional graph of craniometric affinities published in Mukherjee *et al.* (1955, their Figure 5.1: 85), and recreated here in Figure 5, clearly involves translation to geometric distances, like with MDS. In fact, there is a marked concordance between their graph and the current Figure 4. For the most part, there is only some minor shifting of points (e.g. Egyptian 'Negro' is moved toward the sub-Saharan samples, Ibo is closer to Jebel Moya, etc.), which is understandable in their conversion of the D^2 inter-sample matrix values to distances on a hand-made graph. However, there is also one major difference; Mukherjee and associates placed their Badarian Egyptian sample within the sub-Saharan cluster, while puzzling over this unexpected affinity (Mukherjee *et al.*, 1955: 86). Inspection of the original D^2 matrix (their Table 5.6: 84) does, in reality, indicate a Badarian affiliation to North Africans, not sub-Saharan samples. It is therefore likely that an error was made in construction of their original figure when converting inter-sample distances to x- and y-coordinates. A similar plotting inaccuracy would have taken place in Figure 4 if the Badarian (BAD) sample had erroneously received a negative rather than positive x-coordinate.

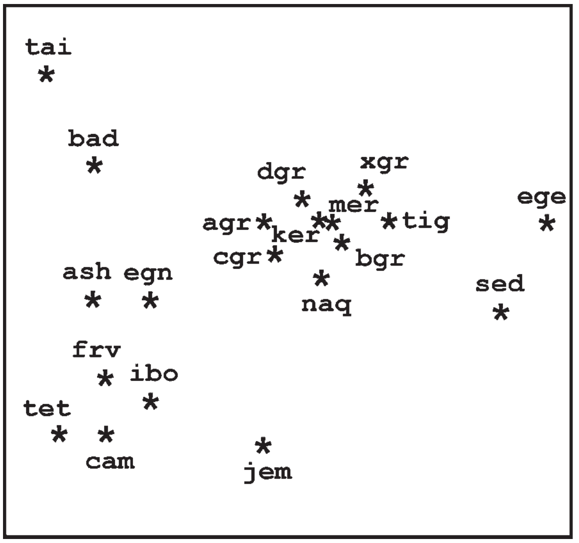

Figure 5. Reproduction of the D^2 craniometric distance graph from Mukherjee *et al.* (1955, Figure 5.1: 85): rotated 90° clockwise and otherwise modified relative to the original to facilitate comparison with Figure 4. Note the erroneous position of the Badarian sample within the cluster of sub-Saharan Africans (see text for details).

The place of Jebel Moya

Beyond a north–south divergence, the most obvious similarity between Figures 3 and 4 is Jebel Moya's relative location. As noted, it appears intermediate to, yet distinct from, sub-Saharan and North Africans in dental trait expression. Similar observations were reported regarding cranial variation (Mukherjee *et al.*, 1955). The main difference is that Jebel Moya, based on individual D^2 values, shows the closest dental affinity to North Africans, whereas cranially it is more akin to sub-Saharan samples. This contrast may involve, among others, differential heritability in dental versus cranial trait expression, a cline in selective forces favouring sub-Saharan cranial features with decreasing latitude (e.g. Hiernaux, 1975) and/or, simply, the several differences in sample composition between studies. In any event, craniodental features characterising both large comparative groupings appear to be manifest in the Jebel Moyans. Therefore, if the present samples are representative of their respective populations, and phenetic approximates genetic relatedness, the reason for this overall affinity may be that Jebel Moyans were: (1) an admixed people, comprising genetic elements from populations living in various regions surrounding central Sudan; and/or (2) a heterogeneous populace consisting of actual individuals from these regions.

As noted, population heterogeneity was first intimated by Addison (1949). Similarities in pottery between regions suggested influence from northern Sudan, while some of the disparate mortuary customs reflect those from farther south. Yet, he believed that the original Jebel Moya settlers came from the west. Although mentioning a stone tool resemblance with far west Africa, the place of origin was said to be the outlying desert west of the White Nile. He then posited that 'physical characteristics of the original settlers would soon become modified by interbreeding with local stocks' (Addison, 1949: 260).

The possibility of a western origin was later reprised. Caneva (1991) reported pottery similarities between the Central Sahara, near Tibesti, Borkou and Ennedi in Chad, and Jebel Moya from the end of the 5th millennium BC. Connah (1981) also noted that bone tools and ceramic figurines at Daima, Nigeria (1st millennium BC to 2nd millennium AD) are reminiscent of those at Jebel Moya. Yet the idea of a northern Sudan link was also sustained. Pottery motifs, vessel forms, lip-plugs, and stone tools of the Butana Industry (ca. 3rd millennium BC), on the Ethiopian border in the Atbara drainage, mirror those at Jebel Moya. C-Group and Meroitic Nubian influences in pottery are also evident (Clark, 1973, 1984; Clark & Stemler, 1975). The presence of Napatan and Meroitic grave items has already been mentioned. However, in concert with Addison (1949), Clark (1973, 1984) asserted that the people of Jebel Moya and nearby sites were, at least culturally, distinctive from these outside groups. Thus, the cultural manifestation of this place and time received a separate designation termed the Jebel Moya Complex (Clark, 1984).

According to Gerharz (1994) the appearance of this culture coincided with the advent of his Phase II (ca. 3000–800 BC) and continued through Phase III (800–100 BC). This sequence corresponds with the recovered archaeological and skeletal remains. Like other workers, Gerharz regards it as a distinctive heterogeneous culture that combined elements of various outside groups. The lack of uniformity in grave types, orientation and inventories (see also Addison, 1949) is especially supportive of this premise. Specifically, he sees Jebel Moya as having been an 'annual meeting place of widely distributed segmentary family units, the common identity of which was maintained by their periodical cohabitation there' (Gerharz, 1994: 330).

In light of these archaeological interpretations the craniodental affinities make sense. In both cases Jebel Moyans exhibit traits characteristic of many groups (i.e. 'intermediate'), while concurrently demonstrating their own distinct biocultural composition. Mukherjee *et al.* (1955) specifically investigated the issue of population make-up. Non-metric traits in crania recovered from different levels were thought to suggest variation over time. Evidence for cultural change between strata was also reported. However, the same stratigraphic control problems (Caneva, 1991; Gerharz, 1994) affecting the original site dating rendered these findings useless as well; additionally, calculations of craniometric standard deviations and, in particular, coefficients of variation yielded contrary findings. Despite some internal variation, the series was not found to be significantly more variable than the Egyptian 'E' sample. In the end, it was concluded that 'physical characters of the Jebel Moyans are reliably represented by the mean values for the sample' (Mukherjee *et al.*, 1955: 64).

The same interpretation is implied by the comparisons of rank-scale dental trait standard deviations among samples. Jebel Moya does not exhibit higher levels of internal dental variability than a number of comparative samples, some of which have been assumed to represent relatively homogeneous populations. An assessment of dental affinity between time-successive Jebel Moya subsamples also provides support. Specifically, using Gerharz' (1994) age indicators (above) with the grave inventory of Addison (1949), it was determined that 31 of the 58 dentitions date to Phase II, whereas the other 27 are definite or probable Phase III. The original trait complement was then compared between these subsamples with the MMD. Use of all 36 traits permits a more complete intra-sample comparison, and the MMD is most effective when comparing the larger number of traits, as long as they are not correlated. The statistic also has a significance test, where MMD $>2 \times$ SD indicates that the null hypothesis of population equality is rejected at the 0.025 level (Sjøvold, 1977). To test for pairwise correlation, the subsamples' non-dichotomised data were submitted to Kendall's tau-*b*. Only 30 of 629 pairwise comparisons are strongly (≥ 0.5) correlated. The resulting MMD of 0.00 patently denotes a lack of significant difference between subsamples. Although the population was probably affected by outside influences, it appears that it may have displayed, to employ an oxymoron, uniform heterogeneity through time. Thus, like the craniometric means, Jebel Moya dental frequencies are probably representative of a population that, although unique, was relatively uniform and stable in its composition over a span of some 3000 years.

Pairwise affinities

Beyond the general relationship of Jebel Moya to the sub-Saharan and North African groupings, specific between-sample comparisons can be used to address briefly the several affiliations suggested by the archaeological evidence. Craniometric affinities support the unlikely concept of a far west African link (Addison, 1949; Connah, 1981); individual D^2 values show Jebel Moya as most akin to the historic Ibo and Cameroons samples, and least like the spatially proximate Tigrean, Taita, and X-Group (Mukherjee *et al.*, 1955). On the other hand, dental D^2 values (Table 4) and Figure 3 seem more intuitively plausible. Jebel Moya is distinct from west Africans, but nearest Ethiopia (ETH) and the A-Group Nubians (AGR). The latter two affinities, in particular, support some of the archaeological links (Clark, 1973, 1984; Clark & Stemler, 1975); the Ethiopia sample, from the northern half of that country, is adjacent to the setting of the Jebel Moya-like Butana Industry, and the A-Group is of a similar age to Butana and early Phase II Jebel Moya. However, Jebel Moya is least like Meroitic (MER) and, to a lesser extent, C-Group Nubians (CGR), which seems counterintuitive based on this same evidence (Clark, 1973, 1984; Clark & Stemler, 1975). The reasons for such discrepancies are not apparent based on the dental data, but it is clear, at least in this case, that cultural influence does not necessarily translate into biological affinity.

Lastly, none of the comparative samples are conducive to exploring the Central Saharan link suggested by Caneva (1991); however, the first author studied a 19th–20th century dental sample ($n = 29$) from the Tibesti, Borkou and Ennedi regions of Chad (Irish, 1993) that was used in a second 14-trait D^2 comparison (not shown). Although it is too recent to explore directly a 5th millennium BC association, the results may, nevertheless, be suggestive. The Chad sample is wholly unlike Jebel Moya and most closely akin to the west Africans (esp. Nigeria–Cameroon). All other individual D^2 distances and inter-sample relationships, as illustrated by Figure 3, remain essentially constant.

Summary and conclusions

A half-century after *The Ancient Inhabitants of Jebel Moya (Sudan)* was written by Mukherjee *et al.* (1955), the craniometric findings correspond with the new dental affinities and previous archaeological data to portray the site's population as a biocultural amalgam. The application of the Mahalanobis D^2 statistic to cranial measurements suggests a sub-Saharan link, particularly with far-west Africans; yet, as Mukherjee and associates observe, the sample still 'deserves a special position in relation to all the series under consideration' (p. 88). The dental study, comparing many of the same samples from the craniometric report, finds some concordance between methods (i.e. 'intermediate-yet-distinct'); yet, the overall place of the Jebel Moyans appears to be within a greater northeast African sphere of biological influence, based on the phenetic affinities to various samples past (e.g. A-Group) and present (e.g. Ethiopia). Lastly, cultural attributes suggest a mosaic of northern, southern and western influence; yet, the site inhabitants incorporated all to yield their own distinct Jebel Moya Complex.

In the end, despite myriad obstacles affecting completion of the Mukherjee *et al.* (1955) report—related to problems during and after the fieldwork, and a subsequent lack of physical anthropological and, to a lesser extent, archaeological study of the collections, it appears that new information can still be gleaned from the old site. The inhabitants were cranially sub-Saharan, dentally North African, culturally aligned with both regions yet, in all instances, distinct. Although ostensibly starting out as a diverse group of individuals, the Jebel Moyans apparently came to comprise what may best be described as a uniformly heterogeneous population that exhibited its own distinctive biocultural identity.

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References

Adams WY. 1977. *Nubia: Corridor to Africa*. Princeton University Press: Princeton.

Addison F. 1949. *Jebel Moya*. Oxford University Press: London.

Addison F. 1956. Second thoughts on Jebel Moya. *Kush* **4**: 4–18.

Bedrick EJ, Lapidus J, Powell JF. 2000. Estimating the Mahalanobis Distance from mixed continuous and discrete data. *Biometrics* **56**: 394–401.

Benzécri JP. 1992. *Correspondence Analysis Handbook*. Dekker: New York.

Bermudez de Castro JM. 1989. The Carabelli trait in human prehistoric populations of the Canary Islands. *Human Biology* **61**: 117–131.

Berry AC, Berry RJ. 1967. Epigenetic variation in the human cranium. *Journal of Anatomy* **101**: 361–379.

Berry AC, Berry RJ. 1972. Origins and relationships of the ancient Egyptians. Based on a study of non-metrical variations in the skull. *Journal of Human Evolution* **1**: 199–208.

Berry AC, Berry RJ. 1973. Origins and relations of the ancient Egyptians. In *Population Biology of the Ancient Egyptians*, Brothwell DR, Chiarelli BA (eds). Academic Press: New York; 200–208.

Brace CL, Tracer DP, Yaroch LA, Robb J, Brandt K, Nelson AR. 1993. Clines and clusters versus Arace: A test in ancient Egypt and the case of a death on the Nile. *Yearbook of Physical Anthropology* **36**: 1–31.

Calcagno JM. 1986. Dental reduction in post-Pleistocene Nubia. *American Journal of Physical Anthropology* **70**: 349–363.

Caneva I. 1991. Jebel Moya revisited: A settlement of the 5th millennium BC in the middle Nile Basin. *Antiquity* **63**: 262–268.

Clark JD. 1973. The University of California, Berkeley, expedition to the Central Sudan. *Nyame Akuma* **3**: 56–64.

Clark JD. 1984. Prehistoric cultural continuity and economic change in the Central Sudan in the Early Holocene. In *From Hunters to Farmers: The Causes and Consequences of Food Production in Africa*, Clark JD, Brandt SA (eds). University of California Press: Berkeley; 113–126.

Clark JD, Stemler A. 1975. Early domesticated sorghum from Central Sudan. *Nature* **254**: 588–591.

Clausen SE. 1988. *Applied Correspondence Analysis: An Introduction*. Sage Publications: Thousand Oaks, CA.

Connah G. 1981. *Three Thousand Years in Africa: Man and His Environment in the Lake Chad Region of Nigeria*. Cambridge University Press: Cambridge.

Coppa A, Cucina A, Mancinelli D, Vargiu R, Calcagno JM. 1998. Dental anthropology of central-southern, Iron Age Italy: The evidence of metric versus nonmetric traits. *American Journal of Physical Anthropology* **107**: 371–386.

Donlon DA. 2000. The value of infracranial nonmetric variation in studies of modern *Homo sapiens*: An Australian focus. *American Journal of Physical Anthropology* **113**: 349–368.

Eliason SR. 1993. *Maximum Likelihood Estimation: Logic and Practice*. Sage Publications: Newbury Park.

Gerharz RG. 1994. *Jebel Moya. Meroitica 14*. Akademie Verlag: Berlin.

Green R, Suchey J. 1976. The use of inverse sine transformation in the analysis of non-metrical data. *American Journal of Physical Anthropology* **45**: 61–68.

Greenacre MJ, Degos L. 1977. Correspondence analysis of HLA gene frequency data from 124 population samples. *American Journal of Human Genetics* **29**: 60–75.

Greenberg JH. 1966. *The Languages of Africa*. Indiana University: Bloomington.

Greene DL. 1972. Dental anthropology of early Egypt and Nubia. *Journal of Human Evolution* **1**: 315–324.

Greene DL. 1982. Discrete dental variations and biological distances of Nubian populations. *American Journal of Physical Anthropology* **58**: 75–79.

Haaland R. 1987. *Socio-economic Differentiation in the Neolithic Sudan*. Cambridge Monographs in African Archaeology 20. BAR International: Oxford.

Haeussler AM, Turner CGII, Irish JD. 1988. Concordance of American and Soviet methods in dental anthropology. *American Journal of Physical Anthropology* **75**: 218.

Hanihara T. 1992. Dental and cranial affinities among populations of East Asia and the Pacific: The basic populations in East Asia, IV. *American Journal of Physical Anthropology* **88**: 163–182.

Hemphill BE. 1998. Biological affinities and adaptations of Bronze Age Bactrians: III. An initial craniometric assessment. *American Journal of Physical Anthropology* **106**: 329–348.

Hiernaux J. 1975. *The People of Africa*. Charles Scribner's Sons: New York.

Hofmann I. 1967. *Die Kulturen des Niltals von Aswan bis Sennar: Vom Mesolithikum bis Zum Ende der Christlichen Epoche*. Kommissionsverlag Cram, de Gruyter & Co: Hamburg.

Howells WW. 1989. *Skull Shapes and the Map: Craniometric Analyses in the Dispersion of Modern Homo*. Papers of the Peabody Museum of Archaeology and Ethnology, **Vol. 79**. Harvard University: Cambridge, MA.

Irish JD. 1993. *Biological Affinities of Late Pleistocene through Modern African Aboriginal Populations: The Dental Evidence*. PhD dissertation, Arizona State University, Tempe.

Irish JD. 1994. The African dental complex: Diagnostic morphological variants of modern sub-Saharan populations. *American Journal of Physical Anthropology* **18** (Suppl.):112.

Irish JD. 1997. Characteristic high- and low-frequency dental traits in sub-Saharan African populations. *American Journal of Physical Anthropology* **102**: 455–467.

Irish JD. 1998a. Dental morphological indications of population discontinuity and Egyptian gene flow in post-Paleolithic Nubia. In *Human Dental Development, Morphology, and Pathology: A Tribute to Albert A. Dahlberg*, Lukacs JR (ed.). University of Oregon Anthropological Papers 54. University of Oregon Press: Eugene; 155–172.

Irish JD. 1998b. Dental morphological affinities of late Pleistocene through recent sub-Saharan and North African peoples. *Bulletins et Memoires de la Societé d'Anthropologie de Paris Nouvelle serie* **10**: 237–272.

Irish JD. 1998c. Diachronic and synchronic dental trait affinities of Late and post-Pleistocene peoples from North Africa. *Homo* **49**: 138–155.

Irish JD. 1998d. Ancestral dental traits in recent sub-Saharan Africans and the origins of modern humans. *Journal of Human Evolution* **34**: 81–98.

Irish JD. 2000. The Iberomaurusian enigma: North African progenitor or dead end? *Journal of Human Evolution* **39**: 393–410.

Irish JD. 2005. Population continuity versus discontinuity revisited: Dental affinities among Late

Paleolithic through Christian era Nubians. *American Journal of Physical Anthropology* **128**: 520–535.

Irish JD. 2006. Who were the ancient Egyptians? Dental affinities among Neolithic through postdynastic peoples. *American Journal of Physical Anthropology* **129**: 529–543.

Irish JD, Guatelli-Steinberg D. 2003. Ancient teeth and modern human origins: an expanded comparison of African Plio-Pleistocene and Recent world dental samples. *Journal of Human Evolution* **45**: 113–144.

Irish JD, Turner CGII. 1990. West African dental affinity of late Pleistocene Nubians: Peopling of the Eurafrican–South Asian triangle II. *Homo* **41**: 42–53.

Ishida H, Dodo Y. 1997. Cranial variation in prehistoric human skeletal remains from the Marianas. *American Journal of Physical Anthropology* **104**: 399–410.

Jackes M, Silva AM, Irish JD. 2001. Dental morphology: a valuable contribution to our understanding of prehistory. *Journal of Iberian Archaeology* **3**: 97–119.

Johnson AL, Lovell NC. 1994. Biological differentiation at predynastic Naqada, Egypt: an analysis of dental morphological traits. *American Journal of Physical Anthropology* **93**: 427–433.

Keita SOY. 1990. Studies of ancient crania from northern Africa. *American Journal of Physical Anthropology* **83**: 35–48.

Keita SOY. 1992. Further studies of crania from ancient northern Africa: an analysis of crania from First Dynasty Egyptian tombs. *American Journal of Physical Anthropology* **87**: 245–254.

Keita SOY. 1996. Analysis of Naqada predynastic crania: a brief report. In *Interregional Contacts in the Later Prehistory of Northeastern Africa*, Krzyzaniak L, Kroeper K, Kobusiewicz M (eds). Poznan Archaeological Museum: Poznan; 203–213.

Kitagawa Y, Manabe Y, Oyamada J, Rokutanda A. 1995. Deciduous dental morphology of the prehistoric Jomon people of Japan: comparison of nonmetric characters. *American Journal of Physical Anthropology* **97**: 101–111.

Kitson E. 1931. A study of the Negro skull with special reference to the crania from Kenya Colony. *Biometrika* **23**: 271–314.

Konigsberg LW. 1990. Analysis of prehistoric biological variation under a model of isolation by geographic and temporal distance. *Human Biology* **62**: 49–70.

Konigsberg LW, Kohn LAP, Cheverud JM. 1993. Cranial deformation and nonmetric trait variation. *American Journal of Physical Anthropology* **90**: 35–48.

Kruskal JB, Wish M. 1978. *Multidimensional Scaling*. Sage Publications: Beverly Hills, CA.

Larsen CS. 1997. *Bioarchaeology*. Cambridge University Press: Cambridge.

Lukacs JR, Hemphill BE. 1991. The dental anthropology of prehistoric Baluchistan: a morphometric approach to the peopling of South Asia. In *Advances in Dental Anthropology*, Kelley MA, Larsen CL (eds). Wiley-Liss: New York; 77–119.

Martin PF. 1921. *The Sudan in Evolution: A Study of the Economic, Financial and Administrative Conditions of the Anglo-Egyptian Sudan*. Constable and Co. Ltd: London.

Mourant AE. 1983. *Blood Relations: Blood Groups and Anthropology*. Oxford University Press: Oxford.

Mukherjee R, Rao CR, Trevor JC. 1955. *The Ancient Inhabitants of Jebel Moya (Sudan)*. Cambridge University Press: Cambridge.

Murdock GP. 1959. *Africa: Its Peoples and Their Culture History*. McGraw-Hill: New York.

Nielsen OV. 1970. *Human Remains: Metrical and Nonmetrical Anatomical Variations*. The Scandinavian Joint Expedition to Sudanese Nubia: Odense, Denmark.

Nurse GT, Weiner JS, Jenkins T. 1985. *The Peoples of Southern Africa and Their Affinities*. Clarendon Press: Oxford.

Phillips D. 1995. Correspondence analysis. *Social Research Update* **7**: 1–8.

Pietrusewsky M. 2004. Multivariate comparisons of female cranial series from the Ryukyu Islands and Japan. *Anthropological Science* 1–13; published online 13 July 2004 in J-STAGE, www.jstage.jst.go.jp

Prowse TL, Lovell NC. 1996. Concordance of cranial and dental morphological traits and evidence for endogamy in ancient Egypt. *American Journal of Physical Anthropology* **101**: 237–246.

Rightmire GP. 1999. Dental variation and human history. *Review of Archaeology* **20**: 1–3.

Roseman CC, Weaver TD. 2003. Multivariate apportionment of global human craniometric diversity. *American Journal of Physical Anthropology* **125**: 257–263.

Roychoudhury AK, Nei M. 1988. *Human Polymorphic Genes World Distribution*. Oxford University Press: New York.

Sakuma M, Ogata T. 1987. Sixth and seventh cusp on lower molar teeth of Malawians in east-central Africa. *Japanese Journal of Oral Biology* **29**: 738–745.

Schneider KN. 1986. Dental caries, enamel composition, and subsistence among prehistoric Amerindians of Ohio. *American Journal of Physical Anthropology* **71**: 95–102.

Sciulli PW. 1990. Deciduous dentition of a Late Archaic population of Ohio. *Human Biology* **62**: 221–245.

Scott GR. 1973. *Dental Morphology: A Genetic Study of American White Families and Variation in Living Southwest Indians*. PhD dissertation, Arizona State University, Tempe.

Scott GR. 1980. Population variation of Carabelli's trait. *Human Biology* **52**: 63–78.

Scott GR, Turner CGII. 1997. *The Anthropology of Modern Human Teeth: Dental Morphology and its Variation in Recent Human Populations*. Cambridge University Press: Cambridge.

Scott GR, Yap Potter RH, Noss JF, Dahlberg AA, Dahlberg T. 1983. The dental morphology of Pima Indians. *American Journal of Physical Anthropology* **61**: 13–31.

Sjøvold T. 1973. Occurrence of minor non-metrical variants in the skeleton and their quantitative treatment for population comparisons. *Homo* **24**: 204–233.

Sjøvold T. 1977. Non-metrical divergence between skeletal populations: The theoretical foundation and biological importance of C.A.B. Smith's mean measure of divergence. *Ossa* **4** (Suppl.):1–133.

Smith P, Shegev M. 1988. The dentition of Nubians from Wadi Halfa, Sudan: an evolutionary perspective. *Journal of the Dental Association of South Africa* **43**: 539–541.

Turner CGII. 1984. Advances in the dental search for Native American origins. *Acta Anthropogenetica* **8**: 23–78.

Turner CGII. 1985a. The dental search for Native American origins. In *Out of Asia*, Kirk R, Szathmary E (eds). Journal of Pacific History: Canberra; 31–78.

Turner CGII. 1985b. Expression count: a method for calculating morphological dental trait frequencies by using adjustable weighting coefficients. *American Journal of Physical Anthropology* **68**: 263–268.

Turner CGII. 1987. Late Pleistocene and Holocene population history of East Asia based on dental variation. *American Journal of Physical Anthropology* **73**: 305–322.

Turner CGII. 1990. Major features of Sundadonty and Sinodonty, including suggestions about East Asian microevolution, population history, and late Pleistocene relationships with Australian Aboriginals. *American Journal of Physical Anthropology* **82**: 295–318.

Turner CGII. 1992. The dental bridge between Australia and Asia: following Macintosh into the East Asian hearth of humanity. *Perspectives of Human Biology 2/Archaeologica Oceania* **27**: 120–127.

Turner CGII, Markowitz M. 1990. Dental discontinuity between late Pleistocene and recent Nubians. I. Peopling of the Eurafrican–South Asian triangle. *Homo* **41**: 42–53.

Turner CGII, Scott GR. 1977. Dentition of Easter Islanders. In *Orofacial Growth and Development*, Dahlberg AA, Graber TM (eds). Mouton: The Hague; 229–249.

Turner CGII, Nichol CR, Scott GR. 1991. Scoring procedures for key morphological traits of the permanent dentition: the Arizona State University dental anthropology system. In *Advances in Dental Anthropology*, Kelley MA, Larsen CS (eds). Wiley-Liss: New York; 13–32.

Williams MAJ, Adamson DA, Abdulla HH. 1982. Landforms and soils of the Gezira: a Quaternary legacy of the Blue and White Nile rivers. In *A Land Between Two Niles: Quaternary, Geology and Biology of the Central Sudan*, Williams MAJ, Adamson DA (eds). A.A. Balkema: Rotterdam; 111–142.

