HIDDEN MESSAGES FROM TEETH OF THE PAST REVEALED; PALAEODONTOLOGY IN THE HOLY LAND

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ABSTRACT

To scholars who are concerned with biblical archaeology, the Late Bronze Age (LBA)–Early Iron Age (EIA) transition in the Southern Levant indicates the emergence of a new ethnicity. This would suggest an invasion of foreigners (i.e., Israelites) into the land of Canaan, in particular their settlement in the highlands surrounding Jerusalem.[1] The settlement of the foreigners has long since raised the question whether it can be proven that the settlers were indeed Israelites. Variation in population would be explained by the existence of population differences in phenetic relationships, gene flow and genetic drift between different sites that are known to belong to this period (Ullinger et al. 2005:466). Various research models have been employed to validate the differences, if any. The utilisation of dental non-metrical traits is suggested to secure a scientific answer to prove or controvert this theory. This paper will highlight the morphological traits and precursors that teeth possess. It will also evaluate certain unswerving and/or anomalous morphological characteristics (traits) and the odontometrics of permanent teeth. This will suggest methods that can measure phenetic relationships between different communities, ethnic groups, nationalities and even racial physiognomies, as well as migratory trends. And lastly, the age at death of an individual can be determined from the development and/or extent of wear of their teeth.

[1] Hoffmeier (1997:226, cf. Dever 2003:23) points out evidence, albeit indirect, that the narrative of the Exodus is indeed plausible. However, Thompson (1999:217) regards the history of the Exodus as well as the settlement of foreigners as a myth. Thompson received support for his concept from two other minimalists, namely Lemche and Finkelstein, who refer to the Exodus as literary fiction (Thompson 1999:xv). Ullinger et al. (2005:474) concluded in their research that there is no dental evidence of a major population incursion at Dothan or Lachish during the period in question. The Arizona State University Dental Anthropology System (ASUDAS) data that Ullinger et al. used in this research does not support the model of an "Israelite conquest" or of any other population group

BACKGROUND TO THE STATUS OF PALAEODONTOLOGY

Disi et al. (1983:515, cf. Eakins 1980:91) assert that archaeologists, especially those in the ancient Near Eastern countries, have not always found bones and teeth to be worthy of investigation. Intensive studies on skeletal and dental remains have since demonstrated that they are no less important or fruitful a subject for archaeological research than pottery, jewellery, architecture or any other artefact from historic and prehistoric periods.

Dan Brothwell (1959:59) pointed out that it was particularly fortunate that teeth are situated in the skull. His explanation is that in the past archaeologists were far from particular about what part of the skeleton was thrown away, provided it did not yield one of the standard measurements. This resulted in many post-cranial remains being thrown into dustbins after initial examination and the skulls retained. Dental remains and the jawbones were thus saved as part of the cranium and today odontological aspects of anthropology have stimulated much interest. Because of the durability and almost indestructability of the enamel of the tooth crown, one could expect to find a number of good quality teeth in a bioarchaeological excavation site, even at times when the rest of the skeleton is in pitiable condition or only fragmentary and no more of any research value (Coppa et al. 1998:371, cf. Kieser et al. 1983:11, Schwartz & Schoeninger 1991:283, Henke 1998:180). Hillson (1996:10) pointed out that teeth are common finds in archaeological sites where human remains are to be found and that teeth are of the best sources of evidence for both identification and studies of demography, biological relationships and health in ancient human communities.

> [T]he only two tissues of the human body that survive time: bone and teeth. Everything else disintegrates, for even the loveliest woman is biochemically just four buckets of water and one bucket of salts. (Martí-Ibáñez 1961:25)

If a body had been buried long enough in either acidic or alkaline soils, everything, even the bones would disintegrate, leaving only the dental tissues “deathless and indestructible”. Humphreys (1951:16–18) wrote that this phenomenon led to teeth being regarded as a vehicle of immortality of the spirit by some prehistoric populations, and even in certain tribal systems in the modern world. Ancient people prized a tooth as a symbol of vitality; their chiefs often wore necklaces sporting human teeth. A whole complex of legends still surrounds the tooth of the Buddha enshrined at Kandy in Sri Lanka; the most sacred object of 400 million Buddhists. The upper left canine tooth of the Buddha has been housed in the Temple Daladā Māligāva (Temple of the Tooth) since 1590 C.E. The largest Buddhist festival in the world today still commemorates the enshrined tooth as a corporeal relic (Gargi 2008, cf. Tan 1979:2429).

In order to understand the discipline of odontology (before the prefix "palaeo-" is attached), a concise overview of the development and morphology of human dentition is presented below. To comprehend the morphology of teeth, an understanding of the process of their development is imperative. Most mammals develop two sets of teeth, a primary and secondary dentition. The primary dentition is shed during growth-changes. Humans therefore possess two sets (diphodont) of differently shaped (heterodont) teeth. The term diphodont is used when describing the successive development of deciduous and permanent sets of teeth; the term heterodont describes the morphological differentiation between the two sets of teeth (Schroeder 1991:314).

DENTAL DEVELOPMENT AND MORPHOLOGY

Because of the limitation of space it would be impractical to impart the necessary information on the macro- and micromorphology of the standard 52 teeth (20 deciduous[2] and 32 permanent). The study of the development of the diphodont dentition elucidates the ultimate eruption sequence, shape and size of human dentition. Interested readers should enlighten themselves concerning the basic anatomy and development of teeth. An anthology of dental anatomy and morphology self-study reference books by authorities in this field has been selected by the author. They are the following: Van Beek (1983); Woelfel and Scheid (2002); Carlson (1987); Berkovitz and Moxham (1981); Schroeder (1991). An assimilation of this collection

[2] The primary dentition is ephemeral in nature. Research into most facets of odontological studies, bar age determination, are therefore only concerned with the permanent dentition.

have been adopted and adapted and was chosen as the standard for the author's thesis (Greeff 2009:43–83).

It is necessary to first identify the standard morphology of teeth before erroneously recognise anomalies as typical characteristic traits. In this study it implies that the important dental traits by which for example the Syro-Palestinian races, populations and groups, can be discerned.

TEETH AND ARCHAEOLOGY

To illustrate the importance of teeth in archaeology, an arbitrary isolated tooth found at an archaeological site of, for argument's sake, the Iron Age I period in ancient Israel, was examined. Without reference to any other finds at the site, Hillson (1986:1–4) takes us on an amazing scientific journey of the anthropological and scientific importance that this single tooth can reveal. It is possible to identify this tooth as a permanent upper right canine with a mesial accessory-ridge trait,[3] of a human being who had died at the age of more than 60; someone who had suffered from health and growth disturbances (due to infections and malnutrition that are revealed through hypoplastic lesions) at around the individual's chronological age of between 3 and 5 years. Poor oral hygiene is suggested from traces of calculus and tartar on one or more tooth surfaces; the level thereof on the tooth may suggest a longstanding periodontal disease. The amount of attrition would, apart from ageing the individual at death, also indicate the possible diet of the individual. In the event that this tooth had a carious lesion and this lesion had penetrated the pulpal tissue, an abscess can be presumed with accompanying morbidity of the individual. It may even have been the cause of death because of an unchecked infection of a compromised immune system due to perhaps a general disease condition or malnutrition. Had this tooth been impacted and unerupted, it may be possible through DNA studies of the pulpal tissue to establish the sex of the individual (Pill and Kramer 1997:673). Radiocarbon dating (Katzenberg (2000:307, cf. Ambrose & Krigbaum 2003:195), as well as

[3] A mesial accessory canine ridge is a rare trait found amid inhabitants of Western Eurasia (4–7%) which fits the description of a conceivable Israelite individual (Leroux 2012:105).

ESR-dating[4] (electron spin resonance) will confirm that the individual had lived in a specific period of antiquity, in this hypothetical period, namely 880 years B.C.E.

The accurate identification of individual teeth is a prerequisite for any archaeologist involved with fieldwork. The field archaeologist should not only be able to identify an artefact like a healthy human tooth per se, but should also be able to identify diseased dental structures, including fragments of teeth and fragments of jawbones. Individual teeth in an archaeological environment are described by Hillson (1986:10) as artefacts that most of the time do not have the appearance of the pearly white objects that are generally known to us; a tooth may be partially annihilated by caries, fractured, or may be unrecognisably discoloured by diagenetic changes that teeth undergo in soil, rendering it almost unrecognisable as a tooth.

The environment's influence on bioarchaeological dental remains

Palaeodontal research focuses on the various natures of evidences like skeletal material, cultic artefacts, pseudopathology and taphonomic changes in human remains. The laws of the Israel Antiquities Authority (IAA) governing the scientific examinations of remains may also influence palaeopathology research.

Nawrocki (1995:49) defines taphonomy or pseudopathology as the study of the processes that cause sampling bias or differential preservation in bone, teeth or fossil assemblages. Taphonomy literally means "the laws of burial" (from the Greek *tafo*, "burial", and *nomos*, "law"). Jones (1992:5,64) describes pseudopathological and pseudodontological changes in human remains as relatively common and such changes as bending or warping of long bones – even the mandibula will not be spared – are due to soil pressure over time. Tracks made by roots or insects mimic venous or arterial imprints in bone; scratches and erosions due to carnivorous animals are all signs which may appear pathological in their origin. Experienced archaeologists often fail to recognise the many conditions which can mimic disease and overlook the changes and simulations which their material may present. Differential diagnoses of

4 The basis of electron spin resonance dating technique is the trapping of free electrons by defects in the enamel apatite crystal lattice (Hillson 1996:225). See also Greeff (2009:293).

gross calculus deposits on teeth may include mineral deposits due to diagenesis (Roberts and Manchester 1995:55) – which is a form of taphonomy.

Reporting on bioarchaeological material is to give detailed information on the research investigations of such procedures. The main purpose of a palaeodontology report is to shed light on research questions pertinent to the site and region of the bioarchaeological remains. A secondary function, but equally important, is to make all palaeodontal data available to the wider scientific community (Mays 2004:46). Data recording standards (scoring) of human skeletal remains are the foundations whereupon all bioarchaeologists are placed on equal footing in the evaluation of scientific information (Buikstra & Ubelaker 1994:1). The assessment of human dental remains in the southern Levant is no different, and should comply with the international standards available.

DENTAL TRAITS (VARIATIONS OF TOOTH MORPHOLOGY)

The morphological characteristics of tooth-form are binary, distinguishable as metrical and non-metrical variations.

Metrical analysis of teeth

Metrical measurement entails the physical measurement of the tooth crown, which is no mean task as the tooth crown is of a nebulous shape with no flat surfaces or right angles. Univariate statistics are the statistics of measurements of the above, not of populations or individuals. Comparisons between populations might proceed by one measurement at a time (i.e., tooth size), unlike multivariate statistics that are used when comparing non-metrical analysis (Howells 1969:312).

The rationale for using occlusal crown size is that it defines the function of a changeable chewing surface (see occlusal wear). The definable point of measurement is one of the fundamental issues in biometry before statistical comparisons can be made between populations. Interproximal or aproximal attrition will affect the mesio-distal measurement of the tooth and should be discerned.

Statistical analysis of measurements of humans (anthropometrics) necessary for the disciplines of palaeopathology, palaeoepidemiology, palaeodemography and palaeodontology, has become an essential tool in the quest of understanding the scientific impact on anthropological research that human remains may have. Pietrusewsky (2000:375) explained the measurement and description of skeletal remains as a paradigm focus on the investigation of human population structures and past biological relationships, including the assignment of unknown specimens to reference groups.

Comparative data can be amassed for the studies concerning the lifestyles of ancient peoples from the examination of recognised standard morphological features, derived from metrical and non-metrical standards (Buikstra & Ubelaker 1994:4). There is no doubt in Rosenzweig's (1970:1425) mind that odontometry has valuable contributions to make and, together with other skeletal parameters, can establish biological differences between populations.

The index of an object in the biological domain is the expression of the ratio of one dimension of an object to another dimension (Agnew 1965: s.v. Index). The tooth crown index in odontology is expressed as:

$$\text{Tooth crown index} = \frac{\text{Buccolingual diameter}}{\text{Mesiolingual diameter}} \times 100$$

The practical implication of the tooth crown index was researched by LeBlanc and Black (1974:417) who reported an average reduction in tooth size of 2% for every thousand years for maxillary teeth and 1% for mandibular teeth in the eastern Mediterranean countries over a period of 9 000 years. Brace (1967:815) discussed the size of teeth of the inhabitants of Israel and the rest of the Middle Eastern countries where "technological elaboration has an antiquity equal to or greater than anywhere else in the world" and found that amongst modern humankind, Israelites have the smallest teeth corrected for body size in the world. The above data is imperative for evolutionary studies. The average tooth size tables below incorporate the crown and root sizes of permanent teeth. Deciduous tooth size statistics are rarely used in archaeological material because of indecisive or indeterminable natural root resorption. The compounded versions of various standard tooth sizes are presented as the tooth index, root length and total length of the teeth of the maxillary and mandibular teeth, and were obtained from Woelfel and Scheid (2002). The statistical data are presented below in tables 1 and 2. Average dimensions are counterbalanced by statistics on the ranges that are possible in most instances. Metrical statistics are known to be largely population specific (Woelfel & Scheid 2002:109). Tooth size statistics, together with the knowledge of tooth anatomy, are important tools in the hands of an archaeologist/anthropologist when dealing with dental artefacts. Austere dissimilarities with standard norms would instantaneously point to either prehistoric hominid or other animal remains. Computed tomography (CT) has a special advantage in the study of prehistoric populations regarding palaeopathology and palaeodontology (Alt & Buitrago-Téllez 2004:258). The authors used CT scan-data to replicate fossil finds using stereo lithographic techniques and for the study of comparative anatomy that aided in differentiating between hominids and modern humans.

Table 1: SIZE OF MAXILLARY PERMANENT TEETH

		Crown index		**Root in mm**		**Overall length in mm**	
Maxilla	Tooth	Average	Range	Average	Range	Average	Range
	Central incisor	11,2	8,6–14,7	13,0	6,3–20,3	23,60	16,3–26,0
	Lateral incisor	9,8	7,4–11,9	13,4	9,6–19,4	22,5	17,7–28,9
	Canine	10,8	8,2–13,6	16,5	10,8–8,5	26,4	20,0–38,4
	1st premolar	8,6	7,1–11,1	13,4	8,3–19,0	21,5	15,5–28,9
	2nd premolar	7,7	5,2–10,5	14,0	8,0–20,6	21,2	15,2–28,4
	1st molar MB	7,5	6,3–9,6	12,9	8,5–18,8	20,1	17,0–27,4*
	DB root			12,2	8,9–15,5		
	P root			13,7	10,6–17,1		
	2nd molar MB	7,6	6,1–9,4	12,9	9,0–18,2	20,0	16,0–26,2*
	DB root			12,1	9,0–16,3		
	P root			13,5	9,8–18,8		
	3rd molar MB	7,2	5,7–9,0	10,8	7,1–15,5	17,5	14,0–22,5*
	DB root			10,1	6,9–14,5		
	P root			11,2	7,4–15,8		

Table 1: Average lengths as well as ranges (minimum and maximum) are given for each tooth (*= overall length from mesio-buccal root apex to the mesio-buccal cusp). Root length is measured from cervical line to the root apex. The crown length is measured from cervical line to the tip of the mesio-buccal cusp. Legend for roots: MB = mesio-buccal; DB = disto-buccal; P = palatal for maxillary teeth. From Woelfel and Scheid (2002:110, 133, 150, 180).

Table 2: SIZE OF MANDIBULARY PERMANENT TEETH							
		Crown index		**Root in mm**		**Overall length in mm**	
	Tooth	Average	Range	Average	Range	Average	Range
	Central incisor	8.8	6.3–11.6	12.6	7.7–17.9	20.8	16.9–26.7
	Lateral incisor	9.4	7.3–12.6	13.5	9.4–18.1	22.1	18.5–26.6
	Canine	11.0	6.8–16.4	15.9	9.5–22.2	25.9	16.1–34.5
	1st premolar	8.8	5.9–10.9	14.4	9.7–20.2	22.4	17.0–28.5
	2nd premolar	8.2	6.7–10.2	14.7	9.2–21.2	22.1	16.8–28.1
	1st molar M	7.7	6.1–9.6	14.0	10.6–20.0	20.9	17.0–27.7
	D root			13.0	8.1–17.7		
	2nd molar MB	7.7	6.1–9.8	13.9	9.3–18.3	20.6	15.0–25.5
	D root			13.0	8.5–18.3		
	3rd molar MB	7.5	6.1–9.2	11.8	7.3–14.6	18.2	14.8–22.0
	D root			10.8	5.2–14.0		

Table 2: Table of measurements of the permanent maxillary and mandibular dentitions. Average lengths as well as ranges (minimum and maximum) are given for each tooth (* = overall length from mesio-buccal (MB) root apex to the mesio-buccal cusp). Root length is measured from cervical line to the root apex. From Woelfel and Scheid (2002:110, 133, 150, 180). Legend: M = mesial; D = distal.

Non-metrical dental variations

Non-metrical variation does not imply not measuring the dental feature, only that it is difficult and impractical to define measurements which cannot consistently be reproduced. Non-metrical features include amongst others presence/absence of teeth, size and number of cusps, shape of grooves in molar occlusal surfaces, presence of pits and form of ridges (Hillson 2005:262).

The term “non-metrical” is generally taken to encompass any minor anomalies of skeletal or dental morphology not normally recorded by measurement. Non-metrical traits were historically recorded as being either present or absent or scored according to the degree of development of the feature (Mays 1997:102). Mays defined dental traits as a heterogeneous group of anomalies, devoid of any sign of a disease condition. Saunders (1989:95) asserted that there are more than 400 non-metrical traits (variants) that have been described for the entire human skeleton in anatomical literature. In one of the classifications of non-metrical dental variants Mays

(1997:103) described the two fundamental categories of dental traits, namely the variations in the number of teeth and the variations in the form of the tooth crowns.

Non-metrical traits are typically heritable. Hillson (2005:273) reported that twins and family studies reveal a strong heritable component of several dental traits (cf. Sofaer & MacLean 1972:811).

Recording of non-metrical variations in skeletal remains can be accomplished either directly from the dentition or from casts made from impressions taken and viewed in a laboratory, and saved for future reference (see an example of a stone model in figures 1 and 2 below).

The rationale for non-metrical dental trait data

The value and use of dental non-metrical traits per se is stated unambiguously by Jackes et al. (2001:97) as being more accurate than the measurements of skulls or what can be inferred from gene frequencies, and often more feasible, cheaper and simpler than studies of ancient DNA. Dental traits provide information on phylogenetic and ontogenetic studies to differentiate within and between races (Palomino et al. 1977:61).

Hillson (1986:271) held that one of the more important objects of using non-metrical trait studies is to find relationships between different populations, otherwise referred to as determining ethnicity. Dental morphology, he pointed out, is a convenient and easily recorded aspect of phenotypic human skeletal variation. It has the advantage of being available to be studied in both living individuals and in archaeological human remains. Dental morphology has a genetic as well as an environmental component that controls it. Tyrrell and Chamberlain (1998:549) pointed out that non-metrical dental traits are expressed very early in tooth development. They are therefore not subject to skeletal remodelling, and functional constraints ensure that dental structures are under relatively strong stabilising selection.

Non-metrical variants may also be used to estimate the frequencies of combinations of relationships of teeth, in short, the genes of a population. The relative proportions of the variants may then be used to calculate a genetic distance between populations. The more genes held in common, the more closely related they are (Hillson 1986:271). Hillson however warned that it must be taken into account that there is a complex relationship between genetics and the environment, involving many genes. Therefore, the degree of genetic control in archaeological material becomes implicit when comparing the dental morphological distance with distances determined from blood groups, geography, linguistics and history (Hillson 1986:273, cf. Cavalli-Sforza et al. 1988:6002).

The importance of non-metrical studies was realised by Brothwell (1965:93) who at the time criticised earlier workers in archaeology and anthropology for concentrating all their attention on the physical measurements of all skeletal bones and teeth. It has become increasingly obvious, he stated, that one field that offers immense promise is the study of non-metrical characters. Risdon (1939:121ff.) for example, has done invaluable work on the statistical nature of the human remains material excavated at Lachish (Tell Duweir) in Israel by means of craniometrical studies, but has regrettably neglected the dental non-metrical features at his disposal.

In the past, the term non-metrical data has been used to refer to any morphological feature that cannot be measured, such as the mastoid size or the chin shape. However, in the event of an explicit morphological feature that for the most part is evidently only present or absent, it should rather be grouped under continuous/discontinuous morphological traits. Brothwell (1965:94) concurred that when one or many genes may control non-metrical differences, it may also be controlled and influenced by the environment. These genetic traits show considerable differences in frequency and this enables them to be employed in order to establish the differences between population groups and in particular the knowledge of group relationships (see table 3 below).

When evaluating a sample, Moskona et al. (1997:227) proposed traits to be divided into three categories: 1) stable traits, occurring in 100% of an entire sample (full genotype penetrance); 2) less stable traits, occurring in 76–99% of cases, relating usually to cusp numbers; and 3) unstable traits, occurring at frequencies ranging between 10% and 75%. A comparison of genetic dental traits across two racial groups and the Semite population is shown below in Table 3, divided into three categories namely High, Low and Pooled. Criteria for the selection of traits for kinship analysis must be high in heredity and low in population trait frequency and must have a distinct trait expression and low dependency on age and sex as well as having small inter-trait correlation. Dental traits should be singled out as the method of choice for kinship analysis (Alt & Vach 1995:101, cf. Alt & Vach 1998:540).

Table 3: A comparison of genetic dental traits across three racial groups

Non-metrical element and Estimation % of individuals investigated		Caucasian		Semitic		Negroid	
Character	Estimate of % A	N	% A	N	% A	N	% A
UI 1 shovel- shape	Low	100	17,0	137	41,5	264	16,6
	High	212	91,0	60	47,0	807	44,4
	Pooled	1833	40,5	197	43,0	1193	37,2
UM 1 cusp Carabelli	Low	91	41,0	30	62,0	389	2,0
	High	140	85,7	30	93,0	274	57,7
	Pooled	3789	59,5	197	73,9	663	25,0
UM 2 cusp number	Low	53	58,0	137	30,5	78	100,0
	High	50	87,5	30	73,0	78	100,0
	Pooled	103	72,3	197	42,1	78	100,0
LM 1 groove pattern	Low	85	86,0	30	53,0	133	86,9
	High	75	96,0	137	70,4	49	100,0
	Pooled	221	91,6	197	65,7	182	90,4
LM 2 cusp number	Low	61	1,0	60	0	167	18,6
	High	356	14,0	137	7,0	69	53,7
	Pooled	611	11,0	197	4,9	285	28,2

Table 3: A comparison of 5 genetic dental traits across three groups. The frequency of affected teeth (as a percentage) and the expression of non-metrical traits for 3 races are compared, after Osborn (1981:153). N is the number of individuals on which frequencies are based (see text). UI 1 denotes upper central incisors; UM 1 = upper first molars; UM 2 = upper second molars; LM 1 = lower first molars; and LM 2 = lower second molars. The data for the Semitic population has been highlighted as relevant to this study.

Table 3 lists the highest and lowest values found in the literature and indicates the variation of some morphological characters in some racial groups. The pooled frequency is used to show the most reliable pattern of affinities between the different racial groups and the Semitic population. Osborn (1981:153) had originally based his outcome on seven ethnic groups but for this exercise only the populations bordering Palestine were selected. In this study it was found that the “dental morphological distance” is closest between the Caucasians and Semites, more than concerning the Semite and the Negroid groups, or between the Semite and the Pacific and Asian groups (not shown). This in turn indicates a closer biological relationship between the

Caucasians and the Semites.

Standardisation of non-metrical dental traits

The establishment of specific dental orientated standards presents a tool through which the individual's dentition can be classified in a certain category. Without standards the classification might be impossible, thwarting a comparative study on the basis of data reported by different scholars and authors (Hanihara 1961:28). Dahlberg mainly worked on the permanent dentition whilst Hanihara's contribution was mainly focused on the deciduous dentition. (See figure 1 and figure 2 below for examples of plaques for permanent teeth traits.) These plaques are from a collection of permanent standardised tooth plaques prepared by Dahlberg (1945:676–690). Plaques are mainly used to ensure objectivity in the classification of each trait character (Hanihara 1967:923) and to reduce interobserver error in trait determination (Mayhall 2000:114).

Figure 1: Stone model plaque of shovel-shape incisor traits with standardised variation scales (scores). The plaque shows the lingual aspect of the upper lateral incisors with the scoring numbers in increased exacerbation. From Scott & Turner (1991:14).

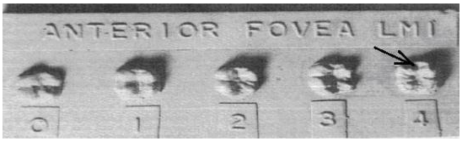

Figure 2: Stone model plaque of the anterior fovea trait with standardised variation scales (score), a presentation of the lower first molar teeth (see arrow) (Scott & Turner 1991:17).

Essential to comparative analysis is the ability to generate accurate expressions for dental characteristics. These expressions must reflect accurate counts of both attributes – presence and absence – and should also be internationally standardised. Illustrations of incremental expressions within traits can be seen in the presentations of the plaques shown: starting with a numerical value of 0, which is an indication of absence, through various aspects of incremental manifestation of presence, starting with a value of 1, 2, or 3 which may denote a bare minimum to intermediate expression, then progressing through severe and sometimes even gross expression with values of 4, 5, and 6. In the event of comparative studies of dental morphological traits, the three-dimensional stone-cast plaques are invaluable and should be available for consultation. It far exceeds two-dimensional photographs. There still exists a dire need for international standardisation of these plaque standards to be utilised by all scholars in reporting data in publications, as no doubt the initiators of the plaques had in mind. It is the opinion of the author that a universal set of plaque standards would be useful and practical in all general dental surveys.

Non-metrical data collection consistent with the Arizona State University Dental Anthropology system (ASUDAS)

The Arizona State University Dental Anthropology System (ASUDAS) trait inventory system was devised by the University's dental students and their tutors. The goal of the ASUDAS inventory system is to impart and introduce replicable, graded distinctions by defining a set of variants which are commonly observed within archaeological dental remains. The prerequisite according to Buikstra and Ubelaker (1994:63) is that the dental samples required should be low in sexual dimorphism and be readily observable. Irish (1998:82) cited that it is standard "system protocol" to pool the sexes since there is usually very little difference between the sexes. The ASUDAS is not recognised as a general dental recording system, but a rather specialised tool to record dental traits. The ASUDAS was developed mainly for the purpose of identifying dental traits in the quest to characterise and individualise groups of people as well as to differentiate between groups and even races by certain unambiguous dental traits. Although some of the other recording systems also have references to similar dental traits, the same scientific information cannot be deduced from it (Turner et al. 1991:27). The recording of, and the data processing, should mostly be left in the capable hands of a person well trained in dental morphology and should preferably be performed in a laboratory environment.

The ASUDAS is based on the assumption that phenetic expressions of teeth approximate genetic variation. Dental morphological traits are utilised to assess phenetic relationships between people at different sites and even of different chronological periods (Ullinger et al. 2005:466). Irish (1998:82) explained that the system comprises a collection of more than 40 common crown, root and intra-oral osseous morphological traits of the human dentition. Procedures used in the ASUDAS are based on well-established criteria for scoring intra-trait variation and have been proved to be reliable in many palaeodemographical studies (see Haeussler et al. 1989:115; Irish 1996:129; Irish & Turner 1997:141–146; Irish 1998:81–98; Irish 2006:529–543 and Turner & Markowitz 1990:32–41).

A list of dental traits (dental crowns and roots), advocated and used by the Arizona State University dental anthropology system (ASUDAS in Scott & Turner et al. 1991:13) are: shovelling, upper incisors; double-shovelling, upper incisors; labial convexity, upper incisors; peg-shaped incisors, upper lateral incisors; interruption groove, upper incisors; tuberculum dentale upper incisors and canines; canine mesial ridge (Bushman canine); canine distal accessory ridge, upper and lower canines; premolar mesial and distal accessory cusps, upper premolars; tri-cusped premolar, upper premolars; distosagital ridge, upper first premolars; metacone, upper molars; tome's root, lower premolar root number; hypocone; upper molar teeth; cusp 5 (metaconule) upper molars; Carabelli's cusp trait, upper molars; parastyle (mesial paracone tubercle); premolar root number, upper premolars; molar root number, upper molars; peg-shaped molar, upper third molar; odontome, upper and lower first and second premolars; Enamel extensions, upper molars and premolars; anterior fovea, lower first molars; deflecting wrinkle, lower first molars; groove pattern, lower molars; cusp number, lower molars; protostylid, lower molars; cusp 5, lower molars; cusp 6, lower molars; cusp 7, lower molars; lower molar root number, first molars; caries; tooth status; wear; cultural treatment, anterior teeth (see further aspects & elucidation of dental non-metrical traits in Greeff 2009:139–157).

Table 4: 17 ASUDAS traits used by Ullinger et al. (2005:472) to determine ethnicity in southern Levant	
Trait	Affected tooth
1. Shovelling	U incisors
2. *Double shovelling*	U incisor
3. *Interruption groove*	*U incisor*
4. *Tuberculum dentale*	*U incisor & canine*
5. Distal accessory ridge	*U & Lower canine*
6. *Upper premolar 2 roots*	U Premolar 1
7. *Lingual cusp*	*L Premolar 2*
8. *Cusp 5*	*U Molar 1*
9. *Hypocone*	*U Molar 2*
10. *Carabelli's cusp*	*U Molar 1*
11. *Parastyle*	*U Molar 3*
12. *Protostylid*	*L Molar 1*
13. *Deflecting wrinkle*	*L Molar 1*
14. *Cusp 7*	*L Molar 1*
15. *Cusp 6*	*L Molar 1*
16. *Groove pattern*	*L Molar 2*
17. *Cusp number*	*L Molar 2*

Table 4: The 17 metrical traits and the teeth used by Ullinger et al. (2005:472) in their bioarchaeological analysis of cultural transition in the southern Levant, in comparing the frequencies of dental traits between Dothan and Lachish in the period LBA–EIA. Legend: U = upper; L = lower and M = mesial.

ESTABLISHING AGE OF SKELETAL REMAINS; TEETH AS AN INDICATOR OF AGE

Because humans have a special interest in their species, and the assessment of age has a diversity of practical values, an intense interest had developed in the human dentition as an indicator of age (Miles 1978:455). Gustafson (1966:102) defined chronological age as the attainment of a certain number of years. On the other hand, ageing is the changes in separate parts of the body or of the body as a whole. Ageing may not necessarily correspond with chronological age, although there is normally a relationship. Physiological age (biological or developmental age) is estimated by the maturation of one or more tissue systems (i.e., teeth), and is expressed in terms of each system studied. These are measures for describing the status of an individual, while chronological age conveys only a rough approximation of this status because of the range in development observed for any given age (Moorrees et al. 1963:1490).

Multifactorial dental systems to determine age in humans

Ageing of skeletal material is of interest to the anthropologist, archaeologist, odontologist and forensic expert alike. The pubic symphysis is a reasonably accurate indicator of age (Kieser et al. 1983:9), since changes in the symphysis can be used to establish age at death in skeletons from 18 to 50 years, with an error of 5 years. Since skeletal material is fragmentary at times, dental tissues may be the only reliable remaining material, therefore dental ageing methods would be the obvious corollary. Gustafson (1950:45–54) identified six age changes within the tooth. Solheim (1993:137) stated that just as an old horse-trader judges the age of a horse by its teeth, so would a trained dentist be able to correctly guess the age of human teeth by visual inspection, regardless of the unscientific nature of the method.

Lucy et al. (1995:421) chose Gustafson's (1950) original method and Johansson's technique of seven ordinal expressions together with a new statistical equation to improve on the previous age estimations. Their conclusion was promising, especially advantageous for estimation of the elderly samples. Most skeletal methods have an upper age limit of 45 years. Above this age degenerating skeletal changes become less dependent on chronological age and become more influenced by pathological changes (Lucy et al. 1995:425). It is generally assumed that life expectancy in antiquity was considerably shorter than it is in modern times. This is true to the extent that Aykroyd et al. (1999:56) proclaimed life expectancy to have been as low as 20 years for the period of about 800 to 1100 C.E. at Libben in Ohio. A child born among the lower classes during the first century in the Roman Empire had a life expectancy of little more than 20 years (van den Heever & Scheffler 2001:40).

The six criteria proposed by Gustafson (1950:47) below make use of single rooted teeth. The capitalised letter in square brackets preceding every criterion is the contracted form that will ultimately be used in depictions and further studies in this regard.

- [T] Translucency of the root (root transparency)
- [A] Attrition of enamel (dental wear)
- [S] Secondary dentine apposition

- [P] Periodontosis
- [C] Cementum build-up
- [R] Root resorption

Gustafson's method for age determination from teeth is simply based on the evaluation of ground sections of single rooted teeth. The six age-associated parameters are evaluated in the ground sections and are then compared to a regression curve of age versus the age-associated changes. Later researchers saw the need to be more conservative in their methods by preserving tooth structure whenever possible. Solheim (1989:189–197) was one of the defenders of non-invasive methods, another being Bang and Ramm (1970:29).

NON-SPECIFIC STRESS INDICATOR; DENTAL HYPOPLASIA

Non-specific-stress indicator structures are not disease conditions per se but rather the effects that a number of chronic perturbations, diseases, malnutrition, starvation and various other metabolic insults have on an organism.

Dental hypoplasia is a quantitative deficiency of enamel. Per definition, dental enamel hypoplasia is a deficiency in enamel thickness (to the extent of total absence) resulting from a disruption in the matrix formation phase of amelogenesis (Goodman & Rose 1991:281, cf. Ash & Nelson 1940:31). The developing tooth is a unique biological recorder of both health and disease, mainly because of the influence that metabolic conditions have on tooth development. Sarnat and Schour (1941:1989) reported that the development of enamel and dentine yield permanent, accurate and punctual records of both the normal fluctuations and pathologic accentuations of mineral and general metabolism. Because of the rhythmic and orderly growth patterns of dental enamel structures, recording of changes can be pinpointed as to when causative factors and resultant defects occurred.

CONCLUSION

The value of teeth in bioarchaeological remains has undoubtedly been proven in the discipline of palaeodemography in all its aspects, as well as in other relevant scientific fields such as archaeology, physical anthropology, developmental biology, palaeoanthropology, anatomy, genetics, primatology, and forensic odontology.

The result of the dental morphology study conducted by Ullinger et al. (2005:474) regarding the question whether an influx in the Late Bronze–Early Iron Age of the southern Levant was feasible, proved to be negative. There is no dental morphological evidence of a major population incursion at Dothan or Lachish during the period in question. The ASUDAS data and the author's research do not support the model of an "Israelite conquest" or of any other population group.

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