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Dental Morphology, Dental Health and its Social Implications

Introduction

Dentists (and doctors) were designated ibHy or swnw (Nunn 1996). The first documented dentist was Hesy-ra in Dynasty III, c. 2650 BC, who was designated as 'chief of doctors and dentists' (Roberts and Manchester 1995). This link between dentistry and doctors is important as it demonstrates the inclusive nature of Egyptian bodily health. There is no written evidence for dentistry before the Old Kingdom, and therefore this study assesses dental health in the Predynastic and early Old Kingdom in order to assess the impact upon individual health and the associated social implications.

Teeth can be studied to obtain a measure of the health of an individual over their lifetime, and to provide information about genetic ancestry, diet, the oral hygiene and dentistry, the level of biological stress experienced in childhood, the occupation and repeated activities undertaken by the individual, cultural behaviours, and the subsistence economy of the population. Of these, health and oral hygiene and their links to diet will be considered in this paper.

Given the changes in social organisation associated with the formation of a unified state, a linked change in food production and distribution is likely. This social transition is marked by a change from a hunter-gatherer mode of subsistence to one increasingly dependent on agriculture, potentially associated with an increase in concentration upon cereal production (Midant-Reynes 2000; Wetterstrom 1993). By the early Predynastic, domesticates included goats, sheep, bovids, and pigs; this was associated with some hunting, such as of gazelles. Barley and emmer were being cultivated, possibly alongside peas, lentils and vetch. By the early Dynastic period there was the relative abandonment of pastoralism and the adoption of intensified agriculture, with increasing use of artificial irrigation. By this period, diet consisted primarily of C3 plant resources forming the staple, largely in the form of bread and beer produced from emmer wheat and barley. Both the loaves of bread and the beer provided plenty of carbohydrate in the diet. Furthermore, artistic representations of beer and bread production are most common from the Old Kingdom (Samuel 1993). A wide range of vegetables were also cultivated. Animals kept for consumption commonly included goats, sheep and pigs, whilst dairy products were supplied by ovicaprids and cattle (Ikram 2000; Osborn and Osbornova 1998).

Fig. 1. Stela of Hesy-ra. Cairo Museum, JdE 28504, image courtesy of Carol Andrews.

Tooth Morphology and Dental Wear

The key feature of tooth anatomy for this study is that, unlike bone, dental tissues are not remodelled during life. This means that tooth dimensions and morphology, where unaffected by dental wear, retain traits that are associated with genetic ancestry.

Dental wear begins with dentine exposure on the occlusal surfaces of a tooth, and is progressive with age. Dental attrition starts with the wearing away of the tips of the cusps, leading to a gradual reduction in cusp height and finally causes flattening of the occlusal surfaces. This can lead to the destruction of a tooth crown in advanced age and can cause teeth to be lost through abscesses and other effects of excessive wear. Dentine exposure generally progresses from one tooth to another in order of tooth eruption, starting with the first molar (M1).

Most adult teeth show some evidence of attrition due to the abrasive nature of the food consumed. In Egyptian populations, most abrasive matter results from grinding corn with stone and contamination of the grain with wind-blown sand (Leek 1972a; Ruffer 1920). Factors involved in dental attrition include:

1. the nature of the diet,
2. the relative toughness of the diet,
3. the abrasiveness of the food,
4. the fibrousness of the food, and
5. the way in which the food is prepared (Ibrahim 1987).

The quality of the food determines the amount of bite force required to perform mastication. Tough fibrous food requires a greater amount of stress to be exerted on and by the teeth, thus producing heavier wear on the occlusal surfaces of the teeth than consumption of soft refined foodstuffs. Dental attrition, including both wear and abrasion, therefore depends not only upon masticatory function, diet, and food processing techniques, but also on the timing and sequence of tooth eruption, tooth form, position of the tooth, sex, and the thickness and hardness of the enamel.

Within Egyptian populations, most studies have suggested that dental wear decreases with increasing technological development. These studies assume that since diet is the major contributor to tooth wear, a change in dietary composition will lead to a change in the masticatory role of the teeth. Grilleto (1977, 1978, 1979) found greater dental wear in early Predynastic individuals from Gebelein than in a wide-ranging Dynastic sample, mainly from Gebelein and Assiut. He argued that this reflected more elaborate food preparation techniques in the later populations. Ibrahim (1987) found that Predynastic samples showed significantly greater wear than Dynastic and Late Period groups, but these results contrast with Hillson (1978, 1979) who noted lower dental attrition in a Predynastic sample than Dynastic (mainly Nubian) populations. Hillson (1978) also noted that the wear in the anterior teeth relative to the wear in the posterior teeth was lower in his earlier sample. Both Ibrahim (1987) and Hillson (1978) also noted greater wear in their Upper Egyptian samples than in their Middle Egyptian samples. This geographical pattern of wear may reflect socio-economic, nutritional, and food quality variations, due to the drier and sandier environmental conditions of Upper Egypt as compared with Middle Egypt. Ruffer (1920) noted greater dental wear in Upper Egyptians, including Nubians, than in a Lower Egyptian potentially temporally later sample. (Ruffer did not divide his sample by time period, but it appears that the northern sample dates from a later period than the southern material.)

Materials and Methods

The samples studied are shown in Table 1. All skeletons were studied by the author and were selected for their relative cranial completeness and preservation, and for the documentation regarding their excavation and collection. Only adult crania were studied, with permanent third molar eruption or complete fusion of postcranial epiphyses being used as marker of skeletal maturity. The sample consists of 418 individuals from whom 2630 teeth were measured. The populations studied are all from a relatively localised area in Upper and Middle Egypt, thereby avoiding skeletal and dental variation due to differing environmental conditions. The Middle Kingdom sample was included here as an out-group for comparison with the earlier periods.

Table 1. Skeletal (dental) samples included in current study

Period	Sample (cemeteries)	Collection	N ♂	N ♀
Badari	El-Badari	Duckworth	22	27
EPD	Abydos, El-Amrah & Gebelein	NHM & Marro	39	41
LPD	El-Amrah & Hierakonpolis	Duckworth & NHM	31	41
EDyn	Abydos & El-Amrah	Duckworth & NHM	55	42
OK	Regagnah, Meidum & Gizeh	NHM & Vienna	60	38
MK	Gebelein	Marro	13	9

Where Badari refers to the Badarian population, EPD to the Early Predynastic, LPD to the Late Predynastic, EDyn to the Early Dynastic, OK to the Old Kingdom and MK to the Middle Kingdom. Duckworth refers to the Duckworth Collection of the University of Cambridge, NHM to the Natural History Museum, Marro to the Marro Collection of the University of Turin and Vienna to the Naturhistorisches Museum in Vienna.

Maximum bucco-lingual and maximum mesio-distal diameters were measured for each tooth in the dental arcade, following Buikstra & Ubelaker (1994). Maximum values were taken rather than contact values in order to reduce intra-observer error, following Calcagno (1986). As all crown dimensions decrease with wear, crown size cannot simply be calculated. The most reliable indicator of size is tooth breadth (bucco-lingual distance) as the mesio-distal diameters are more affected by occlusal and interproximal wear. The scoring technique for dental wear used, following Molnar (1971) and Ibrahim (1987), takes into consideration the location of the tooth in the dental arch and therefore can be used to assess for differences in wear through the arcade.

Tooth Size Results

Using a paired t-test, no statistically significant differences in the size of the bucco-lingual diameters were found between right and left antimeres within individuals. As shown in Table 2, using a type I hierarchical linear model, correcting initially for sex and then assessing for differences in bucco-lingual size through time, only one tooth (lower 2nd premolar) showed significant differences in size by time period.

Table 2. Results of univariate ANOVA, type I model for bucco-lingual tooth diameter.

Tooth	n	Sex		Period		Sex & Period interaction	
		F	p	F	p	F	p
UI1	74	2.99	0.089	0.47	0.795	0.29	0.884
UI2	108	8.94	0.004	0.60	0.702	0.26	0.936
UC	173	15.79	<0.001	2.11	0.067	1.37	0.237
UP1	234	8.31	0.004	1.40	0.224	2.35	0.042
UP2	239	2.03	0.156	1.27	0.280	1.78	0.119
UM1	266	6.94	0.009	0.44	0.820	3.53	0.004
UM2	258	11.19	0.001	1.85	0.103	4.12	0.001
UM3	190	4.27	0.040	1.85	0.105	1.22	0.303
LI1	71	3.91	0.053	0.09	0.986	2.35	0.064
LI2	93	1.54	0.219	0.40	0.808	0.85	0.496
LC	117	12.76	0.001	1.44	0.217	1.84	0.127
LP1	145	4.64	0.033	0.25	0.937	2.75	0.031
LP2	153	0.35	0.554	4.11	0.002	1.31	0.269
LM1	176	0.57	0.450	0.38	0.857	1.98	0.084
LM2	181	8.80	0.003	1.01	0.414	1.97	0.102
LM3	152	3.61	0.060	1.04	0.397	2.03	0.094

Significant results (at the 95% level) are shown in bold.

The table shows that only the lower second premolar (LP2) exhibits significant change through time. As this tooth exhibits no sexual dimorphism, Figure 2 plots bucco-lingual diameter through time with sexes pooled. This graph shows that the significance result arises because the later Predynastic sample is significantly different in size from the early Predynastic and Middle Kingdom samples; the later Predynastic LP2 sample is, however, very small both in absolute terms and in comparison with the other periods.

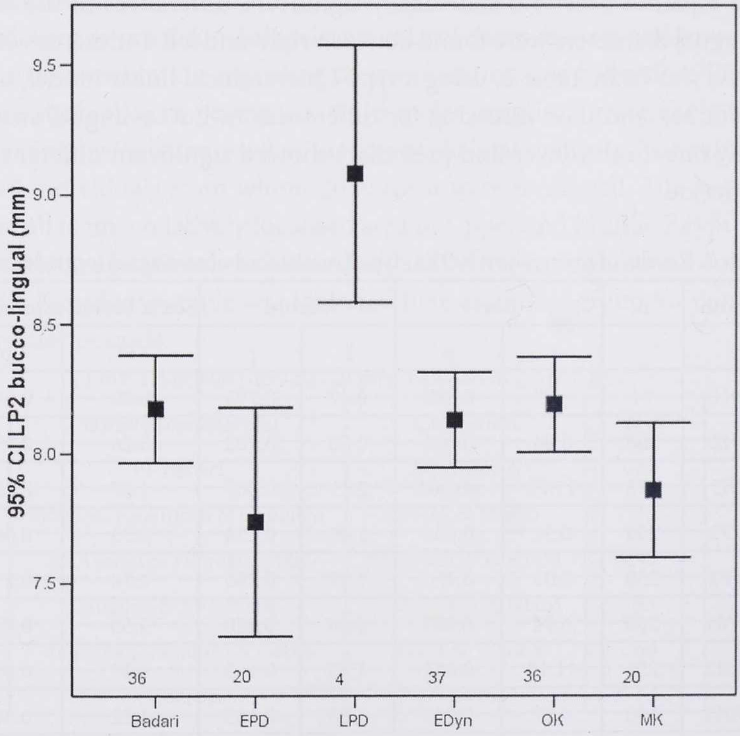

Fig. 2. Change in bucco-lingual diameter of the lower 2nd premolar through time, sexes

Nine of the teeth exhibited significant sexual dimorphism in size, including both canines and first premolars, all upper molars and the second lower molar. As expected, the females generally have smaller teeth than the males.

Dental Health Results

Aspects of adult health are reflected in the teeth through the presence of caries, abscesses and periodontal disease.

The presence of caries is directly related to the presence of sugars in the diet of the population, and may be inversely related to the degree of dental wear and attrition. Thus it would be expected that caries prevalence would increase through time as greater varieties of sugary foods became available to the Egyptian population. This study has relied simply on count of caries. In total, 92 teeth had carious lesions, i.e. 2.36 % of the available teeth.

Since many caries within one individual are intrinsically related, individuals were scored as either having or lacking caries. This was then assessed through time. The Pearson Chi-square indicates that time period and the presence or absence of caries is not independent ($\chi^2 = 19.55$, p=0.002). The variation in the proportions of each time group having at least one carious lesion is shown in Fig. 3.

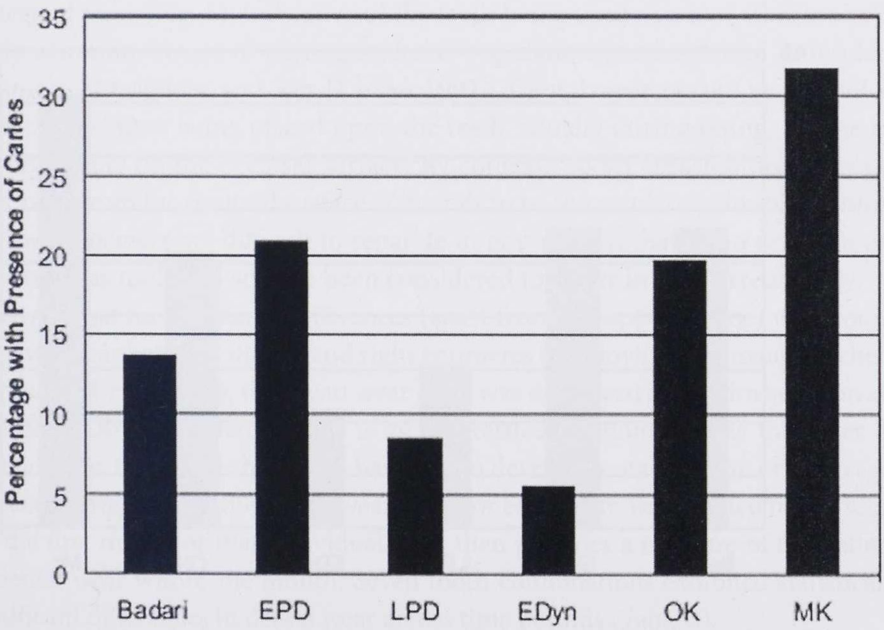

Fig. 3. Percentage of individuals by time period with presence of at least 1 carious lesion.

As expected, the later groups have significantly higher levels of incidence of caries than the early Dynastic group, with the out-group from the Middle Kingdom having highest proportion of the population sample with caries.

Dental Abscessing

Dental caries can predispose the development of a dental abscess. Most abscesses are caused by a caries infection spreading through the pulp chamber of the tooth and into the alveolar bone, or by excessive attrition which results in inflammation of the pulp chamber. Eventually the pus-filled abscess bursts through the bone to release the pus, thus forming a distinctive drain hole. Abscesses can also form if there is an accumulation of plaque between the soft tissue of the gum and the teeth (Hillson, 1996).

Since the presence of many abscesses within one individual may have a common cause, individuals were scored as either having or lacking the presence of at least one abscess. Chi-square analysis of prevalence by sex indicated that abscess presence is independent of sex ($\chi^2 = 2.24$, $p=0.135$). However, like caries presence, abscess presence is not independent of time period ($\chi^2 = 15.54$, $p=0.008$, Fig. 4).

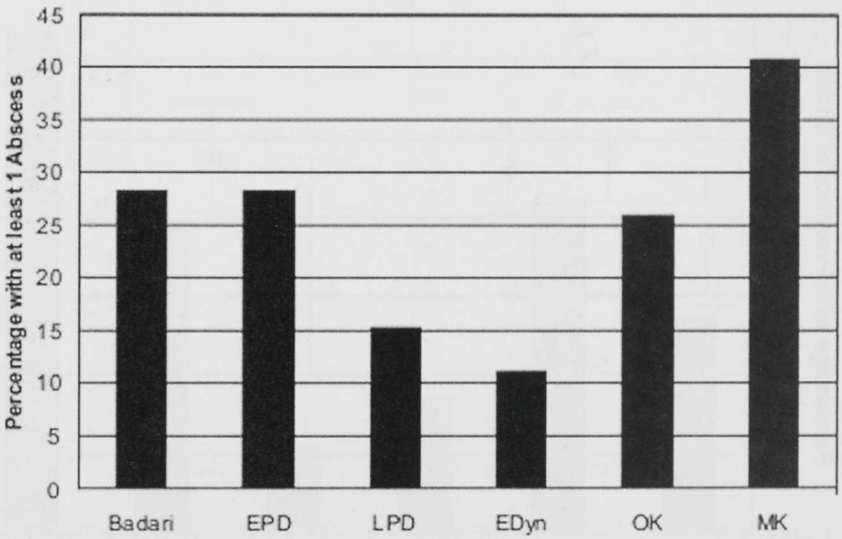

Fig. 4. Percentage of individuals by time period with presence of at least 1 abscess.

The shape mirrors that of caries presence (Fig. 3), suggesting some relationship between the two. This is supported by statistical analysis ($\chi^2 = 26.03$, $p<0.001$).

Dental Wear Results

Each tooth was also awarded a wear code, following Molnar (1971). As noted earlier, this scoring takes into consideration the order of eruption of the permanent dentition; a tooth that erupts earlier should have a higher degree of wear than a later erupting tooth. Codes 1 and 2, for no wear or wear facets only, mean that there is only simple flattening of the enamel cusps and would be asymptomatic to the individual concerned. Codes 3 and 4, which are for teeth with small dentine patches, develop when dentine exposure occurs, leading to some discomfort to the individual. Code 5 is an intermediate wear level, with some moderate level of dentine exposure. Codes 6 and 7, for teeth with large dentine patches and/or the edge of the tooth crown being worn down with exposure of the pulp cavity, occur when the rate of abrasion of the primary dentine exceeds the rate of deposition of the secondary dentine. At this stage of wear the individual would experience severe pain as the nerves become exposed. The last possible code, code 8, is for teeth with very advanced wear, with the tooth roots functioning in the occlusal surface. The most noticeable feature of the teeth from the Badarian sample is the severe pattern of wear (Fig. 5), indicative of the teeth being used as a tool. This is a relatively common feature of non-agricultural populations, and is found in modern Eskimos, Aborigines, and San (Larsen 1997). Dental wear occurs as a result of masticatory stress being placed upon the teeth, usually during biting, and hence mainly occurs on the occlusal surface. By contrast, tooth abrasion normally occurs away from the occlusal surface and tends to be the result of cultural activities. The two processes are difficult to separate in populations that upon occasion use their teeth as tools and so have been considered together in the current study.

Given that no significant differences (apart from the upper canine) were found in dental wear between the left and right antimeres (employing Wilcoxon matched-pairs signed-ranks test), the mean wear code was employed to maximise the available data. Obviously dental wear is an age-related phenomenon as the older an individual is, the longer their teeth have had to develop dental wear. In order to age-correct the wear score, the dental wear score for each tooth was divided by the score for the first molar for that individual. This then provides a measure of the pattern of dental wear within the mouth. Seven tooth combinations exhibited statistically significant differences in dental wear across time periods (Table 3).

Discussion

The results of the dental analyses presented suggest that the individuals studied did having differences in their diet, or at least in some aspects of their diet. The presence of caries is directly related to the presence of sugars in the diet of the population (Hillson 1979). Given the increase in consumption of sugars through time, such as the presence of honey in the Middle Kingdom (Darby et al., 1977),

Fig. 5. Severe pattern of wear in specimen AF.11.5.21 from el-Badari (Duckworth Collection).

it would be expected that caries prevalence would roughly increase through time. In total, 92 teeth had carious lesions, i.e. 2.36 % of the available teeth. Cavities in teeth, due to caries, have rarely been found in Egyptian archaeological samples (Koritzer, 1968; Leek, 1972a, 1972b; Ruffer, 1920), despite being the most commonly dental disease in archaeological populations (Roberts and Manchester, 1995). This study noted significant differences through time in the proportions of the Egyptian population having at least one carious lesion in their dentition (varying from approximately 5% to 35% of individuals in any time period sample being affected). As expected, the out-group from the Middle Kingdom studied here had significantly higher levels of incidence of caries than the Predynastic and early Dynastic groups. This is similar to Hillson (1979), who noted lower levels of caries in a Predynastic sample than a later (mainly Nubian) sample, and attributed this to less extensive plaque deposits on the teeth of the Predynastic individuals due to their lower intake of sugars. The pattern of the current curve of caries presence, with the increase in prevalence through the early Predynastic, followed by

Table 3. Results of Kruskal-Wallis tests, for pooled sex samples, showing differences in dental wear patterns between time periods

Teeth	n	χ^2	p
UI1 / UM1	43	3.25	0.661
UI2 / UM1	57	6.17	0.290
UC / UM1	121	11.9	0.036
UP1 / UM1	204	14.4	0.013
UP2 / UM1	219	13.3	0.021
UM2 / UM1	239	25.6	<0.001
UM3 / UM1	172	21.4	0.001
LI1 / LM1	50	6.79	0.148
LI2 / LM1	64	7.58	0.108
LC / LM1	75	8.17	0.086
LP1 / LM1	124	13.0	0.023
LP2 / LM1	136	16.4	0.006
LM2 / LM1	163	3.04	0.694
LM3 / LM1	130	1.23	0.942

Significant results (at the 95% level) are shown in bold.

decline to the early Dynastic, is unexpected, and suggests a complex relationship with diet and food consumption. The pattern of abscess presence matches that of caries, and hence also suggests changes in diet over time.

Tetracycline in food or beer may have had some effect upon caries and abscess presence, as its presence has been linked to very low levels of bone diseases (Armelagos et al., 1981); this has been suggested as a possible cause of the low level of caries infection (Rose et al., 1993). Tetracycline labelling has been found in the enamel matrix of some teeth dating from the Roman occupation of the Dakhleh Oasis (Cook et al., 1989), and so its presence might be hypothesised in earlier groups.

Extensive dental wear has also been suggested as providing a more difficult environment for decay to begin (Harris et al., 1998). Caries presence is usually considered to reduce in frequency with increasing rates of dental wear (Hillson 1996). The current study, however, found on opposite trend, with caries prevalence tending to increase with grade of dental wear. Within Egyptian populations, most studies conclude that the expression of dental wear decreases through time with increasing technological development. These studies assume that since diet is the major contributor to tooth wear, a change in dietary composition will lead to a change in the masticatory role of the teeth. Grilleto (1977, 1978, 1979) found greater wear in early Predynastic individuals than in a broad range Dynastic sample, which he argued reflected more complex or elaborate food preparation techniques by the later populations. Ibrahim (1987) found greater dental wear in Predynastic populations, including a Badarian sample, than Dynastic and Late Period groups. Hillson (1978, 1979), by contrast, noted lower dental attrition in Predynastic individuals than in Dynastic (mainly Nubian) individuals. Here a temporal change in the pattern of dental wear within the mouth itself has been noted. This means that the degree of dental wear accruing on each tooth is changing through time, suggesting a change in some aspect of diet.

A reduction in tooth size within Nubian Nile Valley populations over time has been noted (Calcagno 1986; Carlson and van Gerven 1977; Chamla 1980; Smith 1980). This is expected because, as food becomes more refined and food preparation techniques more complex and sophisticated, less masticatory force is required to process these softer foodstuffs and therefore complex masticatory apparatus, such as large teeth, are no longer required. No such temporal trend was found in the Egyptian samples, suggesting no real change in the amount of masticatory force required for food consumption. Given the change in dental wear within the dentition found, some particular aspects of diet must be changing.

Aspects of the actual diet of individuals can be reconstructed through stable isotope analyses. This typically involves analysis of the carbon and nitrogen concentrations within the bone collagen. The nitrogen concentration provides an indication of the protein consumption, and therefore is a marker of trophic level. The higher the nitrogen value (^{15}N), the greater the amount of protein consumed by that particular individual. The carbon value provides an indication of the type of plant material being consumed by either that particular person, or by the animals upon which that person subsisted. Scientifically, plants are divided into two photosynthetic pathways, C_3 and C_4, with the former generally covering temperate plants and the latter more arid-loving tropical plants. An individual whose collagen has relatively high carbon values (^{13}C) will have consumed more tropical grasses (such as sorghum or millet) or animals that ate such tropical grasses. Egyptians, from both Nile Valley and oases sites, appear to have had a diet based upon more temperate plants, such as emmer wheat and barley (Dupras et al. 2001; Iacumin et al. 1996, 1998; Macko et al. 1999; Thompson *et al.* 2005). From the Badarian period through to the later Dynastic period, the human isotopic values tend to cluster together, with high$\delta^{15}N$ ratios, potentially due to freshwater fish consumption, and $\delta^{13}C$ values indicating a largely C_3 cereal based diet. These results suggest a lifetime diet based either upon C_3 plants themselves, such as wheat and barley, or upon animals consuming these plants, accompanied by either Nile fish or fauna with unusually high $\delta^{15}N$ values due to high desert aridity. It is worth remembering that given the slow turn-over of bone in the body, stable isotope reconstruction of diet only permits long-term diet to be analysed, and does not enable recent or short-term changes in diet to be identified.

The isotopic results suggest continuity of dietary constituents from the Badarian period through the later Dynastic period. This, therefore, contrasts somewhat with the results from the gross dental analyses. It is likely that what was actually being eaten did not in itself change over the Predynastic and early Dynastic periods, but rather that the way people ate changed or the ways in which the foodstuffs were prepared changed. This links to the hypothesised changes in food processing techniques predicted earlier. It is also extremely likely that these changes in and potential increases in complexity of food preparation techniques might also reflect changes in social organisation.

The link between the morphology of the dentition and social organisation is not unexpected as teeth were used as a social marker from the Neolithic period onwards, e.g. teeth being placed in the orbits during funerary treatment at Gebel Ramlah (Irish et al. 2005). Dental treatment may also occur within early Dynastic Egypt, as most named dentists derive from the Old Kingdom (Miller 2008), even if this treatment might have been somewhat rudimentary. There is little evidence that dentists had much effect on the dental health of the Egyptian samples studied. Some possible cases of tooth extraction were found. At most six individuals had reasonably clear evidence of tooth extraction: five were of incisors and one premolar. Of these possible extractions, two were in the Badarian sample, two from the Dynasty I sample from Abydos, and two from the Old Kingdom. It is unlikely that all dental care involved specialized dentists, but 'dentists' may have been involved in aiding the extraction of teeth when severe periodontal disease was present and the supporting alveolar bone was already naturally lost. It does, however, indicate the importance of the dentition to the ancient Egyptians themselves.

Conclusions

Dental health appears to have declined through the Dynastic period relative to the Predynastic. This may reflect both dietary variation and aspects of social life. Certain features of the diet have been shown to change between the early Predynastic and the Middle Kingdom and these are either linked to or mirror changes in Egyptian social organisation. The actual chemical composition of the foodstuffs themselves does not appear to change, but the processing techniques involved in food preparation appear to have changed the physical consistency of the foodstuffs, thereby affecting the dental wear and hence dental health of the individuals. Teeth, and by implication dentistry, have been shown here to provide a guide to markers of social identity and hence of social organisation within Egypt, and thus indicate the importance of the dentition to the ancient Egyptians themselves.

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REFERENCES

ARMELAGOS, G. J., JACOBS, K. H., MARTIN, D. L. 1981. Death and Demography in Prehistoric Sudanese Nubia. In: S, C. Humphreys, H. King (eds), *Mortality and Immortality. The Anthropology and Archaeology of Death.* London. Academic Press.

BUIKSTRA, J. E. and D. H. UBELAKER (eds). 1994. *Standards for Data Collection from Human Skeletal Remains.* Fayetteville. Arkansas Archeological Society.

CALCAGNO, J. M. 1986. Dental Reduction in Post-Pleistocene Nubia. American *Journal of Physical Anthropology* 70: 349-363.

CARLSON, D. S. and D. P. VAN GERVEN. 1977. Masticatory Function and Post-Pleistocene Evolution in Nubia. *American Journal of Physical Anthropology* 46: 495-506.

CHAMLA, M-C. 1980. Étude des Variations Métriques des Couronnes Dentaires des Nord-Africains, de l'Épipaléolithique à l'Époque Actuelle. *L'Anthropologie* 84: 254-271.

COOK, M., MOLTO, E., ANDERSON, C. 1989. Fluorochrome Labelling in Roman Period Skeletons from Dakhleh Oasis, Egypt. *American Journal of Physical Anthropology* 80: 137-143.

DARBY, W. J., GHALIOUNGUI, P., GRIVETTI, L. 1977. *Food: The Gift of Osiris*. London. Academic Press.

DUPRAS, T. L., SCHWARCZ, H. P., FAIRGRIEVE, S. I. 2001. Infant feeding and weaning practices in Roman Egypt. *American Journal of Physical Anthropology* 115: 204-12.

GRILLETO, R. R. 1977. Carie et Usure Dentaire Chez les Égyptiens Prédynastiques et Dynastiques de la Collection de Turin (Italie). *L'Anthropologie* 81: 459-472.

GRILLETO, R. R. 1978. Osservazioni sulla Carie Dentaria e sull'Usura dei Denti in una Serie di Crani Egiziani Predinastici. *Dental Cadmos* 46: 66-72.

GRILLETO, R. R. 1979. Comparaison entre les Egyptiens Dynastiques d'Asiut et de Gebelen au Niveau de la Carie et de l'Usure des Dents. In: W. F Reineke (ed.), *First International Congress of Egyptology - Actes, 2-10 October 1976*: 249-253. Berlin. Akademie Verlag.

HARRIS, J. E., PONITZ, P. V., INGALIS, B. K. 1998. Dental Health in Ancient Egypt. In: A. Cockburn, E. Cockburn, T. A. Reyman (eds), *Mummies, Disease and Ancient Cultures*. Cambridge. Cambridge University Press.

HILLSON, S. 1996. *Dental Anthropology*. Cambridge. Cambridge University Press.

HILLSON, S. W. 1978. Human Biological Variation in the Nile Valley, in Relation to Environmental Factors. Unpublished PhD thesis, University of London.

HILLSON, S. W. 1979. Diet and Dental Disease. *World Archaeology* 11: 147-162.

IACUMIN, P., BOCHERENS, H., CHAIX, L., MARIOTH, A. 1998. Stable Carbon and Nitrogen Isotopes as Dietary Indicators of Ancient Nubian Populations (Northern Sudan). *Journal of Archaeological Science* 25: 293-301.

IACUMIN, P., BOCHERENS, H., MARIOTTI, A., LONGINELLI, A. 1996. An isotopic palaeoenvironmental study of human skeletal remains from the Nile Valley. *Palaeogeography, Palaeoclimatology, Palaeoecology* 126: 15-30.

IBRAHIM, M. A. 1987. A Study of Dental Attrition and Diet in Some Ancient Egyptian Populations. Unpublished PhD thesis, Durham University.

IKRAM, S. 2000. Meat processing. In: P. T. Nicholson, I. Shaw (eds), *Ancient Egyptian Materials and Technology*: 656-671. Cambridge. Cambridge University Press.

IRISH, J. D., KOBUSIEWICZ, M., KABACINSKI, J., SCHILD, R. 2005. Two Additional Egyptian Neolithic Burials Exhibiting Unusual Mortuary Treatment of Teeth. *International Journal of Osteoarchaeology* 15: 136-139.

KORITZER, R. T. 1968. An Analysis of the Cause of Tooth Loss in an Ancient Egyptian Population. *American Anthropologist* 70: 550-553.

LARSEN, C. S. 1997. *Bioarchaeology. Interpreting Behaviour from the Human Skeleton*. Cambridge. Cambridge University Press.

LEEK, F. F. 1972a. Bite, Attrition and Associated Oral Conditions as Seen in Ancient Egyptian Skulls. *Journal of Human Evolution* 1: 289-295.

LEEK, F. F. 1972b. Teeth and Bread in Ancient Egypt. *Journal of Egyptian Archaeology* 58: 126-132.

MACKO, S. A., ENGEL, M. H., ANDRUSEVICH, V., LUBEC, G., O'CONNELL, T. C., HEDGES, R. E.M. 1999. Documenting diet in ancient human populations through stable isotope analysis of hair. *Philosophical Transcations of the Royal Society of London, Series B* 354: 65-76.

MIDANT-REYNES, B. 2000. *The Prehistory of Egypt*. Oxford. Blackwell.

MILLER, J. 2008. Dental health and disease in ancient Egypt. In: R. David (ed.), *Egyptian Mummies and Modern Science*: 52-70. Cambridge. Cambridge University Press.

MOLNAR, S. 1971. Human Tooth Wear, Tooth Function and Cultural Variability. *American Journal of Physical Anthropology* 34: 175-190.

NUNN, J. F. 1996. *Ancient Egyptian Medicine*. London. British Museum Press.

OSBORN, D. J. and J. OSBORNOVA. 1998. *The Mammals of Ancient Egypt*. Warminster. Aris & Phillips.

ROBERTS, C. and K. MANCHESTER. 1995. *The Archaeology of Disease*. Ithaca, New York. Alan Sutton.

ROSE, J. C., ARMELAGOS, G. J., PERRY, L. S. 1993. Dental Anthropology of the Nile Valley. In: W. V. Davies, R. Walker (eds), *Biological Anthropology and the Study of Ancient Egypt*: 61-74. London. British Museum Press.

RUFFER, A. 1920. Study of Abnormalities and Pathology of Ancient Egyptian Teeth. *American Journal of Physical Anthropology* 3: 335-382.

SAMUEL, D. 1993. Ancient Egyptian Bread and Beer. An Interdisciplinary Approach. In: W. V. Davies, R. Walker (eds), *Biological Anthropology and the Study of Ancient Egypt*. London. British Museum.

SMITH, P. 1980. Regional Diversity in Epipaleolithic Populations. *Ossa* 6: 243-250.

THOMPSON, A. H., RICHARDS, M. P., SHORTLAND, A., ZAKRZEWSKI, S. R. 2005. Isotopic palaeodiet studies of Ancient Egyptian fauna and humans. *Journal of Archaeological Science* 32: 451-463.

WETTERSTROM, W. 1993. Foraging and farming in Egypt. The transition from hunting and gathering to horticulture in the Nile Valley. In: T. Shaw, P. Sinclair, B. Andah, A. Okpoko (eds), *The Archaeology of Africa: Food, Metals and Towns*: 165-226. London. Routledge.