

# Who Were the Ancient Egyptians? Dental Affinities Among Neolithic Through Postdynastic Peoples

Joel D. Irish\*

*Department of Anthropology, University of Alaska Fairbanks, Fairbanks, Alaska 99775-7720*

**KEY WORDS** dental anthropology; crown and root morphology; phenetic affinity; Egypt; Africa

**ABSTRACT** Qualitative and quantitative methods are employed to describe and compare up to 36 dental morphological variants in 15 Neolithic through Roman-period Egyptian samples. Trait frequencies are determined, and phenetic affinities are calculated using the mean measure of divergence and Mahalanobis  $D^2$  statistics for discrete traits; the most important traits in generating this intersample variation are identified with correspondence analysis. Assuming that the samples are representative of the populations from which they derive, and that phenetic similarity provides an estimate of genetic relatedness, these affinities are suggestive of overall population continuity. That is, other than a few outliers exhibiting extreme frequencies of nine influential traits, the dental samples

appear to be largely homogenous and can be characterized as having morphologically simple, mass-reduced teeth. These findings are contrasted with those resulting from previous skeletal and other studies, and are used to appraise the viability of five Egyptian peopling scenarios. Specifically, affinities among the 15 time-successive samples suggest that: 1) there may be a connection between Neolithic and subsequent predynastic Egyptians, 2) predynastic Badarian and Naqada peoples may be closely related, 3) the dynastic period is likely an indigenous continuation of the Naqada culture, 4) there is support for overall biological uniformity through the dynastic period, and 5) this uniformity may continue into postdynastic times. *Am J Phys Anthropol* 000:000–000, 2006. © 2005 Wiley-Liss, Inc.

Determinations of ancient Egyptian origins and affinities have traditionally been based on similarities in cultural remains among the region's peoples. However, because these data were often recorded in predynastic and dynastic cemeteries, the associated skeletal remains also came to be a focus of study to understand the peopling of Egypt. By the mid-20th century, studies of Egyptian crania and related analyses were commonplace (Warren, 1897; Fawcett, 1902; Pearson and Davin, 1924; Stoessiger, 1927; Morant, 1935; Engelbach, 1943; Derry, 1956). Subsequent to this work, much of which has been equated with racial typology (Keita, 1990, 1992, 1996), a second wave of skeletal studies directed toward the concept of population affinity arose (e.g., Berry et al., 1967; Berry and Berry, 1972, 1973; Greene, 1972; Hillson, 1978; Keita, 1990, 1992, 1996; Brace et al., 1993; Johnson and Lovell, 1994; Prowse and Lovell, 1996; Irish, 1998a).

The purpose of the present investigation is to continue and expand upon the population-based "inductive" approach (Greene, 1972, 1981; Keita, 1996) of these more recent studies by analyzing dental traits in a collection of samples representing most ancient Egyptian cultural periods. Specifically, various statistical methods, including multivariate distance analyses, are used to describe and compare up to 36 crown, root, and intra-oral osseous discrete traits in 15 Neolithic through Roman-period Upper and Lower Egyptian samples. The intended goals are to identify influential traits and determine intersample phenetic affinities. Assuming that phenetic similarity provides a reasonable estimate of genetic relatedness (Scott et al., 1983; Rightmire, 1999), and that the samples are representative of their respective populations, the affinities will then be used to further explore several existing Egyptian peopling scenarios.

Five scenarios, as necessitated by sample availability, are presented and summarized. The first three pertain to long-standing questions that are addressed by alternate

hypotheses. The final two are basically informal assumptions that have come to be associated with evidence concerning native vs. foreign cultural influence. Each summary contains cursory background information on the applicable cultures. A thorough population history is beyond the scope of this paper; for that, the reader is referred to the various sources cited here.

First, the origins of the predynastic Badarian culture (ca. 4400–4000 BC) were questioned since being identified by Brunton and Caton-Thompson (1928). Some postulate that the ancestors of this Nile Valley group were non-Egyptians from the east (Krzyżaniak, 1977) or south (Brunton and Caton-Thompson, 1928; Arkell, 1975). Others discounted an outside source, although an eastern origin cannot be completely ruled out (Hendrickx and Vermeersch, 2000), and Keita (1990) found craniometric affinities between Badarian and southern peoples. Today the most widely accepted hypothesis asserts that the source, with potential northern and eastern influence, were Neo-

Grant sponsor: Bioanthropology Foundation; Grant sponsor: Institute of Archaeology and Ethnology, Polish Academy of Sciences; Grant sponsor: Raymond and Beverly Sackler; Grant sponsor: Friends of Nekhen; Grant sponsor: NSF; Grant numbers: BCS-0119754; BNS-9013942; BNS-0104731; Grant sponsor: Arizona State University Research Development Program; Grant sponsor: American Museum of Natural History.

\*Correspondence to: Dr. Joel D. Irish, Department of Anthropology, PO Box 757720, University of Alaska Fairbanks, Fairbanks, Alaska 99775-7720. E-mail: ffjdi@uaf.edu

Received 28 August 2004; accepted 21 December 2004.

DOI 10.1002/ajpa.20261

Published online in Wiley InterScience (www.interscience.wiley.com).

lithic peoples from Egypt's Western Desert (Hassan, 1988; Holmes, 1989; Hendrickx and Vermeersh, 2000; Midant-Reynes, 2000a); this association is predicated on interregional cultural similarities (Caton-Thompson, 1926; Hassan, 1976, 1978, 1979, 1986, 1988; 1997a; Wendorf and Schild, 1980; Hendrickx and Vermeersch, 2000; Kobusiewicz et al., 2004). The present study will specifically test the likelihood of this latter indigenous link.

Second, the genesis of the Naqada is similarly debated. This later predynastic culture comprised three phases: Naqada I (ca. 4000–3500 BC), Naqada II (3500–3200 BC), and Naqada III (3200–3000 BC) (Hassan, 1997a,b; Hendrickx, 1999; Midant-Reynes, 2000b; Bard, 2000). On one hand, they may not be a continuation of the Badarian. There are indications that the latter existed concurrently with the more widespread Naqada I (Holmes and Friedman, 1989; Midant-Reynes, 2000a). Further, cranial metric and nonmetric differences were reported between groups (Keita, 1996; Prowse and Lovell, 1996). Petrie (1939), discoverer of the type site (Petrie and Quibell, 1896), believed the Naqada were non-Egyptians from the west. Baumgartel (1970) suggested a southern source. On the other hand, many postulated Badarian-Naqada continuity based on material culture similitude (Brunton, 1932; Mond and Meyers, 1937; Massoulard, 1949; Arkell and Ucko, 1965; Kantor, 1965; Fairervis, 1972; Hoffman, 1988; Midant-Reynes, 2000a,b). Yet this continuity might have been limited to the Badari region. Elsewhere, Naqada origins may be linked to an influx of refugees from Egypt's Western and Eastern Deserts (Holmes, 1989). A dental comparison of Badarian and Naqada samples will serve to assess the degree of their purported relationship.

Third, the advent of the dynastic period (ca. 3000 BC) was tied to Naqada expansion into most of Egypt (Hassan, 1997b; Bard, 2000; Midant-Reynes, 2000a). During Naqada III, kings at Hierakonpolis and Abydos initiated the unification of Upper and Lower Egypt (Hassan, 1988, 1997b; Holmes, 1989; Midant-Reynes, 2000a); this consolidation resulted in the celebrated civilization that came to rule Egypt for nearly 3,000 years. Therefore, it is commonly held that the dynastic period is a result of an internal development from the Naqada (Childe, 1952; Arkell and Ucko, 1965; Kantor, 1965; Holmes, 1989; Hassan, 1997b; Bard, 2000; Midant-Reynes, 2000a). This idea counters a long-discredited hypothesis suggesting that a foreign "race" invaded from west Asia during Naqada III times (Petrie, 1939; Engelbach, 1943; Derry, 1956; Emery, 1961). If continuity is discerned between Naqada and dynastic dental samples, the latter hypothesis can be further discounted.

Fourth, with the possible exception of 13th and 15th Dynasty Aamu and Hyksos, the first half of the dynastic is thought to have largely been one of indigenous continuity. In other words, this span, which comprises the Early Dynastic (ca. 3000–2686 BC), Old Kingdom (2686–2125 BC), First Intermediate (2125–2055 BC), Middle Kingdom (2055–1650 BC), and Second Intermediate periods (1650–1550 BC), may have been little affected by foreign biocultural influence relative to other Mediterranean-area empires (Trigger et al., 1983; Watterson, 1997; Hornung, 1999; Bard, 2000; Bourriau, 2000; Callender, 2000; Malek, 2000; Shaw, 2000). However, by the second half of the dynastic, Egypt became more cosmopolitan. Foreign input increased in the New Kingdom (1550–1069 BC) with immigrations of Libyans and Asians to complement a Nubian inflow. This influence climaxed with the 21st–25th Dynasty Libyan and Kushite rulers of the Third

Intermediate period (1069–664 BC), and 26th–27th Dynasty Libyan and Persian rulers of the Late Dynastic (664–332 BC) (Trigger et al., 1983; Watterson, 1997; Hornung, 1999; Bryan, 2000; Shaw, 2000; van Dijk, 2000; Taylor, 2000; Lloyd, 2000a). Local culture remained mostly intact through all of this (Lloyd, 2000a), though later peoples may have become physically more diverse due to the gradual infiltration of outside elements (discussed in Shaw, 2000). Dental affinities among samples from the two broad dynastic periods will help test the degree to which this diachronic influence may have affected Egyptian biological makeup.

Lastly, following the relative cultural stability of the dynastic, Egypt came to be wholly dominated by foreign rulers during Ptolemaic (332–30 BC) and Roman (30 BC–AD 395) times. In general, the Egyptian administrative system was maintained and traditional culture mostly continued throughout these periods; regardless, Egypt began to accumulate characteristics of the occupying powers (Watterson, 1997; Lloyd, 2000a,b; Peacock, 2000). To what extent this influence involved gene flow into the native peoples is unknown. Keita (1992, p. 251) suggested that migrations resulting in a "major genetic impact" might have occurred immediately prior to and during this period. However, the numbers of Greek and Roman immigrants (Peacock, 2000), particularly outside the major centers of government, were probably low. As such, indigenous Egyptians may not have differed significantly from their dynastic predecessors. Again, affinities among samples from these two time-successive periods can help gauge the amount of biological influence these outside groups had on the local peoples.

Beyond testing various hypotheses and less formal assumptions, other intersample variation identified by dental analyses will be examined in the light of known Egyptian history, and interpretations of this patterning will be offered. At a more basic level, study of the samples will provide a better assessment of the diachronic occurrence and expression of the 36 dental traits beyond that currently known. Ultimately, it is anticipated that all of this information will complement and expand upon the findings of previous researchers, and lead to an improved understanding of the peoples and peopling of this important time and place in African prehistory.

## MATERIALS

Although far from comprehensive, the 15 samples ( $n = 996$  individuals) compared in the present study provide a representative cross-section of ancient Egyptian populations. Each is identified here by subregion and temporal sequence. Information concerning sample recovery and composition is also presented. Basic summary data are listed in Table 1. More detailed descriptions can be found in the sources cited below.

Nine samples ( $n = 685$  individuals) are derived from sites within Upper Egypt (Fig. 1). The first was excavated at Gebel Ramlah (abbreviated as GRM in tables and figures), in the Western Desert, by the Combined Prehistoric Expedition (Schild et al., 2002; Irish et al., 2003; Kobusiewicz et al., 2004). The remains are from Neolithic seminomadic herders and intensive gatherers (Wendorf et al., 1984; Wendorf and Schild, 2001). Although technically from Lower Nubia and used in a study of that region's inhabitants (Irish, 2005), the sample is included here to provide some representation of this little-known cultural period in Egypt. The second sample is comprised of skele-

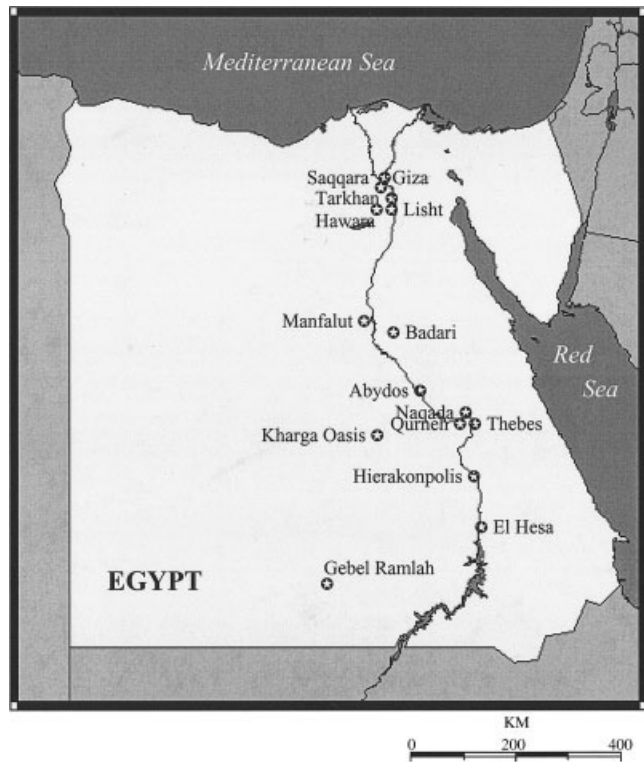
TABLE 1. *Egyptian dental samples*

Sample name <sup>1</sup>	Site(s)	Period	Sub-period	Date	No.	Location <sup>2</sup>
<b>Upper Egypt</b>						
Gebel Ramlah (GRM)	Gebel Ramlah	Neolithic	Final Neolithic	c. 4,650–4,400 BC	59	GRM
Badarian (BAD)	Badari	Predynastic	Badarian	c. 4400–4000 BC	40	CAM
Naqada (NAQ)	Naqada	Predynastic	Naqada I and II	c. 4000–3200 BC	65	CAM
Hierakonpolis (HRK)	Hierakonpolis	Predynastic	Naqada II	c. 3500–3200 BC	247	HRK
Abydos (ABY)	Abydos	Early Dynastic	Dynasty 1–2	c. 3000–2686 BC	54	BMNH, CAM
Thebes (THE)	Thebes	Middle Kingdom	Dynasty 11–12 (?) <sup>3</sup>	2055–1773 BC	54	AMNH
Qurneh (QUR)	Qurneh	New Kingdom (+)	Dynasty 19 (20–22)	1295–1186 BC (+)	67	CAM
El Hesa (HES)	El Hesa	Roman	Roman	AD 200–400	72	AMNH
Kharga (KHA)	Kharga Oasis	Roman	Byzantine	AD 500–600	26	NMNH
<b>Lower Egypt</b>						
Tarkhan (TAR)	Tarkhan	Early Dynastic	Dynasty 1 (?)	c. 3000–2890 BC	51	CAM
Saqqara (SAQ)	Saqqara	Old Kingdom	Dynasty 4	2613–2494 BC	41	MH
Lisht (LIS)	Lisht	Middle Kingdom	Dynasty 12	1985–1773 BC	61	NMNH
Giza (GIZ)	Giza	Late Dynastic	Dynasty 26–30	664–332 BC	62	CAM
Greek Egyptian (GEG)	Saqqara, Manfalut	Ptolemaic	Ptolemaic	332–30 BC	46	MH
Hawara (HAW)	Hawara	Roman	Roman	AD 50–120	51	BMNH

<sup>1</sup> Sample three-letter abbreviations used in all subsequent tables and most figures.

<sup>2</sup> AMNH, American Museum of Natural History; BMNH, British Museum of Natural History; CAM, Cambridge University; GRM, Gebel Ramlah archaeological site; HRK, Hierakonpolis archaeological site, Egypt; MH, Musée de l'Homme; NMNH, National Museum of Natural History.

<sup>3</sup> See text for explanations of parenthetical symbols and information.



**Fig. 1.** Origins of 15 Egyptian samples used in present study.

tal remains from early predynastic farmers (Hendrickx and Vermeersch, 2000) from Badari (BAD). It was recovered by Flinders Petrie for a British School of Archaeology expedition (Stoessiger, 1927; Morant, 1935). The third Upper Egyptian sample, Naqada (NAQ), is from three later predynastic cemeteries thought to vary by social status (Johnson and Lovell, 1994); it too was collected by Petrie (Petrie and Quibell, 1896; Warren, 1897; Fawcett, 1902). All but three specimens in this sample are affiliated

with the lower class. The fourth sample was also recovered from predynastic cemeteries of differing status at Hierakonpolis (HRK). It was excavated by the Hierakonpolis Expedition. Most remains are from the lower class (Hoffman, 1987; Adams, 1996; Friedman, 1999). Much of the fifth sample, Abydos (ABY), comprises Early Dynastic officials and other palace staff who were sacrificed and buried near their First Dynasty kings. Other specimens are less precisely dated to the First and/or Second Dynasties. Petrie excavated the lot in 1899–1901 (Petrie, 1902, 1922; Bard, 2000). The sixth sample is from Thebes (THE); it was assembled in 1904 as part of the Felix von Luschan Collection. Museum records list few details, and the sample is only generally dated to the Middle Kingdom. Still, at the time this collection was made, historians thought the latter period encompassed only the 11th and 12th Dynasties (Callender, 2000). Thus the sample can plausibly be assigned to this more specific time frame. The seventh sample originated in a New Kingdom cemetery near the Qurneh (QUR) mortuary temple (Petrie, 1909). E.W. Budge excavated it in 1887. Museum records show that most specimens recorded for the present study date to the time of Rameses II; a few are of the later New Kingdom or early Third Intermediate period. The eighth sample is from a late Roman middle class cemetery on the now-submerged Nile island of El Hesa (HES) (Elliot Smith and Wood-Jones, 1910; Reisner, 1910). Museum records report that the remains were excavated in 1907–1908 for von Luschan (Irish, 1993). Lastly, the ninth Upper Egyptian sample comes from two Byzantine-period cemeteries in the Kharga Oasis (KHA). Museum documentation regarding excavation or social status of the sample is not available. However, these people may have been lower-class farmers (Irish, 1993).

The six remaining dental samples ( $n = 312$  individuals) originated in Lower Egypt (Fig. 1). The first is from Tarkhan (TAR). Although there is conflicting information about the age of some remains in museum records, those used in this study likely date to the Early Dynastic. Support for this affiliation can be found in reports by Petrie et al. (1913) and Petrie and MacKay (1915) that documented excavations at the site and an adjacent, younger



TABLE 2. Dental trait percentages (%) and number of individuals scored (n) for 15 Egyptian samples<sup>1</sup>

Trait <sup>2</sup>		Upper Egyptian samples									Lower Egyptian samples					
		GRM	BAD	NAQ	HRK	ABY	THE	QUR	HES	KHA	TAR	SAQ	LIS	GIZ	GEG	HAW
Winging UI1	%	0.0	5.6	6.0	5.4	4.4	5.6	5.2	6.4	4.8	6.8	2.8	2.1	4.3	0.0	0.0
(+ = ASU 1)	n	32	36	50	167	46	54	58	63	21	44	36	47	47	41	47
Labial curvature UI1	%	48.4	50.0	12.5	33.0	11.1	47.6	28.6	65.0	50.0	40.0	9.1	45.5	17.7	43.8	15.0
(+ = ASU 2-4)	n	31	20	8	109	9	21	21	20	6	30	11	11	17	16	20
Palatine torus	%	0.0	5.6	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+ = ASU 2-3)	n	28	36	50	125	52	51	61	68	25	44	39	51	47	43	49
Shoveling UI1	%	42.9	25.0	14.3	17.7	40.0	15.8	0.0	29.4	0.0	7.1	0.0	0.0	15.4	5.9	0.0
(+ = ASU 2-6)	n	28	16	7	102	5	19	17	17	6	28	7	10	13	17	17
Double Shoveling UI1	%	6.1	0.0	0.0	4.6	0.0	0.0	0.0	15.8	0.0	0.0	0.0	0.0	0.0	0.0	5.6
(+ = ASU 2-6)	n	33	16	7	110	4	18	22	19	6	26	8	12	16	15	18
Interruption groove UI2	%	18.5	10.0	9.1	25.2	21.4	20.8	3.7	50.0	20.0	8.8	33.3	31.6	4.2	22.2	25.0
(+ = ASU +)	n	27	20	11	115	14	24	27	22	5	34	9	19	24	27	20
Tuberculum dentale UI2	%	59.3	36.4	27.3	36.7	36.4	30.0	52.2	61.9	20.0	28.1	66.7	36.8	25.0	45.8	42.9
(+ = ASU 2-6)	n	27	22	11	109	11	20	23	21	5	32	6	19	24	24	14
Bushman canine UC	%	10.7	0.0	0.0	5.0	17.7	3.1	0.0	6.5	0.0	5.4	0.0	0.0	6.3	0.0	0.0
(+ = ASU 1-3)	n	28	22	22	120	17	33	31	31	9	37	10	27	32	30	26
Distal accessory ridge UC	%	31.8	12.5	15.0	12.6	30.0	10.5	8.7	13.6	0.0	3.9	0.0	0.0	7.1	0.0	31.3
(+ = ASU 2-5)	n	22	16	20	103	10	19	23	22	8	26	6	23	28	24	16
Hypocone UM2	%	91.9	86.7	90.9	86.6	85.7	85.7	87.0	75.4	85.0	75.0	95.7	88.1	84.2	79.3	86.7
(+ = ASU 3-5)	n	37	30	44	157	42	42	46	57	20	40	23	42	38	29	45
Cusp 5 UM1	%	10.5	10.0	17.5	15.5	19.2	14.3	5.3	8.7	6.7	0.0	0.0	15.4	5.7	0.0	6.5
(+ = ASU 2-5)	n	19	20	40	97	26	28	38	46	15	23	9	26	35	24	31
Carabelli's trait UM1	%	88.0	64.7	68.4	80.8	84.4	90.3	70.6	47.6	66.7	67.9	100.0	60.9	72.7	82.6	64.5
(+ = ASU 2-7)	n	25	17	38	104	32	31	34	42	18	28	16	23	33	23	31
Parastyle UM3	%	0.0	0.0	0.0	0.0	2.9	0.0	3.0	2.7	0.0	2.6	0.0	0.0	0.0	0.0	0.0
(+ = ASU 1-5)	n	32	23	28	142	36	37	33	37	16	38	15	32	26	28	30
Enamel extension UM1	%	9.4	6.5	15.2	19.5	9.3	4.8	9.8	3.3	4.4	0.0	0.0	14.9	6.4	13.8	4.8
(+ = ASU 1-3)	n	32	31	46	164	43	42	51	61	23	45	18	47	47	29	42
Root number UP1	%	72.2	70.6	76.1	59.8	71.0	85.3	70.6	63.8	73.9	75.0	89.7	61.9	62.5	64.3	60.0
(+ = ASU 2+)	n	36	17	46	164	31	34	34	47	23	32	29	42	32	28	30
Root number UM2	%	60.6	80.0	73.5	75.6	73.7	81.3	70.0	62.2	66.7	72.2	82.6	77.3	72.7	21.4	82.8
(+ = ASU 3+)	n	33	15	34	119	19	32	30	37	18	18	23	44	22	14	29
Peg-reduced UI2	%	5.3	10.3	0.0	3.6	2.0	0.0	1.6	0.0	11.1	4.0	6.1	0.0	1.8	0.0	2.0
(+ = ASU P or R)	n	38	39	60	197	49	54	62	24	9	50	33	22	57	43	49
Odontome P1-P2	%	0.0	0.0	0.0	1.3	0.0	5.1	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+ = ASU +)	n	27	31	49	156	36	39	50	59	23	43	12	42	42	30	40
Congenital absence UM3	%	15.0	8.6	3.7	8.2	7.4	19.6	18.6	30.8	8.7	4.1	20.0	3.6	15.4	18.2	16.3
(+ = ASU -)	n	40	35	54	184	54	51	59	65	23	49	35	55	52	44	49
Midline diastema UI1	%	12.1	5.3	0.0	3.0	0.0	1.9	0.0	3.0	7.1	4.2	0.0	7.7	0.0	0.0	0.0
(+ ≥ 0.5 mm)	n	33	38	52	168	51	53	61	66	14	48	33	39	52	43	49
Lingual cusp LP2	%	61.9	79.2	95.7	81.4	76.0	70.3	54.3	61.5	62.5	77.8	66.7	66.7	61.9	65.5	77.1
(+ = ASU 2-9)	n	21	24	23	129	25	37	35	52	8	18	12	12	21	29	35
Anterior fovea LM1	%	35.7	9.1	18.8	21.6	66.7	42.9	35.3	32.0	66.7	0.0	14.3	37.5	17.4	35.3	61.5
(+ = ASU 2-4)	n	14	11	16	74	3	14	17	25	3	2	7	8	23	17	26
Mandibular torus	%	2.4	0.0	1.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+ = ASU 2-3)	n	41	40	58	178	41	52	52	72	16	49	37	37	51	40	49
Groove pattern LM2	%	66.7	35.3	45.8	37.1	27.0	25.0	20.0	18.2	10.0	30.6	22.7	37.5	29.6	17.7	39.5
(+ = ASU Y)	n	36	34	48	175	37	48	50	66	10	36	22	24	44	34	43
Rocker jaw	%	20.5	10.3	24.1	22.2	30.6	22.6	9.6	20.0	18.8	16.3	24.3	32.4	13.7	12.5	10.2
(+ = ASU 1-2)	n	39	39	54	144	36	53	52	70	16	43	37	37	51	40	49
Cusp number LM1	%	7.7	0.0	7.9	9.5	0.0	2.8	6.9	1.9	7.1	5.0	0.0	5.6	2.3	3.9	8.3
(+ = ASU 6+)	n	26	24	38	137	20	36	29	53	14	20	10	18	43	26	36
Cusp number LM2	%	78.1	19.1	27.8	36.5	33.3	26.3	22.5	31.0	15.4	50.0	25.0	20.8	25.0	6.9	20.5
(+ = ASU 5+)	n	32	21	36	137	24	38	40	58	13	28	12	24	36	29	39
Deflecting wrinkle LM1	%	31.3	9.5	15.2	20.5	0.0	13.3	29.2	4.6	0.0	12.5	0.0	22.2	5.7	4.0	24.2
(+ = ASU 2-3)	n	16	21	33	112	17	30	24	44	1	16	8	9	35	25	33
C1-C2 crest LM1	%	0.0	9.5	3.0	3.9	0.0	0.0	4.2	6.5	0.0	0.0	0.0	11.1	2.9	5.2	3.0
(+ = ASU +)	n	21	21	33	102	14	26	24	46	3	16	5	9	34	19	33
Protostylid LM1	%	36.0	12.5	22.2	33.1	19.1	12.2	6.3	16.1	30.8	10.0	7.1	53.3	11.4	20.0	14.3
(+ = ASU 1-6)	n	25	24	36	139	21	41	32	56	13	20	14	15	35	25	35
Cusp 7 LM1	%	5.9	13.3	10.9	6.2	3.0	6.8	5.6	6.7	0.0	3.7	0.0	0.0	4.3	6.7	9.3
(+ = ASU 2-4)	n	34	30	46	177	33	44	36	60	14	27	20	23	47	30	43
Tome's root LP1	%	9.5	5.6	10.7	14.3	3.1	11.1	12.9	11.1	12.5	13.6	6.7	8.6	0.0	14.3	9.1
(+ = ASU 3-5)	n	42	18	56	175	32	36	31	45	16	44	30	35	47	28	33
Root number LC	%	4.9	4.2	5.1	6.2	0.0	0.0	0.0	0.0	0.0	4.4	6.1	5.6	1.9	0.0	4.2
(+ = ASU 2+)	n	41	24	59	179	31	35	27	31	17	45	33	36	52	26	24
Root number LM1	%	0.0	0.0	5.1	2.2	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(+ = ASU 3+)	n	43	19	39	136	26	39	29	46	12	33	26	29	34	23	33

TABLE 2. (Continued)

Trait <sup>2</sup>		Upper Egyptian samples									Lower Egyptian samples					
		GRM	BAD	NAQ	HRK	ABY	THE	QUR	HES	KHA	TAR	SAQ	LIS	GIZ	GEG	HAW
Root number LM2	%	80.5	75.0	86.1	89.1	96.3	91.7	85.7	86.7	70.0	85.0	86.7	86.2	82.4	50.0	83.9
(+ = ASU 2+)	n	41	16	36	128	27	36	28	45	10	40	30	29	34	12	31
Torsomolar angle LM3	%	6.8	5.9	2.2	7.4	9.4	22.5	2.7	17.0	53.9	5.6	0.0	30.8	2.9	21.9	5.4
(+ = ASU +)	n	44	34	46	148	32	40	37	47	13	36	23	26	35	32	37

<sup>1</sup> GRM, Gebel Ramlah; BAD, Badarian; NAQ, Naqada; HRK, Hierakonpolis; ABY, Abydos; THE, Thebes; QUR, Qurneh; HES, El Hesa; KHA, Kharga Oasis; TAR, Tarkhan; SAQ, Saqqara; LIS, Lisht; GIZ, Gizeh; GEG, Greek Egyptians; HAW, Hawara (see text for sample details).

<sup>2</sup> ASU rank-scale trait breakpoints from Irish (1993, 1997, 1998a,b) and Scott and Turner (1997).

cemetery at Kafr Ammar. All that is listed about the second sample in museum records is that it came from Saqqara (SAQ) and dates to the Old Kingdom's Fourth Dynasty. General information about the cemetery implies that the sample may have originated from royal or wealthy elite tombs in North Saqqara (Bayfield, 2000; Malek, 2000; Grajetzki and Quirke, 2001a). The third sample is from Lisht, a necropolis that served the Middle Kingdom capital of Itjtawy (Baines and Malek, 1982). Museum records note that it comprises upper-class individuals. Specimens in the fourth sample were recovered at Giza (GIZ) (Petrie, 1907; Pearson and Davin, 1924). Little information is known beyond their Late Dynastic affiliation. The fifth sample consists of Ptolemaic or Greek period Egyptians (GEG). Most originated in Saqqara, but a few contemporaneous crania from Manfalut in Middle Egypt were included. Although the sample is potentially heterogenous, it was compiled to allow some representation of this important Egyptian period. Museum records list no additional information. The final sample was recovered at Hawara (HAW) in an early Roman period burial ground for elite members of the Fayum Oasis populace (Grajetzki and Quirke, 2001b). It was excavated by Petrie (1890).

## DATA COLLECTION METHODS

The present investigation is concerned with morphological variation of the permanent dentition. The same 36 dental and osseous oral discrete traits used by the author in previous African dental affinity studies (Irish, 1993, 1994, 1997, 1998a–d, 2000, 2005; Irish and Guatelli-Steinberg, 2003) were recorded in the Egyptian specimens (Table 2). The rationale for choosing these particular traits was previously detailed (Irish, 1993, 1998d, 2005). Of fundamental importance, however, is the high genetic component reported for many of these traits (Scott, 1973; Larsen, 1997; Scott and Turner, 1997; Rightmire, 1999), which makes them ideal for biodistance analyses (Larsen, 1997).

Except for midline diastema, each trait is part of the Arizona State University Dental Anthropology System (ASUDAS) (Turner et al., 1991); all are documented to be largely independent of one another, based on the genetic investigation of Nichol (1990). Procedures used in ASUDAS are based on well-established criteria for scoring intratrait variation, and proved reliable in many preceding studies (Scott, 1973, 1980; Turner, 1985a, 1987, 1990, 1992; Sakuma and Ogata, 1987; Haeussler et al., 1988; Turner and Markowitz, 1990; Irish and Turner, 1990; Irish, 1993, 1994, 1997, 1998a–d, 2000; Jackes et al., 2001). Traits are recorded with the aid of 23 rank-scale

reference plaques to help standardize scoring (Turner et al., 1991).

After trait selection, a decision regarding which antimeres to score is required. One method entails counting one side in all specimens (Haeussler et al., 1988). A second method is to score both antimeres and, allowing for asymmetry, count the side with the highest expression (Turner and Scott, 1977). To maximize sample size if only one side is present, that side is scored and assumed to represent the highest expression. This standard ASUDAS protocol is used here; it assumes scoring for the individual's maximum genetic potential (Turner, 1985a).

Finally, because there is a demonstrated absence of trait sexual dimorphism (Scott, 1973, 1980; Smith and Shegev, 1988; Bermudez de Castro, 1989; Turner et al., 1991; Hanihara, 1992; Irish, 1993), it is standard ASUDAS procedure to pool the sexes (Irish, 1997). A comprehensive description of ASUDAS is provided in Turner et al. (1991) and Scott and Turner (1997).

## QUANTITATIVE METHODS AND RESULTS

### Dental trait frequencies

The first step in analyzing samples was to determine frequencies of occurrence for all 36 traits. In Table 2, the percentages of individuals exhibiting each trait are listed, along with total number scored. All were dichotomized into categories of present or absent, as evidenced by associated ASUDAS grades; this practice allows for a manageable presentation of many traits and samples, and is necessary before using these rank-scale data with most multivariate statistics (Sjøvold, 1977). Dichotomization is based on each trait's morphological threshold (Haeussler et al., 1988), as ascertained by Scott (1973) and Nichol (1990) according to standard ASUDAS procedure (Turner, 1985b, 1987; Scott and Turner, 1997). Though practical, the full range of data is not presented. A list of traits with alternate breakpoints can be requested from the author.

As often happens with archaeologically derived remains, small sample size is a factor concerning trait frequencies; maxillary incisors in general, and the Kharga and Saqqara samples in particular, are most adversely affected. Such data should be interpreted with caution, as they may not be representative of the populations from which they derive. With this caveat in mind, an inspection of Table 2 suggests that there is some measure of dental homogeneity. That is, the samples exhibit many comparable frequencies and trends across traits, with some obvious exceptions (e.g., Gebel Ramlah = high LM2 Y-groove and five-cusped LM2; El Hesa = high UI2 interruption groove, UM3 congenital absence, and low UM1 Carabelli's trait; Saqqara = high UM1 Carabelli's trait and

TABLE 3. Twenty-two dental traits used in MMD analysis

---

1) Interruption groove UI2
2) Tuberculum dentale UI2
3) Bushman canine UC
4) Distal accessory ridge UC
5) Hypocone UM2
6) Cusp 5 UM1
7) Carabelli's trait UM1
8) Enamel extension UM1
9) Root number UP1
10) Root numbwe UM2
11) Peg-reduced UI2
12) Congenital absence UM3
13) Midline diastema UI1
14) Lingual cusp LP2
15) Groove pattern LM2
16) Rocker jaw
17) Cusp number LM2
18) Protostylid LM1
19) Cusp 7 LM1
20) Tome's root LP1
21) Root number LM2
22) Torsomolar angle LM3

---

two-rooted UP1; Lisht = high rocker jaw and LM1 protostylid; Greek Egyptians = low three-rooted UM2, five-cusped LM2, and two-rooted LM2).

### Mean measure of divergence

The second step in analysis was to submit the trait data to C.A.B. Smith's mean measure of divergence (MMD) (Berry and Berry, 1967; Sjøvold, 1973, 1977). This statistic was used effectively in many previous studies (e.g., Berry and Berry, 1972; Sjøvold, 1973, 1977; Greene, 1982; Scott and Dahlberg, 1982; Turner, 1984, 1985a, 1992; Turner and Markowitz, 1990; Lukacs and Hemphill, 1991; Irish, 1997, 1998a–d, 2005; Donlon, 2000; Jackes et al., 2001; Irish and Guatelli-Steinberg, 2003). Additional justification regarding its application was presented elsewhere (Irish and Guatelli-Steinberg, 2003; Irish, 2005).

MMD calculates intersample phenetic affinities that, in turn, provide estimates of biological divergence. That is, dental phenetic similarity is assumed to approximate or provide an estimate of underlying genetic variation (Scott et al., 1983; Rightmire, 1999). The formula used here includes the Freeman and Tukey angular transformation correction for small samples ( $\geq 10$ ), and low ( $\leq 0.05$ ) or high ( $\geq 0.95$ ) trait frequencies (Berry and Berry, 1967; Sjøvold, 1973, 1977; Green and Suchey, 1976). However, it should be noted that use of this transformation may yield an artificial “negative” MMD when two samples are highly concordant. In these cases, the value is adjusted to 0.00, indicating a lack of divergence. To detect if two samples significantly differ from one another, a distance is compared to its standard deviation. If MMD is  $> 2 \times SD$ , the null hypothesis of Population 1 = Population 2 is rejected at the 0.025 level (Sjøvold, 1977).

It is suggested that as many discrete traits as possible should be used with MMD; however, they cannot be correlated because differential weighting of the underlying dimensions may yield erroneous results (Sjøvold, 1977, personal communication in 1992). In the present study, intertrait correlations were determined by submitting the nondichotomized ordinal data to Kendall's tau-b correlation coefficient. Twenty-eight of 630 pairwise comparisons are strongly correlated (i.e.,  $\tau_b \geq 0.5$ ); these pairs mainly include anterior maxillary traits, such as UI1 labial cur-

vature with UI1 shoveling ( $\tau_b = 0.816$ ) and UI1 shoveling with UI1 double-shoveling ( $\tau_b = 0.852$ ), and posterior mandibular traits like LM1 C1–C2 crest with LM1 anterior fovea ( $\tau_b = 0.650$ ) and LM1 cusp number with LM1 deflecting wrinkle ( $\tau_b = 0.694$ ). Several of these traits also include smaller sample sizes than the Freeman and Tukey transformation is designed to correct for. Thus, traits that are highly correlated and/or exhibit three or more samples of  $< 10$  cases were dropped from analysis. Several traits that are largely nondiscriminatory due to shared low frequencies or absence across samples were deleted as well: palatine torus, UM3 parastyle, and mandibular torus. This editing left 22 minimally correlated traits (Table 3) that provide good discriminatory power and, with a few unavoidable exceptions involving Kharga and Saqqara, are of adequate sample size.

The MMD distance matrix is presented in Table 4. The homogeneity hinted at by the qualitative frequency comparisons is supported by the many low values. Yet a number of sample pairs exhibit significant and, in some cases, large distances. Not surprisingly, samples noted to exhibit relatively high or low frequencies are most divergent. Gebel Ramlah and the Greek Egyptians have identical mean MMD values of 0.126. El Hesa (0.078), Saqqara (0.079), and Lisht (0.083) are also somewhat distinct. In contrast, Badari (0.028), Thebes (0.039), and Hawara (0.041) show a general affinity to all samples. Additional trends are hard to recognize, although several samples that are close in time and space, like Naqada, Hierakonpolis, and Abydos, share low and insignificant values.

An effective way to illustrate MMD distances among samples is multidimensional scaling (MDS). This provides a 1-through-n-dimensional spatial representation of the points (Kruskal and Wish, 1978). Therefore, the plotting of samples into groups shows varying degrees of relationship. In the present case, interval-level MDS was used because the large number of traits causes the matrix of distance values to approximate continuous data.

A three-dimensional MDS configuration of distance values is presented in Figure 2. Upper Egyptian samples are represented by white, and Lower Egyptians by black squares in Figure 2 and all figures following. Although there are a few instances where phenetically similar samples are not positioned near one another, the MDS does provide a good representation of the MMD matrix; Kruskal's stress formula 1 value is 0.122, and  $r^2$  is 0.912. As such, trends mentioned above are evident. For example, Gebel Ramlah and the Greek Egyptians are widely separated along the y-axis, and are somewhat distinct from 11 or so other samples forming a cluster near the diagram's center; Badari, Thebes, and Hawara are at the heart of this cluster. Lisht and El Hesa are removed from the latter grouping along the x- and z-axes, respectively. Lastly, Abydos, Naqada, and Hierakonpolis are located next to one another.

### Correspondence analysis

The third step in the analysis was to detect which of the 22 traits are most influential in generating affinities. Although a qualitative comparison of frequencies can give indications, correspondence analysis (CA) was used to quantify which traits vary most across samples. In the process, CA also provides a plot of intersample variation that is similar in appearance to an MDS diagram of MMD distances. Like MMD, the method was employed in several prior anthropological studies (Greenacre and Degos,



TABLE 4. MMD distance matrix for 22 discrete dental traits among 15 Egyptian samples<sup>1</sup>

Samples	GRM	BAD	NAQ	HRK	ABY	THE	QUR	HES	KHA	TAR	SAQ	LIS	GIZ	GEG	HAW
Gebel Ramlah	0.0														
Badari	<i>0.094</i>	0.0													
Naqada	<i>0.115</i>	0.000	0.0												
Hierakonpolis	<i>0.068</i>	0.012	0.006	0.0											
Abydos	<i>0.058</i>	0.020	0.013	0.000	0.0										
Thebes	<i>0.113</i>	0.011	0.036	0.029	0.000	0.0									
Qurneh	<i>0.144</i>	0.000	<i>0.053</i>	<i>0.064</i>	<i>0.053</i>	0.027	0.0								
El Hesa	<i>0.139</i>	<i>0.058</i>	<i>0.128</i>	<i>0.084</i>	<i>0.055</i>	<i>0.055</i>	<i>0.060</i>	0.0							
Kharga	<i>0.167</i>	0.000	<i>0.102</i>	0.053	0.063	0.005	0.060	0.038	0.0						
Tarkhan	<i>0.102</i>	0.000	<i>0.042</i>	<i>0.052</i>	0.044	0.034	0.027	<i>0.082</i>	0.033	0.0					
Saqqara	<i>0.130</i>	0.054	<i>0.107</i>	<i>0.079</i>	0.050	0.012	0.031	<i>0.098</i>	<i>0.100</i>	0.058	0.0				
Lisht	<i>0.150</i>	<i>0.054</i>	<i>0.069</i>	<i>0.032</i>	<i>0.072</i>	<i>0.058</i>	<i>0.116</i>	<i>0.081</i>	0.000	<i>0.096</i>	<i>0.142</i>	0.0			
Giza	<i>0.130</i>	0.000	0.035	<i>0.048</i>	0.015	0.025	0.000	<i>0.084</i>	0.050	0.008	0.057	<i>0.093</i>	0.0		
Greek Egyptians	<i>0.257</i>	<i>0.092</i>	<i>0.160</i>	<i>0.146</i>	<i>0.178</i>	<i>0.118</i>	<i>0.074</i>	<i>0.105</i>	0.018	<i>0.132</i>	<i>0.135</i>	<i>0.120</i>	<i>0.101</i>	0.0	
Hawara	<i>0.100</i>	0.000	0.005	0.022	0.010	0.020	0.006	0.030	0.064	0.037	0.058	<i>0.084</i>	0.012	<i>0.127</i>	0.0

<sup>1</sup> See Table 1 and text for sample details. Italicized values indicate significant difference at 0.025 level.

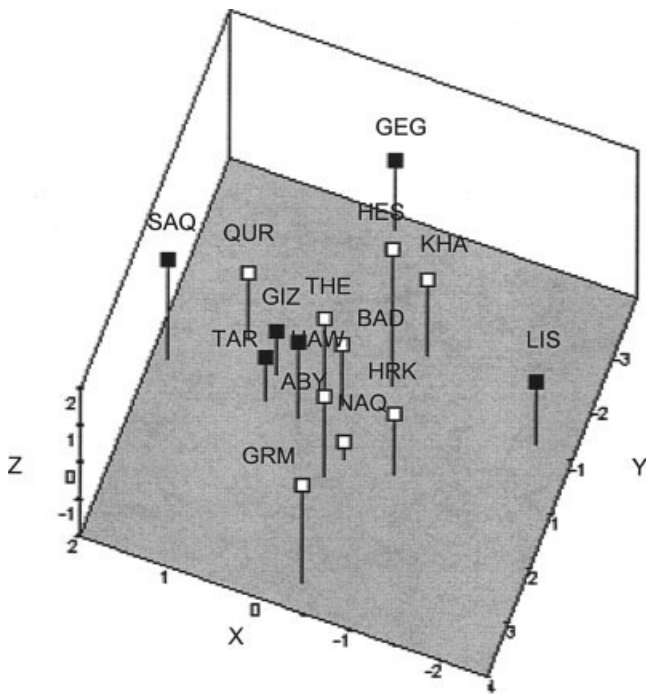


Fig. 2. Three-dimensional MDS of 22-trait MMD distances among 15 Egyptian samples. Upper Egyptians are depicted with white squares, and Lower Egyptians with black. Three-letter sample abbreviations are defined in text.

1977; Schneider, 1986; Sciulli, 1990; Kitagawa et al., 1995; Coppa et al., 1998; Irish, 2005).

Correspondence analysis is a variant of principal components analysis (PCA). It factors discrete data comprising the rows and columns of a contingency, or correspondence table, and displays them in reduced space to illustrate associations; the data comprise trait percentages in the present study. A chi-square distance matrix of the traits is used as input to the PCA. Three plots are then produced that illustrate variation among rows, columns, and rows/columns combined. The x-axis of each plot corresponds to the first dimension and explains the most variation, or inertia, of the chi-square value. The y- and z-axes are orthogonal and explain successively less variance (Greenacre and Degos, 1977; StatSoft, Inc., 1984–2003;

Clausen, 1988; Benzécri, 1992; Phillips, 1995). Additional methodological details are provided in Irish (2005).

An abridged CA table is presented in Table 5. The significant  $\chi^2$  value of 1,432.119 shows that the row and column variables of the correspondence table are related. Fourteen dimensions deemed to be interpretable by the program are listed. The corresponding inertia and total inertia values are seen in the second column. The latter value indicates that 13.8% of the table's variance is explained: a typical amount, considering the number of variables. Lastly, the proportion of inertia for each dimension is tabulated. The first three dimensions account for 60.6% of the variance explained by the CA model.

The three-dimensional row plot in Figure 3 depicts relationships among samples based on the 22 traits. Although shifting of points is evident, the overall intersample pattern of affinities is similar to the MDS portrayal of MMD distances. The column plot in Figure 4 illustrates trait variation. Both are scaled using symmetrical normalization. Much can be learned from the individual plots. However, a principal feature of CA is to combine the two into a single biplot to facilitate direct comparison of sample and trait association. Unfortunately, there are too many row and column points to yield a legible biplot. Thus, despite differences in scale, between-plot comparisons must suffice to identify which traits vary most among samples.

Comparing Figures 3 and 4, the most influential traits separating samples along the first dimension, or x-axis, are UC Bushman canine (abbreviated as 3 in Fig. 4), UC distal accessory ridge (4), and LM3 torsomolar angle (22). Thus, samples on the left side of Figure 3, like Gebel Ramlah and Abydos, have relatively high frequencies of the former two traits, while Kharga and Lisht exhibit high occurrences of the latter. The first dimension accounts for 29.4% of the inertia.

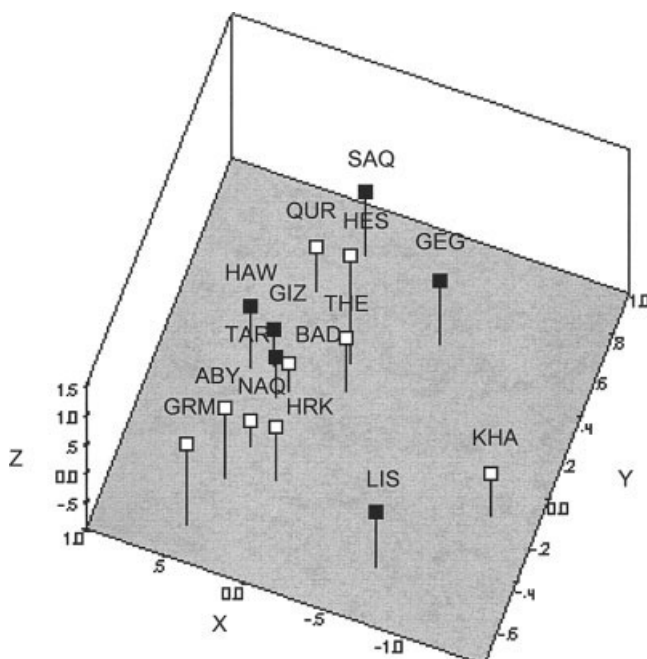
Along the y-axis, the second dimension accounts for 18.6% of the inertia. The important traits are Bushman canine (3), UM1 cusp 5 (6), UI1 midline diastema (13), LM1 protostylid (18), and UM3 congenital absence (12). As such, samples at the bottom of Figure 3, like Gebel Ramlah, Abydos, Hierakonpolis, and Lisht, generally have higher frequencies of the first four traits. Saqqara, El Hesa, Qurneh, and the Greek Egyptians have high occurrences of the last trait.

Important traits along the final dimension, as denoted by the z-axis, are UI2 interruption groove (1), Bushman canine (3), UM3 congenital absence (12), and peg-reduced UI2 (11). To illustrate, El Hesa has extreme rates of the

TABLE 5. Correspondence analysis summary table

Dimension	Inertia (Eigenvalue)	Chi square	Significance	Proportion of inertia accounted for	Cumulative inertia
1	0.040			0.294	0.294
2	0.026			0.186	0.479
3	0.017			0.127	0.606
4	0.013			0.096	0.702
5	0.011			0.080	0.782
6	0.009			0.068	0.849
7	0.007			0.049	0.898
8	0.004			0.029	0.927
9	0.003			0.022	0.950
10	0.002			0.016	0.966
11	0.002			0.014	0.980
12	0.002			0.011	0.992
13	0.001			0.006	0.998
14	0.000			0.002	1.000
Total	0.138	1,432.119	0.000 <sup>1</sup>	1.000	1.000

<sup>1</sup> Two hundred ninety-four degrees of freedom.



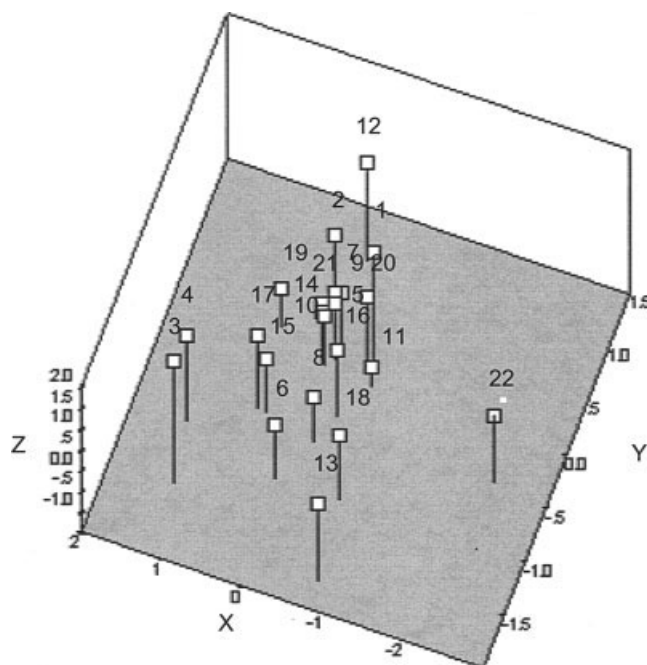
**Fig. 3.** Correspondence analysis three-dimensional row plot, based on symmetrical normalization, illustrating relationships among 15 samples. Upper Egyptians are depicted with white squares, and Lower Egyptians with black. Three-letter sample abbreviations are defined in text.

former three traits relative to Badari, which has a high incidence of the latter. The third dimension accounts for 12.7% of the total inertia.

In sum, of the 22 traits submitted to MMD analysis, nine were identified by CA as being the most influential. They include: UI2 interruption groove, UC Bushman canine, UC distal accessory ridge, UM1 cusp 5, peg-reduced UI2, UM3 congenital absence, UI1 midline diastema, LM1 protostylid, and LM3 torsomolar angle.

### Mahalanobis distances

The final step in analysis was to generate intersample affinities using only the above nine traits to affirm their influence. The Mahalanobis  $D^2$  statistic for discrete traits (Konigsberg, 1990) was used for this purpose instead of

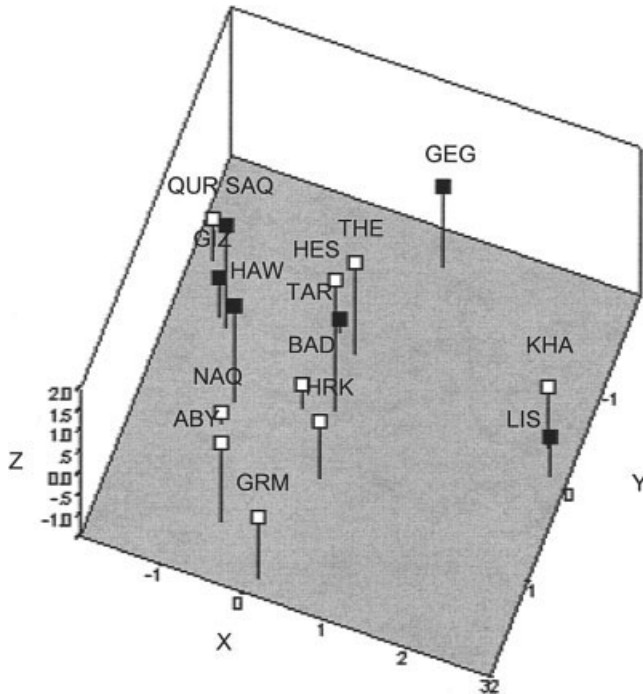


**Fig. 4.** Correspondence analysis column plot, based on symmetrical normalization, illustrating variation among 22 dental traits used for MMD analysis. Numbers correspond to traits listed in Table 3.

the MMD because it is more effective in comparing a smaller number of traits. In brief, this version of the  $D^2$  statistic extends the Mahalanobis generalized distance to discrete data by utilizing a tetrachoric correlation matrix. Correlations are calculated within each sample and pooled using sample size for each trait pair to find the weighted average correlation. As such, the statistic is useful in correcting for small sample sizes that still affect a few traits, and addresses any remaining intertrait correlation, i.e., it avoids undue weight on any traits that may co-occur. Additional methodological details can be found in Konigsberg (1990), Konigsberg et al. (1993), Ishida and Dodo (1997), and Bedrick et al. (2000).

Based on Kruskal's stress formula 1 value of 0.113 and the  $r^2$  of 0.901, three-dimensional MDS (Fig. 5) provides a good representation of distances in the  $D^2$  matrix; the latter





**Fig. 5.** Three-dimensional MDS of nine-trait Mahalanobis  $D^2$  distances among 15 samples. Upper Egyptians are depicted with white squares, and Lower Egyptians with black. Three-letter sample abbreviations are defined in text.

is not shown but may be requested from the author. Shifting of points is evident, but the overall patterning is comparable to that based on 22-trait MMDs (Fig. 2) and the CA row plot (Fig. 3). Gebel Ramlah and the Greek Egyptians remain separated on the y-axis and are distinct from other, more closely grouped samples on the left of Figure 5; as before, Badari, Thebes, and Hawara are at the center of this cluster. Lisht is now joined by the small Kharga sample, yet remains separate from all others on the x-axis. El Hesa is somewhat divergent on the z-axis. Many intracluster affinities appear stable as well; among others, Abydos, Naqada, and Hierakonpolis are spatially proximate.

The fact that these relationships mirror those of the MMD and CA suggests that: 1) the nine traits are indeed responsible for much of the variation among samples, and 2) the affinities are real, and not a product of the statistical or illustrative method. This latter point is supported by two similar MDS diagrams that illustrate, respectively, MMD distances based on all 36 traits, and standardized MMDs (Sofaer et al., 1986; Hemphill et al., 1991) using the reduced set of 22. The former was created before inter-trait correlations were determined; neither diagram is shown. In sum, these multivariate statistics, whether using 36, 22, or nine traits, were not simply run as a statistical exercise, although the results are methodologically informative; rather, the intent was to identify influential traits and, more importantly, confirm the validity of these affinities prior to interpreting them below.

## DISCUSSION

### Intersample variation

The numerically derived affinities (Table 4) and their patterning in the MDS and CA (Figs. 2, 3, 5) suggest that there is some measure of homogeneity among the bulk of

Egyptian samples. Specifically, the clustering of 11 or so samples is reminiscent of that observed among post-Paleolithic Nubians in a previous regional dental study (Irish, 2005). In the latter case, homogeneity was thought to be suggestive of population continuity. Similarly, the potential Egyptian continuity extends across time (as evidenced by affinities among the three predynastic, five of seven dynastic, and two or perhaps three Roman period samples) and space (as indicated by the mostly random distribution of points denoting Upper and Lower Egyptians). If true, the present findings vary from those based on cranial morphometric data that suggest biological heterogeneity, at least in predynastic times (Prowse and Lovell, 1996; Keita, 1996), and a broad clinal variation between populations in the north and south (Keita, 1990, 1992).

The source of any heterogeneity is thought to have stemmed from the makeup of the “proto-predynastic” (Keita, 1992, p. 251) founding population that may have comprised many biologically distinct peoples, including Saharan, Nilotic, and Levant groups (Hassan, 1988; Keita, 1990, 1992; Prowse and Lovell, 1996). This amalgam is still evident in Egypt’s modern peoples (Manni et al., 2002). However, the overall diachronic homogeneity indicated by the dental and other data (e.g., Brace et al., 1993) is likely due to extensive interaction via trade, population movement, and genetic exchange among communities along the Nile between Upper and Lower Egypt (Hassan, 1988). As Hassan (1988) observed, the narrow river valley and its thin strip of habitable land would quickly be populated during the late predynastic expansion. In other words, Egypt “became a melting pot” for the founding groups (Hassan, 1988, p. 135) by the predynastic period and beyond.

This is not to say that all the Egyptian samples are dentally homogeneous. The significant MMDs (Table 4) and distribution of samples (Figs. 2, 3, 5) show that there are 4–5 evident outliers: Gebel Ramlah, Lisht, the Greek Egyptians, and perhaps El Hesa or Saqqara. Although such divergence could be interpreted as evidence of biological heterogeneity, it is useful to explore the background of each outlier to help understand the ultimate cause(s) of the present variation.

A potentially important factor concerning Gebel Ramlah’s distinctiveness may be its remote location in extreme southern Egypt; this possibility is discussed below. Regarding Lisht, its unique frequencies (Table 2) and significant divergence (Table 4; Figs. 2, 3, 5) may reflect genetic drift and/or inbreeding in this upper-class social group from Itjtawy. Because it exhibits the closest (though still significantly different) affinities to Upper Egyptian samples, including Thebes, it may also comprise elite immigrants from the latter region. The Egyptian capital and ruling class were moved from Thebes to Itjtawy in the 12th Dynasty. Similar genetic factors were proposed to explain the biological distinctiveness of high-status remains at Naqada Cemetery T (Johnson and Lovell, 1994; Prowse and Lovell, 1996). Saqqara’s divergence could be related to small sample size; however, if it originated in royal or elite tombs as suggested, then its outlier status may be due to reasons similar to those posited for Lisht. Lastly, potential causes for the uniqueness of Greek Egyptian and El Hesa samples are presented below.

In the end, the outliers are divergent because of their extreme frequencies of the nine influential traits identified by CA. The other closely clustered samples have more moderate expressions of these, and comparable frequencies and trends across the remaining traits (Table 2). How-

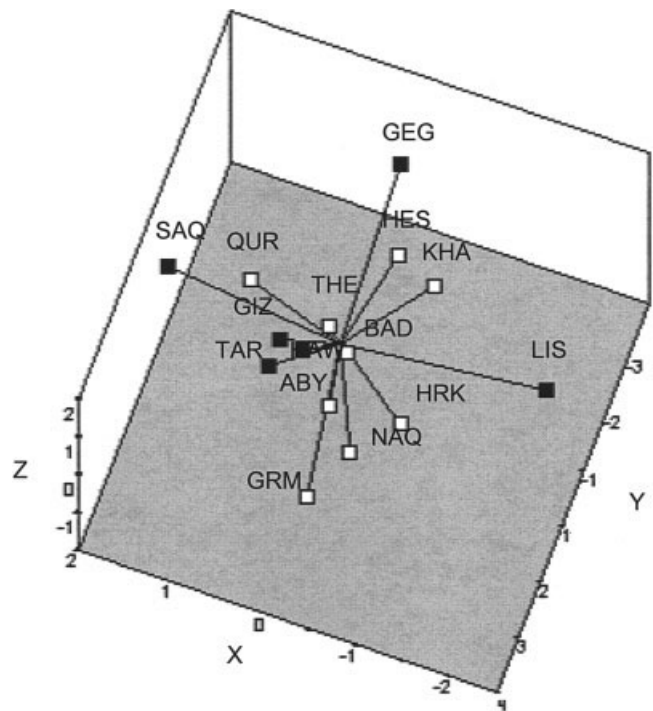
ever, all 15 samples exhibit morphologically simple, mass-reduced dentitions that are similar to those in populations from greater North Africa (Irish, 1993, 1998a–c, 2000) and, to a lesser extent, western Asia and Europe (Turner, 1985a; Turner and Markowitz, 1990; Roler, 1992; Lipschultz, 1996; Irish, 1998a). Similar craniofacial measurements among samples from these regions were reported as well (Brace et al., 1993).

### The Egyptian peopling scenarios

The most systematic way to interpret the remaining intersample affinities is in reference to the five peopling scenarios summarized at the outset. Each is briefly identified and addressed by means of comparison to the present dental findings.

**Were predynastic Badarian peoples descendants of Western Desert Neolithic groups?** If the answer to this question is yes, as suggested by many workers based on cultural affinities between groups (e.g., Hassan, 1986, 1988; Holmes, 1989; Hendrickx and Vermeersch, 2000; Midant-Reynes, 2000a), the Western Desert Gebel Ramlah and Nile Valley Badari samples might be expected to share a close affinity. Gebel Ramlah is, in fact, significantly different from Badari based on the 22-trait MMD (Table 4). For that matter, the Neolithic Western Desert sample is significantly different from all others. Does this divergence then support a non-Egyptian origin for the Badarians, as suggested by some (Brunton and Caton-Thompson, 1928; Arkell, 1975; Krzyżaniak, 1977)? Not necessarily. Despite the difference, Gebel Ramlah is closest to predynastic and early dynastic samples from Abydos, Hierakonpolis, and Badari (Table 4; Figs. 2, 3, 5). The lack of a closer affinity may be a result of purported supplementary influence on the Badarians from the Levant (Hendrickx and Vermeersch, 2000) or Eastern Desert (Holmes, 1989). Moreover, Gebel Ramlah is in the southernmost part of the Western Desert. The primary source of the Badarian culture is thought to have been the oases farther north (Caton-Thompson, 1926; Hassan, 1986, 1988; Holmes, 1989). Final Neolithic artifacts from the south and north are known to be quite different (Wendorf and Schild, 2001). In the end, although the present dental findings do not provide definitive proof, the fact that Gebel Ramlah is closest to early Upper Egyptians, including Badari, suggests that a Western Desert origin remains a viable hypothesis.

**Was there biological continuity between predynastic Naqada and Badarian peoples?** Most researchers believe there is a direct relationship between these groups, based on material culture similarities (Brunton, 1932; Mond and Meyers, 1937; Massoulard, 1949; Arkell and Ucko, 1965; Kantor, 1965; Fairservis, 1972; Midant-Reynes, 2000a,b). A comparison of Badari to the Naqada and Hierakonpolis samples is supportive of this hypothesis, and contradicts the idea of a foreign origin for the Naqada (Petrie, 1939; Baumgartel, 1970). Badari is concordant with both Naqada samples for most traits (Table 2). This correspondence is reflected by Badari's 22-trait MMDs with Naqada (0.000) and Hierakonpolis (0.012). The former affinity indicates no difference between samples, and the latter is insignificant (Table 4). These relationships are also evidenced by the nearness of all three samples in the MDS diagrams (Figs. 2, 5) and CA row plot (Fig. 3). Interestingly, these results are at odds with those of workers who reported significant cranial nonmetric



**Fig. 6.** Same three-dimensional MDS of 22-trait MMD distances as in Figure 2, except spikes are oriented toward centroid of 15 samples. Upper Egyptians are depicted with white squares, and Lower Egyptians with black. Three-letter sample abbreviations are defined in text.

(Prowse and Lovell, 1996) and metric (Keita, 1996) differences between the same Badari and Naqada (NAQ) samples studied here. The reason for this disparity is unknown, but may be related to different sample sizes or types of data employed.

Dental evidence for Badarian continuity does not simply end with the Naqada period. Of all samples, Badari exhibits the closest affinity to the 14 others based on its low mean MMD of 0.028 and central location in all diagrams (Table 4; Figs. 2, 3, 5). In fact, in the 22-trait MDS (Fig. 2), Badari is at the centroid of all 15 Egyptian samples, as shown in Figure 6. These results seemingly run contrary to evidence suggesting that Badarian cultural influence was mostly limited to the vicinity of the type site (Hassan, 1988; Holmes, 1989; Midant-Reynes, 2000a). If the present affinities are indicators of genetic variation, then the Badari sample is a good representative of what the common ancestor to all later predynastic and dynastic Egyptian peoples would be like.

**Was the dynastic period an indigenous outgrowth from the Naqada culture?** Before addressing this question, it is of interest to mention the close Naqada-Hierakonpolis affinity based on trait concordance, the low MMD (0.006), and the proximity of the samples to one another (Figs. 2, 3, 5). At first thought, a close relationship might be expected. After all, the culture is known to have expanded from its center at Naqada to influence north and south by the Naqada II phase (Hassan, 1997b; Bard, 2000; Midant-Reynes, 2000a). However, beginning at this time and intensifying in Naqada III, Hierakonpolis became a major competing political/cultural center (Hassan, 1988; Holmes, 1989; Midant-Reynes, 2000a). There



are indications (Holmes, 1989) that the inhabitants of these two centers engaged in warfare (for an opposing view, see Wildung, 1984); the result may have been the subjugation of Naqada by Hierakonpolis (Baumgartel, 1955; Bard, 1987), perhaps in alliance with a third major center at Abydos (Bard, 2000). Although the impetus for this conflict is unknown, it probably did not involve major biological differences between the peoples of these two cities, based on the dental findings.

Concerning the hypothesized Naqada/dynastic link (Childe, 1952; Arkell and Ucko, 1965; Kantor, 1965; Holmes, 1989; Hassan, 1997b; Bard, 2000; Midant-Reynes, 2000a), the homogeneity among most samples provides positive support. Naqada and Hierakonpolis share low, insignificant MMD values (Table 4) with many dynastic samples, as illustrated by their membership in the cluster of 10–11 samples in the MDS of MMD (Fig. 2) and  $D^2$  distances (Fig. 5) and CA row plot (Fig. 3). Evidence in favor of continuity is also demonstrated by comparison of individual samples. Naqada and especially Hierakonpolis share close affinities with First–Second Dynasty Abydos (MMDs = 0.013 and 0.000, respectively). Abydos, in turn, is not significantly different from First Dynasty Tarkhan (0.044), and both share low MMDs with most later dynastic and postdynastic samples (Table 4; Figs. 2, 3, 5). These findings do not support the concept of a foreign dynastic “race” (Petrie, 1939).

***Did Egyptians in the second half of the dynastic period become biologically distinct from those in the first?*** Ideally, more dynastic samples than those from Abydos, Thebes, Qurneh, Tarkhan, Saqqara, Lisht, and Giza should be compared to address such a broad question. Yet excluding the Lisht and perhaps Saqqara outliers, it appears that overall dental homogeneity among these samples would argue against such a possibility (Table 4; Figs. 2, 3, 5). Specifically, an inspection of MMD values reveals no evidence of increasing phenetic distance between samples from the first and second halves of this almost 3,000-year-long period. For example, phenetic distances between First–Second Dynasty Abydos and samples from Fourth Dynasty Saqqara (MMD = 0.050), 11–12th Dynasty Thebes (0.000), 12th Dynasty Lisht (0.072), 19th+ Dynasty Qurneh (0.053), and 26th–30th Dynasty Giza (0.027) do not exhibit a directional increase through time. Moreover, there is no conspicuous correlation between MMD and geographic distances within and between Upper and Lower Egypt. A similar pattern is evident when comparing First Dynasty Tarkhan to these same five Old Kingdom through Late Dynastic samples. All display moderate frequencies of the nine influential traits identified by CA, and a largely concordant occurrence of, and trends across, the remaining traits (Table 2). Thus, despite increasing foreign influence after the Second Intermediate Period, not only did Egyptian culture remain intact (Lloyd, 2000a), but the people themselves, as represented by the dental samples, appear biologically constant as well. These findings coincide with those of Brace et al. (1993, p. 1), who stated that the Egyptians were “largely unaffected by either invasions or migrations,” and do not support suggestions of increased diversity due to infiltration of outside physical elements.

***Did Egyptians of the Ptolemaic and Roman periods differ significantly from their dynastic antecedents?*** Again, more postdynastic samples would prove useful in answering this broad question. Moreover, any foreign genetic influence on the indigenous populace likely

diminished relative to the distance upriver. However, as it stands, the lone Greek Egyptian (GEG) sample from Lower Egypt significantly differs from all but the small Roman-period Kharga sample (Table 4). In fact, it was shown to be a major outlier that is divergent from all others (Figs. 2, 3, 5). The Greek Egyptians exhibit the lowest frequencies of UM1 cusp 5, three-rooted UM2, five-cusped LM2, and two-rooted LM2, along with a high incidence of UM3 absence, among others (Table 2). This trait combination is reminiscent of that in Europeans and western Asians (Turner, 1985a; Turner and Markowitz, 1990; Roler, 1992; Lipschultz, 1996; Irish, 1998a). Thus, if the present heterogeneous sample is at all representative of peoples during Ptolemaic times, it may suggest some measure of foreign admixture, at least in Lower Egypt near Saqqara and Manfalut. Another possibility is that the sample consists of actual Greeks. Although their total number was probably low (Peacock, 2000), Greek administrators and others were present in Lower Egypt. Future comparisons to actual Greek specimens will help verify this possibility.

Lastly, the Roman-period specimens are much more closely akin to the seven dynastic samples. Kharga and especially Hawara are most similar, based on their trait concordance (Table 2), low and insignificant MMDs (Table 4), and positions within or near the cluster of 11 or so samples (Fig. 2). El Hesa is more divergent (Figs. 2, 3, 5); this divergence was shown to be driven by several extreme trait frequencies, including very high UI2 interruption groove and UM3 absence, and very low UM1 Carabelli's trait. As above, the first two traits are common in Europeans and western Asians; the latter is rare in these areas, as well as greater North Africa (Irish, 1993, 1997). Like the Greeks, the Romans did not migrate to Lower and especially Upper Egypt in large numbers (Peacock, 2000). As such, the distinctive trait frequencies of El Hesa were probably not due to Roman gene flow. There is no evidence that Kharga and Hawara received such influence. Thus the results, at least for these samples, do not support significant biological differentiation in the Egyptians of this time relative to their dynastic predecessors.

## CONCLUSIONS

The determination of trait frequencies, identification of highly discriminatory traits, and computation of phenetic affinities among the 15 samples yields a more comprehensive dental characterization of ancient Egyptians than presented in previous reports. These findings were, in turn, effective for estimating the synchronic and diachronic biological relatedness that was used to test the viability of several long-standing peopling hypotheses and less formal assumptions.

Concerning estimates of relatedness, many samples appear dentally homogeneous. That is, with the exception of four or five outliers, most are phenetically similar enough to imply population continuity from predynastic to perhaps Roman times. Whereas the more divergent samples exhibit extreme frequencies of nine traits identified as most influential, the others share relatively moderate expressions of these traits and comparable frequencies of the rest. If these samples are indeed representative of the populations from which they were derived, then this homogeneity is also important in addressing the various peopling scenarios. Beginning with Gebel Ramlah, its relative proximity to three of four early Upper Egyptian samples, including Badari, provides some indication of the lat-



ter's origins. Affinities among the predynastic and most dynastic and postdynastic samples are then supportive of: 1) continuity between the Naqada and Badarian peoples, 2) an indigenous outgrowth of the dynastic period from the Naqada, 3) with some exceptions, biological uniformity throughout the dynastic period, and 4) continuity between the latter and subsequent Ptolemaic and Roman periods.

Lastly, beyond these relationships, additional intersample variation was identified by the distance analyses. However, without reference to pertinent existing hypotheses, the discussion of such affinities is beyond the scope of this paper. Still, the patterning illustrated by the MDS and CA diagrams is of interest, and will receive attention in future studies comparing Egyptians to samples from elsewhere in northeast Africa, greater North Africa, sub-Saharan Africa, and the western Mediterranean area. Such comparisons will also facilitate analyses of these 15 samples in a broader, more region-oriented perspective that may help shed additional light on the ultimate origins of the Egyptian peoples.

### ACKNOWLEDGMENTS

Mahalanobis distances were calculated with a program provided by Lyle Konigsberg, as modified by Steve Byers. I am grateful to the individuals at the institutions from which the data were collected: Douglas Ubelaker and David Hunt, National Museum of Natural History; Ian Tattersall, Jaymie Brauer, Gary Sawyer, and Ken Mowbray, American Museum of Natural History; Andre Langaney, Frances Roville-Sausse, Miya Awazu Periera da Silva, Alain Froment, and Phillippe Mennecier, Musée de l'Homme; Louise Humphrey, Rob Kruszynski, and Chris Stringer, British Museum of Natural History; Vivian Davies, Derek Welsby, Joyce Filer, and Margaret Judd, British Museum; and Rob Foley, Marta Lahr, and Maggie Bellatti, University of Cambridge. From the Combined Prehistoric Expedition I thank Romuald Schild, Michal Kobusiewicz, and Jacek Kabaciński; work at Gebel Ramlah was funded by the Bioanthropology Foundation and the Institute of Archaeology and Ethnology, Polish Academy of Sciences. My gratitude is extended to Fred Wendorf of Southern Methodist University, and Heba Baset, Antiquities Inspector at the Abu Simbel Office, Egypt. I also thank Renée Friedman from the Hierakonpolis Expedition; work there was funded by Raymond and Beverly Sackler, the Friends of Nekhen, and NSF grant BCS-0119754 awarded to Jerome Rose. The bulk of the research was supported by NSF grants to the author (BNS-9013942 and BNS-0104731), by the Arizona State University Research Development Program, and by the American Museum of Natural History. Lastly, the comments of *AJPA* editor Clark Larsen and the reviewers were appreciated.

### LITERATURE CITED

- Adams B. 1996. Elite graves at Hierakonpolis. In: Spencer J, editor. *Aspects of early Egypt*. London: British Museum Press. p 1–15.
- Arkell AJ. 1975. *The prehistory of the Nile Valley*. Leiden: E.J. Brill.
- Arkell AJ, Ucko PJ. 1965. Review of predynastic development in the Nile Valley. *Curr Anthropol* 6:145–166.
- Baines J, Malek J. 1982. *Atlas of ancient Egypt*. New York: Facts on File Publications.
- Bard KA. 1987. The geography of excavated predynastic sites and the rise of complex society. *Journal of the American Research Center in Egypt* 24:81–93.
- Bard KA. 2000. The emergence of the Egyptian State (c. 3200–2686 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 61–88.
- Baumgartel EJ. 1955. *The cultures of prehistoric Egypt*. Oxford: Oxford University Press.
- Baumgartel EJ. 1970. Predynastic Egypt. In: Edwards IES, Gadd CJ, Hammond NGL, editors. *Cambridge ancient history*. Cambridge: Cambridge University Press. p 463–497.
- Bayfield S. 2000. Saqqara. [www.egyptsites.co.uk](http://www.egyptsites.co.uk).
- 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*. New York: Dekker.
- Bermudez de Castro JM. 1989. The Carabelli trait in human prehistoric populations of the Canary Islands. *Hum Biol* 61:117–131.
- Berry AC, Berry RJ. 1967. Epigenetic variation in the human cranium. *J Anat* 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. *J Hum Evol* 1:199–208.
- Berry AC, Berry RJ. 1973. Origins and relations of the ancient Egyptians. In: Brothwell DR, Chiarelli BA, editors. *Population biology of the ancient Egyptians*. New York: Academic Press. p 200–208.
- Berry AC, Berry RJ, Ucko PJ. 1967. Genetical change in ancient Egypt. *Man* 2:551–568.
- Bourriau J. 2000. The second intermediate period (c. 1650–1550 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 184–217.
- Brace CL, Tracer DP, Yarooh LA, Robb J, Brandt K, Nelson AR. 1993. Clines and clusters versus “race”: a test in ancient Egypt and the case of a death on the Nile. *Yrbk Phys Anthropol* 36:1–31.
- Brunton G. 1932. The predynastic town-site at Hierakonpolis. In: Glanville SRK, editor. *Studies presented to F.L. Griffiths*. London: Egypt Exploration Society, Oxford University Press. p 272–276.
- Brunton G, Caton-Thompson G. 1928. *The Badarian civilization*. London: British School of Archaeology in Egypt.
- Bryan BM. 2000. The 18th Dynasty before the Armana period (c. 1550–1352 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 218–271.
- Callender G. 2000. The Middle Kingdom renaissance (c. 2055–1650 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 148–183.
- Caton-Thompson G. 1926. *The Neolithic industry of the northern Fayum Desert*. *J R Anthropol Inst* 56:309–323.
- Childe VG. 1952. *New light on the most ancient East*. London: Routledge and Kegan Paul, Ltd.
- Clausen SE. 1988. *Applied correspondence analysis: an introduction*. Thousand Oaks: Sage Publications.
- 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. *Am J Phys Anthropol* 107:371–386.
- Derry DE. 1956. The dynastic race in Egypt. *J Egypt Archaeol* 42:80–85.
- Donlon DA. 2000. The value of infracranial nonmetric variation in studies of modern *Homo sapiens*: an Australian focus. *Am J Phys Anthropol* 113:349–368.
- Elliot Smith G, Wood-Jones F. 1910. *The Archaeological Survey of Nubia: report for 1907–1908, volume II, report on human remains*. Cairo: National Printing Department.
- Emery WB. 1961. *Archaic Egypt*. Baltimore: Penguin Books.
- Engelbach R. 1943. The advent of the dynastic race. *Ann Service Antiq Egypte* 42:197–209.
- Fairservis WA. 1972. Preliminary report on the first two seasons at Hierakonpolis. *J Am Res Ctr Egypt* 9:7–27, 67–99.
- Fawcett CD. 1902. A second study of variation and correlation of the human skull, with special reference to the Naqada crania. *Biometrika* 1:408–467.

- Friedman R. 1999. Preliminary report on fieldwork at Hierakonpolis: 1996–1998. *J Am Res Ctr Egypt* 36:1–35.
- Grajetzki W, Quirke S. 2001a. Saqqara. [www.digitalegypt.ucl.ac.uk/saqqara/index.html](http://www.digitalegypt.ucl.ac.uk/saqqara/index.html).
- Grajetzki W, Quirke S. 2001b. Hawara. [www.digitalegypt.ucl.ac.uk/hawara1/index.html](http://www.digitalegypt.ucl.ac.uk/hawara1/index.html).
- Green R, Suchey J. 1976. The use of inverse sine transformation in the analysis of non-metrical data. *Am J Phys Anthropol* 45:61–68.
- Greenacre MJ, Degos L. 1977. Correspondence analysis of HLA gene frequency data from 124 population samples. *Am J Hum Genet* 29:60–75.
- Greene DL. 1972. Dental anthropology of early Egypt and Nubia. *J Hum Evol* 1:315–324.
- Greene DL. 1981. A critique of methods used to reconstruct racial and population affinity in the Nile Valley. *Bull Mem Soc Anthropol Paris* 8:357–365.
- Greene DL. 1982. Discrete dental variations and biological distances of Nubian populations. *Am J Phys Anthropol* 58:75–79.
- Haeussler AM, Turner CG II, Irish JD. 1988. Concordance of American and Soviet methods in dental anthropology. *Am J Phys Anthropol* 75:218.
- Hanihara T. 1992. Dental and cranial affinities among populations of East Asia and the Pacific: the basic populations in East Asia, IV. *Am J Phys Anthropol* 88:163–182.
- Hassan FA. 1976. Prehistoric studies of the Siwa Oasis region, northwestern Egypt. *Nyame Akuma* 9:18–34.
- Hassan FA. 1978. Archaeological exploration of the Siwa Oasis region, Egypt. *Curr Anthropol* 19:146–148.
- Hassan FA. 1979. Archaeological explorations at Baharia and the West Delta, Egypt. *Curr Anthropol* 20:806.
- Hassan FA. 1986. Desert environment and origins of agriculture in Egypt. *Norweg Archaeol Rev* 19:63–76.
- Hassan FA. 1988. The predynastic of Egypt. *J World Prehist* 2:135–185.
- Hassan FA. 1997a. Egypt: beginnings of agriculture. In: Vogel JO, editor. *Encyclopedia of precolonial Africa: archaeology, history, languages, cultures, and environments*. Walnut Creek: Alta Mira Press. p 405–409.
- Hassan FA. 1997b. Egypt: emergence of state society. In: Vogel JO, editor. *Encyclopedia of precolonial Africa: archaeology, history, languages, cultures, and environments*. Walnut Creek: Alta Mira Press. p 472–479.
- Hemphill BE, Lukacs JR, Kennedy KAR. 1991. Biological adaptations and affinities of Bronze Age Harappans. In: Meadow RH, editor. *Harappa excavations 1986–1990: a multidisciplinary approach to third millennium urbanism*. Madison: Prehistory Press. p 137–182.
- Hendrickx S. 1999. La chronologie de la préhistoire tardive et des débuts de l'histoire de l'Égypte. *Archeo Nil* 9:13–81.
- Hendrickx S, Vermeersch P. 2000. Prehistory: from the Palaeolithic to the Badarian culture (c. 700, 000–7000 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 17–43.
- Hillson SW. 1978. *Human biological variation in the Nile Valley in relation to environmental factors*. Ph.D. thesis. Institute of Archaeology, University of London.
- Hoffman MA. 1987. A regional perspective of the predynastic cemeteries of Hierakonpolis. In: Adams B, editor. *The fort cemetery at Hierakonpolis*. London: KPI, Ltd. p 187–202.
- Hoffman MA. 1988. Prelude to civilization: the predynastic period in Egypt. In: Willoughby KL, Stanton EB, editors. *The first Egyptians: an exhibition*. Columbia: McKissick Museum, University of South Carolina. p 33–46.
- Holmes DL. 1989. The predynastic lithic industries of Upper Egypt: a comparative study of the lithic traditions of Badari, Nagada, and Hierakonpolis. Oxford: B.A.R. International.
- Holmes DL, Friedman RF. 1989. The Badari region revisited. *Nyame Akuma* 31:15–19.
- Hornung E. 1999. *History of ancient Egypt: an introduction*. Ithaca: Cornell University Press.
- Irish JD. 1993. Biological affinities of late Pleistocene through modern African aboriginal populations: the dental evidence. Ph.D. dissertation, Arizona State University, Tempe.
- Irish JD. 1994. The African dental complex: diagnostic morphological variants of modern sub-Saharan populations. *Am J Phys Anthropol [Suppl]* 18:112.
- Irish JD. 1997. Characteristic high- and low-frequency dental traits in sub-Saharan African populations. *Am J Phys Anthropol* 102:455–467.
- Irish JD. 1998a. Dental morphological indications of population discontinuity and Egyptian gene flow in post-Paleolithic Nubia. In: Lukacs JR, editor. *Human dental development, morphology, and pathology: a tribute to Albert A. Dahlberg*. University of Oregon anthropological papers 54. Eugene: University of Oregon Press. p 155–172.
- Irish JD. 1998b. Dental morphological affinities of late Pleistocene through recent sub-Saharan and North African peoples. *Bull Mem Soc Anthropol Paris* 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. *J Hum Evol* 34:81–98.
- Irish JD. 2000. The Iberomaurusian enigma: North African progenitor or dead end? *J Hum Evol* 39:393–410.
- Irish JD. 2005. Population continuity vs. discontinuity revisited: dental affinities among Late Paleolithic through Christian era Nubians. *Am J Phys Anthropol*. Published online in Wiley InterScience ([www.interscience.wiley.com](http://www.interscience.wiley.com)) 13 May 2005.
- Irish JD, Guatelli-Steinberg D. 2003. Ancient teeth and modern human origins: an expanded comparison of African Plio-Pleistocene and recent world dental samples. *J Hum Evol* 45:113–144.
- Irish JD, Turner CG II. 1990. West African dental affinity of late Pleistocene Nubians: peopling of the Eurafian-South Asian triangle II. *Homo* 41:42–53.
- Irish JD, Kobusiewicz M, Schild R, Wendorf F. 2003. Neolithic tooth replacement in two secondary burials from southern Egypt. *J Archaeol Sci* 30:281–285.
- Ishida H, Dodo Y. 1997. Cranial variation in prehistoric human skeletal remains from the Marianas. *Am J Phys Anthropol* 104:399–410.
- Jackes M, Silva AM, Irish JD. 2001. Dental morphology: a valuable contribution to our understanding of prehistory. *J Iberian Archaeol* 3:97–119.
- Johnson AL, Lovell NC. 1994. Biological differentiation at predynastic Naqada, Egypt: an analysis of dental morphological traits. *Am J Phys Anthropol* 93:427–433.
- Kantor HJ. 1965. The relative chronologies of Egypt and its foreign correlations. In: Ehrich RW, editor. *Chronologies in Old World archaeology*. Chicago: University of Chicago Press. p 1–46.
- Keita SOY. 1990. Studies of ancient crania from northern Africa. *Am J Phys Anthropol* 83:35–48.
- Keita SOY. 1992. Further studies of crania from ancient northern Africa: an analysis of crania from First Dynasty Egyptian tombs. *Am J Phys Anthropol* 87:245–254.
- Keita SOY. 1996. Analysis of Naqada predynastic crania: a brief report. In: Krzyżaniak L, Kroeper K, Kobusiewicz M, editors. *Interregional contacts in the later prehistory of northeastern Africa*. Poznań: Poznań Archaeological Museum. p 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. *Am J Phys Anthropol* 97:101–111.
- Kobusiewicz M, Kabaciński J, Schild R, Irish J, Wendorf F. 2004. Discovery of the first Neolithic cemetery in the Western Desert of Egypt. *Antiquity* 78:545–557.
- Konigsberg LW. 1990. Analysis of prehistoric biological variation under a model of isolation by geographic and temporal distance. *Hum Biol* 62:49–70.
- Konigsberg LW, Kohn LAP, Cheverud JM. 1993. Cranial deformation and nonmetric trait variation. *Am J Phys Anthropol* 90:35–48.
- Kruskal JB, Wish M. 1978. *Multidimensional scaling*. Beverly Hills, CA: Sage Publications.
- Krzyżaniak L. 1977. *Early farming cultures of the Lower Nile: the predynastic period in Egypt*. Warsaw: Editions Scientifiques de Pologne.

- Larsen CS. 1997. *Bioarchaeology*. Cambridge: Cambridge University Press.
- Lipschultz JG. 1996. Who were the Natufians? A dental assessment of their population affinities. M.A. thesis, Arizona State University, Tempe, AZ.
- Lloyd AB. 2000a. The late period (664–332 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 369–394.
- Lloyd AB. 2000b. The Ptolemaic period (332–30 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 395–421.
- Lukacs JR, Hemphill BE. 1991. The dental anthropology of prehistoric Baluchistan: a morphometric approach to the peopling of South Asia. In: Kelley MA, Larsen CL, editors. *Advances in dental anthropology*. New York: Wiley-Liss. p 77–119.
- Malek J. 2000. The Old Kingdom (c. 2686–2125 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 89–117.
- Manni F, Leonardi P, Barakat A, Rouba H, Heyer E, Klintschar M, McElreavey K, Quintana-Murci L. 2002. Y-chromosome analysis in Egypt suggests a genetic regional continuity in northeastern Africa. *Hum Biol* 74:645–658.
- Massoulard E. 1949. *Préhistoire et protohistoire d’Égypte*. Paris: University of Paris.
- Midant-Reynes B. 2000a. The prehistory of Egypt: from the first Egyptians to the first pharaohs. Malden, MA: Blackwell Publishing.
- Midant-Reynes B. 2000b. The Naqada period (c. 4000–3200 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 44–60.
- Mond R, Myers OH. 1937. *Cemeteries of Armant I*. London: Egypt Exploration Society.
- Morant GM. 1935. A study of predynastic Egyptian skulls from Badari based on measurements taken by Miss B.N. Stoessiger and Professor D.E. Derry. *Biometrika* 27:293–309.
- Nichol CR. 1990. *Dental genetics and biological relationships of the Pima Indians of Arizona*. Ph.D. dissertation, Arizona State University, Tempe, AZ.
- Peacock D. 2000. The Roman period (30 BC–AD 395). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 422–445.
- Pearson K, Davin AG. 1924. On the biometric constants of the human skull. *Biometrika* 16:328–363.
- Petrie WMF. 1890. *Kahun, Gurob, and Hawara*. London: Kegan Paul, Trench, Trubner, and Co.
- Petrie WMF. 1902. *Abydos I*. London: Egypt Exploration Fund.
- Petrie WMF. 1907. *Gizeh and Rifeh*. London: Bernard Quaritch.
- Petrie WMF. 1909. *Qurneh*. London: Bernard Quaritch.
- Petrie WMF. 1922. *Tombs of the courtiers and oxyrynchos*. London: British School of Archaeology in Egypt.
- Petrie WMF. 1939. *The making of Egypt*. London: Sheldon Press.
- Petrie WMF, MacKay E. 1915. *Heliopolis, Kafr Ammar, and Shurafa*. London: British School of Archaeology in Egypt.
- Petrie WMF, Quibell J. 1896. *Naqada and Ballas*. London: British School of Archaeology in Egypt.
- Petrie WMF, Wainright GA, Gardiner AH. 1913. *Tarkhan I and Memphis V*. London: British School of Archaeology in Egypt.
- Phillips D. 1995. Correspondence analysis. *Social Res Update* 7:1–8.
- Prowse TL, Lovell NC. 1996. Concordance of cranial and dental morphological traits and evidence for endogamy in ancient Egypt. *Am J Phys Anthropol* 101:237–246.
- Reisner GA. 1910. *The Archaeological Survey of Nubia: report for 1907–1908, volume I, archaeological report*. Cairo: National Printing Department.
- Roler KL. 1992. Near Eastern dental variation past and present. M.A. thesis, Arizona State University, Tempe, AZ.
- Rightmire GP. 1999. Dental variation and human history. *Rev Archaeol* 20:1–3.
- Sakuma M, Ogata T. 1987. Sixth and seventh cusp on lower molar teeth of Malawians in East-Central Africa. *Jpn J Oral Biol* 29:738–745.
- Schild R, Kobusiewicz M, Wendorf F, Irish JD, Kabaciński J, Królik H. 2002. Gebel Ramlah Playa. In: Lenssen-Erz T, Tegtmeier U, Kröpelin S, editors. *Tides of the desert: contributions to the archaeology and environmental history of Africa in honour of Rudolph Kuper*. Africa Praehistorica 14, monographs on African archaeology and environment. Cologne: Heinrich-Barth Institut, University of Cologne. p 117–123.
- Schneider KN. 1986. Dental caries, enamel composition, and subsistence among prehistoric Amerindians of Ohio. *Am J Phys Anthropol* 71:95–102.
- Sciulli PW. 1990. Deciduous dentition of a Late Archaic population of Ohio. *Hum Biol* 62:221–245.
- Scott GR. 1973. *Dental morphology: a genetic study of American white families and variation in living Southwest Indians*. Ph.D. dissertation, Arizona State University, Tempe, AZ.
- Scott GR. 1980. Population variation of Carabelli’s trait. *Hum Biol* 52:63–78.
- Scott GR, Dahlberg AA. 1982. Microdifferentiation in tooth crown morphology among Indians of the American Southwest. In: Kurtén B, editor. *Teeth: form, function, and evolution*. New York: Columbia University Press. p 259–291.
- Scott GR, Turner CG II. 1997. The anthropology of modern human teeth: dental morphology and its variation in recent human populations. Cambridge: Cambridge University Press.
- Scott GR, Yap Potter RH, Noss JF, Dahlberg AA, Dahlberg T. 1983. The dental morphology of Pima Indians. *Am J Phys Anthropol* 61:13–31.
- Shaw I. 2000. Egypt and the outside world. In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 314–329.
- 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 [Suppl]* 4:1–133.
- Smith P, Shegev M. 1988. The dentition of Nubians from Wadi Halfa, Sudan: an evolutionary perspective. *J Dent Assoc S Afr* 43:539–541.
- Sofaer JA, Smith P, Kaye E. 1986. Affinities between contemporary and skeletal Jewish and non-Jewish groups based on tooth morphology. *Am J Phys Anthropol* 70:265–275.
- StatSoft, Inc. 1984–2003. Correspondence analysis. Electronic textbook. <http://www.statsoft.com/textbook/stcoran.html>.
- Stoessiger BN. 1927. A study of the Badarian crania recently excavated by the British School of Archaeology in Egypt. *Biometrika* 19:110–150.
- Taylor J. 2000. The third intermediate period (1069–664 BC). In: Shaw I, editor. *The Oxford history of ancient Egypt*. Oxford: Oxford University Press. p 330–368.
- Trigger BG, Kemp BJ, O’Connor D, Lloyd AB. 1983. *Ancient Egypt: a social history*. Cambridge: Cambridge University Press.
- Turner CG II. 1984. Advances in the dental search for Native American origins. *Acta Anthropogenet* 8:23–78.
- Turner CG II. 1985a. The dental search for Native American origins. In: Kirk R, Szathmáry E, editors. *Out of Asia*. Canberra: Journal of Pacific History. p 31–78.
- Turner CG II. 1985b. Expression count: a method for calculating morphological dental trait frequencies by using adjustable weighting coefficients. *Am J Phys Anthropol* 68:263–268.
- Turner CG II. 1987. Late Pleistocene and Holocene population history of East Asia based on dental variation. *Am J Phys Anthropol* 73:305–322.
- Turner CG II. 1990. Major features of sundadonty and sinodonty, including suggestions about East Asian microevolution, population history, and Late Pleistocene relationships with Australian Aborigines. *Am J Phys Anthropol* 82:295–318.
- Turner CG II. 1992. The dental bridge between Australia and Asia: following Macintosh into the East Asian hearth of humanity. *Perspect Hum Biol* 2/Archaeol Ocean 27:120–127.
- Turner CG II, Markowitz M. 1990. Dental discontinuity between Late Pleistocene and recent Nubians. I. Peopling of the Eurasian-South Asian triangle. *Homo* 41:42–53.



- Turner CG II, Scott GR. 1977. Dentition of Easter Islanders. In: Dahlberg AA, Graber TM, editors. Orofacial growth and development. The Hague: Mouton. p 229–249.
- Turner CG II, Nichol CR, Scott GR. 1991. Scoring procedures for key morphological traits of the permanent dentition: the Arizona State University dental anthropology system. In: Kelley MA, Larsen CS, editors. Advances in dental anthropology. New York: Wiley-Liss. p 13–32.
- van Dijk J. 2000. The Armana period and the later New Kingdom. In: Shaw I, editor. The Oxford history of ancient Egypt. Oxford: Oxford University Press. p 272–313.
- Warren E. 1897. An investigation on the variability of the human skeleton: with special reference to the Naqada race discovered by Professor Flinders Petrie in his exploration in Egypt. *Philos Trans R Soc Lond [Biol]* 189:135–227.
- Watterson B. 1997. The Egyptians. Cambridge, MA: Blackwell Publishers.
- Wendorf F, Schild R. 1980. Prehistory of the eastern Sahara. New York: Academic Press.
- Wendorf F, Schild R. 2001. Introduction. In: Wendorf F, Schild R, editors. Holocene settlements in the Egyptian Sahara. Volume 1, the archaeology of Nabta Playa. New York: Kluwer Academic/Plenum Press. p 1–10.
- Wendorf F, Schild R (assemblers), Close AE (editor). 1984. Cattle keepers of the eastern Sahara: the Neolithic of Bir Kiseiba. Dallas: Southern Methodist University.
- Wildung D. 1984. Terminal prehistory of the Nile Delta: theses. In: Krzyżaniak L, Kobusiewicz M, editors. Origin and early development of food-producing cultures in northeastern Africa. Poznań: Poznań Archaeological Museum. p 265–269.