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A Multidisciplinary Approach to Third Millennium Urbanism

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Cover art: Bowl on Stand H88-1002/192-17 associated with Burial 194a in Harappan Phase Cemetery (see Figure 13.18).

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Biological Adaptations and Affinities of Bronze Age Harappans

Brian E. Hemphill[1], John R. Lukacs[2], K.A.R. Kennedy[1]

[1]*Division of Biological Sciences, Cornell University*

[2]*Department of Anthropology, University of Oregon*

Cranial and dental metric and non-metric data derived from human skeletal remains of the Harappan phase at Harappa are employed together with comparable data from South Asia and neighboring areas to address questions of biological adaptation and continuity. A progressive decline in dental health is demonstrated to have occurred within the Indus Valley from the neolithic to the urban phase of the Harappan Civilization. This accords well with expectations of the proximate effects of increasing reliance upon agriculture. Sexual differences in dental health and differences in tooth size between humans from South Asian sites of different periods can also be related to diet and food preparation techniques. As for the question of biological continuity within the Indus Valley, two discontinuities appear to exist. The first occurs between 6000 and 4500 BC and is reflected by the strong separation in dental non-metric characters between neolithic and chalcolithic burials at Mehrgarh. The second occurs at some point after 800 BC but before 200 BC. In the intervening period, while there is dental non-metric, craniometric, and cranial non-metric evidence for a degree of internal biological continuity, statistical evaluation of cranial data reveals clear indications of interaction with the West and specifically with the Iranian Plateau.

This paper seeks to employ biological data derived from human skeletal remains recovered from the Harappan phase cemetery ("Cemetery R37") at Harappa to address two current areas of discussion raised by analyses of non-skeletal remains. These areas are progressive agricultural intensification and biological continuity.

The first of these areas concerns biological adaptation. Perhaps the most significant adaptations faced by Bronze Age Harappans were those incurred through dietary changes wrought by increasing dependence on domesticated foodstuffs. Earlier workers consistently emphasized the agricultural economy of Harappan society. In fact some scholars, impressed by the worker's platforms and granaries found in the northern part of the site of Harappa (Mound F), developed elaborate interpretations of cultural development that hinged on forces of economic development (Childe 1950, 1957).

Archaeological evidence of increasing agricultural intensification within the Indus Valley has been well documented (Allchin and Allchin 1982; Fairservis 1975; Meadow 1989). The earliest evidence for settled agriculture in South Asia comes from aceramic and later neolithic levels at Mehrgarh (ca. 6000 BC), where impressions in mud-brick of six-row barley, einkorn, emmer, and durum-bread wheat were identified by Costantini (1984). In the chalcolithic period (ca. 4500 BC), barley continued to be used but was accompanied by a dramatic increase in wheat utilization. Costantini (1979, 1984, 1990), Jarrige (1985), and Meadow (1989) have interpreted archaeobotanical remains from the occupational sequence in the Kachi Plain (Mehrgarh-Nausharo-Pirak) as comprising an early (neolithic) barley/wheat subsistence base established by the mid-sixth millennium BC that came to be supplemented in the early 2nd millennium by use of other cultigens such as rice, millets, and sorghum.

Apart from this direct evidence of cultivated foodstuffs, many important technological developments relating to food storage and preparation are also evident from aceramic and chalcolithic levels at Mehrgarh. These include the development of utilitarian pottery, grindstones, composite microlithic sickles, and grain storage structures (Jarrige 1981, 1985; Jarrige and Meadow 1980; Jarrige and Lechevallier 1979; Lechevallier and Quivron 1981, 1985; Lechevallier et al. 1982). Similarly, faunal remains demonstrate a shift from wild to domesticated varieties of cattle, goat, and sheep during the course of the neolithic period (Jarrige and Meadow 1980; Meadow 1982, 1984, 1987, 1989).

Evidence of increased dependence on agricultural foodstuffs is abundant from the Indus Civilization sites of Harappa, Kalibangan, and Mohenjo-daro (Allchin and Allchin 1982). Archaeological evidence indicates that two varieties of wheat, barley, field peas, sesame, and mustard were cultivated at these sites, while ploughed fields during pre-Harappan times at Kalibangan (Thapar 1973, 1975) suggest considerable antiquity for the contemporary practice of ploughing furrows at right angles to one another in order to accommodate two crops simultaneously. Although there is no conclusive evidence for the so-called "granaries" having been used to store grain, it is reasonable to assume that grain was an important staple during this period of prehistory (for discussion, see Fentress 1984). Harappan sites also present a well developed copper/bronze technology, which includes a variety of vessels and tools that may have been used in the treatment and preparation of cultivated foodstuffs (Allchin and Allchin 1982; Wheeler 1968).

Examination of faunal remains by Meadow (1987, 1989, Chapter 7 in this volume) and Belcher (Chapter 8 in this volume) suggests that the hunting of wild animals and fishing constituted important aspects of the Harappan subsistence strategy. These exploitation patterns are attested by the bones of a wide range of wild species recovered from Harappan sites and indicates a more intensive use of wild species during the Harappan period than at any time since the neolithic. These data suggest that, while the Harappan Civilization was no doubt an agriculturally-based society, non-agricultural foodstuffs nevertheless continued to play a vital role in the Harappan economic system. This continued utilization of non-domesticated foodstuffs may therefore be a factor that calls into question earlier models of the development of the Harappan Civilization which presumed an overwhelming reliance on intensive agricultural exploitation for increasing centralization, state formation, and intra- as well as inter-urban interdependence.

Assessment of tooth size and dental health provides insight into subsistence patterns and dietary change. Recent studies of dental afflictions by age, sex, and social status among contemporary African hunter-gatherer and horticultural groups have demonstrated that differences in subsistence activity patterns are accompanied by differences in dental pathology prevalence patterns (Walker and Hewlett 1990). In addition to these cultural factors, recent studies by Hildeboldt et al. (1988, 1989) demonstrate that the distinctive bio-geochemical features of localized geographic areas also influence dental disease prevalence. Together, these behavioral and geographic factors are responsible for the well-documented inter-populational differences in oral health that accompany changes in dietary behavior.

Although odontometric and dental pathology data are often employed in other areas of the world (Armelagos 1969; y'Edynak and Fleisch 1983; Frayer 1987, 1989; Greene 1972; Hodges 1987; Larsen 1984; Machiarelli 1989; Molnar and Molnar 1985; Powell 1988; Turner 1979), results of these studies are not consistent, and no comprehensive analysis of dental pathology among prehistoric populations of the Indian subcontinent yet exists. The data presented in this paper permit the first diachronic assessment of the consequences of dietary change on tooth size and dental health among prehistoric South Asians. Therefore, the significance of this new South Asian data is two-fold. First, these data may be used to identify biological responses to agricultural intensification shared by Harappans and other South Asians. Second, comparison of this South Asian data with data from other regions of the world allows detection of any unique or distinctive trends in pathology prevalence shared by South Asians commensurate with increased reliance upon domesticated foodstuffs (Lukacs 1991).

The second area addressed by this paper involves biological affinities. The questions addressed here are: Who were the Harappans? To whom do they share greatest biological affinities, and does the pattern of affinities possessed by Harappans indicate biological continuity or discontinuity within the Indus Valley throughout prehistory?

The rise and fall of the Harappan Civilization has been the topic of much research since the discovery of Harappa and Mohenjo-daro. Sir John Marshall, excavator of Mohenjo-daro, was an early proponent of indigenous development of the Harappan Civilization from pre-Harappan cultures within the Indus Valley (Marshall 1931). Later scholars believed the Harappan Civilization to be the product of "stimulus diffusion," or actual migration from the West (Gadd 1932; Gordon 1947, 1958; Heine-Geldern 1956; Mackay 1938; Piggott 1950; Wheeler 1968). Numerous correspondences in ceramic wares, seals, metal artifacts, beads, and other items of material culture have been cited as evidence of contact between the Indus Valley and Mesopotamia.

Further investigations within the Indus Valley, Afghanistan, and Iran since 1960 once again have led many scholars to support a model of indigenous development. Ghosh's (1965) argument for ceramic continuity between "pre-Harappan" times and the "Mature" Harappan period was followed by the "Indigenous Place" and "Three Influences" theories of Dales (1965) and Fairservis (1975). Continued investigation of new sites and re-examination of previously excavated sites in the late 1960s and early 1970s brought additional support for indigenous development of the Harappan Civilization from pre-Harappan cultures within the Indus Valley (Allchin and Allchin 1968, 1982; Jarrige 1982; Jarrige and Lechevallier 1979; Jarrige and Meadow 1980; Mughal 1970, 1990).

However, excavations in Iran, Afghanistan, and western Pakistan have indicated to other workers (Beale 1973; Biscione 1983; Kohl 1978, 1979; Lamberg-Karlovsky 1972, 1978; Lamberg-Karlovsky and Tosi 1973; Santoni 1984; Tosi 1979) that prior to the rise of the Harappan Civilization, the Indus Valley was part of an "early urban interactive sphere" centered on the traders of the Iranian Plateau. Participation of the Harappan Civilization in this "interactive sphere" may have led to considerable extra-Indus Valley input and participation in the rise of the Harappan Civilization.

No less vexing than issues surrounding the rise of the Harappan Civilization, are questions concerning its demise. Tentatively dated to the period between 1900 BC (Dales 1973) and 1750 BC (Agrawal 1966; Allchin and Allchin 1968), the demise of the Harappan Civilization has been attributed to Aryan invaders (Childe 1957; Gordon 1958; Piggott 1950; Wheeler 1968), ecological changes (Dales 1966; Kennedy 1984a; Kenoyer 1988; Lambrick 1967; Misra 1984; Raikes 1964, 1965), and simple progressive degeneration (Fairservis 1975).

Archaeological attempts to resolve questions concerning the rise and subsequent fall of the Harappan Civilization have been plagued by problems in dating, inaccessibility of key research areas, and interpretations of ceramic and other artifactual assemblages. Recent excavations at the Harappan phase cemetery at Harappa allow a unique opportunity to examine these questions from the perspective of skeletal biology. Unlike ceramic styles, decorative motifs, and metallurgical technology, genetically controlled features of the teeth and skeleton cannot be transferred verbally or inherited by others not in actual contact with the reference population. Unfortunately, many previous analyses of skeletal remains in South Asia have been limited by an overt racial-typological approach to human biological variation, by employment of parameters that incorporate an unknown amount of environmental variation, or by questionable attempts to force these data into a model of localized continuity (Dutta 1972, 1975, 1983; Guha and Basu 1938; Gupta, Dutta and Basu 1962; Krogman and Sassman 1943; Kumar 1971, 1973; Sarkar 1954; Sewell and Guha 1931).

This study not only provides new biological evidence from the Harappan phase cemetery (R37) at Harappa, but simultaneously employs several multivariate statistical techniques based on three different types of biological variation (cranial metric, cranial non-metric, and dental non-metric). Employment of several statistical techniques offers the advantage of avoiding conclusions drawn from any one alone, as all contain their own inherent biases. Similarly, use of more than one type of biological variation allows a composite picture of affinities to be drawn from the entirety of variation available at this time. This approach helps to alleviate such problems of biological affinity analysis as directional selection and differential levels of sexual dimorphism.

Materials and Methods

The Harappan phase cemetery at Harappa is located to the south of Mound AB and was designated as "Cemetery R37" by Shastri in 1937-38 (see Possehl, Chapter 2 in this volume) (Figure 11.1). Subsequent excavations in the same general area by Wheeler (1947) and Mughal (1968) also resulted in the recovery of Harappan phase burials. Earlier in the 1920s and 1930s, Vats (1940) excavated in the area between Cemetery R37 and Mound AB and recovered two different types of burials referred to as Cemetery H Stratum II (lower or "earth" burials) and Stratum I (upper or "pot/jar" burials). Both of these burial types belong to the Late Harappan phase and are later than the burials in the Harappan phase cemetery (Cemetery R37).

Excavations by the University of California, Berkeley (UCB) Project have resulted in the recovery of more than 90 individuals from the Harappan phase cemetery (Table 11.1: hereafter termed "R37C"). This number compares favorably with the 106 reported by Dutta (1983) from previous excavations in the same general area (Table 11.1: hereafter termed "R37A"). Unfortunately many of these individuals are extremely fragmentary. When well-preserved individuals are used as the basis of comparison, 33 individuals were recovered in 1987 and 1988 and 34 individuals were recovered from previous excavations. Thus the UCB excavations have led to a doubling of the skeletal information available for the Harappan phase inhabitants of the site.

The R37C sample (from the UCB excavations) represents a young to middle-aged adult population, for few children and juveniles were recovered.

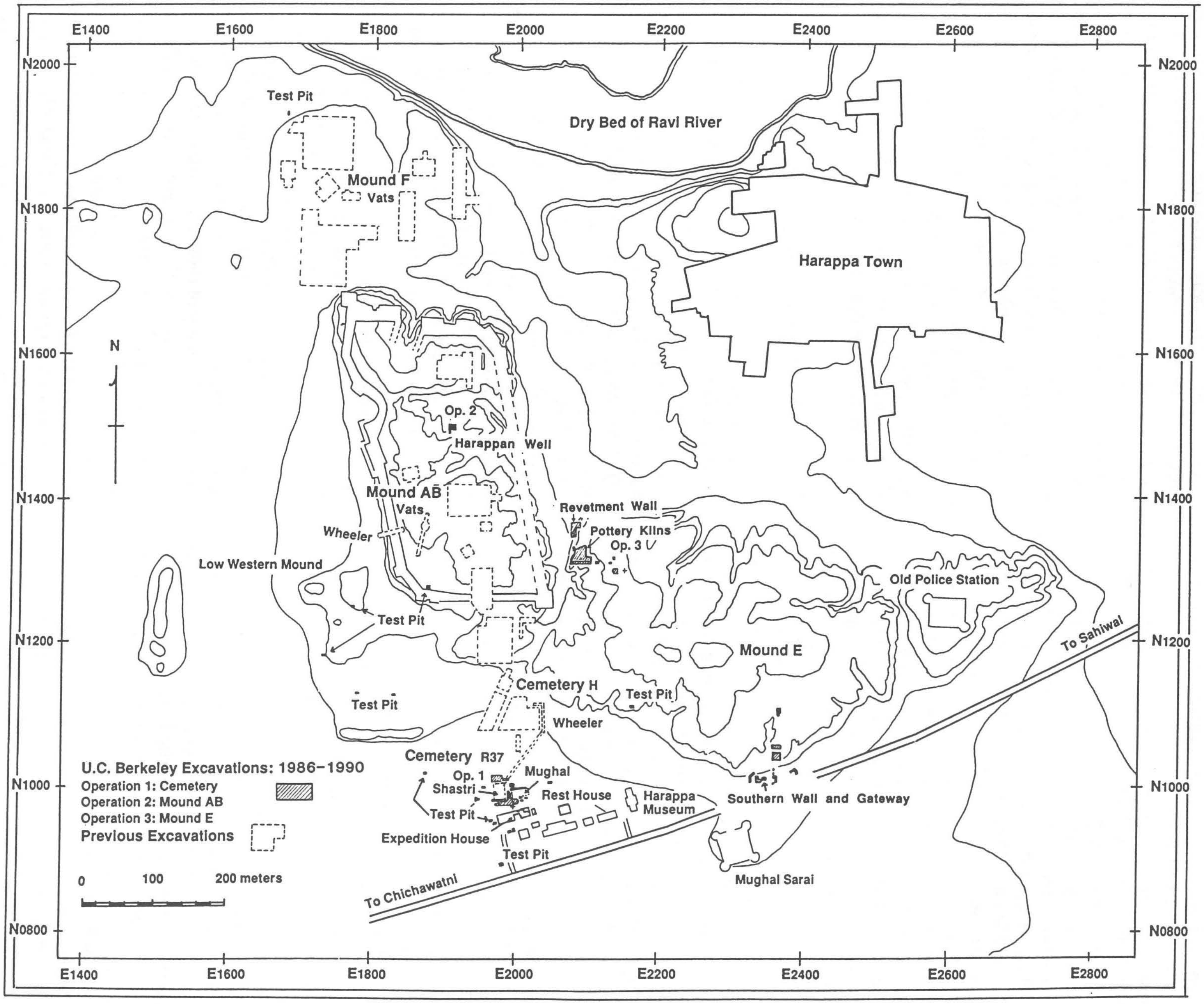

Figure 11.1 Location of the Harappan phase cemetery within the site of Harappa.

Similarly, the number of older adults recovered was also low (Table 11.2).

Dental remains obtained during the UCB excavations were examined by Lukacs. The dental sample was recovered from two different burial contexts: primary and secondary (Table 11.3). Primary context remains are composed of 16 undisturbed burials. Secondary contexts include incomplete skeletal remains displaced from their original context by erosion or by later intrusive interments. Dental remains recovered from disturbed contexts are defined as "secondary" if retained in jaw fragments. Loose teeth not in association with jaw remains are defined as "isolated." Dental remains from primary burials constitute nearly half of the entire sample (48.1%), while isolated remains account for only 15%. Males and females are equally represented, but nearly one-fourth of the sample is derived from individuals of unknown sex.

Analysis of tooth size involves measurement of tooth length and tooth breadth. In this report tooth length is defined as the mesiodistal (MD) diameter of

Table 11.1. Sex Distribution of the Harappan Phase Cemetery Samples

Sample	Males	Females	Unknown	Total
R37A	38	55	13	106
R37C	19	29	42	90
Total	57	84	55	196

Table 11.2. Age Distribution of the Harappan Phase R37C Sample

Category	Age Range	Number
Subadult	< 16 Years	15
Young Adult	17-34 Years	35
Middle-Aged Adult	35-55 Years	27
Older Adult	> 55 Years	13
Total		90

Table 11.3. Harappan Phase R37 Dental Sample by Burial Context and by Sex

Context

	Primary			Secondary			Isolated			Total		
	Max	Man	Total	Max	Man	Total	Max	Man	Total	Max	Man	Total
I1	25	24	49	12	11	23	12	6	18	49	41	90
I2	21	24	45	11	13	24	10	6	16	42	43	85
C	23	28	51	13	13	26	9	4	13	45	45	90
P3	23	26	49	18	19	37	8	5	13	49	50	99
P4	27	25	52	16	20	36	4	10	14	47	55	102
M1	20	20	40	23	28	51	5	9	14	48	57	105
M2	22	21	43	18	30	48	6	12	18	46	63	109
M3	13	19	32	11	21	32	3	4	7	27	44	71
Total	174	187	361	122	155	277	57	56	113	353	398	751

Sex

	Males			Females			Unknown			Total		
	Max	Man	Total	Max	Man	Total	Max	Man	Total	Max	Man	Total
I1	17	16	33	16	16	32	16	9	25	49	41	90
I2	14	16	30	17	18	35	11	9	20	42	43	85
C	16	17	33	18	21	39	11	7	18	45	45	90
P3	16	18	34	18	25	43	15	7	22	49	50	99
P4	18	20	38	19	23	42	10	12	22	47	55	102
M1	18	22	40	16	19	35	14	16	30	48	57	105
M2	17	23	40	15	22	37	14	18	32	46	63	109
M3	13	20	33	6	19	25	8	5	13	27	44	71
Total	129	152	281	125	163	288	99	83	182	353	398	751

the tooth taken at its greatest point. Tooth breadth is defined as the greatest distance in the buccolingual (BL) plane. These diameters and their product (crown area), are determined by methods described by Wolpoff (1971). All measurements were made by Lukacs with a Helios needle-point dial caliper calibrated to 0.05 mm, and crown diameters were rounded to the nearest 0.1 mm. Assessment of intra-observer accuracy is based on repeated measurement of the left side of 30 randomly selected plaster casts. Measurement sessions were separated by a period of ten months. Mean intra-observer difference is –0.06 mm. (s.d. = 0.18), a figure similar to those reported by other investigators (Hemphill 1991; Keiser et al. 1986; Kolakowski and Bailit 1981).

Pathological conditions of the permanent teeth and jaws were also assessed by Lukacs. Pathological conditions investigated include: abscesses, antemortem tooth loss (AMTL), calculus, caries, hypoplasia, hypercementosis, pulp exposure, and alveolar resorption. Methods for assessing the degree of expression of these conditions have been described elsewhere (Lukacs 1989; Lukacs et al. 1989). Frequencies of pathological conditions are assessed by individual count and by tooth count.

Twenty morphological features of the permanent dental crown were assessed for 55 tooth-trait combinations by Lukacs in accordance with criteria set forth by Lukacs and Hemphill (1991a). Intra-observer variation was assessed by repeated scoring of 35 tooth-trait combinations in a random sample of 50 plaster dental casts. Observation sessions were separated by more than one year, and the methods used in quantifying observer variation were those recommended by Nichol and Turner (1986). For each discrete trait four percentages were calculated, and the mean for these four measures of intra-observer error are well within those quoted by Nichol and Turner (1986).

Frequencies of dental traits were calculated for each grade of expression present in the Harappan sample according to the individual count method of Scott (1973, 1977, 1980), and trait expression was dichotomized into presence/absence only for comparison with other South Asian dental series (Table 11.4). In contrast to the method of Sofaer et al. (1986), only tooth-trait combinations scored in all dental series were considered. If a specific trait was completely absent in more than half of the series examined, it was eliminated from consideration. While Sjøvold (1973) accepts a trait if it is present in only one of the samples under consideration, we felt that with the small sample sizes available retention of infrequent variables would unduly magnify the influence of chance occurrence of rare traits. These criteria resulted in a reduction of dental morphology traits included in the comparative analysis to ten traits scored as 16 tooth-trait combinations. In most cases, any degree of trait development was considered a positive expression. The only exception to this pattern is hypocone development, for which only full expressions were scored as positive manifestations.

Contingency chi-square statistics were calculated to determine whether these non-metric dental traits detect significant heterogeneity in specific trait frequencies across all seven dental samples. If the number of significant differences exceeds the number of differences expected by chance alone, these traits were accepted as providing adequate data for determining patterns of relative similarity between these samples.

To place the R37C sample in regional perspective, affinities between sites were assessed by three different statistical methods. Trait frequencies based on presence/absence dichotomization were arcsine transformed according to the formula recommended by Green and Suchey (1976) to stabilize sample variance.

In the first method, arcsine transformed trait frequencies were used as input for cluster analysis, and dendrograms were constructed in euclidian space with Ward's minimum variance technique (Ward 1963). In the second method, mean measure of divergence distances were calculated between each sample pair by means of the formula recommended by Green and Suchey (1976). The standard deviation of these distances were calculated according to the method of Sjøvold (1973), and standardized divergence distances were calculated by dividing the mean measure of divergence of a specific comparison by its standard deviation. These standardized distances are more

Table 11.4. Dental Non-Metric Sample Sizes and Sources

Sample	Abbrev.	Date	N_{max}	Source
Harappa	HAR	Harappan phase	33	This Report
Chalcolithic Mehrgarh	MR2	4500 B.C.	25	Lukacs and Hemphill (1991a)
Neolithic Mehrgarh	MR3	6000 B.C.	49	Lukacs (1988)
Inamgaon	INM	1600-700 B.C.	41	Lukacs (1987)
Mahadaha	MDH	8000 B.C.	11	Lukacs and Hemphill (1991b)
Timargarha	TMG	1400-850 B.C.	21	Lukacs (1983)
Sarai Khola	SKH	200-100 B.C.	25	Lukacs (1983)

appropriate for evaluating and comparing relative distances in cases where widely different sample sizes are involved (Sofaer et al. 1986). Since the pattern of variation of seven different samples from one another—involving 21 different standardized distances—is difficult to visualize, standardized distances were used as input for multidimensional scaling. Kruskal's Stress Formula One (Kruskal 1964) was used, and results were ordinated into three dimensional space.

The third method used to examine group affinities between dental samples is principal components analysis. Arcsine transformed trait frequencies were standardized to have a zero mean and unit variance prior to submission to principal components analysis. Unrotated principle components were used since varimax rotation (Kaiser 1958) served to reduce the percentage of the total variance explained by the first three principal components and offered no improvement in interpreting the patterning of component loadings. Factor score coefficients (eigenvector coefficients) for each variable were multiplied by the standardized arcsine transformed frequency for each sample. These values were summed for each sample according to each of the first three principal components. The resulting scores were plotted into three dimensions to illustrate the position of each sample in multicomponent space.

Analysis of cranial non-metric traits was performed in a manner similar to that described for non-metric traits of the permanent teeth. Twenty-seven non-metric traits were scored for adult individuals in the R37C sample by Hemphill according to the criteria of Berry and Berry (1967). Because of small sample size, fragmentary condition of specimens, and for greater comparability with previously published reports, traits were scored by side, and only full expressions of traits were considered positive manifestations.

In the comparative phase of analysis, the frequency of cranial non-metric traits in the R37C sample were compared with ten other samples from South Asia and the Near East (Table 11.5). Only those samples scored by other workers in accordance with the criteria of Berry and Berry (1967) were accepted. As with dental non-metric variables, each cranial trait had to be considered in every sample in order to be included in the comparative analysis. This resulted in the elimination of two traits (*foramen ovale* incomplete, *foramen spinosum* open). In addition, those traits completely absent in more than half of the samples were eliminated. This resulted in elimination of five traits (bregmatic ossicle, auditory exostoses, bifaceted occipital condyle, palatine torus, maxillary torus). Finally, traits which may be the product of muscular development (highest nuchal line) or whose positive manifestations are subject to widespread differing interpretations (supraorbital foramen complete) were eliminated from consideration. These criteria resulted in a reduction in the number of cranial non-metric traits considered to 18 traits. Chi-square statistics were calculated to detect significant differences in individual trait frequencies across all samples. As described for non-metric dental traits, if the number of significant differences exceeds the number of differences expected by chance, these non-metric cranial variables were considered viable data for examining patterns of inter-group variation. Affinities between cranial series was accomplished with the same three methods described for dental non-metric traits.

All adult crania derived from the Harappan phase cemetery were assessed for 30 metric variables by Kennedy. All measurements have been standardized by both the Biometrika school and by Martin and Saller (1957). Only those variables for which data are available for either males or females in each sample were accepted. This reduced the number of variables considered to fourteen. Samples were then divided by sex and mean values obtained.

Comparative analysis of craniometric variation is in three parts. In the first part, craniometric variation encompassed by samples from two excavation efforts

Table 11.5. Cranial Non-Metric Sample Sizes and Sources

Sample	Abbrev.	Date	N_{max}	Source
Harappa	HAR	Harappan phase	24	This Report
Egyptian	EPT	4000-0 B.C.	250	Berry and Berry (1967)
Ancient Palestinian	APAL	700 B.C.	54	Berry and Berry (1967)
Modern Palestinian	MPAL	Modern	18	Berry and Berry (1967)
Punjabi	PUN	Modern	53	Berry and Berry (1967)
Burmese	BUR	Modern	51	Berry and Berry (1967)
Mahadaha	MDH	8000 B.C.	11	This Report
Lidar	LDR	2300-2000 B.C.	25	Klug and Wittwer-Bakofen (1985)
Kamid el-Loz	KEL	500 B.C.	47	Klug and Wittwer-Bakofen (1985)
Sarai Khola	SKH	200-100 B.C.	26	Klug and Wittwer-Bakofen (1985)
Bedouin	BED	Modern	35	Henke and Disi (1981)

in the Harappan phase cemetery (R37A, R37C) and from two different burial contexts in the Late Harappan cemetery ("H1JAR" = Stratum I—upper jar/pot burials, "H2OPEN" = Stratum II—lower earth burials) are compared against five other prehistoric skeletal series from Pakistan. This phase of analysis seeks to determine the level of within-site variability at Harappa relative to the level of variation encompassed by other prehistoric samples from Pakistan. Samples were divided by sex, and analysis of variance was used to determine whether these craniometric variables detect significant differences across these six samples. As with cranial and dental non-metric traits, if the number of significant differences exceeds the number of differences expected by chance, these variables were accepted as providing adequate data for determining patterns of relative similarity among these prehistoric groups.

Two methods were used to assess relative affinity by sex among prehistoric groups from Pakistan. In the first method, sex-specific mean parameter values were submitted to cluster analysis, and dendrograms were constructed for males and for females in euclidean space with Wards' minimum variance technique. Only those variables for which data were available in all samples were accepted. This criteria resulted in a reduction in the number of variables considered to ten for females and eleven for males. In the second technique, group sex-specific mean parameter values used in cluster analysis were submitted to principal components analysis. These values were standardized by sex across groups to have a zero mean and unit variance. Unrotated principle components were derived, and factor score coefficients (eigenvector coefficients) for each variable were multiplied by the standardized mean parameter value for each sample. These values were summed for each sample by sex according to each of the first three principal components, and resulting scores were ordinated into three dimensions to illustrate the position of each sample in multicomponent space.

The second phase of analysis examines the level of craniometric variation among living and prehistoric South Asians. Samples of modern Veddahs, Nepalese, and Tibetans were compared with the six prehistoric samples from Pakistan used in the first phase of analysis. Samples from the Harappan phase cemetery were pooled, but the two samples from Late Harappan phase Cemetery H were considered separately. These latter samples were considered separately in order to determine if differences in inhumation practices are accompanied by differences in biological affinities. The earlier burials of the Late Harappan cemetery are extended burials with pottery arranged at the head or feet. In the upper levels of the cemetery the burials are secondary inhumations in pots/jars. To control for different sex ratios presented by each sample, group values were calculated as the average between male and female means for each craniometric variable. Group mean values were submitted to cluster analysis, and dendrograms were constructed in euclidean space with Ward's minimum variance technique. Principal components analysis was used to provide a check on the patterns of affinity derived from cluster analysis as well as to gain additional insight into the pattern of variation among these modern and prehistoric South Asian samples.

In the final phase, South Asian craniometric variation is placed in regional perspective by contrasting South Asian cranial series against prehistoric samples from Egypt, Anatolia, Mesopotamia, and the Iranian Plateau (Table 11.6). To provide maximum comparability, the same variables used to examine within-South Asian cranial variation were employed. Group values were derived in the same manner described for South Asian samples, and these values were submitted to cluster analysis and principal components analysis for assessment of biological affinities.

Results

Odontometrics

Mean mesiodistal and buccolingual crown diameters for the sex-pooled sample obtained from R37 are presented in Table 11.7. A paired-samples t-test was used to test for significant differences in tooth size between left-right tooth pairs. Only two crown diameters (LI2MD, LM3MD) exhibit significant differences between right and left antimeres. Since this number of significant differences falls below the number of significant differences expected from chance ($p < 0.05$), mean values presented in Table 11.7 reflect measurements from the left side only.

Mean crown areas (in mm^2) by side are also presented in Table 11.7. Means for right and left sides are nearly equal, confirming the lack of asymmetry found by paired-samples t-tests of individual parameters. Summed crown areas by jaw reveal that maxillary teeth (631 mm^2) are slightly larger than their mandibular isomeres (567 mm^2). When mean crown areas for both right (1189 mm^2) and left (1198 mm^2) are considered, individuals from the Harappan phase cemetery possess an overall tooth size of 1194 mm^2.

Total crown area is used to place the tooth size of the inhabitants of the Harappan phase cemetery in perspective with regard to other South Asian dental series. Differences in total crown area are presented in two ways: as a histogram of total crown area (Figure 11.2), and as a bivariate plot of total tooth size against

Table 11.6. Craniometric Sample Sizes and Sources

Sample	Abbreviation	Date	N_{max}	Source
Harappa: Cemetery R37A	R37A	Harappan phase	34	Gupta et al. (1962)
Harappa: Cemetery R37C	R37C	Harappan phase	30	This Report
Harappa: Cemetery H upper (jar/pot)	H1(JAR)	Late Harappan	15	Gupta et al. (1962)
Harappa: Cemetery H lower (open/earth)	H2(OPEN)	Late Harappan	13	Gupta et al. (1962)
Chatal Hüyük	CHY	5000-64 B.C.	12	Krogman (1949)
Tell al-Judiadah	TAJ	5000-64 B.C.	19	Krogman (1949)
Kish	KISH	2900-2800 B.C.	27	Buxton and Rice (1931)
Tepe Hissar II	TH2	3500-3000 B.C.	16	Krogman (1940)
Tepe Hissar III	TH3	3000-2000 B.C.	138	Krogman (1940)
Naqada	NAQ	7000-5000 B.C.	407	Fawcett and Lee (1901)
Abydos	ABY	1st Dynasty	47	Morant (1925)
Badaria	BAD	Predynastic	58	Stoessiger (1927)
Nepalese	NEP	Modern	56	Morant (1924)
Tibetans	TIB	Modern	25	Morant (1924)
Sedment	SED	9th Dynasty	70	Woo (1930)
Mohenjo-daro	MHD	Harappan phase	16	Sewell and Guha (1931) Guha and Basu (1938)
Timargarha	TMG	1400-800 B.C.	20	Bernhard (1967)
Veddahs	VED	Modern	62	Osman Hill (1941)

Table 11.7. Crown Diameters and Areas of Permanent Teeth from the Harappan Phase Cemetery at Harappa (R37C) [left side in mm]

Maxilla

	Mesiodistal			Buccolingual			Crown Area		
	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
I1	8.89	0.47	11	7.16	0.33	15	63.5	4.5	11
I2	6.80	0.58	10	6.48	0.59	12	43.1	9.0	9
C	7.82	0.42	10	8.23	0.39	13	63.4	3.7	9
P3	7.26	0.84	15	9.44	0.28	17	66.6	4.3	14
P4	6.75	0.47	22	9.29	0.41	22	63.2	6.3	21
M1	10.32	0.50	18	11.61	0.51	19	119.4	9.5	18
M2	9.59	0.68	18	11.01	1.08	15	110.7	12.3	17
M3							101.5	18.0	15

Mandible

	Mesiodistal			Buccolingual			Crown Area		
	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
I1	5.53	0.23	10	5.91	0.16	14	32.5	1.8	10
I2	6.10	0.21	8	6.43	0.26	15	38.4	2.1	8
C	6.82	0.29	10	7.74	0.56	17	51.0	4.3	9
P3	6.75	0.37	17	7.79	0.47	22	52.1	4.8	17
P4	7.02	0.54	20	8.18	0.63	23	57.1	7.7	20
M1	11.18	0.64	16	10.59	0.47	19	117.9	10.3	16
M2	10.61	0.65	24	10.10	0.58	26	107.7	12.3	24
M3	10.38	0.73	15	9.69	0.54	16	101.1	12.3	15

time (Figure 11.3). A total crown area of 1194 mm^2 places Harappan (HAR) individuals just below the mean value (1215 mm^2) for eight South Asian groups, but well within one standard deviation (SD = 60.6 mm^2). Harappan phase individuals are most similar in overall tooth size to dental samples from Inamgaon and Timargarha, both of which date some 800 to 1000 years later.

Figure 11.3 provides a bivariate plot of tooth size in relation to antiquity among South Asians that permits

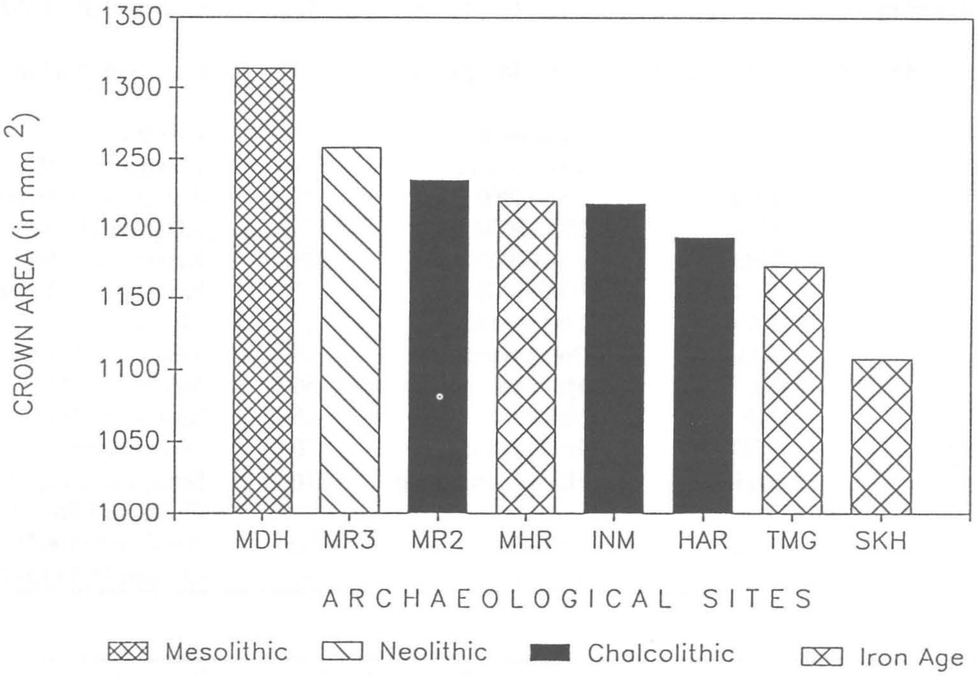

Figure 11.2. Tooth size variation among prehistoric South Asians (see Table 11.4 for abbreviations).

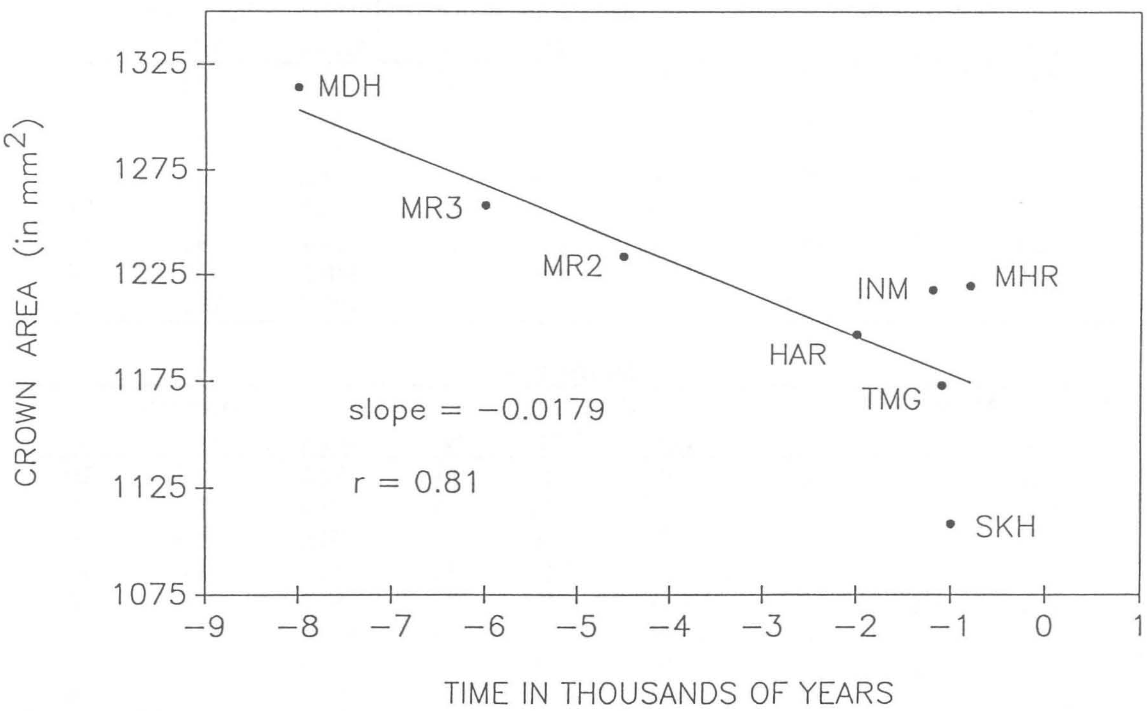

Figure 11.3. Tooth size reduction over time for prehistoric South Asians (see Table 11.4 for abbreviations).

closer examination of the relationship between tooth size, antiquity, and cultural type. This bivariate plot of sites by antiquity and by total crown area yields a correlation coefficient of 0.81 ($p < 0.01$). The negative slope of this regression ($y = -0.018x + 1160$) confirms the impression gained from the histograms presented in Figure 11.2, namely, that South Asians have experienced a progressive reduction in tooth size over time. In fact, these data indicate a dental reduction rate of about 18 mm^2 or 1.7% per 1000 years. This South Asian rate accords well with dental reduction rates recorded for other parts of the world (Brace et al. 1987) and provides a strong argument for a directional selectional relationship between technological development and tooth size reduction (Calcagno 1984; Calcagno and Gibson 1988; Frayer 1987; Lukacs 1982).

Dental Pathology

Documentation of dental pathological conditions among the Bronze Age cultures of the Old World is poor despite the availability of skeletal remains. This paucity of information is especially true in South Asia where description of dental remains from Harappa is woefully incomplete, and description of the dental remains from Kalibangan, Rupar, and Lothal have not yet been published.

Pathological conditions are reported in two different ways—by individual count and by total tooth count. Assessment of pathological affliction by individual count is a logical approach since the individual is the biological entity upon which natural selection acts. Unfortunately, in many prehistoric skeletal samples when the sample is divided by age and sex, the number of individuals available for study becomes too small for effective statistical testing. Assessment by total tooth count is a more logical approach when the effect of dental disease on specific tooth classes or by jaw is of importance. To maximize comparability with other studies, we have chosen to report our results both by individual count and by tooth count.

Individual count prevalence of eight dental pathological conditions by burial context and by sex among Harappan phase (R37C) individuals is presented in Table 11.8 and illustrated in Figure 11.4. Linear enamel hypoplasia, a disruption of enamel formation during tooth development caused by pathological affliction or dietary deficiencies (Goodman and Rose 1990), represents the most frequent dental disorder affecting over 70% of individuals recovered from the Harappan phase cemetery. While more hypoplastic lesions are present among females than among males, there is no difference in mean age of affliction (males = 4.3 years; females = 4.3 years). However, variance in age at affliction is much higher among girls (s.d. = 0.9 years) than among boys (s.d. = 0.7 years). This suggests that R37C girls were affected by growth disruptions across a wider age range than R37C boys. The least frequent disorder is hypercementosis, which affected only 5% of R37C individuals. Other afflictions of low prevalence include abscesses (18%) and pulp exposure (17%). Antemortem tooth loss (32%), calculus (43%), caries (44%), and alveolar resorption (53%) occur with intermediate frequency. Sex differences in pathological affliction were assessed by means of the chi-square test. Higher frequency of caries and pulp exposure among females, while not statistically significant ($p < 0.05$), is large and may be of biological significance.

Frequency of pathological affliction by tooth count is presented in Table 11.9. Dental abscesses are most common among premolar teeth (6.5%) and least common among molars (0.7%). A total of 70 teeth provide unequivocal evidence on antemortem loss. To provide the most accurate estimate of antemortem tooth loss frequency, the number of teeth known to have been lost during life (70), is divided by the total number of teeth present in the skeletal series prior to any tooth loss: that is, the total number of teeth observed (751) plus those teeth known to have been lost antemortem (70). Examined in this manner, antemortem tooth loss occurs with a frequency of 8.5%

Table 11.8. Prevalences of Dental Diseases in Individuals from the Harappan Phase Cemetery at Harappa (R37C) by Individual Count

	Males			Females			Unknown			Total		
	Pres.	N	Pct.	Pres.	N	Pct.	Pres.	N	Pct.	Pres.	N	Pct.
Abscesses	3	17	17.7	4	17	23.5	0	4	0.0	7	38	18.4
AMTL	3	17	17.7	9	19	47.4	1	5	20.0	13	41	31.7
Calculus	8	17	47.1	7	17	41.2	2	6	33.3	17	40	42.5
Caries	6	17	35.5	10	16	62.5	1	6	16.7	17	39	43.6
Hypoplasia	9	16	56.3	13	14	92.9	4	6	66.7	26	36	72.2
Hypercementosis	1	17	5.9	1	19	5.3	0	5	0.0	2	41	4.9
Pulp Exposure	2	16	12.5	5	19	26.3	0	6	0.0	7	41	17.1
Resorption	9	16	56.3	9	18	50.0	2	4	50.0	20	38	52.6

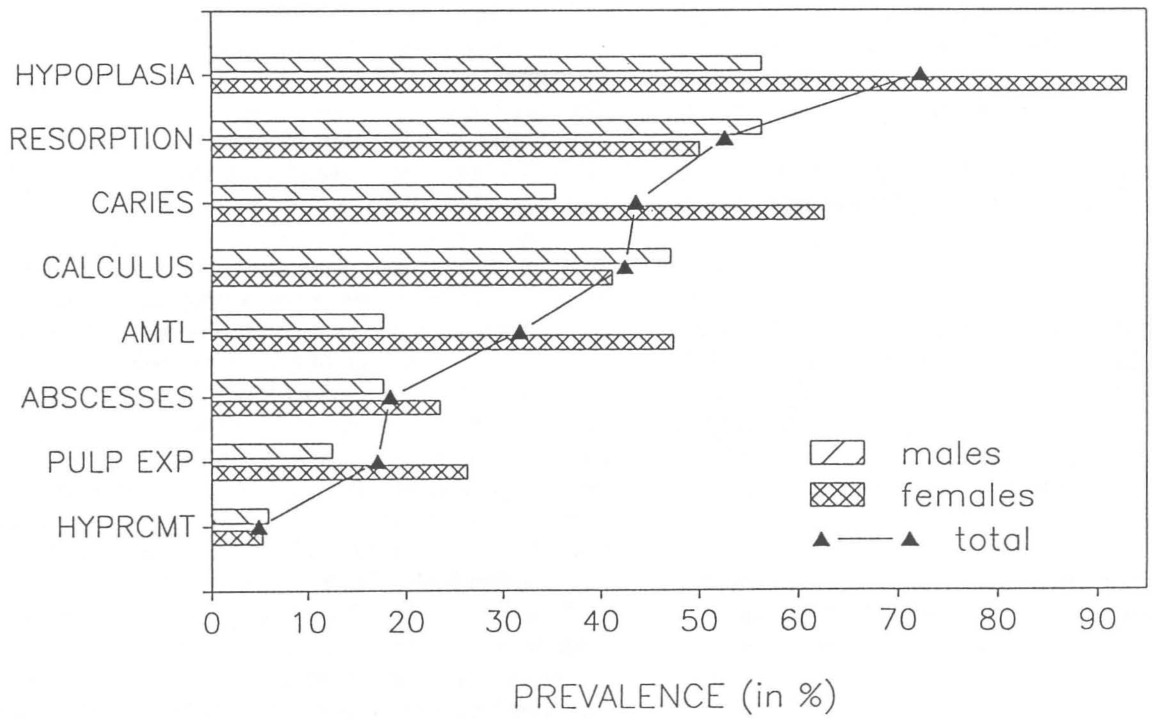

Figure 11.4. Dental pathologies by individual count by sex at Harappa.

Table 11.9. Prevalences of Dental Diseases in Individuals from the Harappan Phase Cemetery at Harappa (R37C) by Tooth Count

	Abscesses		AMTL		Caries		Pulp Exp.	
Tooth Class	N	Pct.	N	Pct.	N	Pct.	N	Pct.
I	4	2.29	9	4.89	4	2.29	6	3.43
C	4	4.44	10	1.10	6	6.67	6	6.67
P	13	6.47	14	6.51	11	5.47	17	8.46
M	2	0.70	46	13.90	30	10.53	8	2.81
Total	23	3.06	70	8.53	51	6.79	37	4.93
Sex								
Male	5	21.7*	13	20.3*	18	38.3	28	75.7*
Female	18	78.3	51	79.7	29	61.7	9	24.3
Jaw								
Maxilla	14	60.9	24	34.3*	32	62.7	28	75.7*
Mandible	9	39.1	46	65.7	19	37.3	9	24.3

*=p<0.05

(70/821). Molar teeth are most often affected (13.9%), while canines are very rarely affected (1.1%). When examined by jaw and by sex, antemortem tooth loss is significantly more common among mandibular teeth than maxillary teeth and more common among R37C females than among males.

Overall caries prevalence at Harappa is 6.8%. Caries affliction does not occur with uniformity throughout the dentition, for caries are much more common among maxillary teeth (9.1%) than mandibular teeth (4.8%), and among posterior teeth (molars and premolars: 8.4%) relative to anterior teeth (incisors and canines: 3.8%). Overall, males and females present a similar pattern of caries affliction with one notable exception: high frequency of caries among maxillary anterior teeth in females. This is a deviation in caries prevalence patterns from those discovered in other populations, for caries are generally very rare among maxillary anterior teeth.

Exposure of the pulp cavity was found in 37 Harappan teeth (4.9%). Premolars are most often affected (8.5%), followed by canines (6.7%), with incisors least often affected (3.4%). Pulp exposures are significantly more common among maxillary teeth (75.7%) than among mandibular teeth (24.3%) and among females (75.7%) relative to males (24.3%). When pulp exposures are divided into those caused by caries and those caused through tooth wear, caries induced exposure (67.6%) occurs with double the frequency of exposures due to tooth wear (34.3%).

If the relative contribution of tooth wear and caries for exposure of the pulp are considered along with the frequency of antemortem tooth loss, a more accurate assessment of actual caries affliction may be obtained (Lukacs 1991). This "caries correction factor" estimates the amount of antemortem tooth loss due to caries (67.7% of 70 teeth lost antemortem: 48 caries induced antemortem tooth losses). If this number of caries induced losses (48) is added to the number of observed caries affected teeth (51) the number of teeth actually affected by caries is 99. This number of caries affected teeth yields a new corrected caries rate of 12.1% among R37C individuals (99/851). While other factors, such as alveolar resorption, traumatic injury, and ritual ablation, may lead to antemortem tooth loss, these conditions are extremely rare among Harappans. Therefore, we regard the caries correction estimate (12.1%) to be a more accurate indicator of the true caries prevalence among Harappans.

Comparison of the dental pathology profile among individuals interred in the Harappan phase cemetery at Harappa with other prehistoric skeletal series from South Asia is performed to examine the relationship between increasing reliance upon cultivated foodstuffs and patterns of dental disease. In this comparative study all pathology data, except from Bellan Bandi Pallasa (Kennedy 1965), were collected by Lukacs. Sites for which comparative data are available range from mesolithic hunter-gatherers at Mahadaha, Sarai Nahar Rai, and Lekhahia (Lukacs and Hemphill 1991b) to the fully agricultural inhabitants of Sarai Khola (Lukacs et al. 1989). Other dental pathology data are available from neolithic and chalcolithic levels at Mehrgarh (Lukacs 1985a; Lukacs et al. 1985), Timargarha (Lukacs et al. 1989), Pomparippu (Lukacs 1976), and Mahurjhari (Lukacs 1981).

The first stage of this comparative analysis focuses on dental pathology and agricultural intensification within the Indus Valley and utilizes sites which feature adequate sample sizes and similar age at death profiles. Comparison of frequencies of dental pathologies at the Harappan phase cemetery to neolithic and chalcolithic skeletal series from Mehrgarh is presented in Figure 11.5. Pathological conditions are arranged from left to right according to decreasing frequency in the Harappa sample. In all three series, linear enamel hypoplasia represents the most common pathological condition, but Harappans possess the highest levels of the three groups compared.

The second phase of this comparative analysis examines caries frequency among prehistoric South

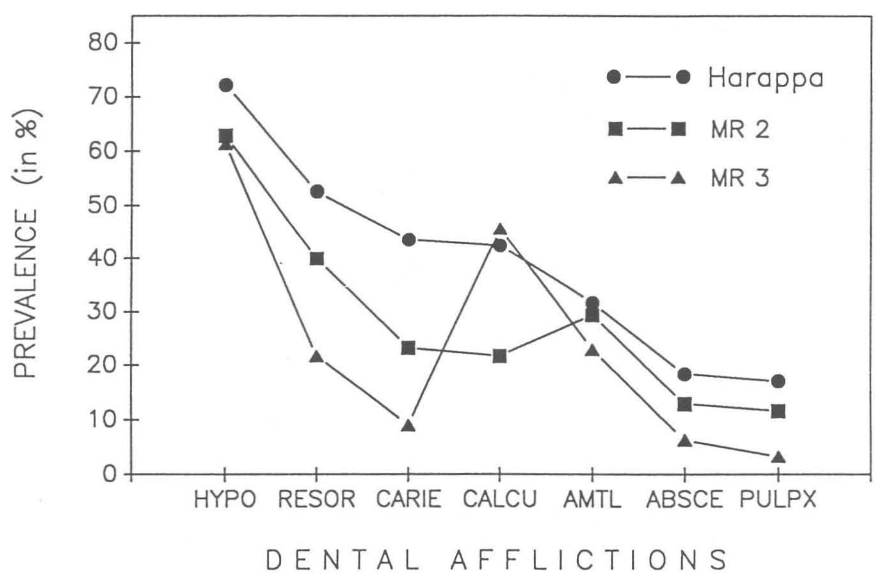

Figure 11.5. Dental pathologies among prehistoric Indus Valley sites by individual count.

Asian dental series. Figure 11.6 reveals that mesolithic caries rates are uniformly low (0.0 to 1.2%), while caries frequency among Iron Age sites is much higher (4.4 to 7.7%). The uncorrected caries rate among R37C (HAR) individuals falls within the range exhibited by Iron Age sites, but when the caries correction factor is used, R37C individuals possess caries at two times the rate of the Iron Age series average (6.1%). The progressive decline in dental health, exhibited by increasing caries rates from neolithic Mehrgarh, to chalcolithic Mehrgarh, to Harappa, reflects the combined influence of both increasing reliance upon cultivated foodstuffs and gradual but significant improvements in food processing technology.

Craniometrics

Fourteen craniometric variables were used to assess similarities among prehistoric samples from Pakistan. Analysis of variance results, adjusted for several instances of incomplete data sets, indicate that, with six significant differences among females (6/14 = 42.9%) and three significant differences among males (3/14 = 21.4%), these variables successfully distinguish differences among these groups (Table 11.10). Mean values were calculated for each group by sex and submitted to cluster analysis (Figure 11.7). Lack of data within several samples when grouped by sex resulted in the elimination of four variables among females and three variables among males.

Cluster analysis of sex-specific mean parameter values reveals that both males and females from prehistoric sites in Pakistan demonstrate a clear dichotomy between those samples derived from northern Pakistan and the only sample from southern Pakistan (Mohenjo-daro). Within northern Pakistan, differences among males and females differ. While both sexes indicate that the two samples from the Harappan phase cemetery at Harappa (R37A and R37C) bear closer affinities to other samples from northern Pakistan than to one another, analysis of male and females differ as to the patterning of these affinities. R37A males appear most similar to post-Harappan males from Timargarha, while R37C males are most closely affiliated with males from Late Harappan upper (jar) burials in Cemetery H (H1). Males from the lower (earth) burials in Cemetery H (H2) are only peripherally associated with these other four samples from northern Pakistan, but are nevertheless much more proximate to these samples than to males from Mohenjo-daro.

The pattern of relationships found among prehistoric females also indicates that the five samples from northern Pakistan are more similar to one another than any are to females from Mohenjo-daro. However, patterns of affinity among females from northern Pakistan differ from those found among males. Again, the two samples from the Harappan phase cemetery bear closer affinity to other samples from northern Pakistan than to one another. R37A females are most proximate to females derived from lower (earth) burials at Cemetery H (H2), while R37C females bear closest affinities to females from Timargarha. Females derived from upper (jar) burials at Cemetery H (H1) are identified as possessing only peripheral affinities to other females from northern Pakistan, but are

Figure 11.6. Caries frequency among prehistoric South Asians.

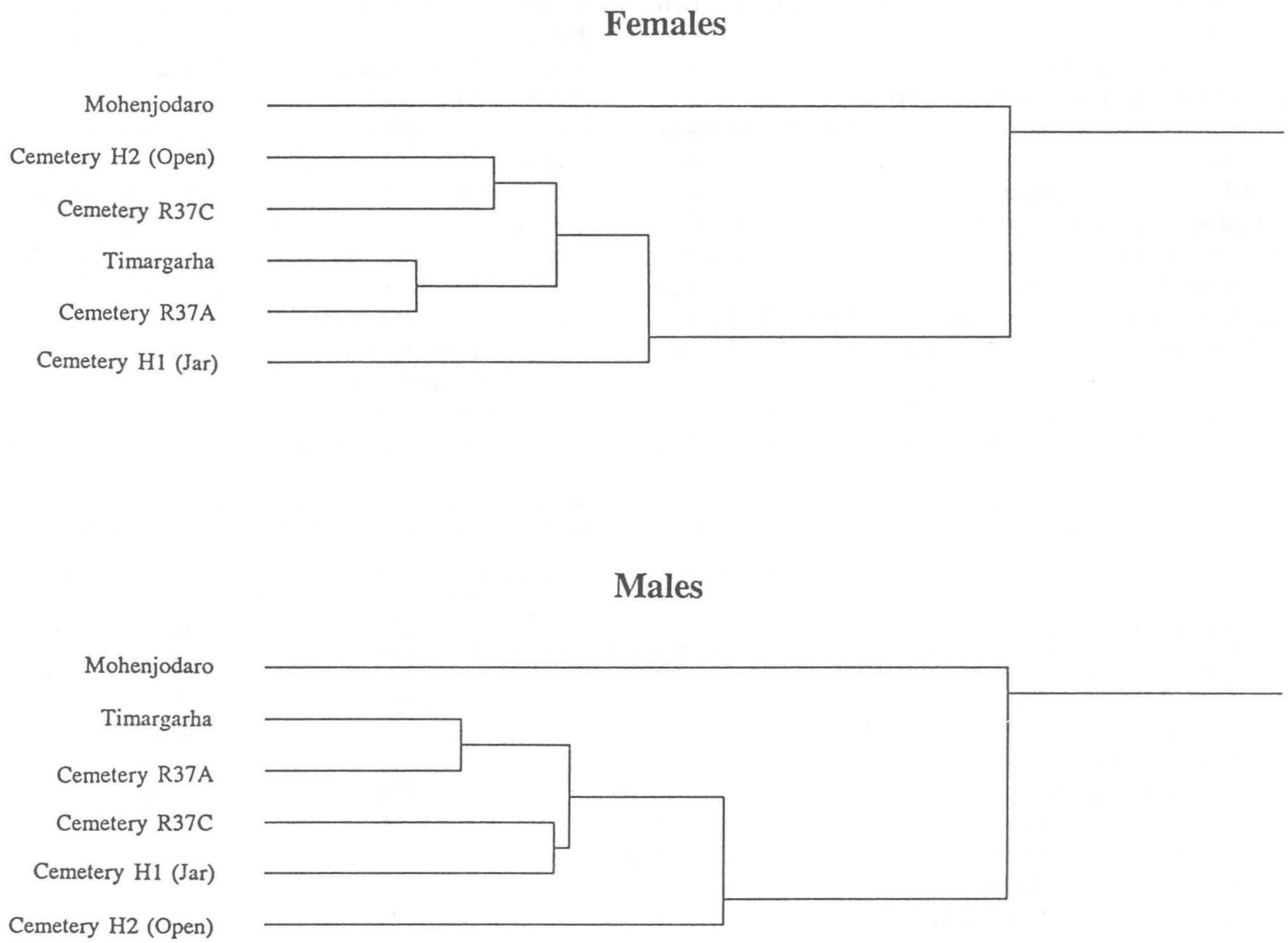

Figure 11.7. Cluster analysis of craniometric variation among prehistoric peoples from Pakistan by sex.

Table 11.10. Analysis of Variance of Cranial Measurements Among Prehistoric Peoples from Pakistan by Sex

	Females			Males		
Craniometric Measurement	F	p	N	F	p	N
Glabello-Occipital Length (GOL)	0.704	0.623	57	0.398	0.847	45
Bieuryonic Breadth (BEB)	3.032	0.019*	51	3.053	0.022*	41
Auricular Height (AVH)	2.206	0.072	48	1.411	0.248	37
Sagittal Arc (SA)	2.444	0.055	39	0.443	0.815	38
Circumference Above Browridges (CAB)	3.407	0.012*	46	0.790	0.565	36
Bifrontotemporale Breadth (BFTB)	2.327	0.056	57	0.677	0.644	42
Nasio-Prosthion Height (NPH)	2.744	0.033*	44	1.002	0.430	42
Nasal Height (NH)	0.742	0.596	55	1.362	0.259	45
Nasal Breadth (NB)	2.343	0.055	55	3.777	0.008*	41
Orbital Height (OH)	1.016	0.418	59	1.752	0.146	44
Orbital Breadth (OB)	1.557	0.189	56	3.172	0.017*	45
Bizygomatic Breadth (BZB)	2.881	0.035*	31	0.624	0.683	27
Internal Palatal Length (IPL)	2.635	0.044*	35	1.622	0.187	34
Internal Palatal Breadth (IPB)	6.636	0.000*	36	1.032	0.417	36

* = $p < 0.05$

nevertheless much more similar to these groups than they are to females from Mohenjo-daro.

Standardized sex-specific mean parameter values were submitted to principal components analysis to provide a check on the results from cluster analysis as well as to gain some insight into what combinations of variables lead to greatest segregation among these samples. Principal components analysis identifies three components that combine to explain 85.2% and 92.3% of the total variance among prehistoric males and females respectively (Tables 11.11a and 11.11b).

Ordination of principal component scores among prehistoric males and females from Pakistan are presented in Figure 11.8. In agreement with cluster analysis, Mohenjo-daro males are clearly identified as possessing the most distant affinities among these groups. Also in agreement with results from cluster analysis, Harappan phase R37C males appear more proximate to Late Harappan upper (jar) burials from Cemetery H (H1) than to Harappan phase R37A males. However, in contrast to cluster analysis, ordination of principal component scores does not indicate that lower (earth) burials from Late Harappan Cemetery H (H2) possess only peripheral affinities to other males from northern Pakistan. Rather, males from the lower (earth) burials exhibit close affinities to Harappan phase R37A males and somewhat more distant affinities to males from Timargarha. Principal components analysis suggests that Harappan phase R37C males represent a peripheral member of the

Table 11.11a. Principal Components Analysis of Craniometric Variation among Prehistoric Females from Pakistan

	Principal Component		
Cranial Measurement	One	Two	Three
Glabello-Occipital Length (GOL)	0.945	0.196	0.190
Bieuryonic Breadth (BEB)	0.972	-0.133	0.187
Bifrontotemporale Breadth (BFTB)	0.990	0.021	0.065
Nasion-Prosthion Height (NPH)	0.065	0.874	0.458
Nasal Height (NH)	0.470	0.718	-0.338
Nasal Breadth (NB)	0.890	-0.264	-0.256
Orbital Height (OH)	0.900	0.264	0.200
Orbital Breadth (OB)	-0.676	0.629	0.128
Bizygomatic Breadth (BZB)	0.715	0.272	-0.629
Internal Palatal Breadth (IPB)	-0.587	0.411	-0.491
Eigenvalue	5.959	2.115	1.159
Percentage of Variance Explained	59.587	21.147	11.589
Total Variance Explained		92.323	

Table 11.11b. Principal Components Analysis of Craniometric Variation among Prehistoric Males from Pakistan

	Principal Component		
Cranial Measurement	One	Two	Three
Glabello-Occipital Length (GOL)	-0.631	0.642	-0.121
Bieuryonic Breadth (BEB)	0.526	-0.140	0.665
Bifrontotemporale Breadth (BFTB)	-0.801	0.355	0.476
Nasion-Prosthion Height (NPH)	0.815	0.274	-0.307
Nasal Height (NH)	0.714	0.355	0.244
Nasal Breadth (NB)	-0.425	0.082	0.823
Orbital Height (OH)	0.668	0.743	0.028
Orbital Breadth (OB)	0.548	0.715	0.075
Bizygomatic Breadth (BZB)	0.937	-0.310	0.124
Internal Palatal Length (IPL)	-0.805	0.408	-0.258
Internal Palatal Breadth (IPB)	0.852	0.060	-0.002
Eigenvalue	5.669	2.188	1.603
Percentage of Variance Explained	51.539	15.626	14.575
Total Variance Explained		85.150	

northern Pakistani group, whose closest affinities lie with males derived from the upper (jar) burials at Cemetery H (H1).

Ordination of group component scores among females from prehistoric Pakistan also demonstrates a strong separation between groups from northern Pakistan and the single sample from southern Pakistan. Closest affinities among northern groups occur between Harappan phase R37A females and females from post-Harappan Timargarha, followed by Harappan phase R37C females. Females derived from the lower (earth) burials at Cemetery H (H2) occupy an intermediate position between these groups and females derived from the upper (jar) burials at this cemetery (H1).

Together, cluster analysis and principal components analysis among prehistoric samples from Pakistan provide good separation between samples from southern Pakistan and those from northern Pakistan. All males and females from the north exhibit relatively close affinities to one another, except for Harappan phase R37C males and females from upper (jar) burials at Cemetery H (H1), both of which possess rather peripheral affinities to other northern Pakistani samples.

In the second phase of analysis, variation among prehistoric samples from Pakistan is examined relative to several modern samples derived from the periphery of South Asia. The two samples from the Harappan phase cemetery were pooled, but the two samples from Cemetery H were considered separately. This was done to reflect the similarities in interment practices at the Harappan phase cemetery (R37) as well as to examine any possible correlation between interment practice and biological affinities in the Late Harappan cemetery (H). Adjusted for cases of incomplete data, analysis of variance indicates that with twelve significant differences among females (12/14 = 85.7%) and fourteen significant differences among males (14/14 = 100.0%), these craniometric variables provide adequate data for distinguishing between the eight South Asian cranial samples considered (Table 11.12). Few of these comparisons (4/28 = 14.3%) exceed the level of inter-group variance heterogeneity that could compromise these results. Therefore, despite small samples a significant amount of heterogeneity in craniometric variation is present among South Asians.

Group mean parameter values for each sample were calculated by taking the average between male and female average values for each variable. These values are presented in Table 11.13. Cluster analysis of group mean parameter values indicates that these eight South Asian samples fall into two main groups (Figure 11.9). The first includes all northern Pakistani sites, while the second includes Tibetans, Nepalese, Veddahs, and Mohenjo-daro. This represents a nearly

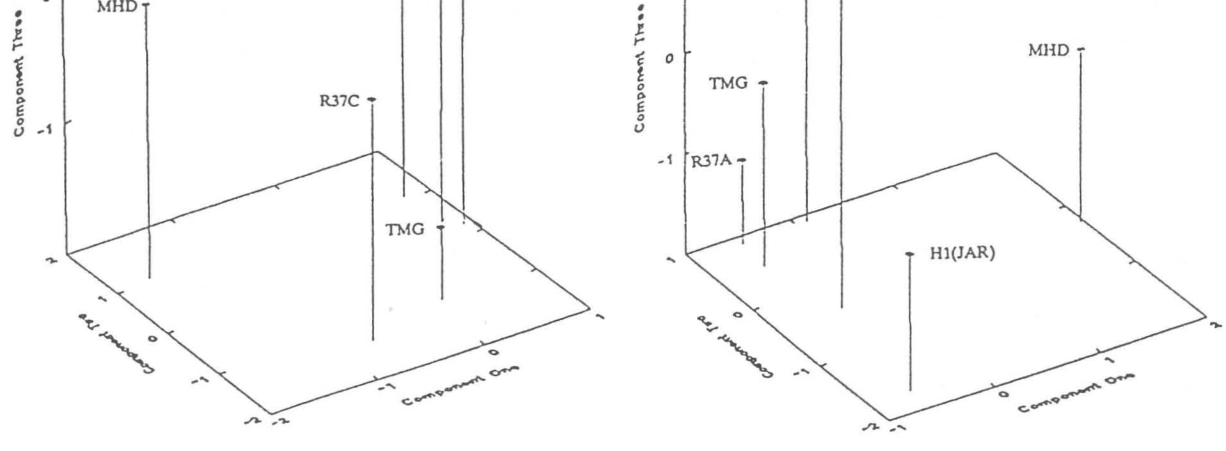

Figure 11.8. Ordination of principal component scores derived from craniometric variation among prehistoric peoples from Pakistan by sex.

Table 11.12. Analysis of Variance of Cranial Measurements among South Asians by Sex

	Females			Males		
Craniometric Measurement	F	p	N	F	p	N
Glabello-Occipital Length (GOL)	6.988	0.000*	85	11.216	0.000*	156
Bieuryonic Breadth (BEB)	5.574	0.000*	79	14.181	0.000*	153
Auricular Height (AVH)	2.107	0.055	72	3.743	0.001*	138
Sagittal Arc (SA)	4.527	0.001*	58	5.183	0.000*	132
Circumference Above Browridges (CAB)	8.025	0.000*	73	10.800	0.000*	147
Bifrontotemporale Breadth (BFTB)	4.416	0.000*	84	4.043	0.000*	154
Nasio-Prosthion Height (NPH)	6.541	0.000*	69	9.912	0.000*	145
Nasal Height (NH)	3.354	0.004*	77	8.050	0.000*	154
Nasal Breadth (NB)	2.515	0.023*	79	3.605	0.001*	150
Orbital Height (OH)	3.397	0.003*	83	1.137	0.343	155
Orbital Breadth (OB)	5.665	0.000*	79	5.760	0.000*	156
Bizygomatic Breadth (BZB)	3.075	0.010*	52	6.318	0.000*	132
Internal Palatal Length (IPL)	2.379	0.036*	57	6.867	0.000*	126
Internal Palatal Breadth (IPB)	2.097	0.067	56	4.420	0.000*	129

* = $p < 0.05$

complete division of samples between those of the Indus Valley and those coming from other parts of South Asia. Mohenjo-daro is the sole exception to this division. Individuals from the Harappan phase cemetery possess closest affinities to Timargarha and to lower (earth) burials at Cemetery H (H2). Upper (jar) burials at Cemetery H (H1) bear only a peripheral relationship to these three samples. Clearly, the two Late Harappan samples do not bear closest relations to one another, the result expected if these samples are representative of the same population. Note, however, that the sample sizes are not large: 15 for jar burials (H1) and 13 for earth burials (H2).

Principal components analysis yields three components that combine to explain 87.2% of the total variance (Table 11.14). The first component draws a distinction between measurements of the neurocranium and face with those of the palate, with the former receiving high loadings and the latter low loadings. Consequently, high scorers along the first component reflect samples that possess relatively large neural and facial measurements in combination with rather small palatal measurements. The second component draws a distinction between paired length and breadth measurements. Cranial length, nasal height, orbital height, and internal palatal length all possess higher loadings than cranial breadth, nasal breadth, orbital breadth, and internal palatal breadth. Thus, high scorers for component two feature relatively long cranial vaults, coupled with narrow nasal apertures, eye orbits, and palates. The distinction drawn by the third component is somewhat similar to that drawn by the second, but in this case breadth measurements are contrasted with measurements of cranial and facial height. Consequently, high scorers for component three are marked by relatively low cranial vaults, faces, nasal apertures, and eye orbits.

Two and three dimensional ordination of principal component scores (Figure 11.10) confirm the nearly complete division between Indus Valley samples and samples coming from other parts of South Asia. With

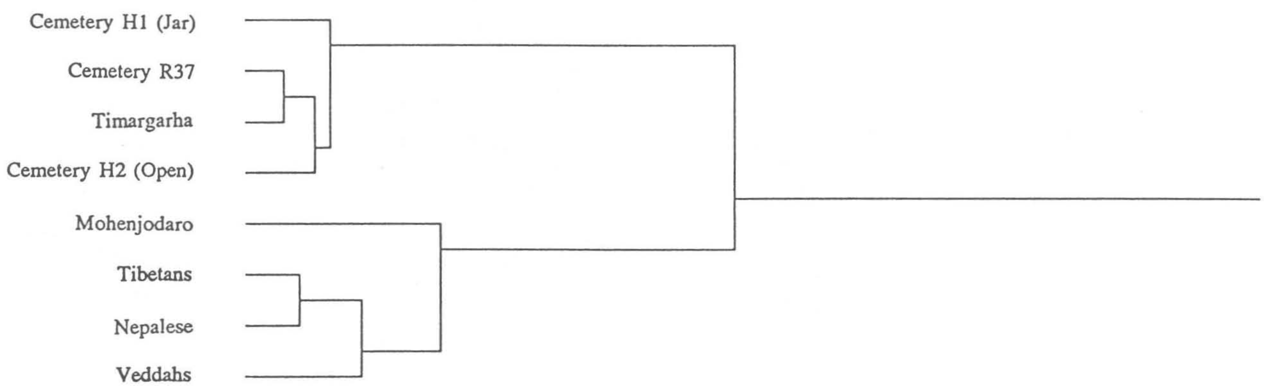

Figure 11.9. Cluster analysis of craniometric variation among South Asians.

Table 11.13. Group Mean Parameters for Cranial Measurements among All Groups

	Abydos (ABY)		Badaria (BAD)		Chatal Hüyük (CHY)		Cemetery H (H1JAR)		Cemetery H (H2OPEN)		Kish (KISH)		Mohenjo-daro (MHD)		Naqada (NAQ)		Nepalese (NEP)	
Meas.	Value	N	Value	N	Value	N	Value	N	Value	N	Value	N	Value	N	Value	N	Value	N
GOL	182.5	46	179.4	58	181.7	12	181.9	13	185.5	10	183.2	26	183.6	13	181.4	403	171.6	55
BEB	134.8	47	130.5	57	138.1	12	134.9	13	138.8	5	134.2	26	126.2	11	132.6	388	129.9	55
AVH	111.6	41	109.7	55	111.4	10	113.2	9	114.3	3	117.8	18	117.7	13	116.7	363	113.0	56
SA	363.4	37	367.5	57	364.5	2	368.7	10	379.0	4	372.1	14	376.2	9	369.3	316	356.7	53
CAB	505.2	39	494.8	58	510.8	11	518.5	13	514.4	5	510.9	19	492.6	10	504.5	306	484.0	55
BFTB	91.5	45	90.2	58	93.0	11	94.3	11	94.4	7	93.5	22	90.2	14	89.7	385	89.2	56
NPH	72.7	41	65.9	54	63.1	6	62.4	8	68.2	8	68.7	4	65.8	9	64.8	245	64.0	51
NH	52.5	42	46.9	54	48.1	3	47.6	10	49.2	11	53.3	4	47.8	12	47.3	256	46.8	56
NB	25.0	43	24.2	54	24.0	5	25.9	10	24.8	10	27.1	5	23.2	11	24.6	249	24.8	56
OH	34.9	43	31.7	55	34.9	3	32.1	10	34.1	11	34.1	11	33.2	13	32.2	261	32.4	56
OB	39.3	42	38.0	53	39.1	3	40.4	11	40.8	12	39.2	10	38.4	13	40.9	260	38.5	55
BZB	125.8	40	120.1	45	126.2	4	127.5	6	126.8	3	117.6	8	116.8	7	121.6	135	120.5	49
IPL	48.9	42	45.5	51	44.1	3	43.0	6	46.8	8	40.5	5	46.4	8	52.1	219	43.4	50
IPB	41.6	36	37.1	47	39.8	3	37.5	3	37.2	10	35.9	5	38.6	8	38.5	221	39.2	50

	Harappan Phase (R37A)		Harappan Phase (R37C)		Sedment (SED)		Tell al - Judiadah (TEL)		Tepe Hissar II (TH2)		Tepe Hissar III (TH3)		Tibetans (TIB)		Timargarha (TMG)		Veddahs (VED)	
Meas.	Value	N	Value	N	Value	N	Value	N	Value	N	Value	N	Value	N	Value	N	Value	N
GOL	183.7	28	181.1	20	177.4	70	171.4	19	183.5	16	183.9	138	170.3	25	185.2	19	175.7	65
BEB	132.6	27	128.5	18	135.9	70	142.0	19	132.1	16	133.0	137	136.0	23	131.5	19	124.7	68
AVH	113.4	27	111.0	15	112.9	69	112.5	19	114.9	16	113.4	133	113.2	23	116.2	19	109.0	47
SA	371.8	23	373.0	17	365.4	63	358.8	11	370.7	16	372.6	135	356.7	25	372.5	15	351.1	39
CAB	512.4	24	505.1	12	501.1	70	499.6	18	507.9	16	506.9	137	489.4	23	511.6	19	486.1	65
BFTB	94.1	29	91.9	22	88.9	70	95.4	19	93.0	16	93.9	138	87.1	24	92.7	17	90.4	65
NPH	67.7	27	65.8	20	69.3	67	63.2	11	69.0	16	67.9	134	65.5	24	68.4	15	58.5	58
NH	50.1	30	46.9	22	50.2	67	48.8	10	49.4	16	49.2	133	48.8	25	49.1	16	41.8	55
NB	25.8	29	24.4	23	24.0	68	23.3	10	24.4	16	24.7	128	25.9	25	22.9	15	23.7	57
OH	34.2	31	32.7	23	33.1	66	32.9	14	32.6	16	31.9	134	33.5	25	33.2	15	32.2	60
OB	41.8	31	38.7	20	38.2	63	38.8	11	39.9	13	40.4	128	39.3	23	40.8	14	37.9	60
BZB	128.6	14	126.9	6	122.3	54	128.8	10	120.7	14	123.8	121	123.4	22	127.7	8	119.3	62
IPL	46.4	22	47.6	22	45.1	60	42.3	9	46.9	14	46.5	121	43.6	23	44.9	4	50.3	47
IPB	39.9	22	34.0	24	39.0	55	38.1	9	39.1	14	39.1	120	40.7	23	38.4	5	46.6	45

Table 11.14. Principal Components Analysis of Craniometric Variation among South Asians

Cranial Measurement	Principal Component One	Principal Component Two	Principal Component Three
Glabello-Occipital Length (GOL)	0.708	0.647	-0.105
Bieuryonic Breadth (BEB)	0.693	-0.583	0.242
Auricular Height (AVH)	0.578	0.320	-0.317
Sagittal Arc (SA)	0.864	0.433	-0.055
Circumference Above Browridges (CAB)	0.857	0.062	-0.119
Bifrontotemporale Breadth (BFTB)	0.660	0.293	-0.151
Nasion-Prosthion Height (NPH)	0.835	0.084	0.206
Nasal Height (NH)	0.877	-0.227	0.017
Nasal Breadth (NB)	0.129	-0.889	0.060
Orbital Height (OH)	0.622	0.132	0.674
Orbital Breadth (OB)	0.923	-0.129	0.064
Bizygomatic Breadth (BZB)	0.752	-0.297	0.095
Internal Palatal Length (IPL)	-0.374	0.680	0.510
Internal Palatal Breadth (IPB)	-0.891	0.113	0.242
Eigenvalue	7.452	2.584	2.169
Percentage of Variance Explained	53.228	18.456	15.495
Total Variance Explained		87.179	

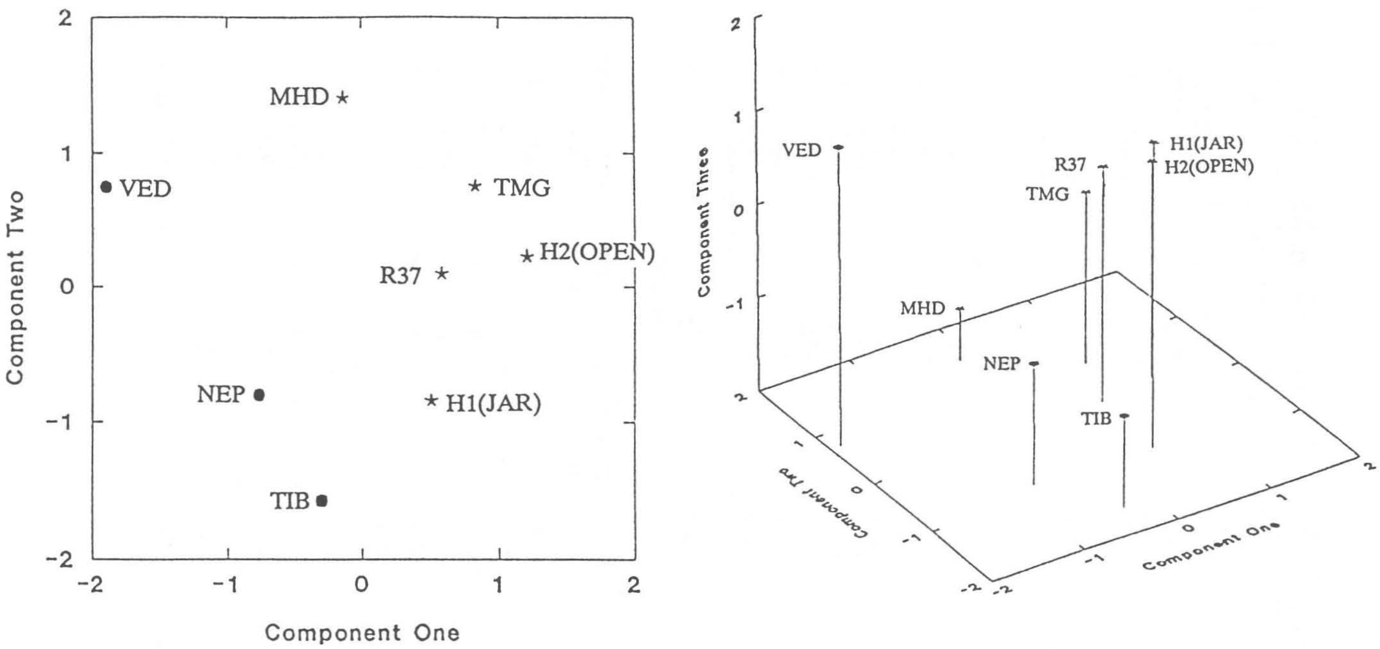

Figure 11.10. Two and three dimensional ordination of principal component scores derived from craniometric variation among South Asians.

the sole exception of Mohenjo-daro, Indus Valley samples (stars) stand apart from other South Asian sites (circles) with high scores along component one. In contrast to cluster analysis, principal components suggest that individuals from the Harappan phase cemetery bear slightly closer affinity to Late Harappan (Cemetery H) earth burials (H2) than to individuals from Timargarha. Component two indicates that individuals from jar burials at Cemetery H (H1) and Mohenjo-daro are only peripherally associated with the other Pakistani sites and are clearly very different from one another. Addition of component three emphasizes the similarities among all Indus Valley sites except Mohenjo-daro.

In the third phase of this craniometric analysis, nine prehistoric samples from Egypt, Anatolia, Mesopotamia, and the Iranian Plateau were contrasted with eight South Asian samples to examine population relationships from a regional perspective. To provide maximum comparability, the same fourteen variables used to contrast South Asians were employed. Samples were divided by sex, and the adequacy of these variables for drawing distinctions across all samples was tested with analysis of variance (Table 11.15). With fourteen significant differences among both males and females (14/14 = 100.0%), analysis of variance confirms that these craniometric variables may be used to examine differences among these samples.

Group mean values were calculated for each variable in each sample according to the method described for South Asian samples above and are listed in Table 11.13. These values were submitted to cluster analysis and dendrograms were constructed in euclidean space with Ward's minimum variance technique. Cluster analysis identifies three main groups (Figure 11.11). Tibetans, Nepalese, and Veddahs share relatively close affinities to one another and are quite distinct from all other samples. The rest of the samples fall into two groups. The first is composed of nine samples and includes all prehistoric Pakistani sites (except Mohenjo-daro), the two samples from Tepe Hissar, and samples from Chatal Hüyük and Kish. The second group is composed of five samples and includes all Egyptian sites, Tell al-Judiadah, and Mohenjo-daro. Individuals from the Harappan phase cemetery bear closest affinities to Timargarha, followed by the two samples from Tepe Hissar. Viewed in the context of these Near Eastern sites, cluster analysis suggests that affinities between the Harappan phase burials and the two Late Harappan samples from Cemetery H are not close.

Principal components analysis results in three components that combine to explain 67.8% of the total variance (Table 11.16). The first component draws the same distinction between measurements of the neurocranium and face with those of the palate found among South Asian samples. Again, neurocranial and facial measurements receive high loadings and palatal measurements low loadings. Thus, as among South Asian samples alone, high scorers along the first component reflect samples that possess relatively large neural and facial cranial measurements in combination with rather small palatal measurements. The second component draws a distinction between neurocranial, facial, and palatal breadth measurements and their paired measurements of height and length. Cranial breadth, bizygomatic breadth, bifrontotemporale breadth, and internal palatal breadth all possess higher loadings than cranial length, sagittal arc, auricular height, nasion-prosthion height, and internal palatal length. Thus, high scorers for component two feature relatively broad and low cranial vaults and faces, coupled with a wide palate. The distinction drawn by the third component is between measurements of the cranial vault and those of the face, exclusive of the palate. With the exceptions of auricular height and orbital breadth, vault measurements possess higher loadings than those of the face. As a result, high scorers for component three feature relatively large but low cranial vaults with large faces. Conversely, low scorers along component three are marked by relatively small but high cranial vaults with rather small faces.

Ordination of principal component scores into two and three dimensions are presented in Figure 11.12. Sites from the Indus Valley are represented by stars, other South Asian samples by squares, Egyptian sites

Table 11.15. Analysis of Variance of Cranial Measurements among All Groups by Sex

	Females			Males		
Craniometric Measurement	F	p	N	F	p	N
Glabello-Occipital Length (GOL)	6.515	0.000*	408	13.613	0.000*	597
Bieuryonic Breadth (BEB)	7.236	0.000*	395	14.800	0.000*	587
Auricular Height (AVH)	2.095	0.008*	369	6.767	0.000*	548
Sagittal Arc (SA)	3.381	0.000*	323	6.100	0.000*	506
Circumference Above Browridges (CAB)	6.367	0.000*	347	11.827	0.000*	539
Bifrontotemporale Breadth (BFTB)	5.641	0.000*	396	4.892	0.000*	582
Nasio-Prosthion Height (NPH)	7.043	0.000*	301	13.113	0.000*	480
Nasal Height (NH)	4.965	0.000*	315	11.547	0.000*	489
Nasal Breadth (NB)	3.018	0.000*	313	2.661	0.000*	483
Orbital Height (OH)	3.998	0.000*	323	3.256	0.000*	506
Orbital Breadth (OB)	12.020	0.000*	316	13.954	0.000*	500
Bizygomatic Breadth (BZB)	3.440	0.000*	203	5.913	0.000*	406
Internal Palatal Length (IPL)	11.903	0.000*	264	25.575	0.000*	435
Internal Palatal Breadth (IPB)	3.304	0.000*	259	6.876	0.000*	426

* = $p < 0.05$

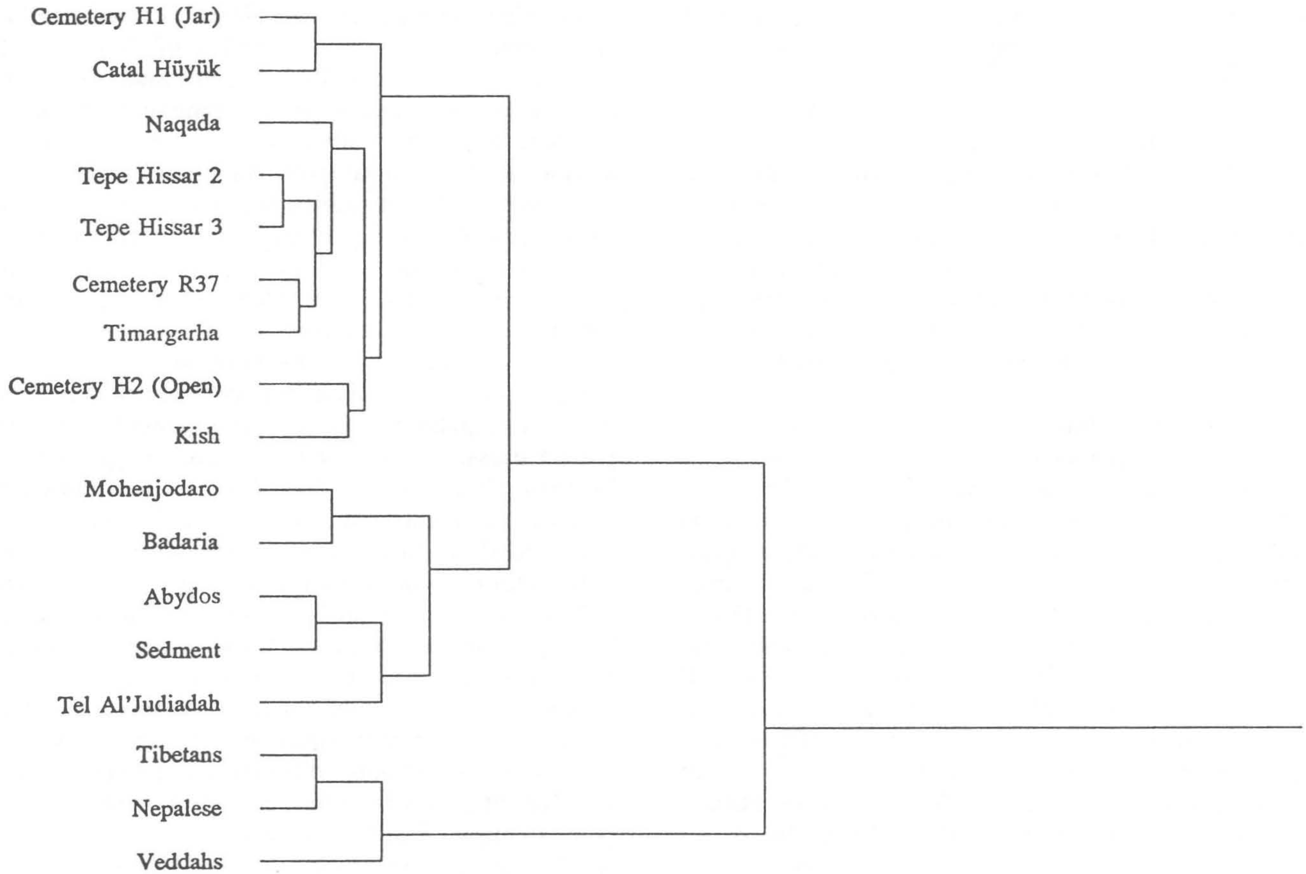

Figure 11.11. Cluster analysis of craniometric variation among all groups.

Table 11.16. Principal Components Analysis of Craniometric Variation among All Groups

	Principal Component		
Cranial Measurement	One	Two	Three
Glabello-Occipital Length (GOL)	0.708	-0.568	0.194
Bieuryonic Breadth (BEB)	0.401	0.736	0.080
Auricular Height (AVH)	0.557	-0.402	-0.397
Sagittal Arc (SA)	0.813	-0.478	0.001
Circumference Above Browridges (CAB)	0.889	0.017	0.333
Bifrontotemporale Breadth (BFTB)	0.610	0.211	0.503
Nasion-Prosthion Height (NPH)	0.626	-0.114	-0.405
Nasal Height (NH)	0.773	0.225	-0.482
Nasal Breadth (NB)	0.347	0.182	-0.397
Orbital Height (OH)	0.447	0.315	-0.185
Orbital Breadth (OB)	0.722	-0.193	0.397
Bizygomatic Breadth (BZB)	0.430	0.498	0.622
Internal Palatal Length (IPL)	-0.244	-0.636	0.390
Internal Palatal Breadth (IPB)	-0.729	-0.054	0.227
Eigenvalue	5.405	2.188	1.903
Percentage of Variance Explained	38.605	15.626	13.593
Total Variance Explained		67.824	

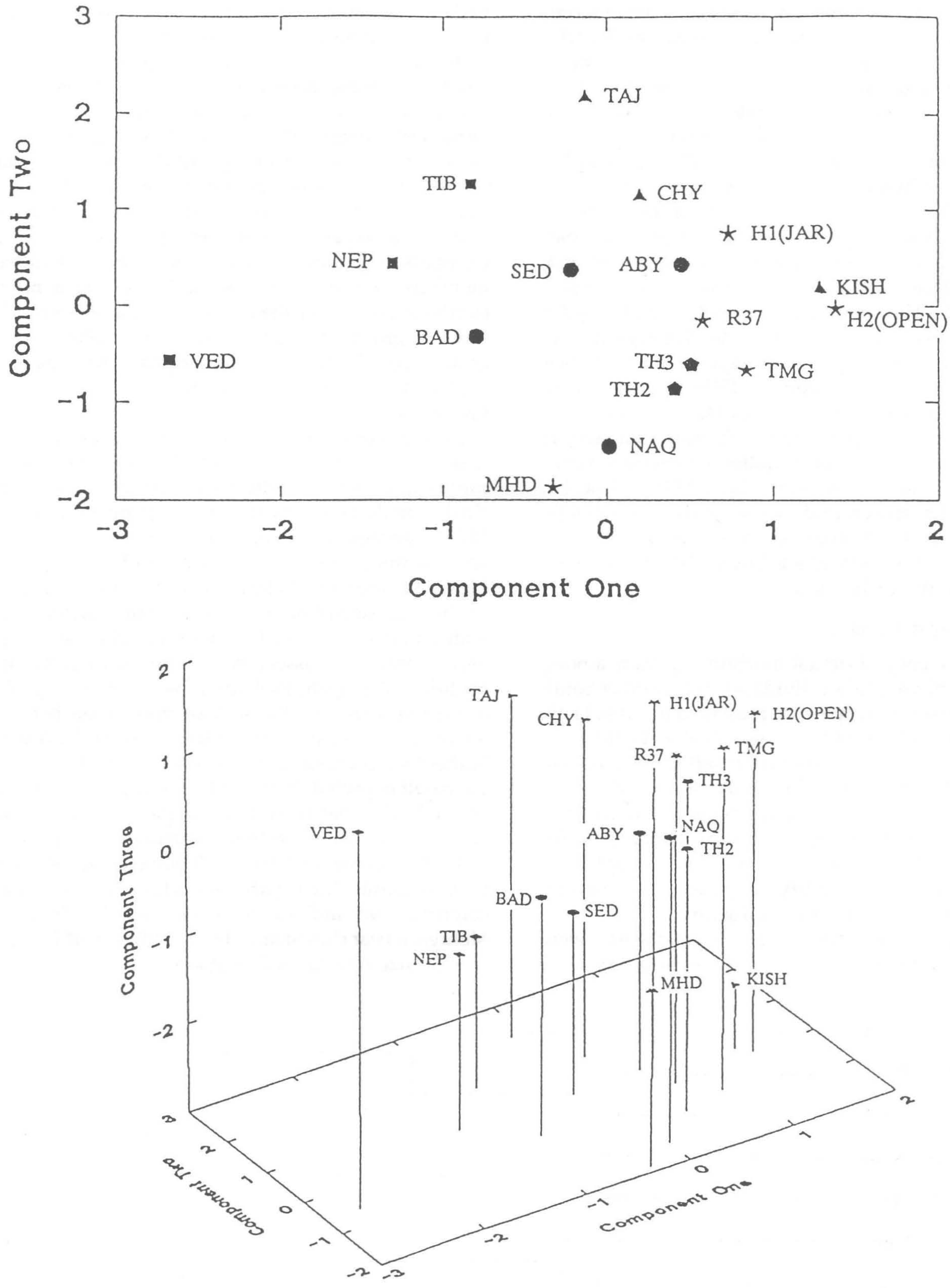

Figure 11.12. Ordination of principal component scores derived from craniometric variation among all groups.

by circles, Anatolian Plateau sites by triangles, and sites of the Iranian Plateau by pentagons. High scores along component one separate all Indus Valley sites except Mohenjo-daro away from all other samples except Abydos, Kish, and the two samples from Tepe Hissar. Component two separates Anatolian Plateau sites with high scores, and samples from Naqada and Mohenjo-daro with low scores, from all other samples. Although ordination of the first two components suggests that individuals from the Harappan phase cemetery possess equally close affinities to samples from Abydos and Tepe Hissar III as to Timargarha, addition of the third component reveals that affinities between the Harappan phase cemetery and Abydos are not close, while affinities to Timargarha are slightly closer than those with Tepe Hissar III. Lower (earth) burials at Cemetery H (H2) possess closest affinities to the Harappan phase cemetery and Timargarha, but upper (jar) burials from Cemetery H (H1) exhibit equally close affinities to these samples as to the Anatolian sample from Chatal Hüyük. Located in the center foreground, Mohenjo-daro is strongly separated from all other Indus Valley samples and possesses no close affinities to any of the other samples included in this ordination.

Dental Non-metrics

The frequency of dental morphology traits among Harappan phase (R37) individuals and six other South Asian prehistoric samples are presented in Table 11.17. Contingency chi-square analysis (Table 11.18) indicates that five of the sixteen traits reflect a significant degree of heterogeneity. Since this number of significant differences is nearly three times the number of significant differences expected from chance ($p < 0.05$; 5/16 = 31.2%), these traits may be accepted as adequate data for identifying patterns of identity among these South Asian dental series.

Arcsine transformed trait frequencies were submitted to cluster analysis, and dendrograms were constructed in euclidean space with Ward's minimum variance technique (Figure 11.13). Cluster analysis indicates that these South Asian samples fall into two main groups. The first includes mesolithic Ganga Valley, neolithic Mehrgarh, and Late Bronze Age Inamgaon. The second includes Sarai Khola, Timargarha, chalcolithic Mehrgarh, and the Harappan phase sample from Harappa (R37). Two important points may be noted from cluster analysis. First, the two samples from Mehrgarh share widely different phenetic associations, with neolithic individuals as members of group one and chalcolithic individuals members of group two. Second, there is a nearly complete division of sites between those of peninsular India in group one and of the Indus Valley sites in group two. The neolithic inhabitants of Mehrgarh, as members of group one, represent the sole exception to this division.

Multidimensional scaling of standardized mean measure of divergence distances (Table 11.19) provides confirmation for the pattern of affinities identified by cluster analysis for members of group one (Figure 11.14). Samples from Pakistan are represented as stars and samples from peninsular India as circles. Mesolithic individuals from the Ganga Valley, located on the right side of this ordination, represent an isolate with no close affinities to any of the other series and only peripheral association with Inamgaon and neolithic Mehrgarh. Perhaps most dramatically, this ordination confirms the lack of association between neolithic and chalcolithic inhabitants of Mehrgarh. Rather than possessing closest affinities to one another, the result expected from *in situ* continuity, dimension one indicates that these two samples from Mehrgarh represent the most strongly separated of the seven series considered. Instead of exhibiting closest affinities to chalcolithic Mehrgarh, multidimensional scaling confirms that individuals from neolithic levels at Mehrgarh bear closest affinities to individuals from the Late Bronze Age site of Inamgaon.

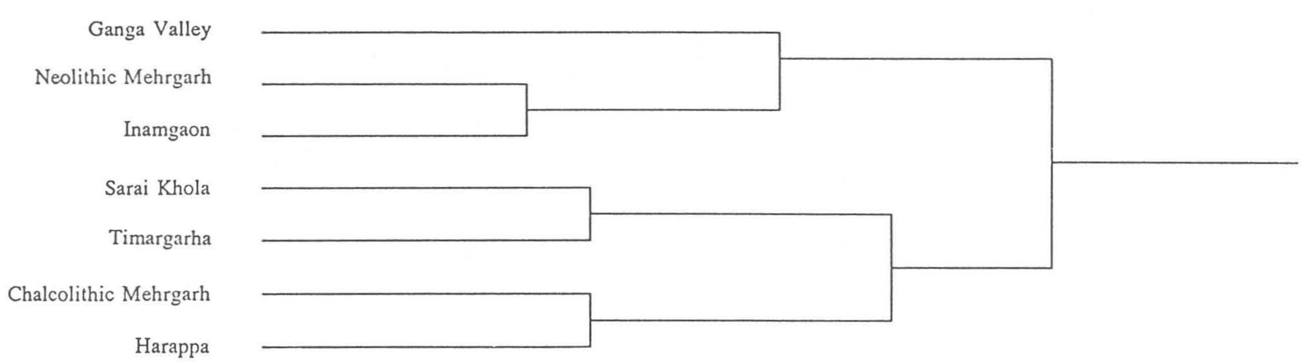

Figure 11.13. Cluster analysis of dental non-metric trait variation among South Asians.

Table 11.17. Frequencies of dental non-metric traits among prehistoric South Asians

		Harappa (R37)			Chalcolithic Mehrgarh			Neolithic Mehrgarh			Inamgaon			Sarai Khola			Timargarha			Ganga Valley		
Trait	Tooth	p	n	f	p	n	f	p	n	f	p	n	f	p	n	f	p	n	f	p	n	f
SHOV	UI1	9	15	0.600	21	25	0.840	25	28	0.893	22	24	0.917	3	9	0.333	5	7	0.714	4	6	0.667
SHOV	UI2	10	16	0.625	21	24	0.875	31	37	0.838	13	19	0.684	2	9	0.222	4	7	0.571	5	7	0.714
MLR	UI1	8	12	0.667	14	25	0.560	15	26	0.577	14	25	0.560	2	11	0.182	3	8	0.375	2	6	0.333
MLR	UI2	6	13	0.462	7	24	0.292	2	29	0.069	1	20	0.050	0	9	0.000	0	7	0.000	2	7	0.286
MIG	UI1	1	13	0.077	2	21	0.095	0	27	0.000	0	25	0.000	1	10	0.100	1	8	0.125	2	6	0.333
HYPO	UM1	16	16	1.000	22	22	1.000	35	42	0.833	27	41	0.659	15	21	0.714	17	22	0.773	9	9	1.000
CARA	UM1	4	9	0.444	11	18	0.611	7	27	0.259	13	40	0.325	5	13	0.385	9	18	0.500	0	8	0.000
MTCNLE	UM1	6	13	0.462	5	19	0.263	7	28	0.250	6	41	0.146	3	13	0.231	4	19	0.211	2	6	0.333
MTCNLE	UM2	4	16	0.250	6	18	0.333	10	25	0.400	3	20	0.150	2	12	0.167	0	13	0.000	1	7	0.143
MTCNLE	UM3	4	13	0.308	0	11	0.000	8	19	0.421	1	6	0.167	3	11	0.273	2	10	0.200	4	8	0.500
ENTO	LM3	0	18	0.000	1	16	0.063	1	34	0.029	1	12	0.083	2	14	0.143	1	6	0.167	1	7	0.143
CUSPN	LM1	17	20	0.850	20	23	0.870	4	43	0.093	7	39	0.179	6	15	0.400	4	6	0.667	2	8	0.250
CUSPN	LM3	10	20	0.500	10	17	0.588	12	38	0.316	6	11	0.545	9	14	0.643	4	6	0.667	1	7	0.143
Y-GROOVE	LM1	15	17	0.882	15	21	0.714	23	25	0.920	32	35	0.914	5	7	0.714	12	17	0.706	4	5	0.800
Y-GROOVE	LM2	3	31	0.097	6	22	0.273	12	37	0.324	7	24	0.292	5	14	0.357	3	18	0.167	4	8	0.500
Y-GROOVE	LM3	2	18	0.111	1	16	0.063	3	27	0.111	1	10	0.100	1	12	0.083	1	6	0.167	2	7	0.286

Table 11.18. Contingency Chi-Square Analysis of Dental Non-Metric Traits among Prehistoric South Asians

Dental Trait	Tooth	X2	p	df
Shoveling (SHOV)	UI1	21.033	0.002*	6
Shoveling (SHOV)	UI2	18.178	0.006*	6
Median Lingual Ridge (MLR)	UI1	8.216	0.223	6
Median Lingual Ridge (MLR)	UI2	18.843	0.004*	6
Mar. Inter. Grooves (MIG)	UI1	11.976	0.063	6
Hypocone Development (HYPO)	UM1	19.095	0.004*	6
Carabelli's Trait (CARA)	UM1	12.507	0.052	6
Metaconule (MTCNLE)	UM1	5.963	0.427	6
Metaconule (MTCNLE)	UM2	10.236	0.115	6
Metaconule (MTCNLE)	UM3	8.785	0.186	6
Entoconulid (ENTO)	LM3	4.932	0.553	6
Cusp Number (CUSPN)	LM1	16.849	0.010*	6
Cusp Number (CUSPN)	LM3	9.332	0.156	6
Y Groove Pattern (Y-GROOVE)	LM1	8.233	0.222	6
Y Groove Pattern (Y-GROOVE)	LM2	9.135	0.166	6
Y Groove Pattern (Y-GROOVE)	LM3	2.751	0.839	6

* = p< 0.05

Table 11.19. Mean Measure of Distance Scores Derived from Dental Non-Metric Variation among Prehistoric South Asians

	Ganga Valley	Neolithic Mehrgarh	Chalcolithic Mehrgarh	Harappa (R37)	Inamgaon	Sarai Khola
Ganga Valley						
Neolithic Mehrgarh	-0.014 0.041 -0.329					
Chalcolithic Mehrgarh	0.158 0.141 1.125	0.189 0.154 1.229				
Harappa (R37)	0.067 0.092 0.735	0.175 0.148 1.182	-0.018 0.047 -0.378			
Inamgaon	0.026 0.057 0.455	-0.026 0.057 -0.453	0.122 0.123 0.987	0.139 0.132 1.055		
Sarai Khola	0.023 0.054 0.430	0.172 0.147 1.174	0.183 0.151 1.209	0.117 0.121 0.968	0.059 0.086 0.686	
Timargarha	0.002 0.016 0.124	0.099 0.111 0.891	-0.025 0.056 -0.448	-0.022 0.052 -0.417	-0.050 0.079 -0.635	-0.088 0.105 -0.839

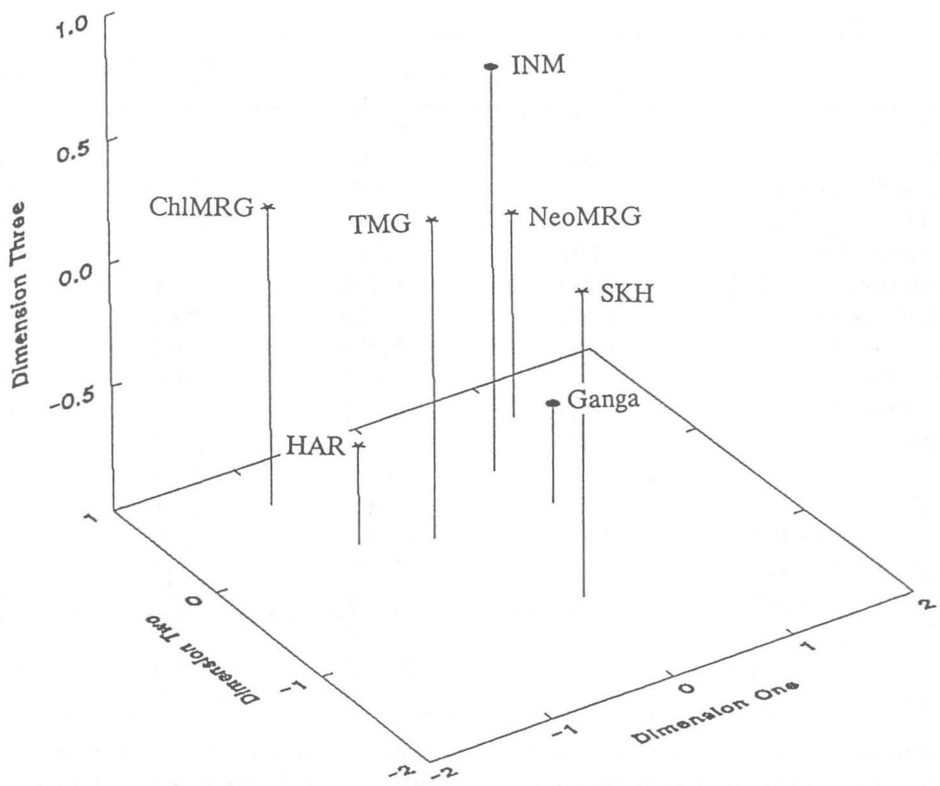

Figure 11.14. Multidimensionally scaled ordination of dental non-metric trait variation among South Asians.

However, when the pattern of affinities identified by cluster analysis among members of group two are considered, multidimensional scaling presents a different interpretation of these relationships. Harappan phase individuals do not possess closer affinities to chalcolithic Mehrgarh than to any other samples; rather this ordination reveals that Harappan phase individuals are equally similar to individuals from chalcolithic Mehrgarh as they are to individuals from post-Harappan Timargarha. Located intermediate between these latter two series in time and space (as well as in this ordination), Harappan phase individuals possess the pattern of affinities expected under conditions of prolonged biological continuity within the Indus Valley from early chalcolithic times (4500 BC) until the early post-Harappan period (800 BC). Identified as the sole occupants in the foreground of this ordination, individuals from Sarai Khola possess no close affinities to any other sample considered, but as expected from cluster analysis, of these other series, Sarai Khola bears closest affinities to Timargarha.

Principal components analysis of standardized arcsine transformed trait frequencies yields three components that combine to explain 82.3% of the total variance (Table 11.20). High scorers along the first component reflect samples that possess relatively high frequencies of marginal interruption grooves on UI2, Carabelli's Trait, and retention of the hypoconulid on all mandibular molars coupled with relatively low frequencies of incisor shoveling, the metaconule, and the Y-groove molar pattern. Similarly, high scorers for component two feature relatively high incidences of incisor shoveling, median lingual ridge development, and maxillary molars which feature Carabelli's Trait, the metaconule and full expression of the hypocone, and retention of the hypoconulid on LM1 combined with low frequencies of the metaconule on UM3, the entoconulid on LM3, and the Y-groove pattern on all mandibular molars. High scorers for component three are marked by relatively high frequencies of median lingual ridge development on UI2, marginal interruption grooves on UI1, full expression of the hypocone and the presence on the metaconule on UM1, and the Y-groove pattern on all mandibular molars accompanied by low frequencies of shoveling on UI1, Carabelli's Trait on UM1, and retention of the hypoconulid among mandibular molars.

Ordination of group component scores for the first three principal components (Figure 11.15) provides strong confirmation of results obtained from cluster

Table 11.20. Principal Components Analysis of Dental Non-Metric Variation among Prehistoric South Asians

Dental Trait	Tooth	Principal Component		
		One	Two	Three
Shoveling (SHOV)	UI1	-0.795	0.080	-0.288
Shoveling (SHOV)	UI2	-0.693	0.434	0.067
Median Lingual Ridge (MLR)	UI1	-0.681	0.619	-0.072
Median Lingual Ridge (MLR)	UI2	0.306	0.771	0.430
Marg. Inter. Grooves (MIG)	UI1	0.776	-0.067	0.565
Hypocone Development (HYPO)	UM1	0.130	0.756	0.577
Carabelli's Trait (CARA)	UM1	0.426	0.631	-0.606
Metaconule (MTCNLE)	UM1	0.274	0.592	0.699
Metaconule (MTCNLE)	UM2	-0.663	0.465	0.230
Metaconule (MTCNLE)	UM3	-0.338	-0.451	0.739
Entoconulid (ENTO)	LM3	0.705	-0.615	-0.123
Cusp Number (CUSPN)	LM1	0.672	0.733	-0.014
Cusp Number (CUSPN)	LM3	0.642	0.179	-0.722
Y Groove Pattern (Y-GROOVE)	LM1	-0.842	-0.121	-0.006
Y Groove Pattern (Y-GROOVE)	LM2	-0.175	-0.646	0.195
Y Groove Pattern (Y-GROOVE)	LM3	0.306	-0.522	0.588
Eigenvalue		5.294	4.569	3.307
Percentage of Variance Explained		33.087	28.557	20.666
Total Variance Explained			82.310	

analysis. Symbol designations are the same as those for Figure 11.14. Thus, three sample groups and one isolate are identified. Individuals from the Harappan phase cemetery at Harappa possess closest affinities to chalcolithic inhabitants of Mehrgarh. The two post-Harappan northern Pakistani samples from Sarai Khola and Timargarha bear closest affinities to one another, and neolithic inhabitants of Mehrgarh are most similar to the Late Bronze age sample from Inamgaon. Mesolithic Ganga Valley inhabitants represent an isolate that possesses no close affinities to any of the other samples included in this analysis.

Cranial Non-metrics

Biological affinities of Harappan phase R37C individuals are placed in broad regional perspective by contrasting them with ten samples from Egypt, the Near East, and South Asia. The frequency of cranial non-metric traits among these eleven cranial series are presented in Table 11.21. Contingency chi-square analysis (Table 11.22) indicates that eleven of these traits reflect a significant degree of heterogeneity. Since this number of significant differences is greater than twelve times the number of significant differences expected from chance ($p < 0.05$; 11/18 = 61.1%), these traits may be accepted as adequate data for identifying patterns of affinity among them.

Cluster analysis of arcsine transformed trait frequencies indicate that all South Asian samples do not cluster together (Figure 11.16). In fact, two major groups may be identified. The first includes Harappan phase (R37) individuals from Harappa and all modern and ancient Near Eastern populations, except Jordanian Bedouins. The second group includes all South Asian samples (except Harappan phase individuals), modern Burmese, and ancient Egyptians. What is clear from cluster analysis is that skeletons recovered from the Harappan phase cemetery represent a South Asian sample that possesses a very different set of phenetic relationships than those possessed by Sarai Khola, Mahadaha, or modern Punjabis.

Multidimensional scaling of standardized mean measure of divergence distances (Table 11.23) indicates that three sample groups and one isolate are present (Figure 11.17). Indus Valley samples are represented by stars, Near Eastern and Anatolian samples as triangles, other South Asian samples by squares, and Egyptians by circles. Harappan phase individuals (R37) along with the two Palestinian samples form one group, southern Anatolian sites form another group, and the rest of the samples form a third group. While Kamid el-Loz and Lidar bear closer affinities to one another than to any of the other samples included in this analysis, Kamid el-Loz is more closely associated with Harappan phase individuals and Palestinians than is Lidar. This last sample appears to be intermediate between the smaller Harappo-Palestinian group and the larger South Asian group, with closest phenetic affinities to Sarai Khola. As indicated from cluster analysis, Jordanian Bedouins exhibit no close affinities to any of the other samples.

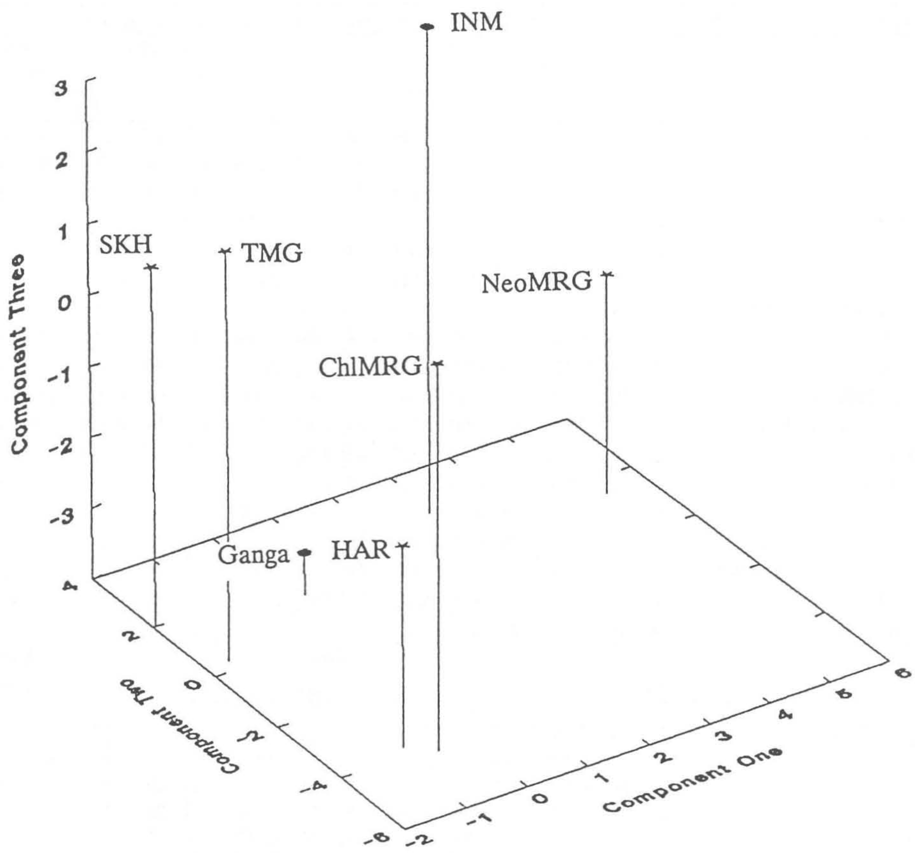

Figure 11.15. Ordination of principal component scores derived from dental non-metric trait variation among South Asians.

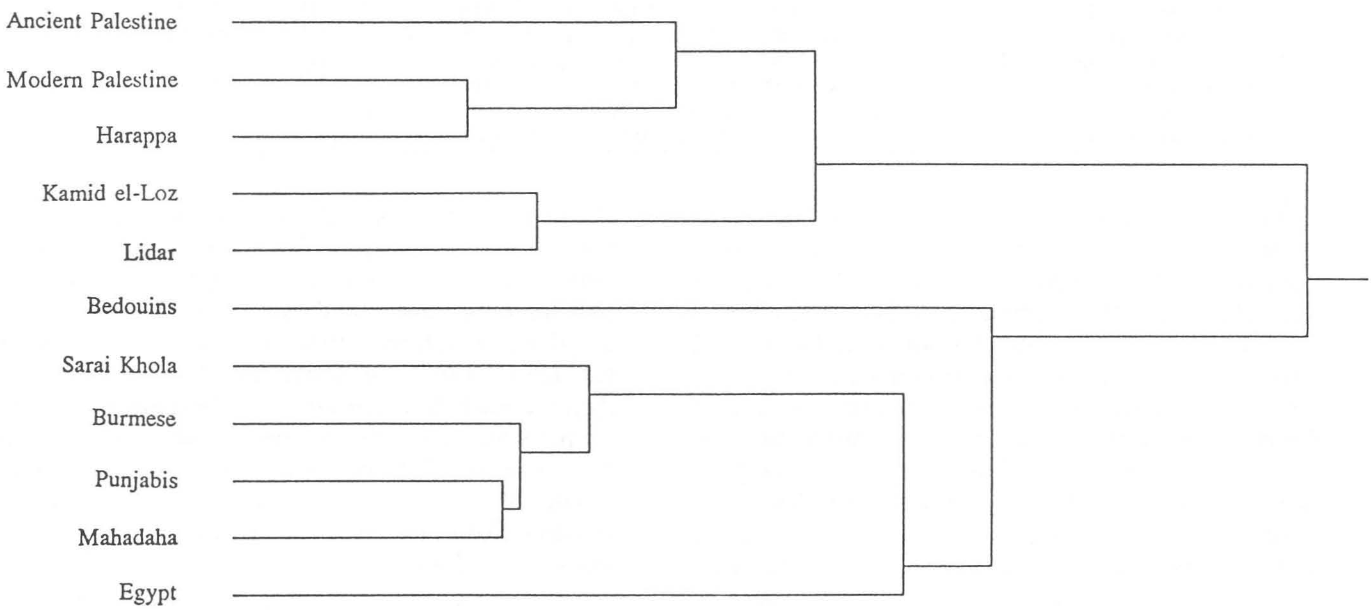

Figure 11.16. Cluster analysis of cranial non-metric trait variation among all groups.

Table 11.21. Frequencies of cranial non-metric traits among all groups (P=no. present; N=sample size; F=frequency).

	Harappa			Ancient Egypt			Ancient Palestine			Modern Palestine			Modern Punjab			Modern Burma		
Cranial Trait	*P*	*N*	*F*	*P*	*N*	*F*	*P*	*N*	*F*	*P*	*N*	*F*	*P*	*N*	*F*	*P*	*N*	*F*
Ossicle at the Lambda (OLAM)	1	16	0.063	37	250	0.148	6	54	0.111	4	18	0.222	11	53	0.208	7	51	0.137
Lambdoidal Ossicle (LOP)	4	35	0.114	161	499	0.323	32	107	0.299	12	36	0.333	34	106	0.321	30	102	0.294
Parietal Foramen (PARF)	8	37	0.216	221	500	0.442	38	108	0.352	8	36	0.222	53	106	0.500	51	102	0.500
Metopic Suture (METOP)	0	21	0.000	18	250	0.072	4	54	0.074	1	18	0.056	3	53	0.057	0	51	0.000
Coronal Ossicle (COROSS)	2	31	0.065	13	498	0.026	4	108	0.037	0	34	0.000	2	106	0.019	1	102	0.010
Epipteric Bone (EPIB)	2	27	0.074	70	487	0.144	10	105	0.095	2	31	0.065	18	106	0.170	15	102	0.147
Fronto-Temporal Articulation (FTART)	1	24	0.042	10	489	0.021	1	106	0.009	3	31	0.097	2	106	0.019	3	102	0.029
Parietal Notch Bone (PNB)	1	37	0.027	37	498	0.074	3	108	0.028	4	36	0.111	8	106	0.076	8	102	0.078
Ossicle at Asterion (ASTOSS)	3	37	0.081	64	497	0.129	7	108	0.065	3	36	0.083	9	106	0.085	10	102	0.098
Foramen of Huschke (FORHUS)	3	33	0.091	69	494	0.140	18	95	0.190	2	33	0.061	24	106	0.226	25	102	0.245
Mastoid Foramen Ex-Sutural (MFEX)	6	32	0.188	190	496	0.383	25	108	0.232	12	36	0.333	49	106	0.462	47	102	0.461
Mastoid Foramen Absent (MFA)	4	33	0.121	62	496	0.125	42	108	0.389	7	36	0.194	19	106	0.179	8	102	0.078
Precondylar Tubercle (PRETUB)	1	35	0.029	34	496	0.069	6	106	0.057	0	32	0.000	6	106	0.057	10	102	0.098
Bifid Hypoglossal Canal (BHC)	1	34	0.029	82	494	0.166	7	100	0.070	3	36	0.083	19	106	0.179	10	102	0.098
Acc. Lesser Palatine Foramen (ALPF)	7	23	0.304	228	469	0.486	12	91	0.132	7	30	0.233	51	106	0.481	31	97	0.320
Zygomatico-Facial Foramen Absent (ZFFA)	14	28	0.500	94	478	0.197	30	100	0.300	13	34	0.382	29	104	0.279	18	101	0.178
Frontal Foramen (FRFOR)	6	35	0.171	161	500	0.322	20	108	0.185	7	34	0.206	34	106	0.321	33	102	0.324
Acc. Infraorbital Foramen (AIOF)	0	24	0.000	23	489	0.047	3	102	0.029	2	31	0.065	7	105	0.067	7	93	0.075

	Mahadaha			Lidar			Kamid el-Loz			Sarai Khola			Modern Bedouin		
Cranial Trait	*P*	*N*	*F*	*P*	*N*	*F*	*P*	*N*	*F*	*P*	*N*	*F*	*P*	*N*	*F*
Ossicle at the Lambda (OLAM)	0	9	0.000	5	25	0.200	4	38	0.105	5	24	0.208	7	25	0.280
Lambdoidal Ossicle (LOP)	1	17	0.059	10	20	0.500	18	37	0.487	9	21	0.429	16	49	0.327
Parietal Foramen (PARF)	8	20	0.400	15	39	0.385	27	69	0.391	24	48	0.500	31	50	0.620
Metopic Suture (METOP)	0	9	0.000	5	20	0.250	3	34	0.088	1	22	0.046	4	25	0.160
Coronal Ossicle (COROSS)	0	16	0.000	0	17	0.000	1	24	0.042	0	18	0.000	3	22	0.136
Epipteric Bone (EPIB)	2	15	0.133	0	13	0.000	4	20	0.200	3	22	0.136	6	40	0.150
Fronto-Temporal Articulation (FTART)	2	13	0.154	0	13	0.000	0	32	0.000	0	21	0.000	4	40	0.100
Parietal Notch Bone (PNB)	1	16	0.063	1	27	0.037	2	62	0.032	2	41	0.049	5	50	0.100
Ossicle at Asterion (ASTOSS)	0	17	0.000	6	34	0.177	5	62	0.081	3	36	0.083	7	51	0.137
Foramen of Huschke (FORHUS)	0	17	0.000	6	31	0.194	4	80	0.050	2	32	0.063	16	23	0.696
Mastoid Foramen Ex-Sutural (MFEX)	7	15	0.467	21	33	0.636	32	68	0.471	29	39	0.744	25	48	0.521
Mastoid Foramen Absent (MFA)	1	11	0.091	4	28	0.143	7	69	0.102	3	12	0.250	22	47	0.468
Precondylar Tubercle (PRETUB)	0	16	0.000	1	8	0.125	2	8	0.250	1	7	0.143	1	22	0.046
Bifid Hypoglossal Canal (BHC)	1	14	0.071	7	15	0.467	4	30	0.133	0	7	0.000	2	19	0.105
Acc. Lesser Palatine Foramen (ALPF)	6	10	0.600	1	8	0.125	0	23	0.000	1	4	0.250	20	40	0.500
Zygomatico-Facial Foramen Absent (ZFFA)	2	14	0.143	18	33	0.546	27	60	0.450	5	28	0.179	10	40	0.250
Frontal Foramen (FRFOR)	4	17	0.235	6	35	0.171	8	44	0.182	15	34	0.441	37	47	0.787
Acc. Infraorbital Foramen (AIOF)	1	11	0.091	0	22	0.000	1	29	0.035	0	21	0.000	5	40	0.125

Principal components analysis of standardized arcsine transformed trait frequencies results in three components that account for 69.2% of the total variance (Table 11.24). Component loadings indicate that high scorers along the first component reflect samples that possess relatively high frequencies of all non-metric variations except absence of zygomatico-facial foramen. High scorers for component two feature relatively high incidences of lambda ossicles, ossicles in the lambdoidal suture, metopism, ossicles in the coronal suture, fronto-temporal articulations at pterion, foramen of Huschke, ex-sutural or absent mastoid foramen, precondylar tubercles, absence of zygomatico-facial foramen, and accessory infraorbital foramen coupled with low frequencies of parietal foramen, epipteric bones, parietal notch bones, ossicles at asterion bifid hypoglossal canals, and accessory lesser palatine foramen. High scorers along component three are marked by relatively high frequencies of ossicles in the lambdoidal suture, metopism, ossicles at asterion, ex-sutural mastoid foramen, precondylar tubercles, bifid hypoglossal canals and absences of zygomatico-facial foramen accompanied by low frequencies of ossicles in the coronal suture, fronto-temporal articulations, parietal notch bones, foramen of Huschke, mastoid foramen absence, accessory lesser palatine foramen, frontal foramen, and accessory infra-orbital foramen.

Ordination of group component scores into three dimensions (Figure 11.18) confirms results obtained by cluster analysis and multidimensional scaling. Symbol designations are the same as for Figure 11.17. Once

Table 11.22. Contingency Chi-Square Analysis of Cranial Non-Metric Traits among All Groups

Non-metric Trait	χ^2	p	df
Ossicle at the Lambda (OLAM)	10.007	0.434	10
Lambdoidal Ossicle (LOP)	21.606	0.017*	10
Parietal Foramen (PARF)	29.388	0.001*	10
Metopic Suture (METOP)	19.767	0.032*	10
Coronal Ossicle (COROSS)	16.283	0.092	10
Epipteric Bone (EPIB)	7.892	0.639	10
Fronto-Temporal Articulation (FTART)	26.547	0.003*	10
Parietal Notch Bone (PNB)	8.217	0.608	10
Ossicle at Asterion (ASTOSS)	10.411	0.405	10
Foramen of Huschke (FORHUS)	76.148	0.000*	10
Mastoid Foramen Ex-Sutural (MFEX)	54.059	0.000*	10
Mastoid Foramen Absent (MFA)	83.382	0.000*	10
Precondylar Tubercle (PRETUB)	11.892	0.292	10
Bifid Hypoglossal Canal (BHC)	28.886	0.001*	10
Acc. Lesser Palatine Foramen (ALPF)	72.895	0.000*	10
Zygomatico-Facial Foramen Absent (ZFFA)	53.298	0.000*	10
Frontal Foramen (FRFOR)	72.727	0.000*	10
Acc. Infraorbital Foramen (AIOF)	11.643	0.310	10

* = $p < 0.05$

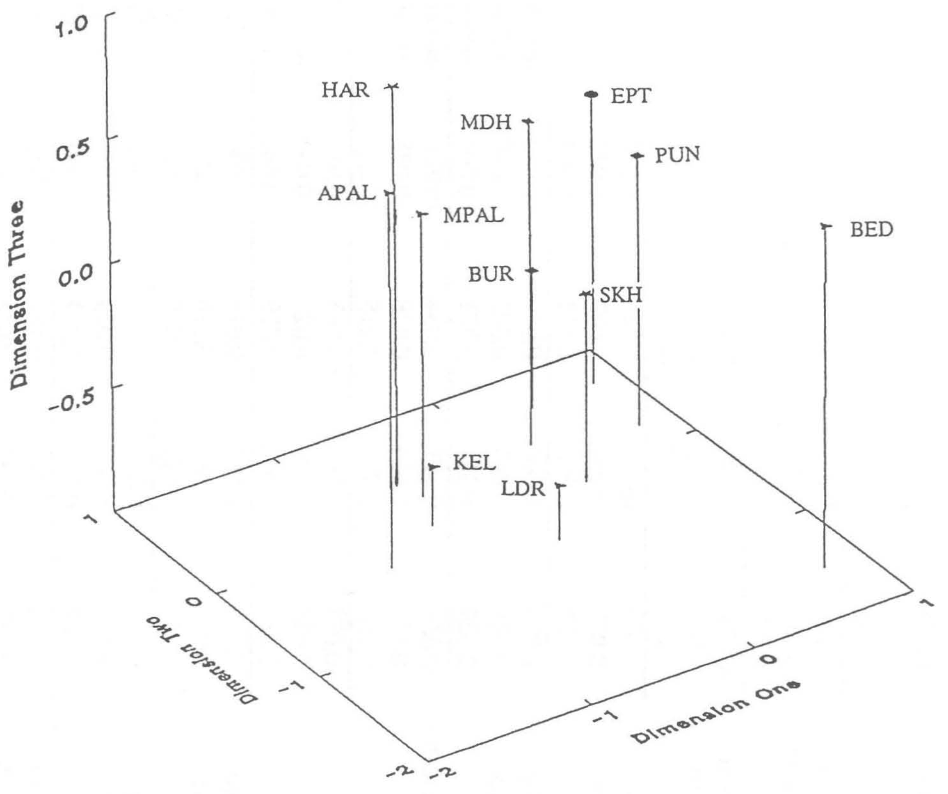

Figure 11.17. Multidimensionally scaled ordination of cranial non-metric trait variation among all groups.

Table 11.23. Mean Measure of Distance Scores Derived from Cranial Non-metric Variation among All Groups

	Harappa (R37)	Ancient Egypt	Ancient Palestine	Modern Palestine	Modern Punjab	Modern Burma	Mahadaha	Lidar	Kamid el-Loz	Sarai Khola
Harappa (R37)										
Ancient	0.034									
Egypt	0.013									
	2.682									
Ancient	0.004	0.052								
Palestine	0.015	0.004								
	0.249	11.711								
Modern	-0.033	0.012	-0.010							
Palestine	0.023	0.012	0.015							
	-1.448	1.057	-0.676							
Modern	0.039	-0.004	0.046	0.010						
Punjab	0.015	0.004	0.007	0.015						
	2.521	-0.961	6.414	0.683						
Modern	0.036	0.002	0.040	0.012	-0.006					
Burma	0.016	0.005	0.007	0.015	0.007					
	2.329	0.373	5.371	0.809	-0.817					
Mahadaha	-0.023	-0.345	0.034	-0.021	-0.030	-0.026				
	0.036	0.025	0.028	0.035	0.028	0.028				
	-0.631	-1.374	1.215	-0.589	-1.066	-0.935				
Lidar	0.075	0.063	0.065	0.014	0.038	0.056	0.082			
	0.030	0.020	0.023	0.030	0.023	0.023	0.043			
	2.454	3.092	2.839	0.460	1.670	2.443	1.935			
Kamid	0.036	0.062	0.029	0.000	0.055	0.036	0.064	-0.015		
el-Loz	0.023	0.014	0.016	0.023	0.016	0.016	0.035	0.032		
	1.533	4.612	1.825	0.015	3.463	2.226	1.803	-0.476		
Sarai	0.067	-0.005	0.035	-0.001	-0.022	-0.025	-0.025	0.006	-0.006	
Khola	0.036	0.027	0.029	0.035	0.029	0.029	0.048	0.045	0.038	
	1.870	-0.193	1.202	-0.030	-0.745	-0.847	-0.524	0.135	-0.170	
Modern	0.242	0.141	0.186	0.189	0.093	0.120	0.152	0.192	0.256	0.079
Bedouin	0.022	0.011	0.014	0.021	0.014	0.014	0.034	0.029	0.022	0.035
	11.121	12.711	13.451	8.998	6.710	8.573	4.445	6.584	11.446	2.263

Table 11.24. Principal Components Analysis of Cranial Non-Metric Variation among All Groups

	Principal Component		
Cranial Trait	One	Two	Three
Ossicle at the Lambda (OLAM)	0.788	0.288	0.099
Lambdoidal Ossicle (LOP)	0.271	0.104	0.826
Parietal Foramen (PARF)	0.817	-0.338	0.025
Metopic Suture (METOP)	0.359	0.570	0.528
Coronal Ossicle (COROSS)	0.282	0.747	-0.204
Epipteric Bone (EPIB)	0.446	-0.525	0.014
Fronto-Temporal Articulation (FTART)	0.278	0.645	-0.382
Parietal Notch Bone (PNB)	0.708	-0.249	-0.295
Ossicle at Asterion (ASTOSS)	0.472	-0.354	0.456
Foramen of Huschke (FORHUS)	0.700	0.306	-0.314
Mastoid Foramen Ex-Sutural (MFEX)	0.610	0.213	0.444
Mastoid Foramen Absent (MFA)	0.153	0.708	-0.310
Precondylar Tubercle (PRETUB)	0.108	0.398	0.610
Bifid Hypoglossal Canal (BHC)	0.376	-0.234	0.730
Acc. Lesser Palatine Foramen (ALPF)	0.486	-0.748	-0.154
Zygomatico-Facial Foramen Absent (ZFFA)	-0.266	0.811	0.293
Frontal Foramen (FRFOR)	0.905	0.004	-0.251
Acc. Infraorbital Foramen (AIOF)	0.690	0.248	-0.470
Eigenvalue	5.209	4.103	3.142
Percentage of Variance Explained	28.941	22.795	17.457
Total Variance Explained		69.193	

again, individuals from the Harappan phase cemetery and the two Palestinian samples form a group distinct from all other samples. The two Anatolian sites, Kamid el-Loz and Lidar, form a second group, and modern Punjabis, Burmese, and the mesolithic inhabitants of Mahadaha form a third group. Post-Harappan Sarai Khola is only peripherally associated with these latter samples. Principal components identify ancient Egyptians and Jordanian Bedouins as possessing no close phenetic associations with any of these Near East and South Asian samples.

Discussion

Agricultural Intensification

As stated in the introduction, perhaps the most significant adaptations faced by the third millennium population of Harappa were those incurred as a response to dietary changes involved with increased agricultural intensification. Examination of the dentition of Harappan phase individuals allows assessment of the biological impact of this cultural behavior from both proximate and ultimate evolutionary perspectives (Frayer and Wolpoff 1985).

Assessment of pathological conditions of the teeth and jaws provides insight into the short term impact of subsistence techniques on the immediate health of Harappan phase individuals. Individuals as the unit of biological adaptation must cope with the deleterious effects of increased sticky carbohydrate consumption and reduced masticatory stress that accompany increased reliance upon cultivated foodstuffs and increased sophistication of food preparatory techniques (Calcagno 1984; y'Edynak 1978, 1989; Greene 1972; Larsen 1983, 1984; Lukacs 1982; Turner 1979).

The first stage of the comparative analysis of dental pathology and agricultural intensification examined the suite of pathological afflictions experienced within the Indus Valley. Comparison of dental pathology affectation patterns at the Harappan phase cemetery to neolithic and chalcolithic skeletal series from Mehrgarh presented in Figure 11.5 demonstrate a progressive increase in all dental pathology conditions except calculus over time. Increased levels of hypoplasia are especially evident from these data, and such an increase in the frequency of hypoplasia with increased reliance upon cultivated foodstuffs has been reported by other workers from North and South America, Africa, Europe, and the Near East (Cohen and Armelagos 1984; Goodman and Rose 1990). This progressive decline in dental health within the Indus Valley from neolithic levels at Mehrgarh to the full urban phase of the Harappan Civilization accords well with expectations of the proximate effects of increasing reliance upon agriculture.

The suite of pathological conditions experienced by the individuals of the Harappan phase cemetery at

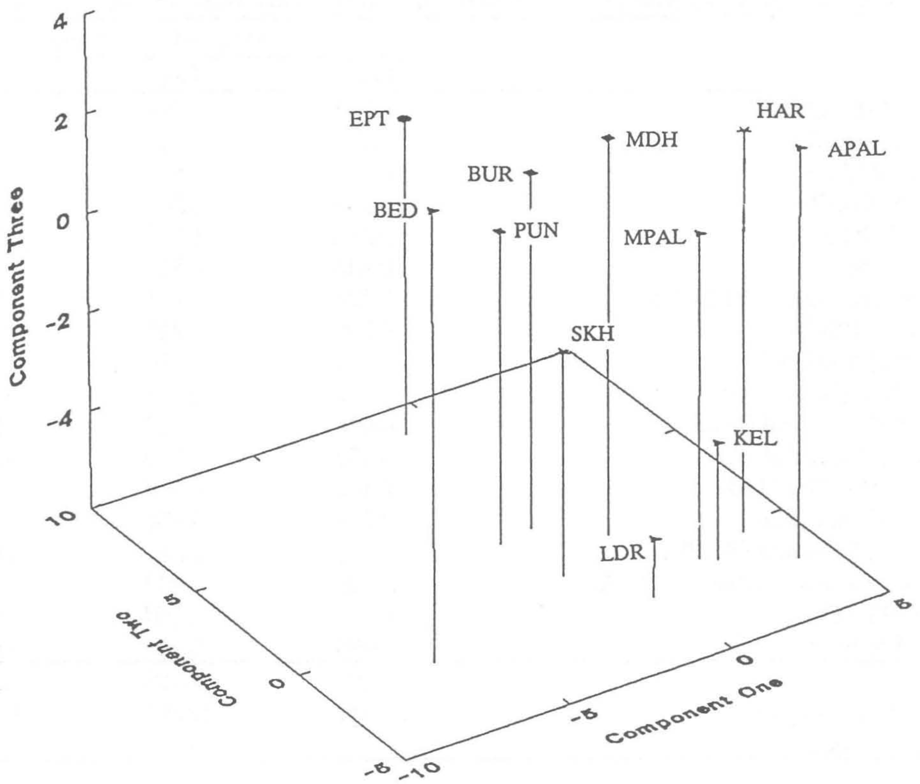

Figure 11.18. Ordination of principal component scores derived from cranial non-metric trait variation among all groups.

Harappa match expectations of the immediate impact of an economy based on intensive exploitation of cultivated foodstuffs. Compared with data from the New World, the degree of deterioration of dental health with increasing reliance on cultivated foodstuffs within the Indus Valley appears not as dramatic (Cohen and Armelagos 1984). Better overall dental health among Harappans may be due to a more diversified diet, which not only continued to include a significant amount of non-domesticated foodstuffs of animal and plant origin, but also included a wide variety of cultigens such as wheat, barley, field peas, sesame, and perhaps rice, millet and sorghum. This dietary diversity enjoyed by Indus Valley cultures may have led to overall better dental health with increased agricultural intensification than was the case with the specialized dependence upon maize, bean, and squash cultivation in North America. However, differences in the bio-geo-chemical features of these two areas of the world may also have exerted an influence on dental pathological affliction.

Examination of caries frequency among prehistoric South Asian dental series provides additional data on the immediate impact of increasing reliance on cultivated foodstuffs on prehistoric South Asians. Figure 11.6 shows a progressive increase in caries rates from lowest levels among mesolithic and neolithic series, moderate levels among chalcolithic cultures, and highest levels among later iron-using (Iron Age) cultures. The uncorrected (6.8%) and corrected caries (12.1%) rates among Harappan phase (R37C) individuals fall within and even exceed the range exhibited by Iron Age sites. The frequency of dental caries among Harappan phase individuals is in accord with the general progressive increase in dental caries from mesolithic to Iron Age cultures and no doubt reflects the combined influence of both increasing reliance upon cultivated foodstuffs and improvements in food processing techniques.

Assessment of tooth size allows an examination of the long term effects of dietary change on the dental elements. Although authorities disagree as to the specific mechanism involved, numerous studies have demonstrated that the transition from hunting and gathering, to incipient agriculturalism, to intensive reliance upon cultivated foodstuffs results in a progressive reduction in the size of the dental elements as well a changes in body size and skeletal tissue development (Kennedy 1984b). Examination of South Asian tooth size by culture type (Figure 11.2) indicates a general trend from largest tooth size among mesolithic and neolithic cultures to smallest tooth size among Iron Age cultures. This confirms Brace's (Brace and Montagu 1977) prediction for tooth size in the Indian subcontinent that populations with the longest traditions of ceramics, sophisticated cooking techniques, and agriculturalism should possess smallest overall tooth sizes. However, with a total crown area in excess of those found among chalcolithic inhabitants of Inamgaon and Harappa, individuals from the Iron Age culture of Mahurjhari (MHJ) represent a departure from this general trend.

Ordination of total tooth size by age in antiquity (Figure 11.3) permits a more detailed analysis of the relationship between total tooth size, culture type, and age in antiquity. While the regression line derived from these data clearly indicate a trend towards dental reduction over time in South Asia, a key feature of this ordination concerns the position of each sample relative to its predicted value from antiquity. Sites which fall above the regression line possess large teeth relative to their antiquity, while sites located below the regression line possess teeth that are small for their antiquity. Three sites (MDH, INM, MHR) lie above the regression line and four sites (MR3, MR2, TMG, SKH) fall below. Harappan phase cemetery individuals (HAR) are located on the right side of the plot with a total crown area quite close to that predicted from the regression line.

Brace and Montagu (1977) predicted that tooth size within the Indian subcontinent should vary along a cline with smallest tooth sizes in the Indus Valley, medium tooth sizes across peninsular India, and largest tooth sizes in South India and Sri Lanka. Of the three sites that lie above the regression line, one—Mahadaha (MDH)—represents an incipient agricultural economy. With a mixed economic pattern which featured a great deal of hunting and gathering the larger than expected tooth size possessed by mesolithic individuals at Mahadaha probably reflects the South Asian dental condition prior to the reductive effect wrought by agriculturalism. The other two dental series which fall above the regression line include Inamgaon (INM) and Mahurjhari (MHJ). These sites are located in peninsular India where agriculture has a more recent history than in the Indus Valley (Lukacs 1985b, 1991). Mehrgarh (MR2, MR3), Timargarha (TMG), and Sarai Khola (SKH) all fall below the regression line, reflecting small tooth size for their antiquity. This is a pattern consistent with their locations near the Indus floodplain where agricultural subsistence practices have much greater antiquity than in peninsular India (Lukacs 1983). Thus, when tooth size is examined across South Asia relative to cultural type and location, Brace and Montagu's (1977) expected relationships for most intensive dental reduction among those cultures which have experienced sedentary agriculturalism for the longest period of time is borne out.

An equally important finding of this research is difference in dental health between the two sexes, with dental caries and hypoplasia significantly more common among females than among males (Table 11.8). Recent studies among hunter-gatherer and farming groups have demonstrated that gender-based divisions of labor are accompanied by differences in diet (Hill and Hurtado 1989; Walker and Hewlett 1990). Female foragers eat more frequently throughout the day and tend to have greater access to cariogenic foodstuffs such as roots, tubers, and grains, all of which are high in starchy carbohydrates. Conversely, men tend to eat less often than women and habitually consume meat during hunting forays. Meat is less cariogenic than roots, tubers, and grains, and this difference in diet based on sex-based activity patterns results in a less cariogenic diet among males than females (Hayden 1979; Larsen 1983, 1984). The difference in dental caries between the sexes at Harappa may not necessarily be a question of what is eaten, but at what state of preparation that food is consumed (Meadow, personal communication 1991). Meadow reasons that if women prepared the food and snacked fairly regularly at different levels of preparation, while men tended to eat set, fully prepared meals, differences may have accrued between the sexes in both the type and quality of what was eaten. Faunal evidence suggests that Harappans, although agricultural, may have regularly hunted wild game and fished (see Chapters 7 and 8 in this volume). Since hunting and fishing have traditionally been male activities, Harappan men may have consumed a higher protein, less cariogenic diet than Harappan women.

Sex differences in hypoplasia are of interest because it suggests that among Harappan phase children, girls were subject to greater stress during growth than boys. Not only is hypoplasia more common among girls than boys, but examination of the number of lines present on the canine indicates that girls experienced growth disruptions more often than boys. This gender difference in hypoplastic prevalence may be the result of differential access to essential resources, including food, health care, and general parental investment. For example, in Hindu society sons are more highly valued than daughters (Beals 1974; Tyler 1973), and a recent study by Hrdy (1990) demonstrates that this difference in offspring preference leads to higher mortality and more frequent illnesses among daughters than among sons. The disparity in hypoplastic occurrence among Harappan boys and girls has also been found from examinations of dental microwear (Pastor 1991) and may reflect the biological impact of preferential treatment of sons at the expense of daughters (Lukacs 1991). These observations on adult caries prevalence and on growth disruptions among children contradict the frequently acclaimed egalitarian nature of the Harappan Civilization (Miller 1985; Shaffer 1982, 1984).

Biological Continuity

The rise and fall of the Harappan Civilization has been interpreted by some authorities to be the product of local indigenous development and decay, while others have suggested that these events reflect cultural and possibly biological input from outside the Indus Valley. Key to resolving this debate is determining the biological affinities possessed by Harappan phase populations. If the rise and fall of the Harappan Civilization were solely the products of local South Asian forces, we should expect biological affinities of Harappan phase populations to reflect continuity with Indus Valley populations that both predate and postdate this civilization. If, however, populations from outside the Indus Valley exerted influence over the rise and fall of this Civilization, then we should expect the biological history of the Indus Valley to be marked by biological discontinuities.

One of the major problems in examining biological affinities among South Asians in general, and Harappan phase individuals in particular, is the lack of comparable data sets from a number of relevant prehistoric and living samples. This problem is clearly reflected by the fact that all three lines of biological evidence are available only from the Harappan phase cemetery at Harappa. Nevertheless, the data that are available permit a preliminary analysis of Harappan phase biological affinities.

For clarity, discussion of Harappan phase biological affinities is divided into three related questions. First, what is the relationship between Harappan phase and post-Harappan phase groups at Harappa? Do they share closest biological affinities to one another despite differences in chronology and inhumation practices—the result expected from *in situ* biological continuity? Second, what are the patterns of relationship among South Asians? When considered against samples derived from other parts of the subcontinent, do patterns of affinity indicate biological continuity over time within the Indus Valley? Third, when South Asian samples are contrasted against samples from outside the subcontinent, do patterns of biological affinity indicate that the biological history of South Asia is one of prolonged continuity without significant biological perturbations from adjacent parts of the Near East and Asia?

With the data currently available, relationships between Harappan phase and Late Harappan individuals at Harappa can only be examined from cranial measurements. Contrasted with other prehistoric samples from Pakistan, cluster analysis (Figure 11.7) and principal components analysis (Figure 11.8) indicate that individuals from the Harappan phase cemetery at Harappa possess closest biological affinities with lower (earth) burials from Cemetery H (H2) and with post-Harappan Timargarha. Craniometric data indicate that there is no close relationship between the two Late Harappan Cemetery H samples. This suggests that the dramatic differences in inhumation practices evident in these Late Harappan samples may reflect populations with very different biological affinities. However, this suggestion must be considered tentative, as sample sizes for these Late Harappan burial contexts are small.

Biological relationships among South Asians may be examined from craniometric, dental non-metric, and cranial non-metric data. Craniometric variation among prehistoric populations from Pakistan indicate a strong separation between inhabitants of northern Pakistan (Harappa, Timargarha) and those of southern Pakistan (Mohenjo-daro). This dichotomy is reinforced when these prehistoric samples from Pakistan are compared with modern groups derived from other parts of South Asia. From Figures 11.9 and 11.10, cluster analysis and principal. components analysis consistently identify all prehistoric groups from Pakistan as most similar to one another, with one notable exception—Mohenjo-daro. Mohenjo-daro presents no close affinities to any other South Asian sample, although it must be remembered that not only is the sample from Mohenjo-daro small in number, but its association with the Harappan phase is questionable (Dales 1964; Kennedy 1984a).

Variation in dental non-metric traits among prehistoric South Asians suggests that individuals from the Harappan phase cemetery possess closest biological affinities to individuals from chalcolithic levels at Mehrgarh. Somewhat surprisingly, the neolithic inhabitants of Mehrgarh possess closer affinities to the late chalcolithic inhabitants of Inamgaon than they do the later chalcolithic inhabitants of Mehrgarh. Cluster analysis (Figure 11.13) and principal components analysis (Figure 11.15) indicate that the two post-Harappan northern Pakistani sites of Timargarha and Sarai Khola possess closer affinities to one another than they do to any of the other prehistoric South Asian dental series. These groups possess slightly closer affinities to individuals from the Harappan phase cemetery and chalcolithic Mehrgarh than they do to individuals from the mesolithic Ganga Valley, late chalcolithic Inamgaon, or neolithic Mehrgarh. Multidimensional scaling of standardized mean measure of divergence distances (Figure 11.14) supports the relationships identified by cluster analysis and principal components analysis with one notable exception. Multidimensional analysis suggests that Timargarha possesses affinities equally close to the Harappan phase cemetery and to Sarai Khola.

Together these dental non-metric results among prehistoric South Asians raise three important points concerning biological continuity within the Indus Valley. First, neolithic and chalcolithic inhabitants of Mehrgarh do not share closest biological affinities to one another, the result expected if these two occupations are reflective of *in situ* continuity. When considered in tandem with the closer relationship of neolithic Mehrgarh to the late chalcolithic inhabitants of Inamgaon, this strong difference between neolithic and chalcolithic inhabitants of Mehrgarh may be indicative of a biological discontinuity within the Indus Valley at some point between 6000 BC and 4500 BC. Second, individuals from the Harappan phase cemetery possess closest affinities to individuals from chalcolithic levels at Mehrgarh, and somewhat distant affinities to post-Harappan individuals from Timargarha. Third, Sarai Khola possesses closest affinities to Timargarha, but no close affinities to any other series. These last two sets of relationships suggest that biological continuity may have existed within the Indus Valley from the early chalcolithic period at Mehrgarh (4500 BC) until the post-Harappan period at Timargarha (800 BC). After this time, however, another discontinuity appears in the biological history of the Indus Valley, for the Early Iron Age inhabitants of Sarai Khola (200 BC) possess a very different set of affinities than those possessed by post-Harappan individuals from Timargarha.

Biological relationships between South Asians and individuals from adjacent parts of the Near East and Asia can be examined from cranial non-metric and craniometric data. Variation in non-metric traits of the cranium confirm that Harappans possess a pattern of biological affinities very different from those found among the inhabitants of Sarai Khola (Figs. 11.16-18). While Sarai Khola possesses somewhat intermediate affinities with mesolithic inhabitants of the Ganga Valley and with modern inhabitants of India (Punjabis) and Burma, Harappans share closest affinities with ancient and modern groups from the Near East. These cranial non-metric results corroborate dental non-metric data that suggest a biological discontinuity exists in the history of the Indus Valley at some point after the end of the Harappan Civilization (1750 BC), but before the Early Iron Age at Sarai Khola (200 BC). In addition, cranial non-metric data suggest that the source of this disruption did not come from the Indian subcontinent but from the West.

Examination of craniometric variation among South Asians and prehistoric samples from the Near East, Anatolia, Egypt, and the Iranian Plateau raises four important points concerning Indus Valley biological continuity and possible biological perturbations from outside the subcontinent. First, there is reasonably good separation between Egyptians, Anatolians, and other South Asians. Second, all Indus Valley sites, except Mohenjo-daro, possess relatively strong affinities to one another. Third, apart from Timargarha and the lower (earth) burials from Cemetery H (H2), Harappan phase cemetery individuals possess closest affinities to individuals from Tepe Hissar 3. Fourth, individuals from Mohenjo-daro possess no close affinities to any other sample included in this analysis.

So what does all this say about Harappa, the Harappan Civilization, and peopling events in South Asia? Renfrew (1987, 1989) has recently put forward two hypotheses to account for the introduction of Indo-European languages into the Indian subcontinent. The first theory, known as the "Neolithic Arya Hypothesis," calls for introduction of Indo-European speakers into South Asia with the development of agriculture. In fact, he specifically states that this would imply that the neolithic inhabitants of Mehrgarh were Indo-European speakers. The second theory is the "Mounted Nomads of the Steppe Hypothesis." This latter theory postulates a movement of Indo-European speakers into South Asia after the end of the Harappan Civilization but before composition of the *Hymns of the Rigveda*. This would imply a movement of Indo-European speaking peoples into the Indus Valley at some point after 1750 BC but before 1000 BC.

The results of this research do not support Renfrew's Neolithic Arya Hypothesis. Rather than demonstrating biological continuity within the Indus Valley from neolithic times to the dawn of the Christian Era, two discontinuities exist. The first occurs between 6000 and 4500 BC and is reflected by the strong separation between the two samples from Mehrgarh. While this discontinuity stands in marked contrast to the archaeological interpretation of Jarrige (1981, 1985; Jarrige and Lechevallier 1979) and others (Lechevallier and Quivron 1981), this discontinuity accords well with archaeological evidence for increasing craft specialization, trade networks, and ceramic similarities to the northwest with Kili Ghul Muhammed and Damb Sadaat (Jarrige 1982). This discontinuity also fits well with recent glottochronological studies which place the entrance of Dravidian languages into South Asia around the 4th millennium BC (Fairservis and Southworth 1989; Gardener 1980;

Southworth 1979), as well as current linguistic research that not only ascribes a common origin to the Dravidian and Elamitic languages (MacAlpin 1974, 1975, 1979, 1981), but suggests that the peoples of the Harappan Civilization were Dravidian language speakers (Fairservis 1983; Mallory 1989; Parpola 1984a,b, 1986).

Together, these data suggest that Harappan phase individuals—and by extension the inhabitants of chalcolithic Mehrgarh and post-Harappan Timargarha —bear closest affinities to populations from the West, i.e., from the Iranian Plateau and the Near East. Similar conclusions have been reached from craniometric analysis by others working with somewhat different data sets (Bartel 1979; Cappieri 1959, 1970; Dutta 1983; Rathbun 1982). Coupled with their differences from the earlier neolithic Mehrgarh sample and from Early Iron Age individuals from Sarai Khola, this pattern of biological relationships complements the ideas of Lamberg-Karlovsky and Kohl who proposed an "early interactive sphere" of trade and communication between the Indus Valley and the Iranian Plateau beginning in the 4th millennium BC. With closest biological affinities outside the Indus Valley to the inhabitants of Tepe Hissar 3 (3000-2000 BC), these biological data can be interpreted to suggest that peoples to the west interacted with those in the Indus Valley during this and the preceding proto-Elamitic period and thus may have influenced the development of the Harappan Civilization.

The second biological discontinuity exists between the inhabitants of Harappa, chalcolithic Mehrgarh, and post-Harappan Timargarha on one hand and the Early Iron Age inhabitants of Sarai Khola on the other. This implies another discontinuity at some point after 800 BC but before 200 BC. The loose association of the post-Indus site of Sarai Khola with the two Anatolian sites, along with their separation from the Harappan and pre-Harappan groups indicate a change during the millennium following the end of the Harappan Civilization. This latter difference could be interpreted as support for Renfrew's "Mounted Nomads of the Steppe" hypothesis, but clearly much more work needs to be done in this area.

The biological data discussed here presents no strong disagreement with the archaeological evidence presented by Mughal (1990). The Harappan Civilization does indeed represent an indigenous development within the Indus Valley, but this does not indicate isolation extending back to neolithic times. Rather, this development represents internal continuity for only 2000 years, combined with interactions with the West and specifically with the Iranian Plateau.

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