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A STUDY OF THE MOLAR TEETH OF THE BRONZE AGE HARAPPANS IN THE CONTEXT OF EVOLUTIONARY BIOLOGY

ABSTRACT. — Using the molar teeth of the Bronze Age Harappans, this study examines the two different hypotheses that have been postulated at explaining the reduction in human dentition since the end of the Pleistocene. The study discusses inappropriateness of these two hypotheses. The information available from this investigation clearly suggests that selection pressure favoured smaller molar size, and thereby smaller grinding area, adapted to the need to grind and chew soft cooked food. A set of large molars, earlier beneficial for mastication of tough food, would indeed be unfit.

KEY WORDS: Molar Teeth—Bronze Age—India—Harappa.

INTRODUCTION

Structural reduction in human dentition during the post-Pleistocene has been studied and recorded by many. Notable among them are Keith (1920, 1923, 1924, 1928), Brabant & Twiesselmann (1964), Lunt (1969), Greene (1970, 1972), and Brace & Mahler (1971). This phenomenon of change in dentition is a product of ongoing biological evolution.

Two different kinds of hypotheses have been postulated at explaining this phenomenon of size reduction in human dentition. One of these seeks to explain the reduction not on the basis of positive selection pressure. It is argued upon that cooking pots make possible transformation of hard food items to drinkable consistency. This means, otherwise, that teeth are no longer really necessary for survival. Furthermore, the substitution of tools, e.g. knives, for rendering and tearing substances in place of larger dentition is viewed to have resulted in relaxation from selection pressure. It is therefore proposed that this lack, or relaxation, will result in dental reduction through the mechanism of the Probable Mutation Effect (Brace, 1963, cf. Brace & Mahler, 1971). The proposition, as claimed, is somewhat analogous to the condition of relaxed selection pressure as suggested in the case of defective colour vision (Post, 1962, cf. Dutta, 1966).

The other hypothesis contends the reduction in size and complexity of teeth on the basis of positive selection for caries-resistant teeth in increasingly cariogenic environment after the Neolithic period (Greene, 1970). It is viewed that after the introduction of cariogenic carbohydrate cooked food "natural selection favoured less complex teeth with their propensity towards fewer caries and consequently smaller teeth" (Greene, 1972).

With this background, the study intends to investigate the phenomenon of reduction utilising the molar teeth of the Bronze Age Harappans who lived in the Indus Valley during the third millennium BC. First, it examines whether molar teeth of the Harappans provide evidence for a relative reduction in size compared to other chronologically earlier populations. And, secondly, if it is affirmative, and with a pattern, how then that could meaningfully be explained commensurate with the dynamics of evolutionary biology. It needs to be said that the molars have only been utilised for investigation because, of the dentition, they are believed to be particularly, relatively stable throughout the process of human evolution (Kraus, 1963: 87).

Contextually, mention may be made that the result of a detailed odontometric analysis of molar teeth of Harappa people has recently been reported upon by Dutta (1983).

MATERIAL AND METHOD

Cross-sectional area (CSA) of molar crown is considered as a good indicator of biological response because of its variation over populations (Brace & Mahler, 1971: 194). This has been calculated on the basis of two metric measurements of molar crown diameters, namely buccolingual (BL) and mesiodistal (MD), obtained from 323 molars of the Harappa series, as given in Gupta, Dutta & Basu, 1962). The CSA of each molar is the product of its BL and MD diameters, i.e. $CSA = BL \times MD$. This measure, also known as the Robustness value (Weidenreich, 1937; Pederson, 1949; Senyürek, 1959), provides indication of the overall size of tooth crown.

The method of comparative analysis with the help of a non-parametric statistical approach has been adopted for drawing inferences.

ANALYSIS AND RESULTS

Table 1 presents the data on mean cross-sectional area (CSA) of molars for various available prehistoric populations that preceded the Bronze Age Harappans. The populations compared are: the Middle Palaeolithic Neanderthals inferred mostly from the Krapina material (Brace, 1962) including some others (Patte, 1962), the Upper Palaeolithic populations principally derived from Předmostí series (Matiegka, 1934) together with some from other sources, the Mesolithic populations from Wadi Halfa in Sudan (Greene, Ewing & Armelagos, 1967) and from Palestine (Dahlberg, 1960), and the Neolithic population from Jarmo in Iraq (Dahlberg, 1960). It may be mentioned that information on *Homo erectus,* which antidates the Neanderthals, has not been taken into account here because of their reportedly metric similarity in molars. It is thus believed that Neanderthal dentition should serve as better general model for the condition from which all modern forms evolved (Brace & Mahler, 1971: 192).

Comparison of data clearly reveals great differences in the CSA values between the Harappans and all other groups. The differences are so apparent that there is perhaps no need of any test to confirm them statistically. The evidence that the molars of the Bronze Age Harappans are smallest is indeed undeniable.

Furthermore, the information available from these populations suggests a systematic trend of reduction in molar size in a progressive order. This may readily be appreciated from the illustrations in *Figures 1—4.* From the reference population of the Middle Palaeolithic, a progressive reduction in molar size could be discerned in the Mesolithic and onto the Bronze Age. The Mesolithic Wadi Halfa molars do not fit well into the sequence, however. It has been suggested that the Wadi Halfa had attained large and complex teeth owing to rigor of selection (Greene, Ewing & Armelagos, 1967). Again, the Upper Palaeolithic Předmostí presents perhaps a case of distinct departure from this general trend, as an exception. But, on the whole, a trend of overall progressive reduction in molar size concomitant with the development of cultural complexity cannot escape attention.

TABLE 1. *Mean cross-sectional areas (CSA) in square millimetres of molars of various prehistoric populations*

Population	Maxillary molars			Mandibular molars		
	M^1	M^2	M^3	M_1	M_2	M_3
Middle Palaeolithic:						
Neanderthal	142.44(52) ±21.51	133.98(53) ±15.91	119.94(48) ±17.39	128.59(54) ±18.83	134.63(65) ±19.51	130.00(65) ±17.49
Upper Palaeolithic:						
Předmostí-East-Central Europe	129.45(31) ±14.62	127.37(30) ±18.27	117.00(22) ±19.97	125.48(58) ±15.22	121.69(52) ±17.15	117.53(34) ±20.33
Mesolithic:						
Wadi Halfa, Sudan	138.99(8)	136.53(9)	110.92(10)	139.75(9)	135.70(8)	135.70(6)
Natufian, Palestine	134.07(14)	127.05(11)	105.09(8)	124.20(16)	116.60(16)	113.36(13)
Neolithic:						
Jarmo, Iraq	123.12(5)	116.28(5)	89.88(1)	119.70(6)	111.10(6)	119.88(2)
Bronze Age:						
Harappa, Indus Valley	115.23(73) ±12.27	104.19(77) ±14.28	89.46(57) ±17.25	109.70(36) ±10.89	97.19(39) ±17.68	90.55(37) ±16.73

Note: The figures in parentheses are the sample size and ± indicates the standard deviations wherever they are available; comparative material drawn from Brace and Mahler (1971).

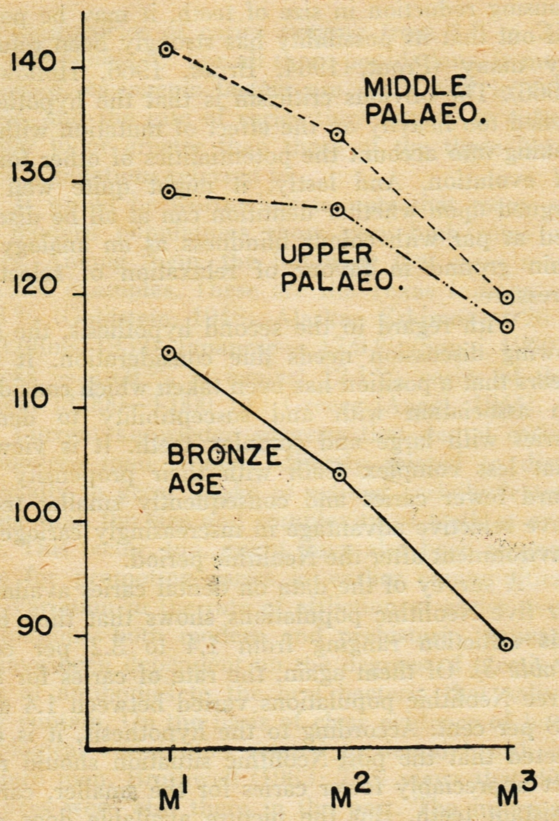

FIGURE 1. *Cross-sectional areas in square millimetres for the maxillary teeth of the Middle Palaeolithic, Upper Palaeolithic and Bronze Age populations.*

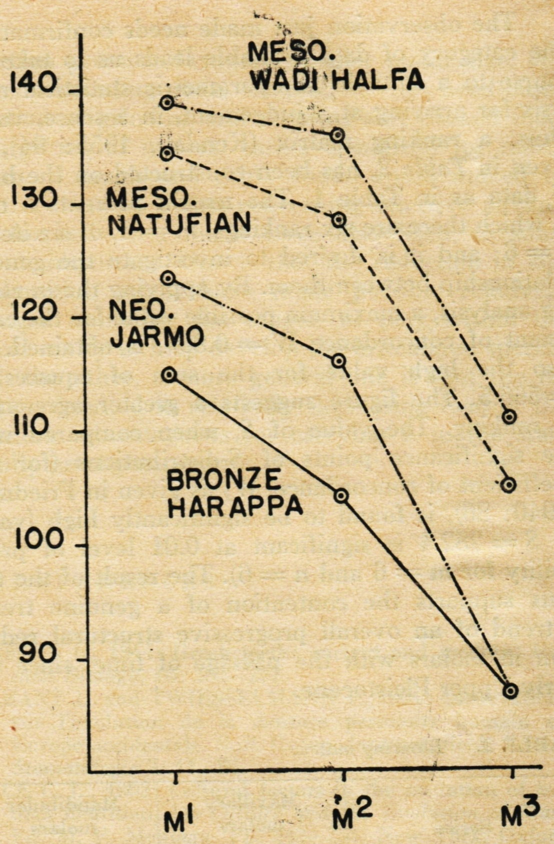

FIGURE 3. *Cross-sectional areas in square millimetres for the maxillary teeth of the Mesolithic, Neolithic and Bronze Age populations.*

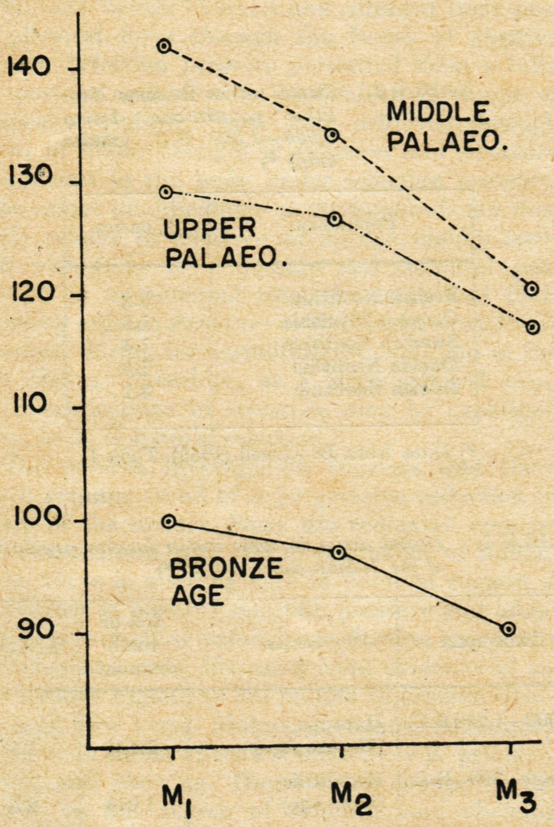

FIGURE 2. *Cross-sectional areas in square millimetres for the mandibular teeth of the Middle Palaeolithic, Upper Palaeolithic and Bronze Age populations.*

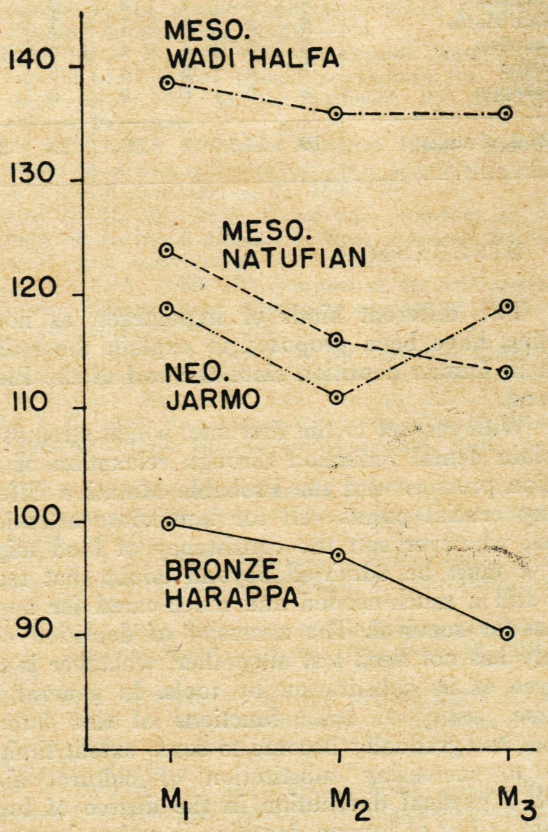

FIGURE 4. *Cross-sectional areas in square millimetres for the mandibular teeth of the Mesolithic, Neolithic and Bronze Age populations.*

The observation just made needs confirmation. The category of data available leads us to take recourse to a suitable non-parametric statistical analysis for arriving at a judgement, in a sense, valid. Thus, a ranking matrix (Kendall, 1955: 94), as given in *Table 2,* has been constructed on the basis of data as in Table 1. The matrix presents a case in which there are six rankings, $m = 6$, of six items, $n = 6$; and it is desired to investigate the general relationship between them. By applying the m ranking analysis, a maximum possible value for the coefficient of concordance $W = 0.899$, is obtained. So also the high value for the sum of squares, $S = 566.5$. The figure suggests a greater agreement in ranking. The value of S, when compared with the significance points of S-distributions (for the coefficient of concordance, W) as given in Friedman (1940: 86), is found to be significantly high (value of $S = 282.4$ is significant at 0.01 level of probability for $m = 6$ and $n = 6$). The result of the test thus supports the contention of a genuine trend, a trend of an overall progressive structural reduction in molars with the passage of time, since the early Upper Pleistocene.

TABLE 2. *Ranking matrix*

Series	Maxillary molars			Mandibular molars		
	M^1	M^2	M^3	M_1	M_2	M_3
Neanderthals	1	2	1	2	2	2
Předmostí	4	3.5	2	3	3	3
Wadi Halfa	2	1	3	1	1	1
Natufian	3	3.5	4	4	4	5
Jarmo	5	5	5	5	5	4
Harappa	6	6	6	6	6	6
Total of ranks	10	18.5	9	23.5	29	36

DISCUSSION

Two different kinds of hypotheses, as noted earlier, have been proposed to explain the reduction in human dentition since the end of the Pleistocene.

With respect to the first one, which attemps to explain dental reduction through relaxation of selection pressure and the Probable Mutation Effect, many crucial points call for immediate attention. First, whatever soft the consistency of food might be, it must be admitted beyond doubt that teeth are still a much-needed and much-cared for apparatus for survival. The necessity of dentition certainly has not been lost altogether, whatever is the degree of its substitution by tools. In general, of course, utility of basic functions of this human organ has gradually become to some extent limited due to increasing substitution of cultural aids. Such a gradual diminution in the degree of functional utility of human dentition is rather inversely related to the cultural development. Secondly, on the issue of the suggested Probable Mutation Effect causing reduction in size of teeth, it may be pointed out that its possibility has strongly been refuted by many (Prout, 1964, Brues, 1966, Holloway, 1966). The obvious criticism is that the hypothesis relied too heavily on the effect of mutation without taking into account the potentialities of other forces of evolution. And lastly, it might quite well be argued upon whether dentition can at all be discussed at par with colour blindness as an analogy to gain ground in favour of relaxation of selection pressure.

With regard to the second hypothesis, the following discussion needs due consideration. It appears that a position has been taken which considers an association with and susceptibility to dental caries with large and complex teeth. It is viewed that less complex teeth with their propensity toward fewer caries and consequently smaller teeth have selective advantage in increasingly cariogenic environment after the Neolithic period.

A survey of the data on dental caries available for five Neolithic populations shows that they had this affliction ranging from 1.4 to 3.2 per cent *(Table 3).* Of them again, the rate of caries for the three Neolithic populations varied between 1.4 and 1.8 per cent. According to the hypothesis, it is expected that the post-Neolithic situation should reflect appreciably fewer caries for the smaller, caries resistant teeth. But the picture available does not perhaps portray the same. The teeth of the Bronze Age Harappans, Iron Age Megalithic, and Early Historic populations, studied by Pal (1981), pre-

TABLE 3. *Dental caries in some Neolithic populations, dating 3,000—1,000 B.C. (adults only) *)*

Population	% caries
French Neolithic	3.2
German Neolithic	1.8
Swedish Neolithic	1.4
Danish Neolithic	1.6
British Neolithic	3.1

*) Data from Brothwell (1963), *Table 1.*

TABLE 4. *Dental caries in some earlier human populations of the Indian subcontinent**)*

Time span	Series	No. of teeth examined	% caries
2,300—1,750 B.C.	Harappa (Bronze Age)	1,501	1.8
900—300 B.C.	Megalithic (Iron Age)	1,013	2.5
300 B.C.	Early Historic	431	2.1

**) Data obtained from Pal (1981).

sent frequencies of caries ranging from 1.8 to 2.5 per cent *(Table 4).* For all these populations, it may be noted, cariogenic factors are quite well in evidence, and the rate of caries they display is either similar to or greater than those of the three Neolithic populations referred to.

It would be worthwhile to note that many of the modern populations show very high rates of caries. Among them, the following few cases may be cited examples. These are the Texas Indians — 34.6 % (Goldstein, 1948), Alaskan Eskimos — 26.7 % (Collins, 1932), Japanese — 17.9 % (Sanui, 1960), Greeks — 15.9 % as against 12.1 % caries of the ancient (3,000—1,000 BC) Greece (Angel, 1944).

Current knowledge suggests that dental caries in modern man is more directly related to diet, especially to great intake of refined carbohydrates, rather than the size and complexity of teeth at any rate. This factor, too, might have also been responsible for promoting caries in earlier communities. The variation in the rate of affliction of caries over populations, both modern and prehistoric, appears to have been dependent on the degrees of efectiveness of antibodies to the oral bacteria that saliva may contain. On the basis of clear evidence of bacteriological variabilities related to dental health in modern man, Brothwell (1963: 776) views that differences were also there in the past. The information thus available does not support the proposed selective advantage for caries-resistant teeth and thereby reduction in size of teeth.

Human beings evolved and attained their present physical form through the forces of positive selection. Selection pressure permitted them a fully erect posture and effective bipedalism in course of biological evolution. These were achieved through a series of major changes in function and structure of organisms in the body under selection pressure. All the major modifications in the hominids are thus directly related to selective advantage, chiefly associated with fully erect posture and cursorial gait. Although at an unequal rate, the teeth and their supporting organic structure as well underwent transformations during the vicissitude of evolution in the genus *Homo.* Therefore, as a more general principle, modifications in structure may be explained on the basis of natural selection.

The present investigation suggests that there exists a genuine trend of a progressive reduction in the size of the molars. Since the reduction appears to be concomitant with the development of human culture, there is a strong case in point to suggest it as a product of positive selection pressure and adaptation. The selective value for reduction in molars can perhaps be only discerned from evidence of indirect nature. Functions are related to organic structures, and vice versa. Molars, too, must necessarily be related to molar-specific functions, e.g. primarly grinding and chewing. Therefore, a change in the intensity or the degree of grinding and chewing functions of molars will cause, under selection pressure, suitable modification in the structure of molars for a better adaptation.

Thus, there is clearly a case for suggesting that selection pressure favoured smaller molar size, and thereby grinding area, adapted to the need-based function of grinding and chewing soft cooked food. A large set of molars, earlier beneficial for mastication of tough and gritty food, would indeed be unfit. Two more points concerning selective advantage for reduction might have also been, to some extent, important. One is that the reduction in size of dentition might have made possible relatively a larger room for the tongue to play within the buccal cavity to help develop the articulated speech. And, the other, a more general one is that the reduction resulted in relatively decreasing load of the dentition advantageous for carrying it in the state of fully erect posture.

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