CHAPTER 11

Bioarchaeology of the Indus Valley Civilization: Biological Affinities, Paleopathology, and Chemical Analyses

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INTRODUCTION

The term "bioarchaeology" has its intellectual origins in the United Kingdom and the United States in the 1970s. Its meaning has evolved over the years (see Buikstra, 2006: xvii–xix), but it is now generally agreed to refer to reconstructions of past people's lives based on a multidisciplinary analysis of archaeological human remains. Research designs are based on individual- or population-level data; bioarchaeologists can focus either on the life histories of individuals or the characteristics of past populations. Bioarchaeology is one of the few fields of inquiry that emphasizes integration of three subdisciplines of anthropology: biological anthropology, archaeology, and sociocultural anthropology. Data from human skeletal remains are contextualized within the ecological, social, and cultural contexts of the past human lives using the archaeological record, but inferences and explanations increasingly consider social and cultural processes. Topics often considered in bioarchaeology include: (1) the biological relationships within and between past populations, (2) health and disease, (3) demography, (4) diet, (5) migration, (6) habitual activity patterns, (7) characteristics of growth and development, and (8) ante- and postmortem cultural modifications of the dead. State-of-the-art technologies, such as high-resolution radiography, computed tomography, isotopic and ancient DNA (aDNA) analyses are now routinely applied to address many of these research questions.

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In this chapter, I review published scholarship of the past 30 years related to the examination of biological affinities, paleopathology, and chemical analyses of human bones and teeth recovered from sites of the Indus Valley civilization (see Map 3). I have chosen these three topics because of the historical nature of the research problem (biological affinities), the suitability of preserved remains for study (paleopathology), and the illustration of avenues that may be fruitfully explored in the future (chemical analyses). It must be noted, however, that our current ability to reconstruct the life histories of the inhabitants of the ancient cities is severely limited. As indicated in the site reports and research publications discussed throughout this chapter, the preservation of skeletal remains from the Indus civilization is extremely poor. Many skeletons are incomplete, the preserved remains are usually highly fragmentary, and the organic material in bones is almost completely destroyed due to taphonomic factors (for a review of taphonomy and the nature of archaeologically derived skeletal assemblages, see Stodder, 2008). These taphonomic factors are not restricted to natural processes. The concept of taphonomy extends to all agents or processes that modify human remains from death until analysis, including the reuse of a cemetery over time, damage from excavation equipment or farming, and selective curation. Some of the most important cemeteries of the Indus civilization, such as those at the recently discovered sites of Farmana and Sanauli, were uncovered and damaged extensively by the action of local villagers who sought to put the land to cultivation (Sharma et al., 2007; Shinde et al., 2010). At Sanauli, part of the cemetery was excavated and more than 100 graves were exposed, but the extent of the cemetery and the existence of an associated habitation site could not be determined because of the existence of standing crops (Sharma et al., 2007). In spite of these limitations, however, bioarchaeological research has provided us with provocative insights into the effects of social and cultural processes on the lives of the ancient inhabitants of the Indus Valley.

Biological Affinities

The earliest and perhaps most enduring topic of interest to scholars of South Asian prehistory has been the biological relatedness of the inhabitants of the ancient Indus Valley cities to populations in South Asia and adjacent parts of the Near East. Some scholars believe that Indus people were autochthonous, that the civilization developed from local antecedent people, while others posit that biological and cultural influences from outside the Indus Valley are in large part responsible for the development of the civilization. The same controversy dogs explanations of the decline of the Indus civilization. For some, the Indus Age suffered an in situ decay related to both environmental change and the reduced availability of resources; for other scholars, it lost its identity through immigration or invasion. A case in point is the supposed relationship of people of the Indus Valley to the "Aryans" who, to some scholars, caused the demise of the Indus Valley civilization when they invaded from the Iranian Plateau (e.g., Wheeler, 1968: 130–132; but see Danino, Chapter 13 in this volume). This idea was tested through analyses of cranial dimensions—most commonly the cranial length/breadth, facial, and nasal indices, as well as the shape of the head and face in profile—which were used to determine the racial "type" to which a population "belonged."[1] Crania that deviated from the average shapes and sizes were thought to represent foreign racial elements.

Although racial typology has not disappeared from the recent literature (Kennedy, 2000), contemporary researchers more commonly investigate past biological affinities by applying a variety of statistics to frequencies of metric and nonmetric features of the skull and teeth to calculate the biological distance between these groups. Metric and nonmetric features, which have been treated as proxies for genes for more than a century, are known to reflect biological inheritance. While we can learn about population histories through analysis of DNA from extant groups, and it might be preferable to studying relationships within ancient populations using DNA obtained from the human skeletal remains,[2] metric and nonmetric trait analyses provide some information about biological affinities; the techniques are comparatively fast and inexpensive, do not require specialized equipment, and are nondestructive. Bioarchaeologists use the term "biological distance" to indicate that the morphological traits under consideration, like any aspect of phenotype, are the product of genetic, molecular, developmental, ontogenetic, historical, social, and cultural factors. Although we are using morphology to reconstruct relatedness both between and within groups, no attempt is made to sort out these factors.

The most recent comprehensive analysis of this type used cranial measurements and nonmetric traits of the skull and teeth to measure biological affinities within and outside the Indus Valley (Hemphill et al., 1991). Results from this analysis provide at least initial answers to some of the basic questions pertaining to the nature of population relationships in the Indus Valley. According to Hemphill and colleagues, the Harappan people who were buried in the urban phase cemetery most closely resemble other people from the northwestern sector of the Indian subcontinent. This resemblance supports the proposition that gene flow occurred along trade routes between Mesopotamia and the Indus Valley, resulting in phenotypic variability along an east–west axis (Hemphill et al., 1991; Kennedy, 2000). The study also shows that people from Cemetery R-37 at Harappa have the closest affinity with the people buried in Stratum II of Cemetery H; thus there is no evidence of marked biological discontinuity in occupants of the city through time. However, individuals in the small skeletal sample from Mohenjo Daro, which were found in disarray in several localities of the site, exhibit a unique and diverse pattern of morphometric characteristics that sets them apart from other populations of the urban phase of the Indus civilization. They do not demonstrate close biological affinity with the preceding inhabitants of the city; instead they may represent the kind of populational diversity that is characteristic of most cosmopolitan centers, with ethnic enclaves composed of groups that had migrated from peripheral areas (Kennedy, 2000), contrary to the situation at Harappa. Those skeletons from Mohenjo Daro, however, have not been directly dated and could instead belong to a post-Harappan period.

Of particular interest are the results that point to within-group phenotypic variability at Harappa: in contrast to a high degree of variability among males, females form a relatively homogeneous group and have closer affinities to individuals in the later period Cemetery H than to contemporaneous males buried in Cemetery R-37 (Hemphill et al., 1991). Previously it was noted that males from rural sites in the Indus Valley can be discriminated from males in Cemetery R-37 (Bartel, 1979), and these results considered together suggest that matrilocality was a cultural practice long established in the Indus Valley (Kennedy, 2000).

PALEOPATHOLOGY

The most common pathological conditions identified in skeletal remains from the Indus Valley civilization are infection, trauma, joint disease, and dental disease. Lesions consistent with nutritional and metabolic disorders, congenital and developmental disorders, and benign neoplastic conditions have also been observed (Robbins Schug and Blevins, Chapter 16 in this volume). An important factor that complicates our reconstructions of health among past populations concerns the kinds of pathological conditions that leave their mark on the skeleton. The majority of infectious diseases, for example, are rarely observed among past populations because they do not affect the skeleton. In many cases, this is because the individual either recovers or dies before the skeleton is affected; in other cases it is because the disease process only affects soft tissue. Many childhood conditions are difficult to detect once a child lives to adulthood because bone remodeling often erases the evidence.

Infection

In the sample of skeletal remains excavated from Cemetery R-37 at Harappa in 1987–1988 (see Kenoyer and Meadow, Chapter 10 in this volume), five individuals exhibited proliferative lesions on long bone shafts that indicate chronic inflammation of the periosteum (Lovell, 2014a). None of these lesions were associated with features elsewhere in the skeleton that could be considered diagnostic of a specific infectious agent. Robbins Schug and colleagues, however, identified rhinomaxillary lesions consistent with a diagnosis of leprosy in the skeletal remains of 9 of 160 individuals that were recovered during earlier excavations, which occurred between 1923 and 1967, at three locales at Harappa (Cemetery R-37, Cemetery H, and Area G). They also describe a variety of postcranial lesions that likely form part of the complex of features resulting from leprosy as well as lesions in two individuals that are consistent with tuberculosis infection (Robbins Schug et al., 2013). Also noted in the Harappa remains are cases of localized infection/inflammation, likely secondary to trauma, in four individuals (Lovell, 2014a; Robbins Schug et al., 2013).

Other individuals display bone formation and resorption in the maxillary sinus that may be part of a complex of lesions attributable to leprosy or tuberculosis but the remains were too fragmentary to permit specific diagnosis (Robbins Schug et al., 2013). Maxillary sinus infection was observed in four individuals from Harappa, one from Cemetery R-37, one from Area G, and two from stratum II in Cemetery H (Robbins Schug et al., 2013). All four individuals had periapical abscessing that most likely led to the infection. The most common, but not exclusive, site for the direct introduction of infectious agents into the maxillary sinus after pulp chamber exposure would be if the root(s) of the permanent maxillary first premolar penetrated the anterior portion of the sinus, permitting apical drainage into the sinus. Alternatively, maxillary sinus infection can occur when a periapical abscess, developing from the root apex of a posterior tooth, erodes into the sinus, destroying the intervening bone. Periapical abscesses may arise from destruction of the tooth by caries, or from exposure of the pulp chamber by heavy tooth wear. Unfortunately, the maxillary sinuses are not easily observable if the maxillae and articulating bones are intact or otherwise obscured, so infection rates may be underestimated in many samples. For example, the maxillary sinuses (as well as nasal passages and the intracranial space) in 12 crania excavated at Harappa in 1987 and 1988 could not be examined because they were obscured by a filling of hardened burial sediment that could not be removed without damage to the bone; neither Lukacs (1992) nor Lovell (2014a) report any sinus lesions in maxillary fragments that were recovered during those excavations.

In recent years many researchers have turned to aDNA analysis to identify the pathogens responsible for infectious disease in the past (Donoghue et al., 2004; Haas et al., 2000; Mays et al., 2002). Claims have been made for the identification of malaria, tuberculosis, and leprosy in skeletal remains, but it should not be assumed that these technological advances can be applied to Indus Valley skeletal remains. Poor organic preservation remains a serious impediment, but it is also the case that caution may be exercised in selecting samples, diseases, and disease markers for analysis (e.g., Bouwman and Brown, 2005; Gilbert et al., 2003; 2005; Müller et al., 2015; Pilli et al., 2013; Wilbur et al., 2009). Samples from an individual with leprosy from the Indus outpost at Balathal (Robbins et al., 2009) have been sent for analysis of pathogen DNA at three separate labs that specialize in genetic and genomic analyses but, thus far, only negative results have been obtained (Gwen Robbins Schug, personal communication). While mycobacterial DNA was recovered, base pair lengths were insufficient for a positive identification to species.

Trauma

Robbins Schug and colleagues report frequencies of trauma among human remains that were excavated between 1929 and 1947 in three locations at Harappa and which covered two time periods: Cemetery R-37 (Mature Harappan, or urban period), and Cemetery H and an apparent ossuary in Area G (Late Harappan, or post-urban period). Postcranial trauma affected only three of 160 individuals (1.9%), in bones of the wrist, hand, and foot, and could be due to either accident or interpersonal violence (Robbins Schug et al., 2012). I also observed postcranial trauma in remains excavated at Harappa in 1987 and 1988 that affected wrist, hand, and foot bones but, in addition, noted trauma to two ribs and a scapula (Lovell, 2014a; 2014b). While the nature of the scapular fracture was likely caused by interpersonal violence, the other injuries could be also attributed to accident.

More interesting are the results related to cranial trauma. Robbins Schug and colleagues argue that the cranial trauma they observed in their skeletal sample (15.5% of observable crania) is largely an expression of interpersonal violence, including blunt-force injuries to the cranial vault, circular depression fractures on the frontal squama, sharp-force trauma to the facial skeleton, and fractures of the nasal bones. Furthermore, they identified a number of lesions that were likely fatal, and found that several individuals were injured more than once in their lifetime. These patterns of cranial trauma, when assessed in the context of differences in mortuary treatment, led them to conclude that interpersonal violence at Harappa was structured along lines of gender and community membership. My sample is comparatively small and derives from only Cemetery R-37, but my findings (Lovell, 2014b) are not inconsistent: blunt-force injuries to the head and torso in two females could have been caused by interpersonal violence, and trauma to manual and pedal phalanges in males might represent the use of the hands and feet to inflict injury by punching or kicking. In addition, a case of healing cranial trauma due to blunt force was observed in a male from the Harappan period cemetery at Farmana (Mushrif-Tripathy et al., 2012); unfortunately only the cranium of the individual was recovered and most of the excavated remains from that site were poorly preserved, rendering further examination difficult.

Eighteen skeletons excavated from a cemetery at Lothal in 1958–1960 were studied by Sarkar, who notes that the crania and a few long bones showed fractures that could not be attributed to postmortem damage and that one skeleton displays marks of sharp-force trauma on its tibiae (Sarkar, 1972: 8; 1985: 296). Three other skeletons did not have skulls, and, in the context of apparently careless disposal of the remains, Sarkar concluded that the cemetery was at the scene of a battlefield (Sarkar, 1972: 9; 1985: 296); the excavator of the cemetery stresses, however, that the skeletal remains did not come from one stratum and hence the individuals did not die simultaneously (Rao, 1979: 145). Among the skeletal remains recovered from Kalibangan in the 1962–1963 season, Sharma reports a case of sharp-force trauma to the knee in an adult male, with no evidence of healing (Sharma, 1999).

Joint disease

Joint disease is the condition that is most common in the postcranial remains from the Indus civilization. It predominantly affects the joints of the spine, both the synovial posterior facet joints and the nonsynovial intervertebral joints. In my examination of the vertebral elements excavated at Harappa in 1987 and 1988 (Lovell, 1994; 2014a), I found that marginal bone proliferation (marginal lipping) of vertebral bodies is relatively consistent between the three vertebral segments, ranging from 32% to 37% of the elements affected, and is more common on the vertebral bodies than on the posterior facets. Bone formation around the margins of the Harappan vertebral bodies is usually accompanied by erosive lesions (pitting) on the superior and inferior surfaces of the bodies. The cervical spine exhibits the most frequent and severe expressions of marginal lipping and pitting on vertebral bodies. Particularly in the cervical spine, new bone formation often is found around the edges of the erosions on vertebral bodies and may indicate a form of joint disease known as spondyloarthropathy (Lovell, 1994; see Burt et al., 2013 for a review of joint disease in the spine). A case of "doubtful" vertebral lipping in the lumbar spine is reported for a young male from Farmana, but other joints in the skeleton were not well enough preserved for the full extent of joint disease to be assessed (Mushrif-Tripathy et al., 2012: 60).

Among the synovial joints in the spine, the lumbar vertebrae have the highest frequency of marginal lipping of posterior facets, but the cervical spine is notable for the severity of lesions on the posterior facets (Figure 11.1), including exuberant marginal lipping, severe pitting, and three cases of eburnation, which is a hallmark of osteoarthritis (Lovell, 1994; 2014a). When both synovial and nonsynovial joints are considered, I attribute the frequency and severity of joint disease in the cervical spine at Harappa to the accumulation of microtrauma, caused by habitual daily activity stresses rather than heavy physical labor (Lovell, 1994).

Among the joints of the appendicular skeleton at Harappa, the knee is most affected by degenerative change and is the only joint that displays all three types of lesions

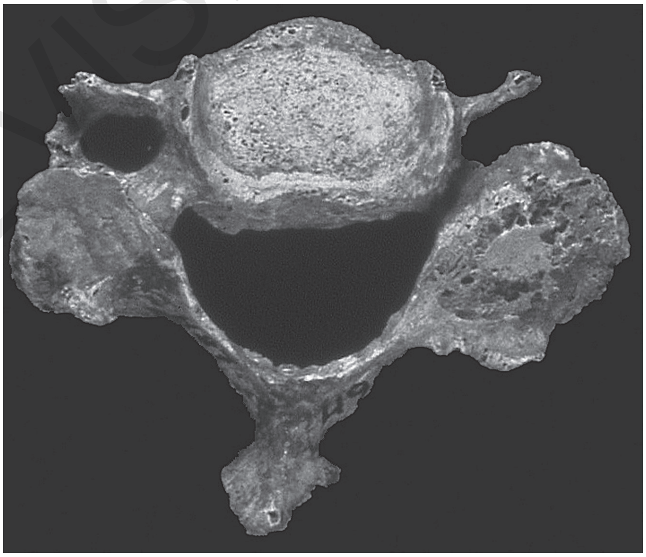

Figure 11.1 Arthritis of the posterior facet of a cervical vertebra in an adult male (H87/49h)

indicative of osteoarthritis: marginal lipping, erosions of subchondral bone, and eburnation (Lovell, 2014a).

Dental disease

Dental enamel is the hardest tissue in the human body, and hence preservation of dental remains in archaeological settings can be much better than the preservation of bone. This is true for the known skeletal remains of the Indus Valley civilization, but, regrettably, the assessment of dental disease in the remains has rarely been undertaken (for a review, see Lukacs, 1992). It might be expected that recent archaeological expeditions would facilitate the participation of bioarchaeologists when human remains are to be excavated and studied. For example, a preliminary study of the remains of 40 individuals from the site of Sanauli was undertaken by S.R. Walimbe and associates of Deccan College, Pune, who found evidence of dental disease including calculus, enamel hypoplasia, and dental discoloration (Sharma et al., 2007: 174); further details will be forthcoming. However, from the site of Farmana (Shinde, 2011; Shinde et al., 2010) only 214 teeth of an expected 1120 teeth could be studied as a result of poor preservation and the removal of some teeth for isotopic analysis before they could be examined for dental disease (Mushrif-Tripathy et al., 2012).

The only comprehensive analysis of dental disease in the Indus Valley is restricted to remains excavated at Harappa in 1987 and 1988 (Lukacs, 1992). Linear enamel hypoplasia (LEH) is the most common condition when the frequencies of the conditions are calculated by the number of individuals affected, at 72.2% of 36 individuals. LEH is known to reflect physiological stress during the period of tooth formation, that is, in childhood, and remains an indicator of this stress through life since teeth do not remodel. Lukacs (1992) found that females at Harappa have a greater frequency of LEH than males, and he suggests that this disparity may indicate that male children had a greater value in the society. Further, the higher variance in age at which growth disruptions occur among females may mean that they were less well buffered against nutritional and disease stresses during their growth and development.

Overall, the results are consistent with a population whose subsistence base is agriculture, shown by presence of carious lesions and their sequellae. Dental caries is an infectious disease that is caused when bacteria feed on carbohydrates on tooth surfaces, producing acids that destroy tooth enamel. At Harappa, caries is present in 6.8% of the teeth and 43.6% of the completely preserved dental specimens, and nearly half of the carious lesions advanced sufficiently for bacteria to invade the pulp tissue, which led to abscessing and tooth loss (Lukacs, 1992). To account for tooth loss from this process, Lukacs recommends the use of a correction factor when calculating the frequency of caries: with the application of the correction factor, the frequency of teeth affected by caries increases from 6.8% to 12.1%. Application of the correction factor allowed Lukacs to discern dramatic differences in the frequencies of caries between males and females at Harappa, which he interprets as indicating that sex-based division of labor and activity patterns associated with food production, preparation, and consumption resulted in different patterns of dental disease (Lukacs, 1996).

Two unusual dental lesions also were noted in the Harappa sample. In one case, carious decay of a tooth led to an abscess that apparently was so painful that the tooth was therapeutically probed, probably with a bone needle, to relieve pain, and this habitual probing created a groove on the tooth (Lukacs and Pastor, 1988). In another case, a traumatic root fracture was noted in a right lateral maxillary incisor: a small fragment of the root apex was retained in the alveolus and displayed a concave profile while the articulating portion of the coronal portion of the root (with attached crown) displayed a convex profile; the coronal fragment apparently had been displaced from the alveolus after the oral soft tissues that held it in place had decomposed after burial (Lukacs and Hemphill, 1990).

Nutritional and metabolic disorders

The metabolic disorder that has been most commonly identified in skeletal remains is anemia, diagnosed from lesions that are primarily resorptive in nature. For several decades researchers considered lesions on the cranial vault (porotic hyperostosis) and the orbital roofs (cribra orbitalia) to be symptoms of chronic iron-deficiency anemia (e.g., Stuart-Macadam, 1987), usually acquired during childhood (Stuart-Macadam, 1985; Lewis, 2007: 111). This diagnosis of acquired anemia has become the subject of debate, however. Stuart-Macadam, for example, revisited the source of the iron deficiency and concluded that iron withholding as a short-term response to systemic infection was an important consideration (Stuart-Macadam, 1992). That interpretation did not gain a large number of adherents and the ultimate cause of the anemia continues to elude researchers. Walker and colleagues (2009) suggest that the two lesions represent different etiological and pathological processes: porotic hyperostosis resulting from genetic hemolytic anemia (e.g., sickle cell anemia and thalassemia) and cribra orbitalia resulting from megaloblastic anemia caused by dietary deficiency or malabsorption of vitamins B9 (folate, or folic acid) and B12. Oxenham and Cavill (2010) and others dispute that conclusion, however, arguing that iron-deficiency anemia remains a plausible diagnosis for these lesions, although it has been shown that cribra orbitalia is sometimes diagnosed in error, having been confused with bony alterations resulting from either inflammation or postmortem erosion (Wapler et al., 2004) or with subperiosteal hematomas due to scurvy (Walker et al., 2009).

Kennedy (1984) reports that his analysis of the total collection of skeletal remains from the Indus Valley civilization, completed in 1980, revealed that the frequency of porotic hyperostosis could be as high as 25%, and is documented for both sexes and for children and adults. Notably, 18% of the individuals from Mohenjo Daro exhibit porotic hyperostosis, and there is compelling circumstantial evidence for the presence of genetic anemia in the southern reaches of the Indus civilization, particularly in the deltaic region in which Mohenjo Daro is situated (for discussion, see Kennedy, 1984; Lovell, 1997).

In contrast to the frequency of porotic hyperostosis reported by Kennedy, only two possible cases of anemia have been reported in the remains from Cemetery R-37 that were excavated at Harappa in 1987 and 1988 (Lovell, 1997), and both, unfortunately, are documented only by remains from debris contexts. The lesions are primarily resorptive and are not consistent with postmortem erosion, nor are they consistent with scorbutic lesions, which are primarily proliferative in nature. In one case, cribra orbitalia was noted in a young adult female, appearing as slight, remodeled porosity, localized to the anterior region of both orbits. Although both parietals were observable, no lesions were evident. Postcranial lesions could not be assessed because only the cranium was preserved for this feature. Another 28 crania were preserved in primary and debris contexts but none exhibit porotic hyperostosis or cribra orbitalia. A fragment of parietal bone from a miscellaneous collection of fragmentary remains displays "pin-prick" porosity (see Lovell, 1997: figure 2). This may represent healed porotic hyperostosis, although the porosity may alternatively be due to the advanced age of the individual, a possibility that can be neither confirmed nor refuted because of the small fragment and hence an inability to estimate the age of the individual at the time of their death.

In my examination of those remains from Cemetery R-37 at Harappa, I found no lesions consistent with the effects of genetic anemia in any of the 92 individuals for which postcranial remains were preserved, and concluded that an acquired iron deficiency was the most likely cause of the lesions. I interpreted the low prevalence of anemia at Harappa as being associated with generally good nutrition and a low prevalence of infection due to with high standards of hygiene. However, the remains excavated at Harappa in 1987 and 1988 exhibit dental enamel hypoplasia in adults, which represent physiological stress endured during childhood. Since iron-deficiency anemia is most common in infants and younger children, who were not commonly buried in Cemetery R-37, we cannot examine more fully the likely causes of physiological stress, although nutritional stresses associated with weaning are commonly invoked. It is important to note that it is difficult to identify a single nutritional deficiency because children who are nutritionally stressed are likely to be deficient in several micronutrients, as well as in protein and calories. The synergistic relationship between infection and under-nutrition must also be considered when attempting to interpret skeletal and dental lesions of nutritional and metabolic disorders such as these.

Robbins Schug and Blevins (Chapter 16 in this volume) report evidence for abnormal porosity in the infants' and childrens' remains from the pre-partition excavations at Harappa, which yielded a surprisingly large number of immature skeletons (N = 33) compared to the 1987–1988 excavations studied by myself and Kennedy. Although there are no cases of metabolic imbalance from the urban cemetery R-37, they found that a relatively large number of infants and children were affected by abnormal porosity in combination with periosteal new bone growth in Area G (3/9) and in the Chalcolithic sample from Cemetery H (5/15 from stratum I, 1700–1300 BCE). In both mortuary populations, 33.3% of the immature skeletons present had lesions they interpreted as possible evidence for vitamin C deficiency (scurvy). They acknowledge it is difficult to develop a secure diagnosis in cases of fragmentary skeletons; however, scurvy seemed possible based on the presence of abnormal porosity on the sphenoid, maxilla, and mandible, and in combination with evidence for subperiosteal hemorrhage in the orbits, proliferative bone on the endocranial and ectocranial surface of the cranial vault bones, including porotic hyperostosis. They suggest scurvy is more likely than anemia based on the absence of thickened diploë, hair-on-end appearance of the diploë, or evidence for expansion of the hematopoietic spaces. The authors also describe evidence for periosteal new bone formation as it occurred in combination with other markers of increased vascularization and in cases where it occurred in isolation. In the latter situation, it was considered indicative of inflammation and was used as a nonspecific biocultural stress marker.

Congenital and development disorders

In a detailed discussion of the developmental characteristics of abnormal skull shape, Kennedy and colleagues describe irregularities of cranial suture closure in an adult female recovered from Cemetery R-37 at Harappa and attribute the observed abnormalities of the cranial morphology to a disorder known as scaphocephaly (Kennedy et al., 1993). I have suggested recently that, since the posterior section of the sagittal suture is not closed (Kennedy et al., 1993), the synostosis in this individual conforms to the type of premature sagittal suture closure in which only the anterior portion of the suture closes prematurely, and that the deformation likely was exacerbated by postmortem fracturing of the sides and front of the cranium (Lovell, 2014a).

There are only five other examples of congenital and developmental disorders from sites of the Indus civilization. Partial sacralization of the fifth lumbar vertebra was observed in a male from Cemetery R-37 at Harappa (Lovell, 2014a): the transverse process of the fifth lumbar vertebra was fused to the sacrum on one side, but since the condition is usually asymptomatic when identified clinically it would not likely have caused pain or impaired the individual's mobility. As yet not illustrated and not described in detail is the case of an individual recovered from Sanauli who apparently suffered from a pronounced kyphosis, or hunchback (Sharma et al., 2007: 176). At Kalibangan was found the skeleton of a man with extreme contracture of the left hand and left radius and ulna several centimeters shorter than those bones on the right side (Sharma, 1999). The size and shape of a child's cranium from Kalibangan is suggestive of hydrocephaly, and three small trephination holes may indicate an attempt to treat the condition (Sharma, 1999); a child's cranium from Lothal also appears to be suggestive of hydrocephaly and is also accompanied by trephination (Sarkar, 1985: 273).

Neoplasia

Benign neoplastic growths were observed in remains from Harappa in the form of "button" osteomas on the cranial vault in two individuals and a small, elongated growth on a foot bone, but no lesions consistent with primary malignant neoplasia of bone or cartilage or consistent with the spread of cancer from soft tissues to the skeleton were seen (Lovell, 2014a).

CHEMICAL ANALYSES OF BONES AND TEETH

The characterization of chemical variation in the constituent parts of bones and teeth is used increasingly in bioarchaeology to identify past diets, weaning regimens, and patterns of residence and mobility. In addition, as noted above, aDNA analysis of bone collagen and tooth dentine may be used to examine genetic relationships of past populations and to identify pathogens that caused disease in ancient times. Ancient DNA analysis has not yet been successfully applied to human remains from the Indus Valley, however, in large part because of the poor preservation of organic material in existing skeletal collections.

Diet and weaning patterns

The reconstruction of ancient diets through the chemical analysis of preserved skeletal tissues dates to the 1970s, when stable carbon isotope variation in the principal protein fraction (collagen) of bone was used to trace the introduction and growth of maize agriculture among prehistoric peoples of eastern North America (van der Merwe and Vogel, 1978; Vogel and van der Merwe, 1977). Since that time a plethora of studies based on the stable isotopes of carbon and nitrogen in preserved human tissues have tested a variety of hypotheses about ancient health and nutrition, including the importance of terrestrial and marine food sources, the identification of trophic levels in food webs, the role of freshwater resources, and the effects of disease, water, and protein stresses on isotopic values (reviewed by Katzenberg, 2008). Carbon and nitrogen stable isotopes are most commonly used to explore health and diet but stable sulfur isotope analysis also shows promise for dietary applications (e.g., Nehlich, 2015; Privat et al., 2007; Richards et al., 2003).

After early successes with stable isotope analyses (Lovell et al., 1986a; 1986b) I attempted to explore the importance of different dietary components at Harappa and the presence of status, age, and sex differences in food consumption using stable isotopes of carbon and nitrogen from human and animal bone samples collected at Harappa during the 1987 and 1988 seasons. Unfortunately, no collagen could be extracted from the bone, a result of the very alkaline burial environment. At that time no other tissues had been identified as being useful for paleodiet reconstructions, but it has since been shown that preserved hair and dentine (an organic component of teeth), as well as enamel (an inorganic component of teeth), can contain isotopic signatures reflecting paleodiet (e.g., D'Ortenzio et al., 2015; Dupras and Tocheri, 2007; Loftus and Sealy, 2012; Webb et al., 2013).

The use of tooth enamel as a sample material is illustrated in the recent analysis of stable carbon isotopes in enamel from human remains at Harappa (Kenoyer et al., 2013). The results of the study (Kenoyer et al., 2013: table 2) show isotopic values that are consistent with a diet primarily based on plants such as local and African millets, rather than wheat and barley, the latter having formed the primary agricultural produce on which the Harappan civilization was founded. Although this discrepancy is not addressed by Kenoyer and colleagues, who focus in their paper on the geographic origins of Harappa residents rather than the reconstruction of paleodiet, the analysis of archaeobotanical remains shows that local millets were cultivated in some parts of South Asia before the third millennium BCE, with African millets becoming significant cultigens throughout South Asia by the mid-second millennium BCE (Weber, 1998; 2003).

Chemical variation in components of the mineral fraction of bone has also been explored as a means to reconstruct paleodiet, but early research has largely been discounted. Early research focused on major elements in bone mineral, such as strontium–calcium ratios; these are higher in herbivores than in carnivores and it was assumed that these ratios could reveal whether prehistoric humans were primarily vegetarian or meat-eating, and subsequent research examined concentrations or ratios of barium, lead, magnesium, and zinc (for a review, see Burton, 2008). Unfortunately, postmortem alteration of bone minerals rendered many applications of elemental analysis incorrect: instead of measuring chemical characteristics as a function of diet, the methods measured contamination from the burial soil. For example, Radosevich (1989; 1993) and Link and Lovell (1994) found that trace elemental analysis of the inorganic fraction of bones from Harappa did not reflect dietary components but, instead, gave spurious results owing to postmortem contamination from, and exchange with, elements in the burial environment. Recent research into methodological refinements that combine trace metals determination with statistical data analysis (e.g., Corti et al., 2013) may make it possible to examine the inorganic fraction of bones and teeth from the Indus Valley in the future.

Fortunately, tooth enamel is more resistant than bone to the effects of elements in the soil. Typically, fewer than 30 μm of the outer layers of enamel are affected by exposure to such elements (including topical application of fluoride or tooth-whitening treatments in modern dentistry) and sample preparation for chemical analysis of enamel thus requires the removal of the outer surface of enamel. Thus, enamel can be sampled for the stable isotopes of carbon and nitrogen in order to reconstruct paleodiet and can also be sampled for other elements, such as strontium and oxygen, which, while not suitable for paleodiet work, reflect characteristics of the underlying geology in different regions and have been used successfully to reconstruct patterns of residence and mobility.

Residence and mobility

Stable isotopes of oxygen and radiogenic isotopes of strontium have been used successfully to examine shifts in residence over an ancient individual's lifetime, and hence to inform interpretations of individual migration and population movements (e.g., Bentley, 2006;

Harvig et al., 2014; Hemer et al., 2014; Prowse et al., 2007; Slater et al., 2014; Toyne et al., 2014; Waterman et al., 2014). For the Indus Valley, Kenoyer and colleagues measured strontium in tooth enamel from archaeological human and faunal remains recovered from Harappa in order to examine their usefulness in paleomobility studies. They report substantial variation among the human samples, with nine individuals having isotope ratios consistent with the range of local faunal values, 19 individuals having ratios below the faunal range, and seven individuals having ratios above the faunal range (Kenoyer et al., 2013: table 2). They interpret this variation to mean that inhabitants of the city had multiple homelands within the Indus River Basin.

Kenoyer and colleagues note that differences in strontium isotope ratios between tooth enamel and bone mineral in a single individual would reflect changes in the residential history of that individual: strontium in the mineral component of teeth reflects the chemical features of the geology of the area (through the consumption of groundwater and foodstuffs) where the individual was living at the time of tooth formation (i.e., childhood) and this chemical composition does not much change after it is formed; by contrast, the chemical composition of bone can change markedly during life because bone is constantly remodeling and hence could incorporate the chemical signatures of different groundwater and foodstuffs if these changed over a lifespan (Kenoyer et al., 2013). Unfortunately, because bone at Harappa was much altered by the chemical constituents of the burial soil and of groundwater, it could not be analyzed in their study.

In addition to the strontium values, Kenoyer and colleagues obtained oxygen isotope values on some teeth from Harappa. Like strontium, oxygen reflects geographic sources of water and varies according to climate, roughly speaking. They plot the oxygen values against the strontium values (Kenoyer et al., 2013: figure 8) and conclude that the data indicate a separation of two large groups of people at Harappa, those of local origin and those of nonlocal origin; they further suggest that "many of what appear to be local individuals at Harappa are females and they are associated in burial with nearby males who are clearly not local" (Kenoyer et al., 2013: 2295).

These encouraging results have been confirmed by a study in which strontium and lead isotope analysis of human and animal teeth from Harappa and the more distant Indus Valley site of Farmana were used to investigate paleomobility (Valentine, Chapter 12 in this volume; Valentine et al., 2015). The results indicate that the individuals changed their place of residence at least once during childhood. Furthermore, sex differences in the isotopic signatures are interpreted as reflecting sex-structured migration, with males from the northwestern and northeastern hinterlands migrating to Harappa, perhaps following trade routes. This interpretation is consistent with the strontium isotope results from Harappa that are described above, and also with the results of a cranial morphological study that indicate a pattern of matrilocality at Harappa (Hemphill et al., 1991). Valentine and colleagues (2015) propose a more complex rationale, however, one that incorporates burial practices and which suggests that certain individuals from the hinterland moved to Harappa at a very young age, perhaps through a system of fosterage that was reserved for first-generation immigrants, and that it is these immigrants that are buried in Cemetery R-37 at Harappa.

FINAL THOUGHTS

In my review of the literature, I sought to identify major achievements as well as directions for future research in the bioarchaeology of the Indus civilization. It soon became clear, however, that in some ways we are still at the stage of collecting data and describing skeletal features rather than attempting broader interpretive approaches, because the analysis of human remains is often poorly integrated with archaeological data. In addition, a continuing problem faced by researchers is that the skeletal samples examined and reported on are only small portions of the accumulated dead from the recognized burial areas, which may have been used for hundreds or thousands of years. Only parts of what were much larger burial areas have been excavated, and the excavated sample is not necessarily representative of the living population because of the possibility of different mortuary treatments for different status, ethnic, or age groups within a community. Paleodemographic reconstructions, historically a common objective of bioarchaeological analyses, are ill-advised because difficulties in estimating fertility and adult age at death introduce problems that cannot be overcome with the small and nonrepresentative skeletal samples that characterize the Indus Valley skeletal assemblages (for a review of these issues, see Jackes, 2011). Furthermore, preservation issues have plagued researchers from the earliest excavations to the most recent. If we did not look beyond these problems we would be loath to move beyond descriptions to proffer any interpretations at all.

However, some groundbreaking interpretations, based on the applications of new technologies and new perspectives, have been developed. For example, the results of biological affinities assessments indicate that Harappans of the urban phase were descendants of peoples from the northwestern sector of the Indian subcontinent, likely due to the movement of people along trade routes between Mesopotamia and the Indus Valley (Hemphill et al., 1991; Kennedy, 2000), and the phenotypic variability at Harappa suggests that matrilocality was a well-entrenched cultural practice (Hemphill et al., 1991). The results of chemical analyses of teeth from Indus Valley sites are consistent with these interpretations, the data indicating that there were people of local origin and of nonlocal origin living at Harappa, with males from the northwestern and northeastern reaches of the Indus Valley migrating to Harappa (Kenoyer et al., 2013; Valentine, Chapter 12 in this volume; Valentine et al., 2015).

Future research on biological affinities should proceed on two fronts. First, the preliminary results of chemical analyses should be expanded on by sampling individuals from other sites and time periods in the Indus core and peripheral areas, as well as from sites along identified trade routes to the east and west. Future research on migration might be able to pinpoint the ages of immigration to Harappa through the analysis of multiple teeth within one individual. For example, two different teeth were measured in three individuals and gave differing isotope ratios, varying by 0.0003, 0.0023, and 0.0025, and, since the teeth sampled were not antimeres, the differences may reflect time differences for the formation of the teeth. To illustrate, the strontium isotope values of 0.7160 and 0.7183 were obtained on the lower first molar and lower third molar, respectively, yet the lower first molar tooth crown is formed between 2.5 and 3 years of age while that of the lower third molar is formed between 12 and 16 years of age. In this example the values are both within the faunal range but, supposing that they were not (i.e., if the value from an early-forming tooth was outside the expected range for Harappa while that for a later-forming tooth was within the expected range for Harappa), the difference may lead to identification of the age at which an individual moved to Harappa.

Second, effort should be aimed at teasing out details related to matrilocality. Although matrilocality can be defined in simple terms, it has a complex relationship with matrilineality and hence there exist a number of social and cultural processes that can have significant effects on health. A discussion of these is beyond the scope of this chapter, but possibilities include the physical abuse of women and children where male parentage is uncertain, and the involvement of men in warfare or other territorial activities rather than involvement in economic systems such as farming. These scenarios may have links to the physical abuse of women and children at Harappa (Lovell, 2014b; Robbins Schug et al., 2012) as well as the dental disease evidence of an apparent sexual division of labor related to food production, preparation, and consumption (Lukacs, 1992). Likewise, dental evidence for son preference and daughter neglect (Lukacs, 1992) could be a function of attempts to solidify affiliations related to the system of fosterage proposed by Valentine and colleagues (Valentine et al., 2015).

Similarly complex is the analysis of the interactions of resources, sociocultural processes, and health, and a critical assessment of these interactions has led to important new interpretations of health among the ancient Harappans. In addition to the discovery of the physical abuse of women and children (Robbins Schug et al., 2012), Robbins Schug and colleagues found skeletal evidence of leprosy and tuberculosis at Harappa. They posit that an increased risk of chronic infectious diseases such as these may be a consequence of climate change and socioeconomic disruption during the post-urban period at Harappa, with socially and economically marginalized communities most vulnerable to the health effects of these processes (Robbins Schug et al., 2013). Given the importance of these findings regarding health and the variables that affected health in the past, future research on newly excavated skeletal samples must take great care to ensure that skeletal and dental remains are carefully examined for pathological lesions, and that the observed conditions are interpreted in the context of past physical and sociocultural environments.

In addition to the contributions of chemical analyses to the study of mobility and migration in the Indus civilization, recent results also point to the potential for interdisciplinary reconstructions of past diets. Since the results of isotopic analyses of human remains and the results of archaeobotanical studies constitute independent lines of evidence for diet, further research that integrates these has the potential to overthrow traditional interpretations of diet, will help to increase our knowledge of the variation of food that was available, and will allow researchers to explore possible differences in the consumption of different foodstuffs according to age, sex, or status in the Indus Valley. In addition, developments in the stable isotope analysis of teeth that now permit the study of diet in infancy and early childhood (e.g., Burt, 2013; Burt and Garvie-Lok, 2013; Sandberg et al., 2014) have the potential to expand our understanding of weaning processes and could contribute to the discussion of migration and fosterage.

In spite of the challenges that face bioarchaeological research in South Asia, the results obtained from the investigations of the past 30 years have revolutionized our understanding of the peoples of the ancient Indus Valley, providing contemporary, scientifically informed interpretations from skeletal collections that were often collected decades ago. With the recent discoveries of new sites and cemeteries, the development of new methods of analysis, and the integration of human remains with archaeological data, the bioarchaeology of the Indus Valley civilization has a very promising future.

NOTES

1 The history of the study of racial identities in the South Asian prehistoric skeletal record, including the Indus Valley, is beyond the scope of this chapter and I refer readers to Kennedy's comprehensive review (Kennedy, 2000: 358–380).

2 In the case of remains from Indus Valley sites, bone is usually poorly preserved and may not contain recoverable DNA. Thus, should ancient DNA analysis be entertained, it is likely that teeth will have to be investigated as a sample material.

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