DENTAL DEDUCTIONS: WHY AND HOW ANTHROPOLOGISTS STUDY TEETH

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The news crew gave blank stares of disbelief, then replied, “Dental anthropology!” “I had no idea!” “You’re kidding, is it really a field of study?” The local hospital had just donated their radiographic and CT scan services to assist us in the analysis of Iron Age jaws and teeth from the Sultanate of Oman. The hospital public relations office notified the press about the unusual nature of the afternoon’s patients, and representatives of two TV stations and the local newspaper were there to cover a unique story.1 My German colleague, Paul Yule, an archaeologist specializing in South Asian and Arabian Gulf cultures, had sent me several boxes containing the teeth and jaws of people he had excavated from 2,500-year-old burials at Samad Oasis (Figure 1). He had requested a thorough anthropological analysis of these fragmentary but ancient specimens. At this point you might rightfully interrupt to ask several pointed questions: (1) “Why would Professor Yule, or anyone else for that matter, request an ‘anthropological analysis’ of a collection of ancient teeth and jaws?” (2) “What does an anthropological analysis of human teeth and jaws include?” (3) “How is such a study conducted?” (4) “What kinds of information and insights can be gained from the study of ancient teeth?” These are the kinds of questions that will be answered in the following pages. This introduction to the design, conduct, and results of research in the field of dental anthropology will use examples from my fieldwork in India and Pakistan to illustrate the research process in this unique but exciting subfield of biological anthropology.

The discipline of dental anthropology can be defined as the study of teeth and jaws of living or prehistoric people and their ancestors for insights concerning human behavior, health and nutritional status, or genetic relationship of populations to one another. Any process or mechanism that influences the structure or function of teeth, jaws, or face is within the domain of dental anthropology.2 The wide range of ways in which culture and environment interact with the human dentition makes dental anthropology a diverse discipline; one that embraces subjects as different as genetic influences on the formation of dental tissues of modern humans, to the varied nondietary ways in which Neandertals may have used their teeth. This area of study differs in several important ways from dentistry, orthodontics, and other clinical approaches to the dentition. Anthropologists are concerned primarily with the interaction of biological and cultural systems in a natural setting. Dentists and their clinical colleagues seek to preserve the health or eliminate diseases of the teeth and jaws of their patients. Dentists treat individuals and family members who are
often from ethnically diverse backgrounds. For anthropologists, the primary unit of study is a sample derived from a natural biological or breeding population, and ideally all anthropological studies of the dentition are conducted within the analytic framework of evolutionary biology. Anthropologists see variation in the morphology (form and structure), size, and patterns of disease of modern human teeth as the outcome of a long evolutionary history in which the interaction of biology, culture, and environment has produced different dental variations in every human population.

The importance of teeth in anthropological studies derives from attributes of the teeth themselves and from the indelible marks that bio-cultural interactions leave on the teeth during and after they form. First, since teeth and jaws are among the hardest parts of the body, they preserve better and more abundantly than other body parts in archaeological sites and in fossil deposits. Initially this may seem strange, given the high rates of dental decay documented for many agricultural and industrial societies; however, during life the oral cavity contains food debris as well as chemical and bacterial conditions that may lead to their rapid decay.
destruction in the absence of good hygiene. Once buried, and free from the bacterio-chemical environment of the living oral cavity, teeth and jaws may be preserved in excellent condition for thousands or millions of years. Second, many aspects of dental anatomy, including size of the teeth, their morphological details, and the timing of their development, for example, are known to be under genetic control. This feature of the dentition leads to the corollary that populations that display many similarities in tooth structure and size are more closely related to one another than those whose dental structure is quite different. Third, since our two sets of teeth develop slowly over a long period of time, and are not easily modified after they form, our teeth provide an indelible and retrospective indicator of physiological status during development—from prenatal times to about twenty years of age.

The Iron Age Omani specimens revealed an interesting finding. Most adults in this series had experienced some loss of their permanent teeth before death. This is not necessarily an unusual situation in archaeologically derived skeletal collections, depending on the age structure of the sample and on the diet and the environment in which the group lived. However, in the Omani series, molar teeth were lost quite early in life—adolescents and young adults commonly suffered loss of one or more molar teeth. A review of the archaeological record shows that date palms were a common feature of the Samad Oasis. These trees provided shade for humans and crops, and also provided an abundant source of sweet foods for youth of the Iron Age. Frequent consumption of dates, perhaps coupled with somewhat less frequent episodes of dental hygiene, resulted in high rates of dental caries (popularly called cavities), dental infections, and early loss of teeth. The radiographic analysis of the Samad jaws, so intriguing to the press and public, showed that no root fragments were imbedded in them. This finding implies that crude dental extractions were not practiced by these ancient Omanis, and that loss of teeth early in life was exclusively due to dietary factors—consumption of dates. This finding is of interest to archaeologists because it permits them to gain a more complete picture of behavioral patterns in the Samad Oasis 2,500 years ago. Yet it is only one aspect of our multifaceted analysis of the Samad dentition. In association with the analysis of dental diseases, the size and morphology of the teeth have also been documented so that interrelationships between tooth size, morphology, and dental disease can be investigated.
This review will begin by introducing several key concepts in dental anthropology. These concepts are prerequisite to considering three examples in which the careful study of teeth has enhanced our knowledge of biocultural interaction among prehistoric humans in Asia.

**Basic Concepts in Dental Anthropology**

Teeth are composed of four biological tissues: enamel, dentine, pulp, and cementum. Enamel is the white outermost covering of the portion of the tooth that projects into the oral cavity (Figure 2). It is the most durable tissue in the body and is derived from the embryonic tissue ectoderm. Due to its embryonic origin, enamel is the only dental tissue that lacks recuperative power; it cannot respond to stress or regenerate if damaged. Dentine is the tissue that comprises the bulk of a tooth’s substance. Dentine formed at the time a tooth is initially developing is referred to as primary dentine. It is yellowish in color, softer than enamel, and derived from mesodermal tissue embryonically. In response to decay or heavy chewing stresses, cells lining the internal surface of the dentine layer will respond by initiating additional dentine production. This recuperative dentine is called secondary or reparative dentine, and can be visually differentiated from primary dentine. The third dental tissue, cementum, is also of mesodermal origin and covers the roots of the tooth. Teeth are held in their sockets (or alveoli) by the periodontal ligament, a band-like tissue that is anchored in cementum on one end and attaches to the alveolar bone on the other. The dental pulp is composed of loose connective tissue that fills the internal chamber of the tooth—the pulp chamber. Blood vessels and nerves enter the pulp chamber through a small opening at the apex of the root. Major anatomical parts of the tooth are the crown, neck (cervix), and root (Figure 2). The crown may be more specifically designated as the anatomical crown, or the portion of the tooth above the cemento-enamel junction, or the surgical crown, that portion of the tooth projecting into the oral cavity or visible above the gum. The dental cervix is the line of contact between the enamel and cement, known as the cemento-enamel junction.
Humans, like most mammals, have two sets of teeth. The first set of teeth is generally called the “baby” or “milk” dentition, though anthropologists commonly refer to them as the “primary” or “deciduous” dentition. You may think of deciduous teeth, which are lost and replaced by their permanent successors, as similar to deciduous trees that lose their leaves each fall but are replaced by new ones each spring. Modern humans have twenty deciduous teeth, which are normally replaced by thirty-two permanent teeth. Differences in morphology and size of crown and roots make it easy, after training and some practice, to identify isolated teeth as either deciduous or permanent. Another mammalian feature of the human dentition is the morphological difference between tooth types, a characteristic known as heterodonty. The permanent dentition consists of four tooth classes: spatulate incisors, conical and single cusped canines, premolars with two or more cusps, and the rectangular, complexly structured molar teeth. Different structures are associated with different functions; the nipping and cutting of incisor teeth is distinct from the crushing and grinding function of the molars. A heterodont dentition
permits mammals to masticate, or thoroughly chew food, thus beginning the digestive breakdown of food in the oral cavity. This is essential for animals such as mammals that have a high and constant body temperature in association with an energetic activity pattern. The single, holding-grasping function of the reptilian mouth is associated with a homodont dentition (teeth with the same shape), low and variable body temperature, and a less active lifestyle. This contrast between mammalian and reptilian dental structure shows that tooth shape and function are closely interrelated, and dental function is tightly linked to the behavioral activity pattern of an organism. Having established the basic fundamentals of dental anthropology, a series of examples will be considered with the intention of revealing both the methods and techniques used, as well as the significance of the results and conclusions derived from this research.

**Getting the Facts:**

*Fieldwork Places Dental Data in Cultural Context*

The three examples of research in dental anthropology to be discussed below involve the analysis of: (1) dental disease and subsistence, (2) dental morphology and biological relationships, and (3) tooth size, technology, and biological relationships. Each of these topics represents an area of dental anthropology research to which I have personally contributed. My research involves the field excavation (Harappa) and laboratory preparation of human skeletal and dental remains (Ganges Plains sites, Inamgaon, Mehrgarh) for analysis. Such work is very time consuming and requires repeated visits of several months duration each year to remote field locations in Baluchistan and Punjab Provinces, Pakistan, and to laboratory and field sites in the cities of Pune and Allahabad, India. The results reported here are based upon skeletal remains from archaeological sites excavated within the past twenty years, and represent new insights into the prehistoric peoples and cultures of the Indian subcontinent.

Late stone age cultures of the middle Gangetic Plains north of Allahabad consist of microlithic tools and grinding stones, but
lack pottery, and date approximately from 8000 to 5000 B.C. (see Figure 1 for site locations). A similar pattern of “mesolithic” culture, including a nomadic hunting and gathering lifestyle and dependence on wild plant and animal species, was discovered from archaeological excavations at Damdama (DDM), Mahadaha (MDH), and Sarai-Nahar-Rai (SNR).\textsuperscript{5} Archaeological sites in the greater Indus Valley of Pakistan include: Neolithic Mehrgarh (MR 3), a preceramic, early agricultural site with a mixed economic subsistence pattern found in Baluchistan Province ca. 6000 B.C.; Chalcolithic Mehrgarh (MR 2), where agriculture, animal husbandry, and wheel-made pottery was common at approximately 4500 B.C.; and Bronze Age Harappa (HAR) to the northeast, in Punjab Province, a significantly more urban and intensively agricultural site of the Indus Valley (or Harappan) Civilization (ca. 2500 B.C.).\textsuperscript{6} In western India, the early agricultural village site that has yielded abundant human skeletal remains, mostly of infants, is known as Inamgaon (INM).\textsuperscript{7} Associated with a chalcolithic culture known as Jorwe, most human remains from Inamgaon derive from levels dating between 1100 and 700 B.C. Two post-Harappan, early iron-using cultures of northwestern Pakistan that have provided dental remains for analysis, include Sarai Khola (SKH) and Timargarha (TMG).\textsuperscript{8}

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**Dental Disease and Subsistence Transitions**

The study of dental disease in prehistoric human skeletons is usually undertaken for different reasons by different anthropologists. The absence of archaeological indications of diet may lead one investigator to analyze the pattern of dental disease in a skeletal series to gain insight into the kinds of food people consumed. In another case, dental disease patterns may be investigated to determine if sex or status subgroups within an ancient society consumed the same or different kinds of food, and how this relates to their general health status. While people may rely on one key staple or resource, differences in food preparation methods between societies may produce distinctive patterns of dental disease of interest to the anthropologist. In the example given below, dental diseases in several skeletal series from one region are compared to
reveal how changing patterns of subsistence have a direct impact upon changing patterns of dental health.

One of the most profound and significant changes in human subsistence systems (how people get their food) is the shift from hunting and gathering for food to reliance upon the products of agriculture and of domesticated animals. This transition in subsistence behavior, and its corollaries such as increased population density and increased sedentary habits, has directly affected human health, the robustness of our skeletal system, the degree of sexual dimorphism, and the type and frequency of dental diseases that afflict us. The investigation of a relationship between dental disease and subsistence pattern requires the adoption of a research design consisting of a specific methodology that is consistently applied to several skeletal collections whose archaeological context provides a clear indication of subsistence pattern.

Generally, the anthropologist will observe and record the presence or absence of several pathological dental lesions in all skeletons from a site that contains a large collection of teeth and jaws. A typical list of dental disease lesions to be studied might include abscesses, antemortem loss of teeth, caries, calculus, enamel hypoplasia, exposure of the pulp chamber, hypercementosis, and resorption of alveolar bone. A dental abscess, for example, is a well-defined pocket of pus associated with an infected tooth. Bone resorption within the jaw accompanies a chronic infection and produces a bony space within the jaw. Antemortem tooth loss refers to loss of teeth prior to death, a condition recognized by the partial or complete obliteration of tooth sockets through the process of bone resorption and remodeling. An affliction commonly observed in agricultural peoples is dental caries, or a demineralization and cavitation of tooth surface. Oral bacteria produce acidic byproducts that cause the breakdown of dental tissues. Enamel hypoplasia is a deficiency in enamel thickness due to reduced activity of enamel forming cells at the time of enamel formation. Defects appear as linear grooves, pits, or depressed areas, especially evident on the anterior surfaces of incisor and canine teeth. The results of a pathological analysis of the dentition are often portrayed in two ways: individual count frequency and tooth count frequency. The first method presents the number of individuals afflicted with a dental disease divided by the total number of individuals for which a dental condition could be observed. Since human skeletons derived from archaeological contexts are often incompletely preserved or damaged, the sample size for computing the individual
frequency of dental conditions will vary. The second, or tooth count method, presents results as the number of teeth affected by a dental condition divided by the total number of teeth in which the condition could be observed.

Dental pathology profiles based upon individual count frequencies for three archaeological sites in the greater Indus Valley—Neolithic Mehrgarh (MR 3), Chalcolithic Mehrgarh (MR 2), and Bronze Age Harappa (HAR)—are presented in Figure 3. The progressive increase in most dental diseases with time and increasing cultural complexity is clearly evident. The gradual deterioration of dental health through time in the greater Indus Valley appears to coincide with an increasing dependence upon agriculture as a means of subsistence. The greater reliance upon agriculture and more sophisticated food processing equipment results in foods that are more refined, finer in texture, and stickier—features that increase the potential for causing dental caries. Similar relation-

![Dental Disease at Harappa: A Comparative View](image)

**Figure 3**
Dental Pathology Profiles of Archaeological Sites in the greater Indus Valley
ships between diet and dental disease have been demonstrated elsewhere, especially among Native North Americans, whose dental health declined even more dramatically with the adoption of maize (corn) as a dietary staple.

Caries is the dental condition most responsive to changes in diet, and serves as an accurate barometer for the shift from a coarse and varied diet like that of hunters and gatherers, to one that is less diverse, soft, and sticky—typical of many agriculturalists. The use of an alternative reporting method, based on tooth count frequencies, confirms the findings reported above on the basis of individual count frequencies. The tooth count frequency for dental caries in prehistoric human skeletal series from the Indian subcontinent shows that mesolithic hunting and foraging peoples have very low dental caries rates (between 0.0 percent and 1.2 percent) compared with Iron Age peoples (between 4.4 percent and 7.7 percent), who are generally more reliant upon agriculture. Second, within the greater Indus Valley, tooth count caries rates increase dramatically through time, in association with developing material culture and increased reliance upon agricultural products. This trend is visible in the progressively higher caries rates from Neolithic Mehrgarh (MR 3; 1.8 percent) to Chalcolithic Mehrgarh (MR 2; 6.9 percent) to Harappa (HAR; 12.1 percent).\(^1\)

In conclusion, a clear relationship has been shown between major cultural variables of diet and subsistence, and their impact on dental health. Generally, the subsistence shift from hunting and foraging to agriculture, and the attendant dietary change from coarse, unrefined food to soft, finely textured, and highly processed foods results in a dramatic increase in dental disease. This escalation of poor dental health is evident in both the number of individuals afflicted and the percentage of teeth affected by specific dental diseases.

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**DENTAL MORPHOLOGY AND BIOLOGICAL RELATIONSHIPS**

The question of biological relationships between people is an important one. Some people worship their ancestors, others seek genealogical links to colonists (Mayflower descendants), or to important people in world history. Anthropologists investigate the
biological relationships of prehistoric and living peoples of the world for a variety of reasons. One goal is to better understand the early history of human populations and how they dispersed and colonized the earth. A biological history of humanity is the ultimate objective of this research. This research approach is well illustrated by the attention anthropologists have devoted to people whose biology and culture appear inconsistent with their modern surroundings. The Ainu of Japan, pygmies of the Andaman and Philippine Islands, the Gypsies of eastern Europe, and the Lapps of northern Europe are some typical examples. Unfortunately, tracing the biological history of human populations through time is difficult. Complications arise in part because the genetic traits upon which the assessment of biological relationship are typically based, such as blood types and variation in DNA structure, are not always reliably determined for prehistoric skeletons. Another complicating factor is that human skeletons are not available from all time periods or from all regions of the world, so availability of data is patchy. Relying on genetic features of the dentition, anthropologists are able to trace human and prehuman history over millions of years into the distant past when we shared a common ancestor with the great apes of Africa. In the absence of DNA and genetic features of blood, teeth are ideal for reconstructing biological relationships between human populations because they preserve well after burial, display many genetically controlled variations of the crown and root, are easily observable in living and prehistoric specimens, and vary in anatomy from one region of the world to another.

The early farming village of Inamgaon in western India is unique in many ways. In addition to several unusual clay coffin burials of adults, abundant child and infant burials were discovered at this site. Infants and children are very rarely found in prehistoric cemeteries because their bones are incompletely developed, thin, and much more fragile than adult bones. However, at Inamgaon 85 percent of the skeletons are immature. In this unique case infants and children were buried in twin urns placed mouth-to-mouth beneath the house floor, thus protecting the bones from destruction by soil compaction and chemical deterioration. The abundance of children’s teeth preserved at the site provided an opportunity to investigate the question of the biological identity or affinity of the people of Inamgaon. Since Asian and European people differ in a number of their genetically determined dental features, a question arose regarding which dental pattern the people
of Inamgaon were most like. The dental traits generally included in a study of morphological variation may include twenty-five or more variations in shape and form of crown and root. Typical observations might note the number of cusps on a molar tooth, distinctive shape of incisor teeth (shovel shape), the pattern of grooves on a molar crown, or the presence or absence of several specific extra cusps on molar teeth. The vocabulary of dental morphology is complex, and standards have been established so anthropologists studying dental morphology can be assured that they evaluate and compare similar attributes. Typically observed morphological traits, including those that distinguish Asian and European dental patterns, are listed in Table 1 and illustrated in Figure 4.

Table 1

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<th>Definition of Dental Morphological Traits</th>
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<tr>
<td><strong>Shovel Shape</strong> (incisors): Elevated margins or ridges along the lingual surface of the upper incisor teeth give this surface of the tooth a shovel-like appearance. Variation is categorized as absent, slight, moderate, or marked.</td>
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<tr>
<td><strong>Carabelli’s Trait</strong> (upper molars): A variation in enamel surface on the anterior lingual aspect upper molar teeth. Expression is graded as absent, pit, groove, or cusp.</td>
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<tr>
<td><strong>Cusp Number</strong> (premolar and molar): A simple count of the number of cusps (elevated or projecting points) on the tooth crown. Normally molars display either three, four, or five cusps; less frequently six or seven may be present.</td>
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<tr>
<td><strong>Cusp-6 or entoconulid</strong> (lower molars): A specific extra cusp that occasionally appears on the posterior margin of lower molar teeth. It may be recorded as present or absent, or scored along a size continuum.</td>
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<tr>
<td><strong>Cusp-7 or metaconulid</strong> (lower molars): A specific extra cusp that may be expressed between the two major cusps on the lingual surface of the tooth. Variation is scored in the same way as cusp-6.</td>
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<tr>
<td><strong>Protostyloid</strong> (lower molars): A trait occurring on the anterior cheek surface of lower molar teeth that displays a pattern of variation similar to Carabelli’s trait. Variation evaluated as pit, groove, or cusp.</td>
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A graphic presentation of primary differences in deciduous dental trait frequencies that distinguish Asian and European dental complexes is provided in Figure 5. The Asian dental complex is characterized by high frequencies of incisor shoveling, extra molar cusps six and seven, and the protostylid, but Carabelli’s trait is infrequent. By contrast, the European dental complex is distinguished by low frequencies of incisor shoveling and molar cusp six, moderate frequencies of Carabelli’s trait and molar cusp seven, and low incidence of the protostylid. These patterns of deciduous dental variation, and similar frequency differences that are found in the permanent teeth of adults, were initially described by the Japanese anthropologist Kazuro Hanihara. The pattern of dental trait frequencies found in primary teeth at prehistoric Inamgaon displays values intermediate between the

**Figure 4**

**Dental Morphological Traits of the Deciduous Dentition**

INM-163. Lingual surface of maxillary central incisor teeth. Note double median lingual ridges and trace shovel.

INM-163. Upper left first molar. Note well developed metaconule (C-5) and Carabelli’s trait (top).

INM-177. Occlusal view, lower first molar teeth. Note Y groove pattern and moderately developed entoconulid (C-6).
Asian and European dental complexes. In the frequency of molar cusp six, Inamgaon and Europeans are essentially similar; and in two traits, molar cusp seven and the protostylid, the Inamgaon dentition displays values lower than either Asian or European dental patterns. The overall impression one gains from this trait-by-trait comparison is that the prehistoric people of Inamgaon exhibit a dental trait pattern that is in some features intermediate between the Asian and European dental complexes, but that certain traits are clearly closer to the European pattern. This greater degree of affinity in dental variation between prehistoric Inamgaon and Europeans is generally consistent with archaeological and recent historical evidence suggesting the importance of population movement into the Indian subcontinent from the northwest. By contrast, the Himalayas form a less easily penetrated geographical barrier between India and east Asia, precluding major biological influences from central and eastern Asia.

In summation, genetically controlled morphological traits of the human dentition provide very different insights about past
populations than the study of dental diseases. The study of morphological variations of the deciduous and permanent teeth yields clues about the biological relationships among prehistoric peoples and between past and living peoples. In conjunction with archaeological and linguistic evidence, clues of genetic relationship derived from the teeth assist anthropologists in tracing the biological history of humanity. Documenting the northeast Asian origins of Native Americans and the northwest African origins of Canary Islanders on the basis of dental traits are examples of the success of this research approach.13

**TOOTH SIZE AND TECHNOLOGY:**

“WHAT BIG TEETH YOU HAD, GRANDMA!”14

The most conspicuous aspect of biological diversity in human populations is skin color. While differences in body shape, hair color and texture, blood proteins, and DNA also characterize human populations, they are not nearly as strikingly obvious. Variations in tooth morphology (see earlier section) and tooth size (this section) are more subtle and are concealed from the eyes of most people (with the exception of dentists and dental anthropologists). While discrimination has primarily been based upon differences in skin color, cases of differential treatment based on body size (fat people) and stature (short people) also occur. By contrast, no cases of differential treatment of people with large or small teeth are known to exist, despite the considerable variation that exists in size and morphology of our teeth. The purpose of this section is to show how anthropologists study tooth size, to describe patterns of tooth size variation through space and time, and to explain how and why this variation exists.

Unlike morphological traits of the teeth which are either present or absent, tooth size varies along a continuous scale, like stature or body weight. While sophisticated methods of analyzing dental dimensions are continuously being developed and tested, such as moiré contourography and digital photography, they are often expensive and laborious, and may require technical equipment.15 The most widely used technique of dental measurement is
MEASUREMENT OF DENTAL CROWN DIAMETERS

DENTAL CROWN INDICES

CROWN AREA = MD x BL, measures occlusal surface area
CROWN INDEX = MD/BL x 100, measures crown shape
CROWN MODULE = (MD + BL)/2, measures crown perimeter

Figure 6
the simple measurement of two dimensions of the tooth crown: length (mesio-distal dimension) and breadth (bucco-lingual dimension) (see Figure 6). Many other aspects of tooth size are occasionally measured by researchers for specific purposes. These include crown height, root length, cusp volume, and intercuspal distance, for example. However, common problems associated with normal tooth use or structure prevent easy determination of dental dimensions. For example, loss of enamel and dentine through wear reduces crown height, roots are often concealed in the bony tissue of the jaws, and the lack of systematic standards for dental measurement results in variations between researchers. On a worldwide basis our current knowledge of tooth size variation is largely based upon the mesio-distal and bucco-lingual dimensions of unworn, or very slightly worn teeth. Variation in dental dimensions has been described for many living and prehistoric people of the world, though some continents, like Europe, are much better documented than others, like Africa and South America. Many published studies of dental dimensions, however, are of little value to anthropologists. These clinical studies, often conducted by orthodontists for the purpose of understanding dental crowding and malocclusion, are based on groups comprising people from a variety of different ethnic backgrounds. Such groups do not represent valid biological populations, nor do they represent populations that shared a specific culture or adapted to a particular environment over long periods of time.

Two different perspectives have been employed in attempting to understand human variation in dental dimensions: (1) the techno-cultural approach, and (2) the genetic affinity approach. The techno-cultural approach, championed by anthropologist C. Loring Brace, envisions an inverse relationship between tooth size and culture. The basis for this perspective is that populations with small teeth generally tend to exhibit technologically developed or complex material culture. Agriculturalists with complex food-processing equipment and pottery have smaller teeth than hunter-gatherers and foragers whose cultures and food processing technologies are much more basic, and associated with much larger teeth. This approach is based upon the overall size of the dentition and stresses the role that teeth play in food processing. Variation in tooth size among peoples reflects differences in the extent to which material culture has replaced the functions of teeth in food-processing activities.
The techno-cultural approach focuses on crown area as a biologically meaningful measure of tooth size. Crown area is easily computed by multiplying crown length by crown breadth. Individual values for each tooth can then be summed for all upper and lower teeth, resulting in a quantity known as total crown area that is expressed in millimeters squared. Australian aboriginals display very large teeth with a total crown area of 1,500 mm², while some European and Chinese populations exhibit crown areas of between 900 and 1,000 mm² and have the smallest teeth yet recorded.

The progress of tooth size reduction through time can be readily seen in South Asia, where over a period of about 7,000 years human tooth size decreased by about 125 mm². Adherents to the techno-cultural perspective on tooth size envision this progressive decrease in dental dimensions as being causally linked to changes in diet and improvements in material culture. The pres-
ence of a loose but obvious correlation between increasing cultural complexity and decrease in tooth size is graphically displayed for South Asia in Figure 7. Techno-cultural complexity increases from left to right across the horizontal axis, while the vertical axis indicates total tooth crown area in mm². Note that sites included in this graph embrace a broad range of cultural adaptations, from late stone age cultures on the left to iron-using cultures on the right. In association with the increase in cultural complexity, tooth size reduces. The evolutionary mechanisms that bring about the observed reduction in dental crown dimensions are a matter of continuing controversy, and little consensus exists over competing models that favor one or another of the primary forces of evolution.¹⁶

The dental dimensions and biological affinity approach to variation in dental dimensions, espoused by Ed Harris, emphasizes similarities and differences in the patterning of dental dimensions between populations. In this approach, multivariate statistical methods are used to elucidate a small number of genetic factors that influence the pattern of dental dimensions in a population.¹⁷ Populations with similar factors and patterns are interpreted to be more closely related to one another than populations that display different factors and patterns. Principal components analysis (PCA) is a multivariate method that is used to reduce the sixty-four length and breadth measurements on thirty-two teeth to three or four major components that account for the pattern of variation in dental dimensions in a population. A comparison of these components and other factors derived from PCA are interpreted to reflect genetic controls that contribute to patterns of tooth size variation between tooth classes (incisor, canine, premolar and molar) and dimensions (length and breadth). Principal components analysis was recently used in a study of permanent tooth size in an eighteenth century slave population of South Carolina.¹⁸ As comparative samples, dental dimensions of permanent teeth from Inamgaon and Neolithic Mehrgarh were included in the analysis with interesting results. When components of permanent tooth size are plotted graphically, the group most similar to Inamgaon is a sample of American whites, an observation that reaffirms the results of dental morphology reported above on the basis of deciduous teeth. This plot of tooth size components also reveals a close relationship between the prehistoric dental sample from Neolithic Mehrgarh and the Inamgaon sample, a relationship initially dis-
covered during my comparative analysis of dental morphological traits among prehistoric South Asians. The high level of correspondence between results obtained from the independent analysis of dental morphology and tooth size variation is encouraging, especially since different data sets and distinct statistical methods point to identical results. More recently, Hemphill has applied multivariate statistical methods to the dimensions of permanent teeth of living castes and tribes of India. His findings reveal that patterns of tooth size in South Asia are indirectly influenced by the impact of social organization and linguistic factors on mating systems.

In summary, each approach to variation in human tooth size emphasizes a different aspect of dental dimensions: The tooth size and technology school stresses the functional importance of total tooth size, while the dental dimensions and biological affinity school regards patterns of dental variation—from incisors, to canines, to premolars, to molars—as indicative of underlying genetic determinants of size variation and consequently indicative of genetic relationships between human populations.

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**DENTAL ANTHROPOLOGY: SUMMARY AND PROSPECTS**

This brief review of the field known as dental anthropology provides a limited introduction to the kinds of questions, methods, and results often derived from an analysis of the dentition of living and prehistoric human populations. The topics selected for discussion in this review included diet, subsistence and dental health, dental morphology as a measure of biological affinity, and tooth size variation in relation to masticatory function and population relationships. These are topics in which I have had personal research experience, and though they appear to be wide-ranging, these subjects represent a limited array of the potential fields of enquiry within dental anthropology. Other exciting topics in the discipline of dental anthropology include: the rates of dental maturation and age assessment, dental indicators of tooth wear and tool use, enamel defects as a measure of health and nutritional deficiency, dental wear and dietary differences between the sexes. The sources cited in the notes below
and in the Suggested Reading list will direct you to more
detailed discussion of many of these specific topics. If this intro-
duction to dental anthropology inspires some students to read
and study further in the area of biological anthropology gener-
ally, or dental anthropology in particular, it will have accom-
plished its main objective.

**Notes**

1. Thanks are due to Dan Steinberg, Public Relations; and thanks
   are due to the Department of Radiology, Sacred Heart Hospital,
   Eugene, Oregon, for collaborative assistance in research and for
   taking the initiative in organizing news coverage for this phase
   of our research. The analysis of the human remains from Oman
   was conducted by University of Oregon graduate student Greg
   Nelson, under my supervision.

2. For additional information about the discipline of dental anthro-
   pology and examples of the range of research topics embraced
   by it, see G. Richard Scott, “Dental Anthropology,” *Encyclopedia
   G. Turner, II, “Dental Anthropology,” *Annual Reviews in

3. For further information refer to Greg C. Nelson and John R.
   Lukacs, “Early Antemortem Tooth Loss Due to Caries in a Late
   Iron Age Sample from the Sultanate of Oman,” *American Journal
   of Physical Anthropology*, suppl. 18 (1994): 152. For additional
details on the dental health of prehistoric people of the Arabian
Gulf states, consult Judith Littleton and Bruno Frohlich, “An
Analysis of Dental Pathology and Diet on Historic Bahrain,”
*Paleorient* 15 (1989): 59–75; Judith Littleton and Bruno Frohlich,
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427–447.

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9. Questions regarding changes in human health and longevity associated with the transition from hunting and gathering to agriculture have been addressed in a general overview by Mark


14. The subtitle of this section is derived from the clever title of an


19. The first comparative study of dental morphology to document a close relationship between Neolithic Mehrgarh and Inamgaon was by John R. Lukacs, “Dental Morphology and Odontometrics of Early Agriculturalists from Neolithic Mehrgarh, Pakistan,” in D. E. Russell, J. P. Santoro, and D. Sigogneau-Russell, eds., Teeth Revisited: Memoires du Museum, serie (C) 53 (Paris: Musee d’Histoire Naturelle, 1988), pp. 287–305. This study was based upon a univariate analysis of trait frequencies, and has subse-
quenty been reaffirmed by multivariate methods of comparison
in John R. Lukacs and Brian E. Hemphill, “Dental Anthropology
of Prehistoric Baluchistan and the Peopling of South Asia,” in
M. A. Kelley and C. S. Larsen, eds., Advances in Dental

20. The statistical analysis of dental dimensions among south
Indian castes and tribes has been presented in Brian E.
Eugene, University of Oregon, 1991); Brian E. Hemphill, John R.
Lukacs, and V. Rami Reddy, “Tooth Size Apportionment in
Modern India: Factors of Caste, Language, and Geography,” in
John R. Lukacs, ed., Culture, Ecology, and Dental Anthropology
(Delhi: Kamla-Raj Enterprises, 1992), pp. 231–253; and Brian E.
Hemphill and John R. Lukacs, “Odontometry and Biological
Affinities in South Asia: Analysis of Three Ethnic Groups from

SUGGESTED READINGS

Archaeological Reports, International Series, S 291, 1986. Provides a good example of the interdisciplinary nature of
research in dental anthropology.

range of dental topics (attrition, occlusion, pathology, morphology, and cultural modification), as well as several that focus on
the teeth of people from specific geographical regions.

Kieser, Julius A. Human Adult Odontometrics. Cambridge: Cambridge
University Press, Cambridge Studies in Biological
Anthropology, no. 4, 1990. Reviews the methods and objectives
employed in the analysis of tooth size in human populations.

Hillson, Simon. Teeth. Cambridge: Cambridge University Press,
Cambridge Manuals in Archaeology, 1986. A good introduction
to dental anthropology that includes microscopic structures and
a summary of dental evolution. This book also includes draw-
ings that help in identifying teeth of animals often found in
archaeological sites.

Biology 2 (1991): 789—804. A brief introduction to the field that
includes examples of cultural modification of teeth and use of teeth as tools in manufacturing and manipulating objects.