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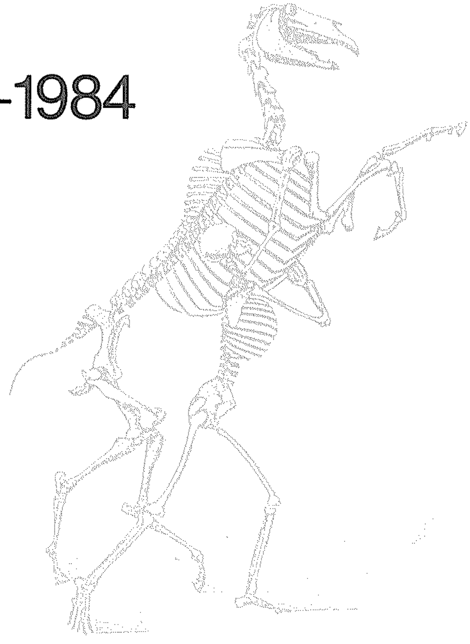

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The Case of a Slowly Growing Tumor Destructing the Face of a Skeleton from Viborg Domkirke, Denmark

JESPER BOLDSEN and OVE PERSSON

OSSA

The skeletal and especially the facial appearance of a skeleton found just south of the Cathedral in Viborg, central Jutland in Denmark, is described. The dating of the skeleton is terminal or post-Medieval. There is evidence of a slowly growing benign tumor which has destroyed nearly the entire facial skeleton. The tumor started growing in the childhood and by age 20 it had probably invalidated the man. He must have been confined to his bed for more than one decade.

Keywords: Facial disintegration - Benign tumor.

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Introduction

In the 1980 excavation campaign at Viborg Cathedral skeletal remains of 51 human beings were found. The excavations were carried out just south of the present church in an area that always has been outside of the church. The site has been utilized for burials from the early Middle Ages through to just after 1800. The skeleton which is the object for the present description came from a group of "late" graves, i.e. graves having no indications usable for a precise dating but certainly from a later part of the period. This means that the skeleton known as G26 is of terminal or post-Medieval dating, most likely this person died in the 17th or 18th century.

The interior of the cathedral in Viborg was used as the burial-place for the Jutland nobility. The cathedral did not function as parish church before after the abandonment of the churchyard in the early 19th century, however, members of the clergy were interred outside the cathedral with their families and servants after the Middle Ages as were members of and servants for the better off bourgeois of the city (Trap, 1962).

When possible anatomical terms are in pure Latin. The terms are in accordance with Töndury (1968). Martin and Saller (1957), Gejvall (1960) and Töndury (1968) are used as references for normal skeletal conditions in European populations as are our experiences with large series of excavated skeletons from the same historical and geographical frame.

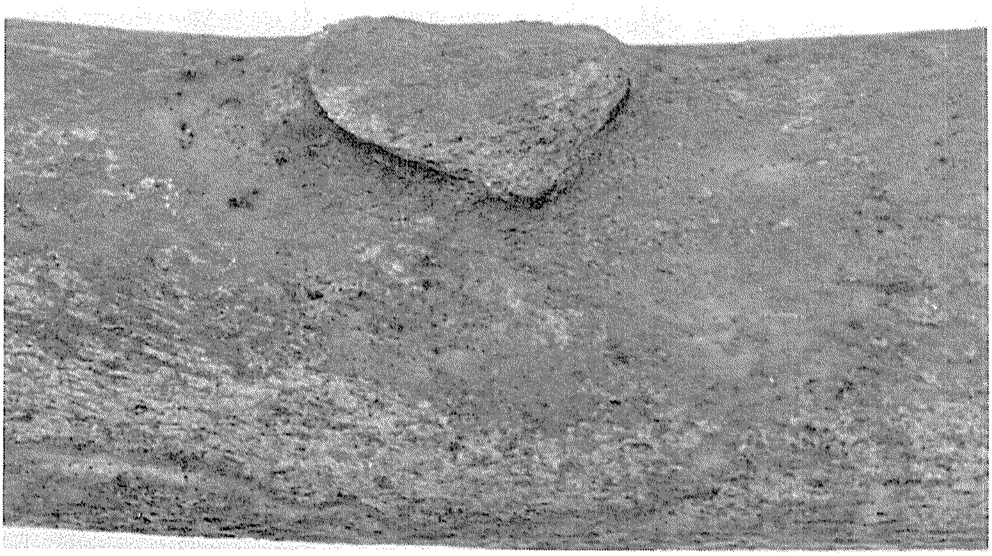

Fig. 1. A flat exostosis on the distal half of Facies medialis Tibiae dextrae.

The skeleton

The grave G26 contained a nearly complete skeleton of an adult man. The left Ulna and Radius are missing. However, in spite of the absence of the forearm several bones of the left hand were recovered. On the basis of the length of the Femora the height of the man when alive has been estimated to 170 cm (by a formula given by Boldsen, 1984). The height is just below the average height of the men buried by the cathedral.

As a consequence of the comprehensive pathological changes of the facial part of the skull it has not been possible to evaluate the facial morphology, but the neuro-cranial morphology is within the range of normal variation for Medieval and Renaissance skeletons from central Jutland be it in the brachy-cephalic end of this range.

Concerning the discrete anatomical variation of the skull the present one exhibits conditions fully compartible with its historical and geographical origin (cf. Sellevold, 1977). Appendix 1 gives a summary of anthropometrics for G26.

The skeleton shows rather few pathological conditions which are not related to the facial destruction. There is a slight build up of laminar tissue on the bones of the lower leg in both sides and on the distal third of the right Ulna.

Near the middle of the distal half of Facies medialis Tibiae dextrae there is a flat exostosis measuring 15 by 15 mm (fig. 1). The exostosis is situated in a depression measuring around 50 by 20 mm. The exostosis does only protrude the normal bone surface by some tenths of millimetres so the depression is more probably the pathological sign in this place. An x-ray examination has not been carried out so a precise diagnosis cannot be given, but the site on form of the changes hint at a lesion with or without a following infection as a possible cause. This condition has surely originated during life, post mortal changes can be excluded.

Even though G26 reached maturity before dying there are no signs of degenerating processes in the spinal column. The only spinal pathology seems to be a very little subperiosteal destruction formed centrally on Corpus vertebrale of the 5thtoracicvertebra. This could be a sign of tuberculosis at an early stage, but the appearance and size is not typical for this disease and this make tuberculosis an unlikely diagnosis. Trauma seems an equally improbable diagnosis as only one vertebra is affected. As the ventro-caudal angle of the Corpus Vertebrae in the affected area has retreated cranially but is still clearly identifyable there is some indication of a slowly developing destructive process.

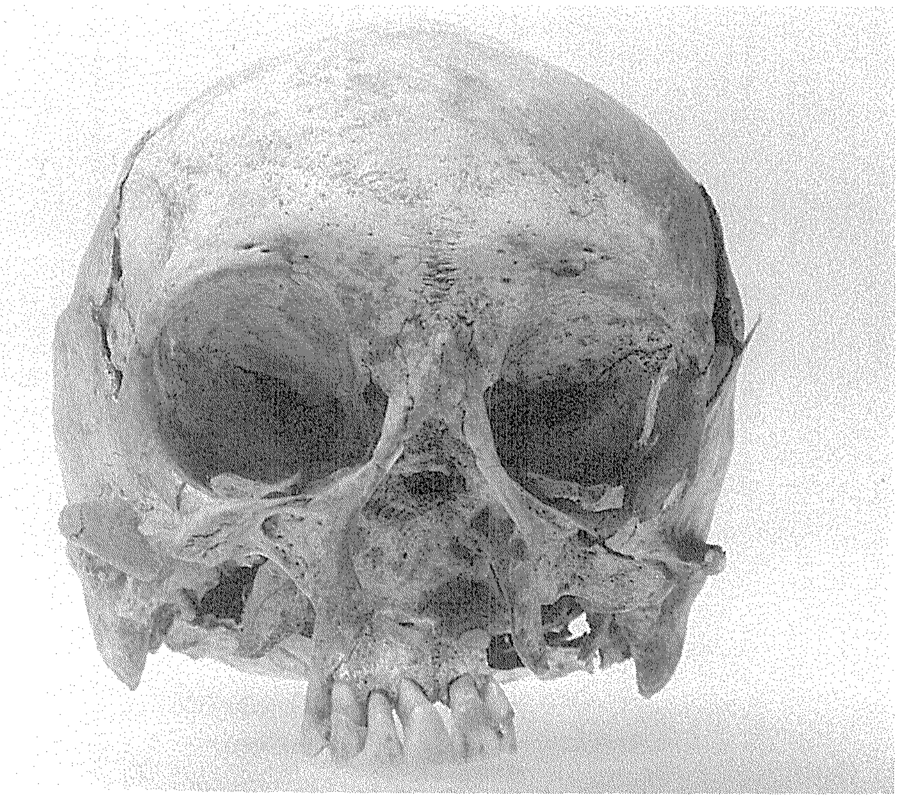

Fig. 2. Norma facialis. The appearance is described and discussed in the text.

It is remarkable that there is no signs of any degenerative joint disease in this mature man. Even though the populations of Viborg seem to be less affected by these diseases than other Danish Medieval populations it is also in Viborg rare to find a mature skeleton with no signs of them (Boldsen, 1978).

Two minor depressions in the right side of Os frontale are seen as marks after minor childhood lesions.

The facial appearance

Norma facialis (fig. 2)

Orbitae appear abnormly enlarged. Processus frontalis Ossae zygomatici are laterally curved and displaced in both sides. Margo infraorbitalis is set very low on the face in both sides causing the distance between Orbita and Fossa canina to be abnormly little. Both Ossa lacrimalia have disappeared intra Vitam creating large holes between Orbitae and Cavum Nasi.

Pars frontalis Ossis nasalis is normal in both sides. However, only 7 mm below Sutura fronto-nasalis Os nasale turns sharply towards Cavum Nasi. The bone is evidently pathologically shortened, its lower margin is drawn in to Cavum Nasi where it is fused with what is left of Vomer.

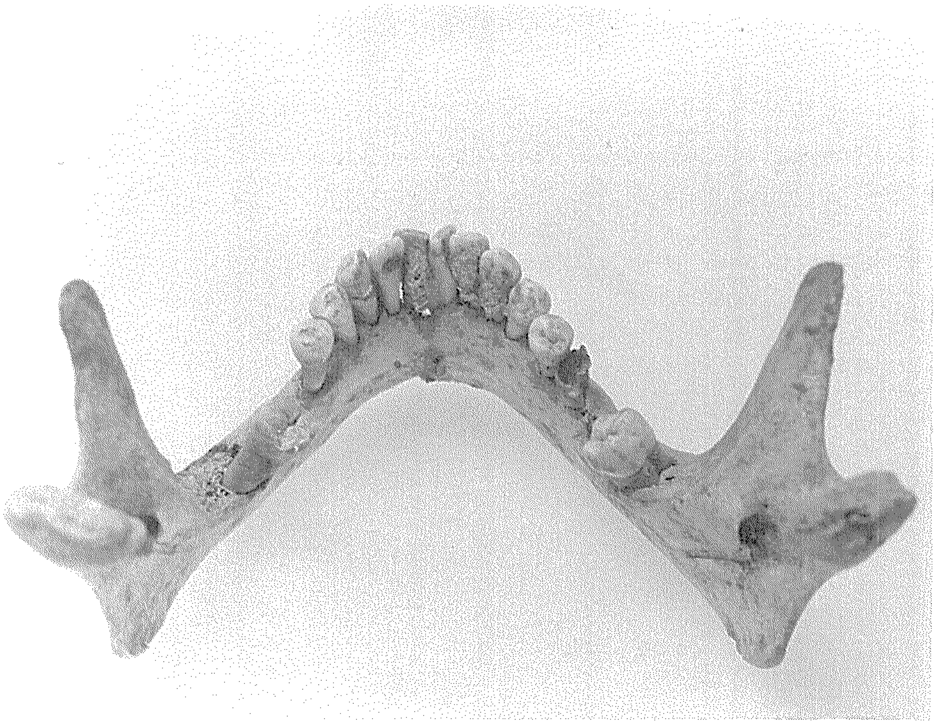

Fig. 3. The mandible. The appearance is described and discussed in the text.

The central parts of Ossa zygomatici have disintegrated so that Processus temporalia Ossa zygomatici are separated from the rest of the bones forming independent small bones attached to Ossa temporalia. In the left side this little part of Os zygomaticum has fused with Processus zygomaticum Ossis temporalis or it has completely disappeared intra Vitam.

Apertura piriformis is abnormly widened separating what is left of Corpus Maxillae from the rest of this bone in the left side. Spina nasalis anterior has degenerated to a tiny tubercle.

Most of the two Corpus Maxillarum have disintegrated during life leaving only the foremost part with teeth 4+ through +2 in Maxillae. The teeth +3 and +4 seem only to have been supported by soft tissue. The distal premolar and all the molars of Maxillae are lacking and probably were so at death. The teeth of Maxillae are nearly unworn. Only in the centra incisors dentine is exposed in a very narrow rim.

<u>Mandibula (fig. 3)</u>

Mandibula is not directly involved in the gross anomaly of the face, but several pathological conditions in Mandibula are probably consequences of the facial deformity.

The articulation surface of Caput mandibulae is rough in both sides. This condition is often seen in skeletons of people dying at advanced ages.

There is extensive alveolar bone degeneration especially in the area of the molars and around the roots of the central incisors.

The first and second molar have been lost intra vitam in both sides, and the distal right premolar is severly affected by caries. The dental wear is very moderate, a little

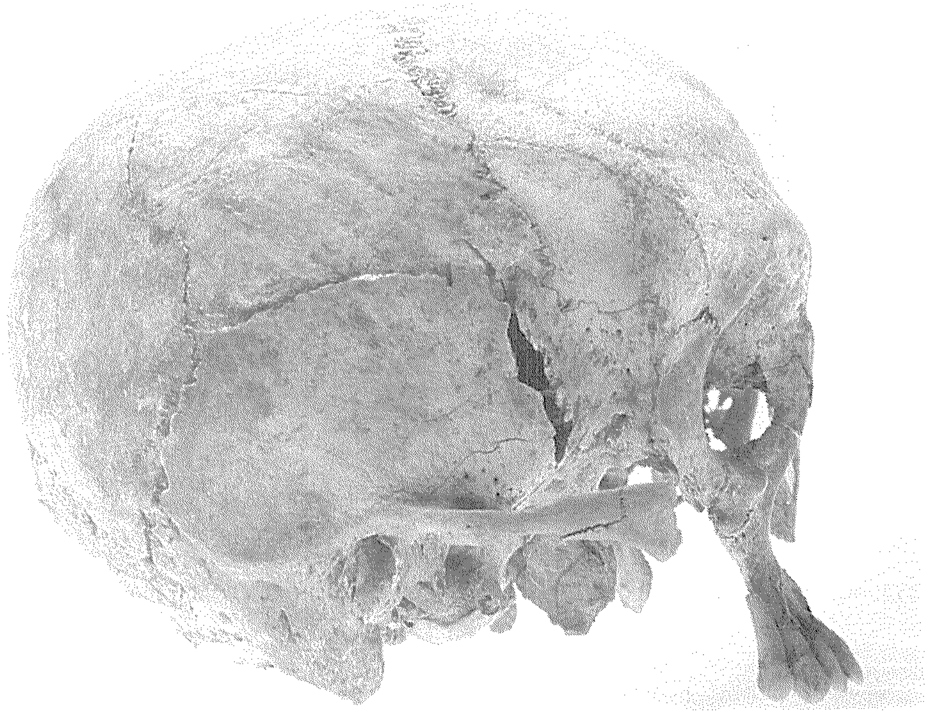

Fig. 4. Norma lateralis dx. The appearance is described and discussed in the text.

bit heavier in the left than in the right side. All the teeth even the third molars show evidence of intra Vitam wear.

A considerable amount of calculus has been formed on most of the teeth of Mandibula, the calculus formation is weaker in the back than in the front of Mandibula.

Even though most of the teeth are still in Mandibula there is a clear indication of the degeneration of Corpus Mandibulae usually associated with total tooth lack and senility.

Norma lateralis (figs. 4 and 5)

Two abnormal conditions are clearly identifyable in the lateral aspect of the skull.

1) The total lack of projection of the nose, and

2) the missing of the major part of the Corpus Maxillae and nearly the whole palate.

The only part of the posterior portion of the upper jaw that is left is Laminae lateralia Processus pterygoidei. These Laminae are part of the posterior support of the upper jaw.

Norma basalis (fig. 6)

In this aspect the changes of the facial skeleton just described become more coherent. All bones within a sphere with a diameter of around 5 cm and with center in the middle

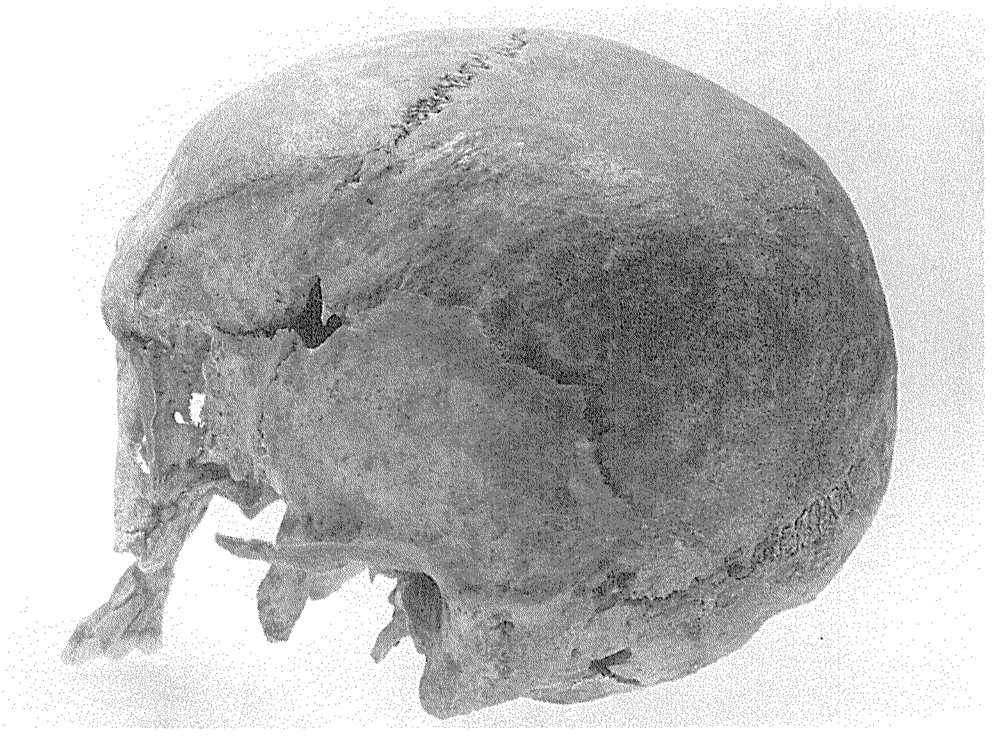

Fig. 5. Norma lateralis sin. The appearance is described and discussed in the text.

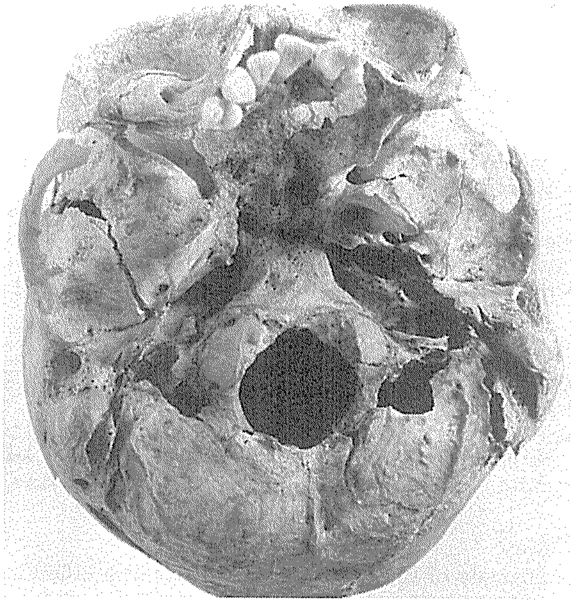

Fig. 6. Norma basalis. The appearance is described and discussed in the text.

of Cavum Nasi has desintegrated. The margins of this sphere is evident on Os ethmoidale, Os frontale, Os sphenoidale, Ossa nasalia, Vomer, Maxillae. Vomer has nearly disappeared, and Ossa palatina and Ossa lacrimalia are completely gone.

The surface of the bone bordering this cavity is quite porosic on the bones bordering the brain and it gets more and more smooth as the distance to the braincase increases.

Sinus sphenoidalis and Sinus maxillaris in both sides have nearly ceased to exist independently, they are involved in the spherical hole. Sinus frontalis is bordering the hole but there are no apparent changes of the bone surrounding it.

There has not been made x-ray examination of the skull, but before reconstruction it was noted that none of the changes described involved the bony surface bordering the brain.

Discussion

The facial destruction was caused by a very slowly expanding process that only involved the bone surfaces and did not alter the internal structure of the bones. The process had its origin in Cavum Nasi or on the palate. Only a few infectious diseases are known to cause facial destruction like just described, Lepra, Syphilis, Yaws and Bejel completes the list.

Facial Lepra is characterized by alveolar destruction around the upper incisors (cf. Møller-Christensen, 1961). In G26 the least involved part of the facial skeleton is just the part one should expect to be the most destructed if the disease were Lepra. The lack of involvement of Falanges also talks against Lepra. During the 15th century Lepra disappeared from Denmark so Lepra is from historical reasons hardly a possible diagnosis for G26.

The remaining infectious diseases are all Treponematoses. Yaws is likely to cause severe facial destruction and Bejel might do it, but both these diseases are strictly tropical or subtropical and they are known not to have occurred in Denmark. Syphilis, however, was present in Denmark from the latter part of the first half of the 16th century, but the facial changes are not typical for Syphilis and the lack of frontal and postcranial involvement more or less excludes this diagnosis (cf. Steinbock, 1976).

The alternative to an infection being the cause for the destruction of the face is some sort of neoplasm.

There is no doubt that the destructive process started in the soft tissue. It is extremely difficult to fix a diagnosis to a soft tissue tumour from the appearance of the bones alone, but it is possible to characterize the disease and reconstruct some stages in its progress.

The mandibular teeth are worn as they would be in a 15-20 year old person from the relevant period. The maxillary teeth are only worn as they should be in a child of a little less than 10 years.

We think that these "dental ages" give good indications of the age at certain stages of the disease. The destruction of the facial skeleton must have been so extensive before age 20 that chewing was minimal. As the age at death was over 30 years (probably over 50) G26 must have lived on very soft food-stuffs for at least one decade - probably more than three.

The growth of the tumour causing the facial destruction must have started several years before chewing was reduced substantially. As the growth of Synchrodrosis sphenooccipitalis does not seem to be affected the tumour can not have reached Basis Cranii before G26 was in his late teens.

The posterior part of Corpus Maxillae must have disintegrated after 3rd molars had come in occlusion. The pattern of wear on the 3rd molars of Mandibula could only be generated by the 3rd molars of Maxillae. However, the wear facets indicate a very short period of occlusion; hence the posterior part of Corpus Maxillae must have disintegrated shortly after age 20.

The stages of the disease may have been the following: Sometimes in the childhood of G26 a benign tumour started to grow in Cavum Nasi. This tumour must have perforated the palate between age 10 and 15 making mastication increasingly difficult. From this hole in the palate, probably near the center, the destruction spread to Corpus maxillae causing the molars to fall out the 3rd molars being the last to go.

After age 20 the pace of the growth of the tumour probably dropped. At some stage the wall of Orbitae was perforated and the eyes were displaced laterally and possibly pushed forward. At this time the fleshy nose had disappeared leaving a hole in the face and giving G26 a loathsome appearence which was only worsened by the protruding eyes.

From a rather early stage of the illness respiration through the nose was impossible and that must have invalidated G26. He must have spent many years in bed. His confinement to bed can explain the laminar hypertrophism of the bone on Tibiae and Ulna. It further explains why he did not suffer from any sort of degenerative joint disease.

The small destruction in a Corpus Vertebrae could be a sign of a second, also slowly growing, tumour which might have been founded by a cell from the facial tumour.

G26 must have been very dependent on his surroundings for care and feeding. He probably lived unable to work for several decades. The loathsome looking skull of G26 tells the story of a miserable life, but it also talks about care for the sick, only possible with a certain economical and human surplus.

Acknowledgements

We are grateful to cand. mag. Jens Vellev for the possibility for examining the skeleton and for useful historical information.

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APPENDIX 1. Anthropometrics of G26. The measurements were taken in accordance with Martin and Saller (1957). All measurements are in millimetres. The figures stated are the averages of two measurements.

Cranial measurements

1.	max. length	176	17.	Basion-Bregma h	129
5.	Nasion-Basion l.	90	23.	circumference	522
8.	max. breadth	147	25.	sagital arc	366
9.	min. frontal b.	90.9	66.	bigonial breadth	95.3

Postcranial measurements

		R	L			R	L
Humerus				Femur			
1.	max. length	-	332	1.	max. length	463	466
4.	bicondylar b.	-	61.5	8.	cir. on middle	85	85
				20.	cir. of caput	-	155
Radius							
1.	max. length	264	-				
Ulna							
1.	max. length	282	-				

Discrete variables

metopism	-		Foramin parietale	+	+
lambdoid ossicles	+	+	Can. hypoglossi div.	-	-
parietal noch bone	-	+	mylohyoid arch.	-	-

The Usefulness of Tests for Multivariate Normality in Physical Anthropology

JESPER BOLDSEN and MICHAEL SØRENSEN

OSSA

The paper reviews a number of methods for evaluation of the normality of multidimensional samples. Such an evaluation must include a check of the marginal normality as well as an assessment of the kind of interaction between the variables in the sample. The purpose of a proper evaluation of the normality of a multidimensional sample is either to strengthen the basis of multivariate statistical procedures or to indicate the presence of some major factor, possibly of biological interest, affecting the normality of the sample. The methods are demonstrated by applying them to four samples of measurements of Danish Medieval skeletons.

Keywords: Multivariate normality - Marginal normality - Linearity of regression - Major factors.

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1. Introduction

Multivariate statistical procedures have been among the favourite tools of anthropometric research for a long time. The methods have grown more and more complicated and the results have become difficult to interpret. In spite of this nearly all advanced studies in anthropometry rely on multivariate statistical analyses.

Generally the reason why multidimensional analysis is used instead of the far more simple one-dimensional analysis of each variable separately is that the multidimensional procedures take the effect of the relationship between the variables into consideration.

An extensive critisism of multivariate statistics in anthropometric research is summed up by Kowalski (1972). On the one hand he recommends the continued use of classical methods like the calculation of indices (e.g. the cephalic index), on the other hand he points out the need for a consolidation of the more modern types of multivariate analysis through a thorough testing of the models underlying the methods.

Most methods of multivariate data analysis rely on the multidimensional normal distribution. Therefore, a sample of multidimensional biological measurements should be tested for normality before applying the methods to them.

Analyses of very large samples of uni-variate biological measurements have shown that apparently the non-normal distribution of many samples is generated by some major factor affecting the otherwise normally distributed populations (Boldsen and Kronborg, 1984). The possibility of finding and describing biologically interesting major factors affecting the distribution is a second reason for testing the normality of a given sample.

In many cases data needs transformation before becoming normally distributed. If data after suitable transformation (e.g. log- or squareroot-transformation) are normally distributed, the non-normality of the original data does not signify the presence of major factors. In most of these cases the transformed, normally distributed variable will be the interesting thing to study.

The purpose of this paper is to review and discuss tests for multivariate normality, and show that these tests can be used to strengthen the basis for multivariate statistical analyses and to indicate the presence of biologically interesting major factors affecting the distributions under consideration.

2. Properties of the multivariate normal distribution

In order to understand the tests reviewed in the next section one has to be familiar with the properties of the multivariate normal distribution. Since textbooks on theoretical or applied statistics give thorough descriptions of the multi-dimensional normal distribution (see e.g. Anderson, 1958), only a brief summary of the most important properties of this class of distributions will be given here.

1. Any one-dimensional marginal of a multivariate normal distribution follows a univariate normal distribution, so marginal normality is a necessary condition for multivariate normality. It is, however, not sufficient. Examples of non-normal bivariate distributions with normally distributed marginals are known (Lancaster, 1959, and Waswani, 1950).

2. The regression of one marginal variable on the others in a multivariate normal distribution is linear with constant residual variance. Therefore the normal model cannot be applied to data with non-linear allometric relations without a suitable transformation of data. The covariance matrix sums up all information about the dependence.

3. Any linear combination of the marginal variables is normally distributed. This means that principal scores and other sorts of factorial scores are normally distributed if the original sample is drawn from a multivariate normal distribution.

4. Uncorrelated marginal variables in a multivariate normal distribution are independent. This is the reason why the finding of uncorrelated linear combinations is of particular interest for the analysist when dealing with multidimensional data. It can only be deduced that uncorrelated linear combinations are independent if the data actually are normally distributed.

5. The sum of many small, independent effects is approximately normally distributed if certain weak conditions are met (the Lindeberg theorem, Feller, 1966: p. 256). If these effects work relatively, i.e. multiplicatively, the result is a log-normal distribution.

3. Methods for checking multivariate normality

In this section we review a number of methods for checking whether a sample of p-dimensional observations can be assumed to be normally distributed. Along with the presentation of the various methods we will illustrate most of them by applying them to four samples of skeletal measurements. The material for these examples are Medieval Danish skeletons from two sites, Lille Sct. Mikkelsgade and Øm Kloster, respectively. The sexes from the two sites are analyzed separately.

Lille Sct. Mikkelsgade is an urban site situated in the outskirts of Medieval Viborg. Through the Middle Ages Viborg was an ecclesiastical and administrative center in central Jutland (Boldsen, 1978).

Øm Kloster was a monastery in a remote part of central Jutland. It was founded in 1172 and stood until 1560, when it was demolished (Isager, 1938).

In the examples the distribution of five measurements from the skeletal populations are investigated in order to tell whether they are in accordance with the five-dimensional normal distribution. The measurements are: 1) the maximum length of left femur (femur M 1, sin.), 2) the medial sagital arc of the braincase (M 25), 3) the circumference of the braincase (M 23), 4) the width of the nose (M 54), and 5) the height of the nose (M 55). All the measurements were made in accordance with Martin and Saller (1957) and the numbers in brackets refer to the numbers given to these measurements in this edition of "Lehrbuch der Anthropologie". Together the five measurements evaluate three important aspects of skeletal variation; viz. size, neurocranial morphology and facial morphology.

Since the one-dimensional marginals of a multivariate normal distribution are normally distributed the normality of the marginals must be investigated. This can be done by the well-known probit-analysis and by significance tests based on skewness and kurtosis. The observed skewness and kurtosis are asymptotically (as $n \to \infty$; n denotes the sample size) independent and normally distributed. The exact mean and variance for a finite sample size appear in the following diagram (Cramér, 1946: p. 386):

	skewness	kurtosis
mean	0	$-\frac{6}{n+1}$
variance	$\frac{6(n-2)}{(n+1)(n+3)}$	$\frac{24n(n-2)(n-3)}{(n+1)^2(n+3)(n+5)}$

The estimated skewness and kurtosis should therefore be evaluated in normal distributions with means and variances equal to the values in the diagram.

The marginal normality can also be tested by applying Shapiro and Wilk's W-test (cf. Shapiro and Wilk, 1965), to each of the coordinates.

The probit analyses of two of the one dimensional marginals from the four samples of skeletal measurements are shown in figure 1 (the numbers of observations in the diagrams appear in Table 1). The estimates of skewness and kurtosis for all the coordinates are given in table 1. The probit diagrams of the second coordinate of the two Øm Kloster populations are the most critical for the hypothesis of marginal normality in the four samples, but seen in isolation these diagrams are acceptable.

None of the 20 marginal distributions are significantly skew or kurtotic at the 5% level.

When applying two significance tests, i.e. skewness and kurtosis, to each marginal we obtain 2p test-statistics. It is a problem how to evaluate these statistics simultaneously. The most significant of these statistics can be used as test-statistic, but it is difficult to assess the level of significance. However, the Bonferroni bound gives us an upper bound for the significance level. The Bonferroni bound is obtained by multiplying the most extreme significance level by the number of statistics, in this case 2p (Cox and Hinkley, 1974: p. 78). If the marginals are independent so are the test-statistics, and as a consequence the Bonferroni bound closely approximates the exact significance level. The evaluation of the test-statistics is therefore facilitated if the normality of independent combinations of the marginals is tested. Independent combinations can be estimates by standard methods such as the method of principal scores.

The fact that any linear combination of the marginals of a multi-dimensional normal distribution is normally distributed has led some authors to test for multivariate normality by evaluating the most extreme values of the estimated skewness and kurtosis or of the Shapiro-Wilk's W-statistic among the values calculated from all possible linear combinations of the marginals (cf. Malkovich and Afifi, 1973).

The important property of the normal distribution that the regression of one marginal on the others is linear can most directly be studied by plotting every pair of marginals

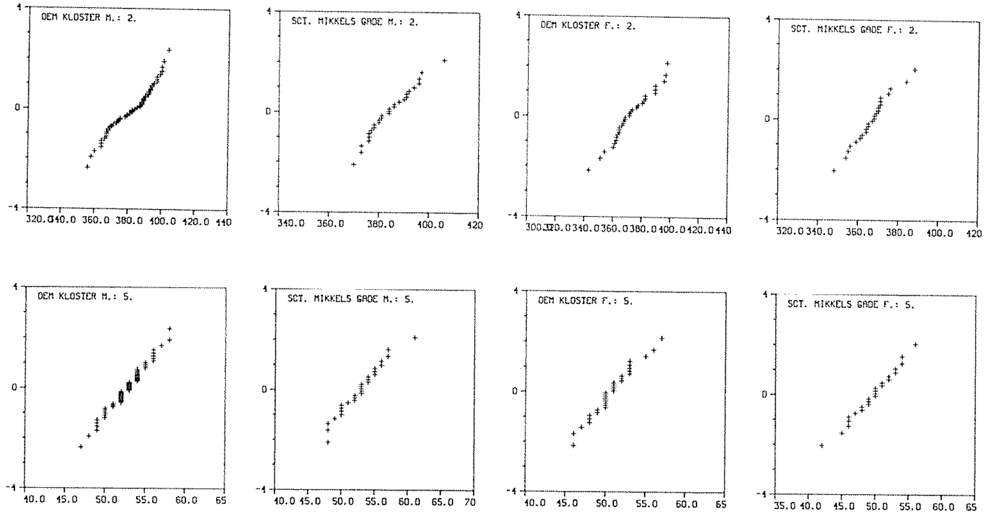


Fig. 1. Probit diagrams illustrating the marginal distribution of coordinates 2 and 5 of the four examples. The upper row shows coordinate 2 and the lower row shows coordinate 5. It appears that coordinate 2 of the Øm Kloster male sample conforms badly with the normal distribution. No other probit diagram indicates any important deviation from normality.

agains each other in scatter-plots. If the two marginals are bi-variately normally distributed the bulk of the points will form an ellipse. In figure 2 examples of such scatter-plots of the bi-variate marginals are given. Scatter-plots like these are generally difficult to interpret, but it appears that the scatter-plots from the Øm Kloster populations are not as well in accordance with the normal distribution as are those from the Lille Sct. Mikkelsgade populations.

The linearity of the regression can be assessed if the difference between one marginal and its expectation given the other marginals is plotted against each of the other marginals. This difference is called the residual. The residual of the j'th coordinate in the i'th observation is denoted R_{ij}, and the plots are called residual plots. R_{ij} is calculated from the observations and the estimated covariance matrix by the formula:

$$R_{ij} = x_{ij} - \bar{x}_{\cdot j} - ({}_{(j)}x_i - {}_{(j)}\bar{x})\,{}_{(j,j)}S^{-1}\,{}_{(j)}S_j,$$

where x_{ij} denotes the value of the j'th coordinate in the i'th observation vector, and $\bar{x}_{\cdot j}$ is the average of the j'th coordinate in the sample. The symbol ${}_{(j)}x_i$ denotes the i'th observation vector with its j'th coordinate deleted, and the average of these (p-1)-dimensionl vectors is called ${}_{(j)}\bar{x}$. Finally ${}_{(j,j)}S$ is the estimated covariance matrix with its j'th row and column deleted, and ${}_{(j)}S_j$ is the j'th row in the estimated covariance matrix without its j'th element.

Figure 3 gives examples of residual plots. Again it appears that the plots from the samples from Lille Sct. Mikkelsgade are in a better accordance with the normal model than are the ones from the samples from Øm Kloster.

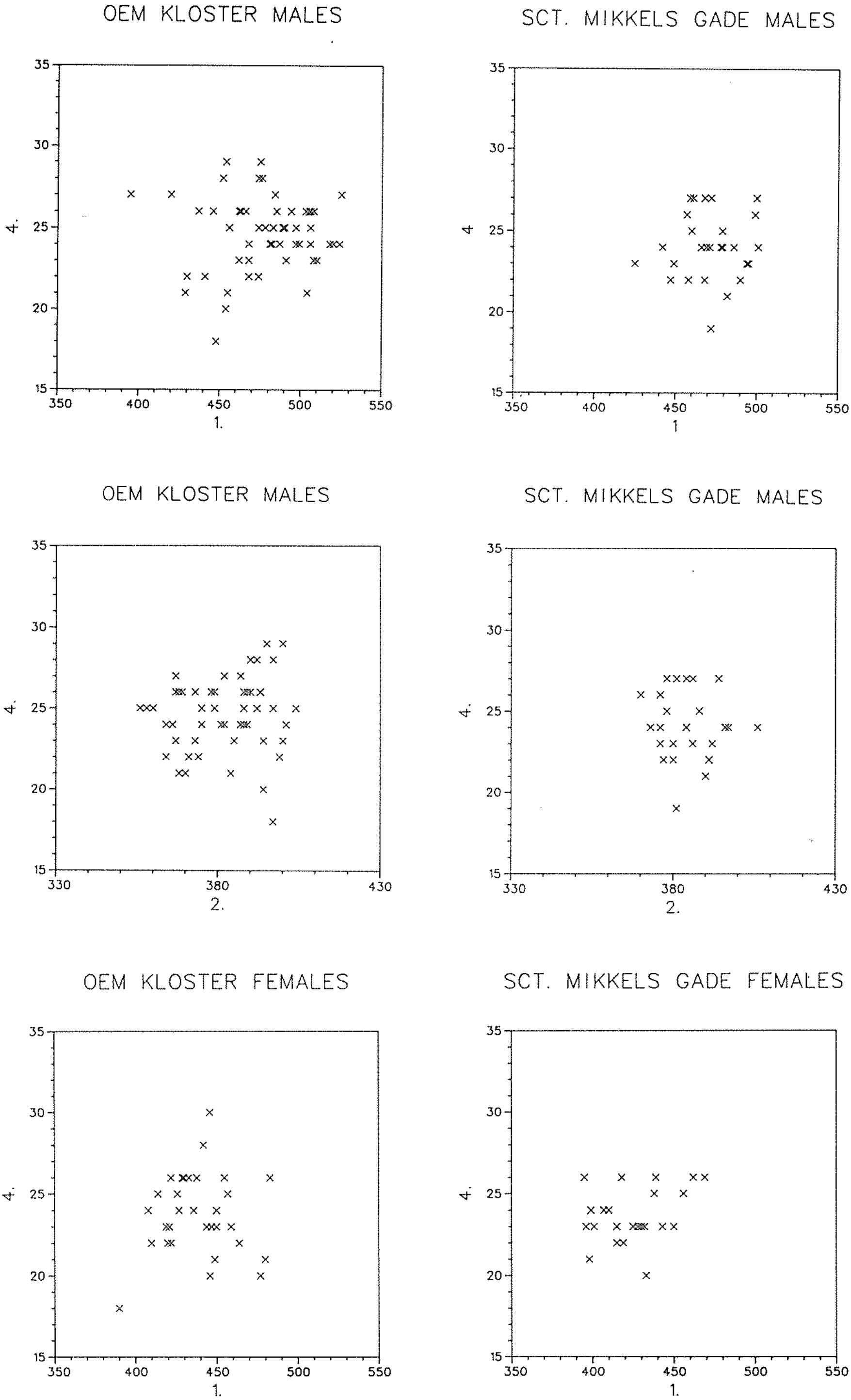
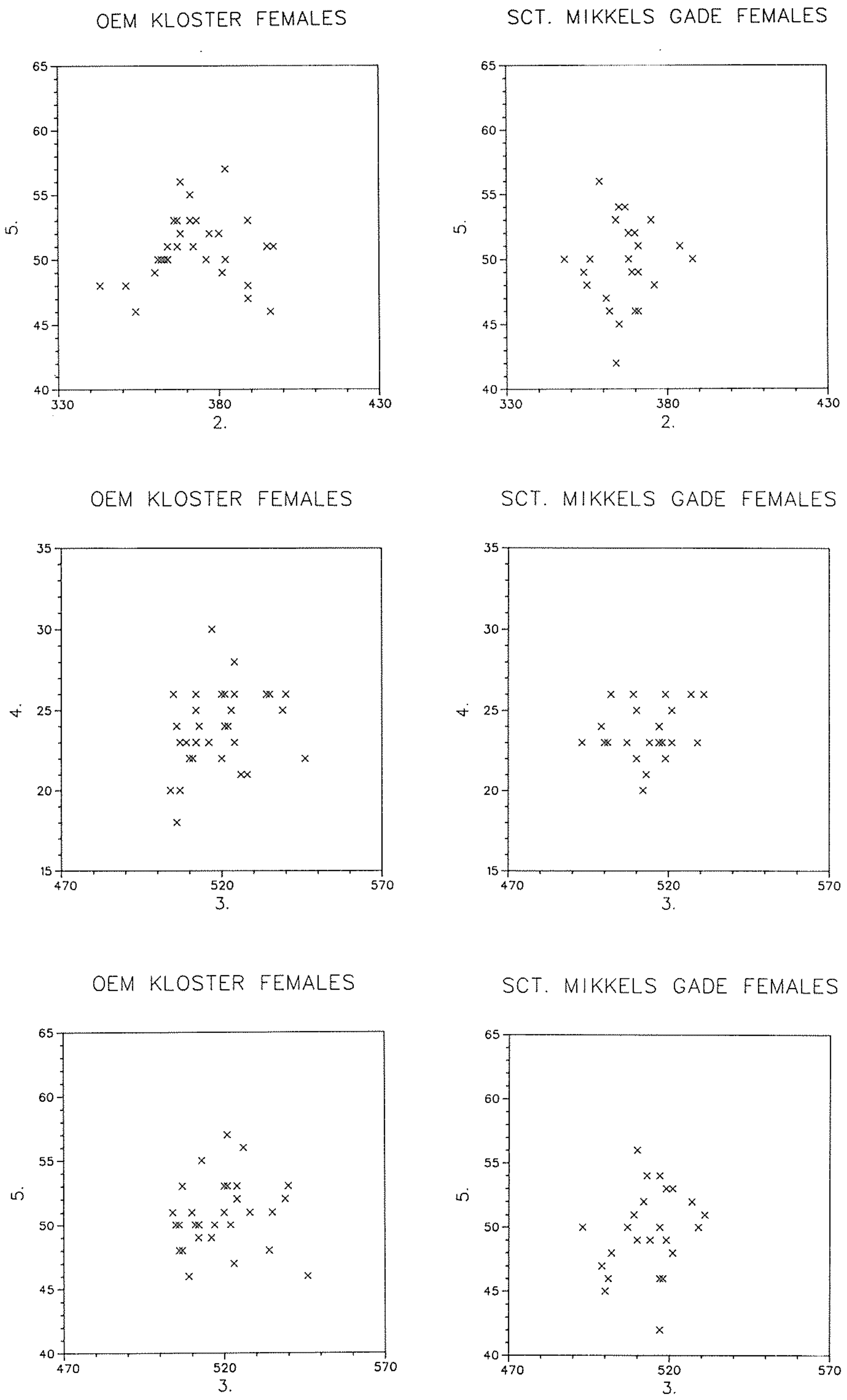


Fig. 2:1.

Fig. 2. Scatter plots showing examples of two-dimensional marginals from the four examples. For the sake of comparison the same coordinate pairs are shown for the same sex from the two sites. The coordinate pairs were chosen because they gave Cox-Small statistics which individually seen were significant at the 5% level (cf. Table 2).


OEM KLOSTER FEMALES
SCT. MIKKELS GADE FEMALES
5.
2.
330
380
430
40
45
50
55
60
65
OEM KLOSTER FEMALES
SCT. MIKKELS GADE FEMALES
4.
3.
470
520
570
15
20
25
30
35
OEM KLOSTER FEMALES
SCT. MIKKELS GADE FEMALES
5.
3.
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520
570
40
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65

Fig. 2:2.

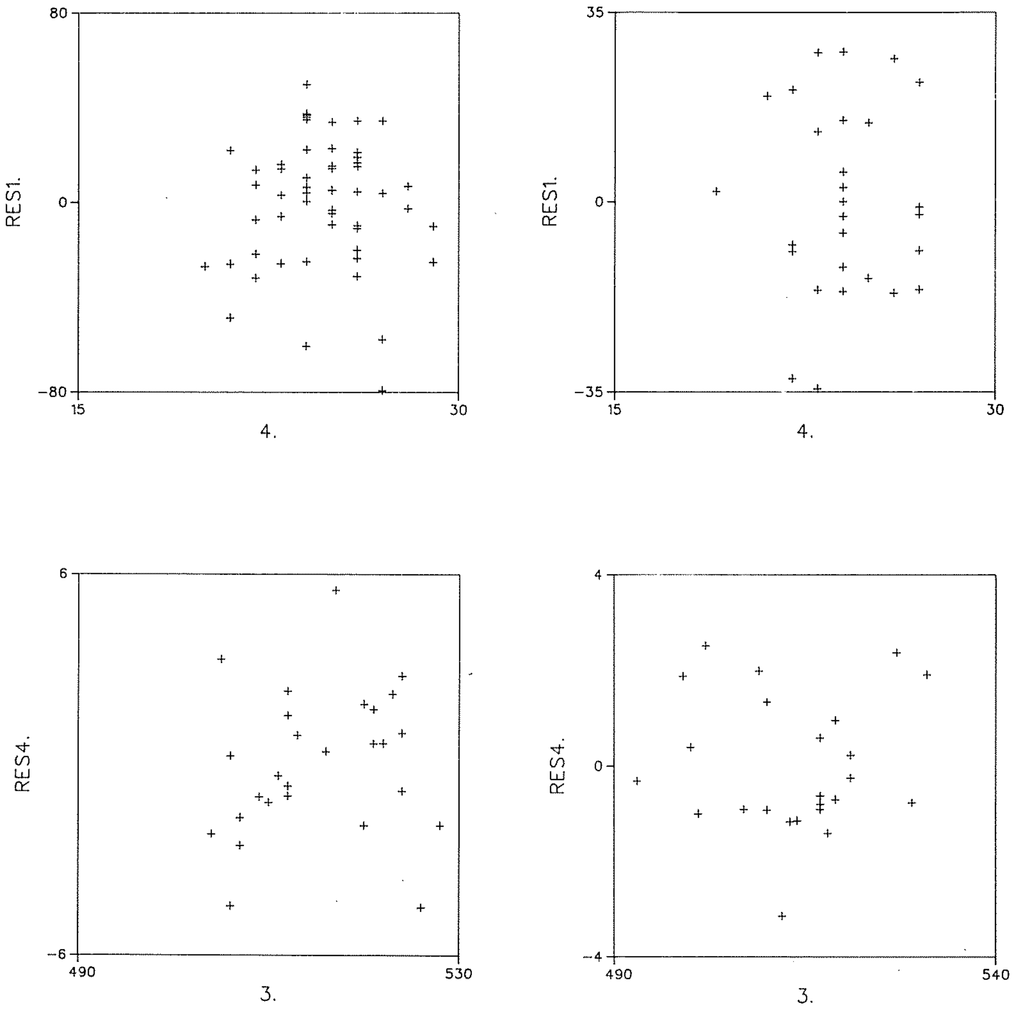

Fig. 3. Residual plots. The upper row shows the residual of the first coordinate plotted against the fourth coordinate for the Øm Kloster (left) and the Lille Sct. Mikkelsgade (right) male samples. The lower row shows the residual of the fourth coordinate plotted against the third coordinate for the Øm Kloster (left) and the Lille Sct. Mikkelsgade (right) female samples. Corresponding ordinary scatter plots appear in figure 2.

A significance test of the hypothesis of linearity of the regression has been proposed by Cox and Small (1978). By interpreting one marginal as a dependent variable and the other variables as regression variables a sample of one-dimensional, independent and normally distributed observations with the same variance is obtained. Using this sample one can test the hypothesis that the regression of the dependent variable on the others is linear by testing the hypothesis:

$$H_1 : \beta = 0$$

under hypothesis

$$H_0:\ E(X_j) = \alpha_j + \sum_{i \neq j} \alpha_i X_i + \beta X_k^2, \qquad k \neq j.$$

For each $k \neq j$ the t-statistics is

$$t_{jk} = \hat{\beta}/\sigma(\hat{\beta}),$$

where $\hat{\beta}$ is the maximum likelihood estimator of β given H_0, and $\sigma(\hat{\beta})$ is the corresponding estimator of the standard deviation of β^*. The t-statistic has a Student's t-distribution with (n-p-1) degrees of freedom. By choosing different dependent variables and squared variables p(p-1) t-statistics are obtained. Here, again, we are faced with the problem of evaluating many test-statistics simultaneously. The statistics are not independent, but if the number of observations is sufficiently large, and the marginals are not too correlated, they can be evaluated by a p-p plot (Gnanadesikan, 1977: p. 199).

It is useful to have a single quantity to evaluate. For this purpose the most extreme among the p(p-1) statistics can be used, and the Bonferroni bound gives an upper bound of the level of significance for this test.

In table 2 the Cox-Small statistics of the four examples are given. It appears that only the samples from Øm Kloster give statistics that evaluated individually are significant at the 5% level. Using the Bonferroni bound none of the samples deviates significantly from ultivariate normality at the 5% level. Figure 4 gives the p-p plots of the Cox-Small statistics of the four samples. The 95% limits of random variation plotted in the diagrams are calculated from the exact distribution of the order variables from a uniform distribution on (0,1); see e.g. Cox and Hinkley (1974: p. 466). On the basis of these plots the hypothesis about five-dimensional normality of the female sample from Øm Kloster would be rejected, and one would be sceptic about the normality of the male sample from Øm Kloster.

Cox and Small (1978) have also propsed a coordinate independent test of the hypothesis of linearity of the regression. In this test a measure of the non-linearity of the worst possible regression of any linear combination of the marginals on any other linear combination is used as test-statistic.

The following methods are characterized by the fact that they do not check a particular property of the multivariate normal distribution but rather check them all simultaneously.

The usual goodness-of-fit test can be used if the number of observations is large enough, which it rarely is. The p-dimensional space is divided into reasonable regions, and the observed and the expected number of observation vectors in the regions can be compared by the χ^2 test-statistic. However, the goodness of fit tests are weak and it is difficult to define reasonable regions in a multidimensional space.

A popular method of checking multivariate normality is by evaluating the Mahalanobis' generalized distances D_i^2 between the individual observation vectors and their mean (Hald, 1952, Healy, 1968, Cox, 1968, Gnanadesikan and Ketterring, 1972, and Hawkins, 1981). In some cases the covariance matrix is known from earlier investigations (see e.g. Boldsen, 1983), in these cases the known covariance matrix should be used when calculating the distances. When the observations are simultaneously normally distributed the D_i^2 distances calculated using a known covariance matrix have

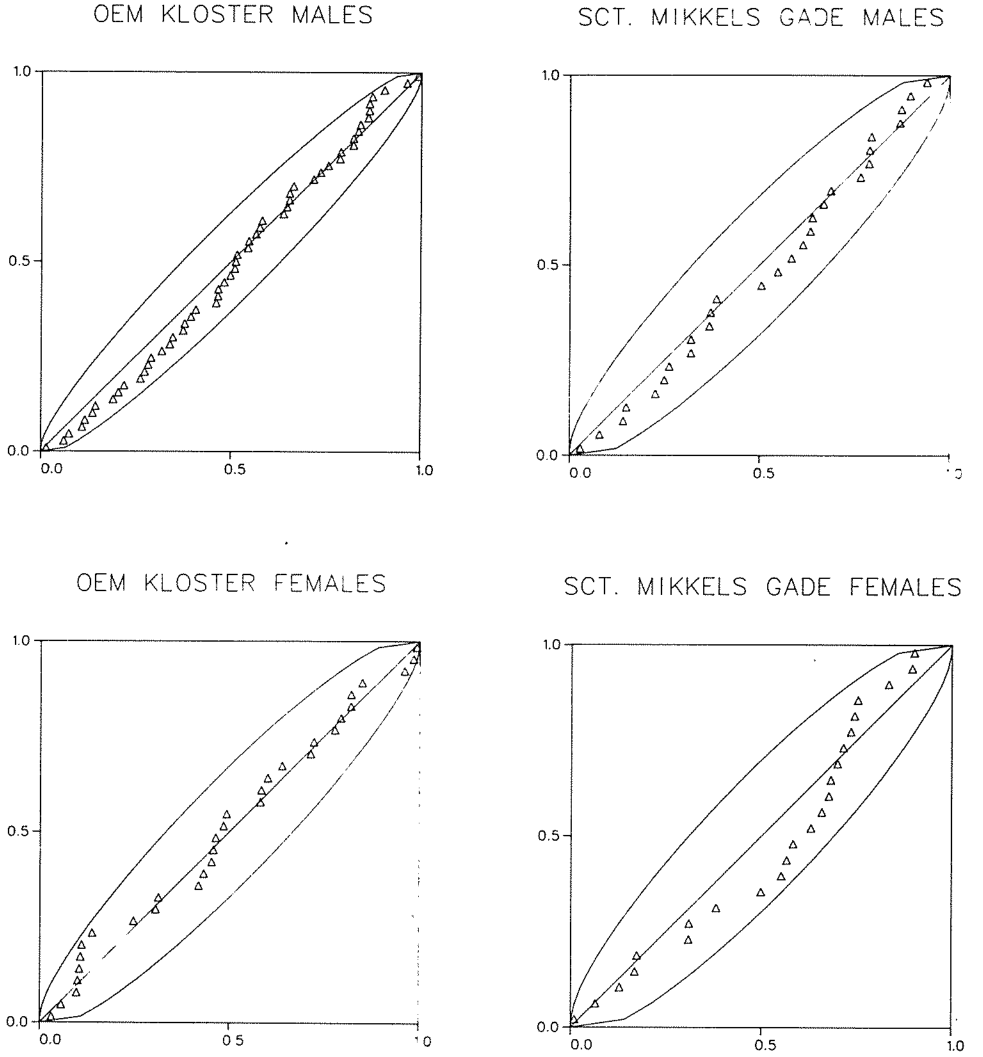

Fig. 4. p-p plots of the Cox-Small t-statistics from the four examples. The 95% limits of random variation are plotted in the diagram.

a χ^2-distribution with p degrees of freedom, and a scale parameter (n-1)/n. If the covariance matrix is not known the sample covariance matrix must be used in estimating the D_i^2 distances. In this case the distances can be transformed to the quantities F_i given by

$$F_i = \frac{n-p-1}{p} \frac{nD_i^2}{(n-1)^2-nD_i^2} .$$

The F_i statistics have a F-distribution with p and (n-p-1) degrees of freedom.

The distribution of D_i^2 can be evaluated by p-p plots, cf. Gnanadesikan (1977). The distributions of the D_i^2 values calculated using the sample covariance matrices in the four examples are illustrated in figure 5. The plots give no reason to doubt the normality of the four samples.

We define:

$$p_i = \begin{cases} P\{\chi^2(p) \le (\frac{n}{n-1})D_i^2\}, & \text{known covariance matrix} \\ P\{F(p,(n-p-1)) \le F_i\}, & \text{estimated covariance matrix.} \end{cases}$$

If the samples are normally distributed the P_i values are uniformly distributed on the interval (0.1). If a significance test is needed Fisher's omnibus-test can be used (cf. Fisher, 1925), i.e. evaluate

$$T = -2 \sum_{i=1}^{n} \log_e(p_i)$$

in a χ^2-distribution with 2n degrees of freedom. If the p_i values are expected to cluster near the end points of the interval (0,1), Pearson (1933) proposed to replace the p_i's in the calculation of T by quantities $\tilde{p}_i$ obtained by the formula:

$$\tilde{p}_i = \begin{cases} 2p_i & \text{if } p_i \le 1/2 \\ 2(1-p_i) & \text{if } p_i > 1/2. \end{cases}$$

If large as well as small values of

$$\tilde{T} = -2 \sum_{i=1}^{2} \log_e(\tilde{p}_i)$$

are considered critical this test is also sensitive to clustering of the P_1 values around the center of the interval (0,1).

4. Discussion

A test for univariate normality should consist of a significance test and a graphical analysis. The significance test can either be an evaluation of skewness and kurtosis or Shapiro-Wilk's test. Skewness and kurtosis are easy to compute but this test is weak. Shapiro-Wilk's test is more powerful, but the involved computations are troublesome.

Among the standard methods of graphical analysis of univariate samples the probit diagrams (i.e. the normal distribution type Q-Q plots) are preferable. Alternatives like histograms or p-p plots are generally less informative and the p-p plot requires that the mean and variance of the normal distribution is known. The shape of a non-linear curve in a probit diagram gives some indication of the type of deviation from normality. Sokal and Rolf (1969: p. 12) give an introduction to the interpretation of types of non-linearity in probit diagrams.

If there are indications that a coordinate is non-normally distributed one should try to transform the coordinate by some reasonable transformation (e.g. logm or square root transformation, but not probi-transformation). If the transformed data are not normally distributed one can construct (ϕ-p, Q)-plots (Fowlkes, 1979) in order to see whether a mixture of two normal distributions is a reasonable model for the distribution.

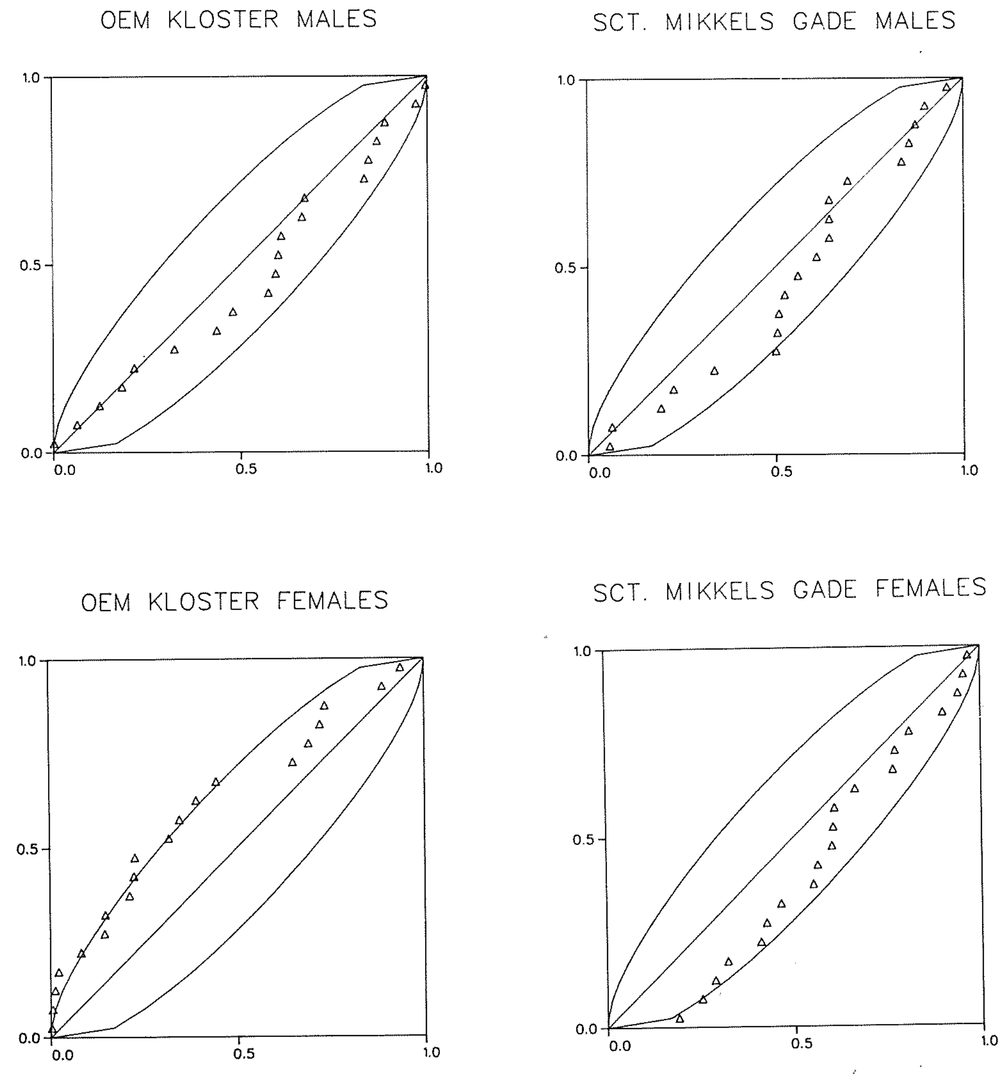

Fig. 5. p-p plots of Mahalanobis' D_i^2 -distances between the sample average and the the individual observations. The 95% limits of random variation are plotted in the diagram.

In general it is a good idea to test the hypothesis of univariate normality under the hypothesis of some larger class of distributions (e.g. a mixture of two or more normal distributions) by a likelihood ratio test if such a hypothesis seems reasonable. The second coordinate of the Øm Kloster male sample was thus significantly better described by a mixture of two normal distributions than by one normal distribution ($\chi^2_{(2)} = 7.58$, $p \simeq 0.02$). The analysis of mixtures of univariate normal distributions is a promising area, but it lies outside the theme of this paper (see e.g. Boldsen and Kronborg, 1984, for an application).

When testing several coordinates of the same sample one shall not be detered by a single significant statistic be it a value of skewness or kurtosis or a Shapiro-Wilk's test-statistic as long as this statistic is not too extreme, but if significant statistics are found too often (i.e. in significantly more than 5% of the tests) the hypothesis of marginal normality in the sample must be rejected. A test based on the skewness, kurtosis or Shapiro-Wilk's W-statistic of the worst possible linear combination of the marginals as proposed by Malkovich and Afifi (1973) will remove the problem of evaluating several test-statistics. This kind of tests are, however, generally weak.

Marginal normality, linearity of the regression of each variable on the others and the constancy of the variance around the regression plane are each necessary and together sufficient conditions for multivariate normality, so having tested for marginal normality of each coordinate, logically, the next thing to do is to examine the linearity of the regression. This is most adequately done by applying the coordinate dependent Cox-Small test to the sample. The point is not that second order polynomials are expected to be the typical departure from linearity, but that the test to our experience is sensitive to other types of departure, too.

In case of a significant test-statistic the actual departure can be evaluated from the scatter plots or the residual plots. Residual plots from samples with a low or moderate level of corelation between the marginal variables show the same structures as do the corresponding scatter plots. A comparison of figures 2 and 3 will demonstrate this. When the marginal variables are not too correlated it is safe to evaluate the deviation from linearity of the regression by scatter plots instead of residual plots. However, Atkinson (1981) has proposed a way of making residual plots which will enhance the possibility of detecting outlying observations. These plots will involve extensive calculations, when the dimension of the data and the number of observations are large.

A coordinate dependent test is preferable to a coordinate independent procedure, at least in antropometry, because it indicates which coordinates cause the problems. The coordinate invariant test will give the two linear combinations of the marginals that causes the worst departure from a linear regression. Such linear combinations may be difficult to interpret. If, however, the only aim of the analysis is to investigate the feasibility of using a given sample as a reference population for multivariate analyses of other samples the coordinate independent Cox-Small test may be the proper test to perform, but tests like this taking the worst of a vast number of statistics as the test statistic are generally weak.

Tests like the multivariate goodness of fit test and the evaluation of the D_i^2's will in most cases be unacceptably weak, because they test for marginal normality and linearity of the regression simultaneously. Furthermore, the goodness of fit test requires an enormeous number of observations. If D_i^2's calculated using a "known" covariance matrix are evaluated, the result is a test for two things, namely whether the sample is normally distributed and whether the covariance matrix equals the "known" matrix. This is essentially what Hawkins (1981) proposes to do when testing the multivariate normality of several samples simultaneously. It seems to us to be a better idea, and indeed more informative, to test the normality of each sample separately and then afterwards to compare the covariance matrices by a likelihood ratio test.

If some sort of factor analysis has been applied to a sample which has not been tested for multivariate normality, it will strengthen the reliability of the results considerably to test for univariate normality of the factorial scores of at least the most important factors.

Having rejected the hypothesis of multivariate normality of a given sample of multivariate observations one should not use this sample as a reference population for further multivariate analyses. Instead one must find the reasons why the sample is not normally distributed. In samples of biological measurements there are two main reasons for non-normality:

a) the sample consists of two or more normally distributed subsamples,

b) the sample is homogeneous, but the measurements require some sort of transformation to become normally distributed marginally and/or insure the linearity of the regression.

However, a third possibility exists, the measurements may follow some strictly non-normal distribution. If was found that a large set of biological data, viz. Johannsen's beans, formed a homogeneous sample which could not be transformed to normality. It has been shown that a two-dimensional hyperbolic distribution gives a far more satisfactory description of these data (Blæsild, 1981).

Only one of the single tests for an aspect of multivariate normality of the examples rejected the hypotheses unequivocally, but almost all the others indicated that the samples from Øm Kloster conformed to a lesser degree with the multivariate normality than the samples from Lille Sct. Mikkelsgade. Together all the tests forced the rejection of the hypothesis of normality of the samples from Øm Kloster, since they all indicated the same kind of deviation from normality. A subsample of the Øm Kloster male sample has in fact been subject to a cluster analysis (Boldsen, 1983) and this analysis clearly indicated that the sample consists of two subsamples. On this background it is reasonable to assume that both of the samples from Øm Kloster owe their non-normality to the pattern of burial which allowed two morphologically different segments of the Danish Medieval population to be intered in the same grave-yard.

The samples from Lille Sct. Mikkelsgade show no significant deviation from multivariate normality, so they can be and have been used as reference populations for further multivariate analyses (Boldsen, 1983).

In conclusion we will sum up the procedures recommended when faced with the problems of testing the normality of a sample of multi-dimensional anthropometric measurements. First, test for marginal normality using probit diagrams and the Shapiro-Wilk's test or skewness and kurtosis, and then having accepted the marginal normality of the sample use the coordinate dependent Cox-Small test for the linearity of the regression. If this procedure does not lead to rejection of the hypothesis about multivariate normality, it is safe to use the tested sample as a reference population for further multivariate analyses.

Acknowledgements

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TABLE 1. Estimates of mean, variance, skewness, and kurtosis for each of the five coordinate-variables in the four examples.

	Males					Females					
coordinate	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.	
n	55	55	55	55	55	32	32	32	32	32	Øm Kloster
$\bar{x}.$	477.72	381.74	536.91	24.61	52.80	438.22	372.00	518.94	23.84	50.78	
s^2	775.56	162.69	226.09	5.03	6.17	461.79	175.74	123.48	6.27	6.69	
skewness	-0.57	-0.21	-0.43	-0.43	-0.09	0.19	0.17	0.69	0.00	0.31	
kurtosis	0.17	-1.08	-0.31	0.34	-0.34	-0.19	-0.45	-0.29	0.14	0.31	
coordinate	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.	
n	28	28	28	28	28	24	24	24	24	24	Lille Sct. Mikkelsgade
$\bar{x}.$	471.36	384.43	535.57	24.04	52.82	425.25	366.29	513.46	23.62	49.62	
s^2	344.68	76.25	72.48	4.04	9.71	447.41	85.26	94.00	2.68	10.85	
skewness	-0.31	0.47	0.42	-0.22	0.38	0.33	0.26	-0.23	-0.04	-0.22	
kurtosis	-0:13	-0.40	-0.77	-0.13	0.04	-0.72	0.32	-0.48	-0.46	-0.25	

TABLE 2. The t-statistics of the Cox-Small tests for linearity of the regression.

	Males					Females					
	squared variable:					squared variable:					
dependent variable:	1	2	3	4	5	1	2	3	4	5	
1	–	0.97	0.28	-3.05**	1.92	–	-0.77	-0.48	-0.28	0.64	
2	-0.91	–	1.02	2.74**	0.19	-1.08	–	-1.43	-0.14	-0.76	
3	1.23	-0.46	–	-1.17	0.26	0.39	1.59	–	-0.40	1.25	Øm Kloster
4	-0.16	0.24	-0.05	–	-0.79	-2.72*	-0.81	-2.37*	–	-1.07	
5	0.43	-1.55	0.45	1.12	–	0.60	-2.99**	-2.11*	0.51	–	
	squared variable:					squared variable:					
dependent variable:	1	2	3	4	5	1	2	3	4	5	
1	–	-0.88	-1.58	0.15	1.00	–	0.16	-0.68	0.13	-0.09	
2	1.31	–	1.80	-0.43	0.37	0.76	–	1.33	0.90	-0.90	
3	-1.64	1.17	–	0.06	0.37	-0.47	-0.19	–	-0.57	0.74	Lille Sct. Mikkelsgade
4	0.51	0.37	-0.76	–	0.01	1.97	0.28	1.64	–	-0.23	
5	1.09	0.28	0.02	0.00	–	0.43	0.27	0.26	1.80	–	

* $p < .05$
** $p < .01$

Varnish Replicas: A New Method for the Study of Worked Bone Surfaces

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OSSA

An account is given of a new method for the study of worked bone surfaces. A metallography varnish is used to obtain transparent replicas that can be examined under a reflected or transmitted light microscope or by SEM. They are folded out to enable a surface to be investigated on a single plane and do away with the difficulties of illumination and shading encountered when original objects are examined under a stereoscopic microscope. Experiments showed that various stone tools and different methods of polishing left typical marks that can be used to trace the technological history of the manufacture of prehistoric bone artifacts.

Keywords: Varnish replicas - Bone artifacts - Striae - Prehistoric technology.

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During the course of prehistory, lithic industries adapted their technology to the size and workability of the raw material at their disposal. The output of bone industries was necessarily confined to the use of skeleton of the contemporary macrofauna. Within this unavoidable morphological and dimensional interval, the manufacture of bone products displayed an appreciable predetermination of the final result and a tendency to use the same materials. In the case of bone products, the techniques employed are of by no means negligible cultural value. Their identification is likely to offer an idea, inter alia, of the importance attached to the parts chosen for working and the animals from which they were derived. Research in this field is thus aimed at establishing the anatomical provenance of the material, and above all at investigating such traces of working and use that can be discerned on the artifacts themselves.

Secondary markings produced by a variety of agents are much more likely to be left on a bone artifact than on a stone tool in the time between its abandonment and its discovery and examination. Once the study of bone industry is carried beyond the establishment of their type and morphology, an attempt must be made to detect signs of secondary alteration of the surface due to trampling, erosion and the action of animals and plants, and to distinguish such marks from those due to human actions.

This paper describes a method that can be employed in working out the pattern of manufacture and utilisation of bone artifacts. Early work in the 1960s has recently been followed by a marked increase in the number of studies and experiments on the microtraces discernable on prehistoric instruments. Attention has primarily been directed to traces of wear on stone rather than bone artifacts (Keely and Newcomer, 1977; Brink, 1978; Keely, 1980; Meeks et al., 1982). Bone products have mainly been the subject of typological and typological-evolutive studies and experimental working (Biberson and Aguirre, 1965; Dauvois, 1974; Camps-Fabrer and D'Anna, 1977; Dauvois, 1977; Newcomer, 1977; Stordeur, 1977; Barge, 1980), sometimes in conjunction with ethnographic parallels (Berke, 1977; Hahn, 1977). Even though it has so far received relatively little attention, the study of worked or worn bone surfaces has led to promising results and the formulation of attractive working hypotheses (Semenov, 1964; Dauvois, 1974; Bouchud, 1974 A and B, and 1976). It would seem that indications of how various stone instruments were used and how objects were smoothed and polished can be derived from the traces left on worked bone surfaces.

These surfaces are usually examined under a stereoscopic microscope at various magnifications. The scanning electron microscope (SEM), of course, has proved capable of supplying a vast amount of information. Its employment, however, is not without drawbacks: heavy management costs, the difficulty of examining large objects, and the need to metallise the surface in a virtually irreversible manner. Little use has so far been made of SEM in the study of resin casts obtained from elastomer negative impressions of the originals (tooth surfaces: Gordon, 1982; cutmarks made on bones by stone tools: Potts and Shipman, 1981). This is because the inevitable loss of detail caused by the two-steps negative-positive transfer is compounded by retraction of the resin (about 1/200) during polymerisation. The results are also dependent on the quality and hence the cost of the resin used. Metallisation of the original is rendered unnecessary, but the high cost and complexity of the technique remain.

Varnishes commonly employed in metallography, on the other hand, would seem to be decidedly more suitable for the study of worked bone surfaces. Their efficacy has already been demonstrated by one of the present writers on tooth surfaces (Puech, 1976 and 1980; see also Gordon, 1982).

At low magnification, microscopic observation in transmitted or reflected light of varnish replicas is thus a practical compromise between the techniques described above and avoids many of their drawbacks. At high magnification, a negative impression gives more detail of the wear (Puech, 1982).

Method

The varnish used is a nitrocellulose compound supplemented with a solvent and a plasticiser (Vernis Replic, supplied ready for use in 250 ml vials by PRESI, 2 avenue Hector Berlioz, 38320 Eybens, France). It should be allowed to stand for a few days before use to remove the bubbles that form during its transportation. These can be removed more quickly by warming the bottom of the vial.

The surface to be examined can be cleaned by taking a series of replicas from the same area. This will take off the deposits in the furrows by adhesion. Before using the varnish, therefore, it is sometimes advisable to take replicas with sheets of plastic softened in a solvent. For example, one can use 0.034 mm thick cellulose acetate films (Bioden, Ernest Fullan Inc., P.O. Box 444, Schenectady, N.Y. 12301, U.S.A.). These soften in acetone without dissolving and are applied on an acetone-soaked bone surface. The acetate film is transformed into a very thick liquid that evaporates on contact with the bone and engulfs unwanted particles.

"Replic" varnish is then poured on. The surface is left on a slant for the approximately 2 hr drying time at room temperature to allow the excess varnish to slump to the bottom. A dentist's double spatule, for example, can now be used to peel off the replica. Wrinkled or cracked surfaces can be advantageously pretreated with 0.2-0.3%

vaseline in double distilled benzene to facilitate the peeling off of the replica. A drop of water mixed with a detergent such as Teepol can also be inserted for this purpose between the bone and the replica at the point where detachment is begun. Capillary attraction assists peeling and so prevents the replica itself from being bent or stretched out of shape.

Replicas of suitable size are best inserted in slide mounts for examination in transmitted light under a light microscope. They can also be viewed like ordinary slides, so that particular parts can be selected for examination at higher magnification. Examination in reflected light or by SEM must be preceded by metallisation in the usual way. Dimensional changes due to ambient factors (temperature, humidity) are less than 2%, and reliable morphometric data can thus be collected. Normal photographic procedures are used. The microphotographs presented in this paper were taken with a Leitz Aristophot II on Agfaortho Professional 25 orthocromatic film. A Summar f 12 lens was used in most cases.

Results

Replicas were used to determine the superficial features of bone worked experimentally with a variety of stone tools (end-scraper, denticulate end-scraper, burin, blade, borer), and by polishing with sand or on a stone. Replicas were also taken of prehistoric bone artifact surfaces of various epochs. Their patterns were then interpreted in the light of the experimental findings. Deer antlers and recently slaughtered horse and cattle long bone shafts were used for experimental working. All the experiments were carried out by the same person and each was repeated several times.

The shape and distribution of the striae left by the various techniques revealed constant differences between them. Length, width, depth, pattern and direction were indicative in this respect, as were the general appearance of the set of striae, and, where recognisable, the pattern of the contact surfaces between the tool and the bone. In the following descriptions, attention will be primarily directed to the main features permitting the differentiation of techniques in the light of the marks they leave. Low magnification (3-10 X) is enough to illustrate shapes and general patterns, whereas 15-20 X is needed to detect the characteristic features of individual striae. Excellent pictures were in any event obtained from the replicas at all magnifications (Fig. 1).

Experimental findings

a) Unretouched blade. Working of a deer antler with an unretouched flint blade as illustrated in Fig. 2A left the striae shown in Fig. 2B. Examination of the replica revealed very thin, but always distinct, long straight striae (Fig. 2C). The contact between the blade and the surface was formed of bundles of thin, parallel striae. The general appearance of the striae and their shape at high magnification (Fig. 2D) displayed no outstanding features, apart from the presence of very thin striae. It may be supposed that the striae are produced by the continuous formation of micro-retouches due to wear/use on the edge of the blade (Kantman, 1971).

b) End-scraper. A flint end-scraper used on deer antler as illustrated in Fig. 3A, left deeper striae on the bone than those made by the blade (Fig. 3B). The replica showed that they were elongated, of varying width and arranged in sometimes convergent, subparallel bundles (Fig. 3C). Their depth was often greater than that of the marks left by the blade. The individual areas of contact between the tool and the bone surface could frequently not be separated from each other. One particular feature of the action of the scraper was the microwave formation of the marks left by its denticles. The replica showed these microwaves as "steps" on the bundles of striae. They were particularly evident at the beginning and end of the action of the tool (Fig. 3D).

c) Denticulate end-scraper. The tool used on this occasion was a carinate denticulate flint end-scraper. It was employed on a bone surface (horse long bone shaft) as illustrated

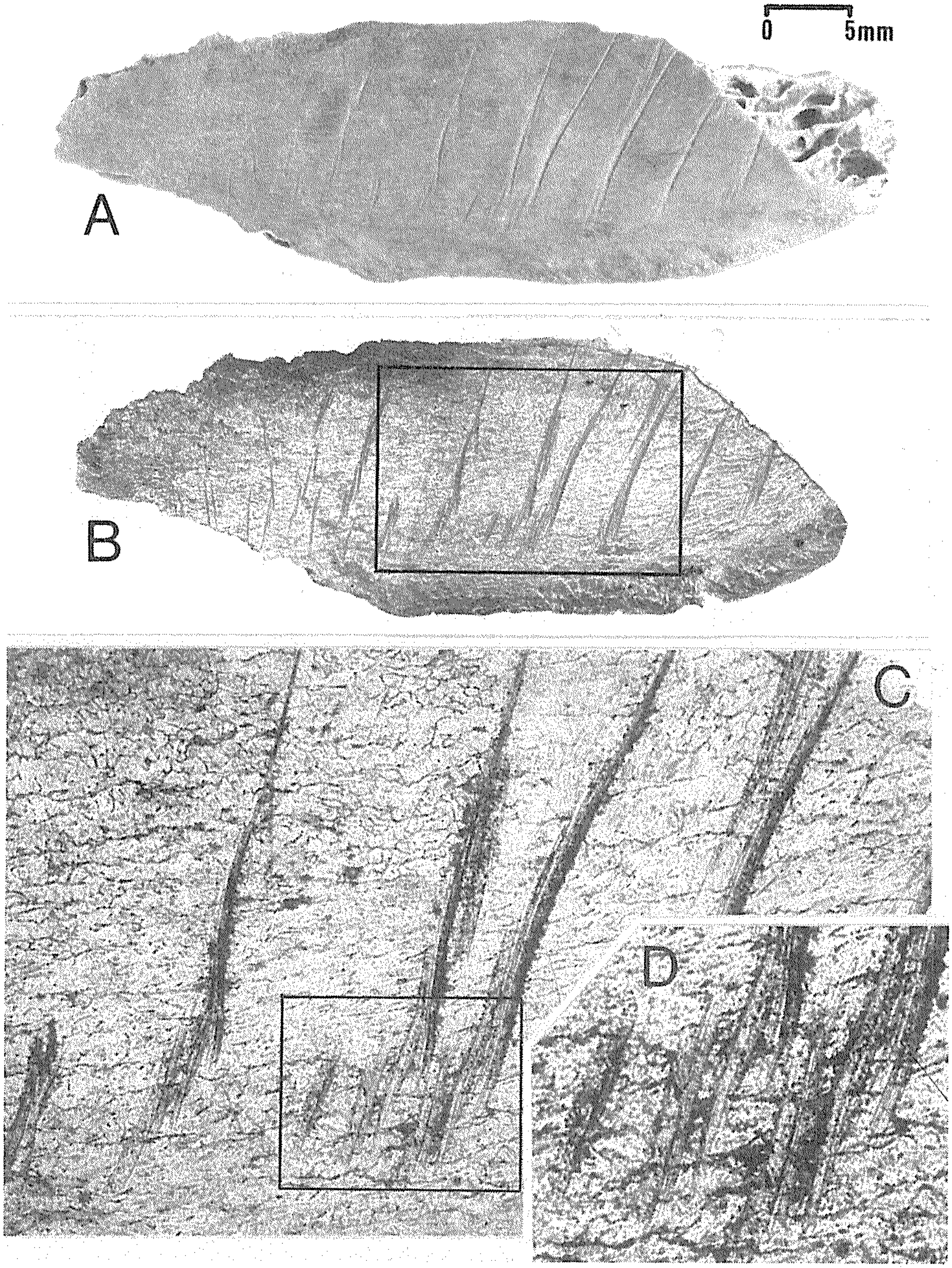

Fig. 1. Magdalenian bone plaque (Petite Grotte de Bize, Aude, France) with subparallel incisions. A) Macrophoto; B) Replica; C-D Squares marked on B and C at higher magnifications.

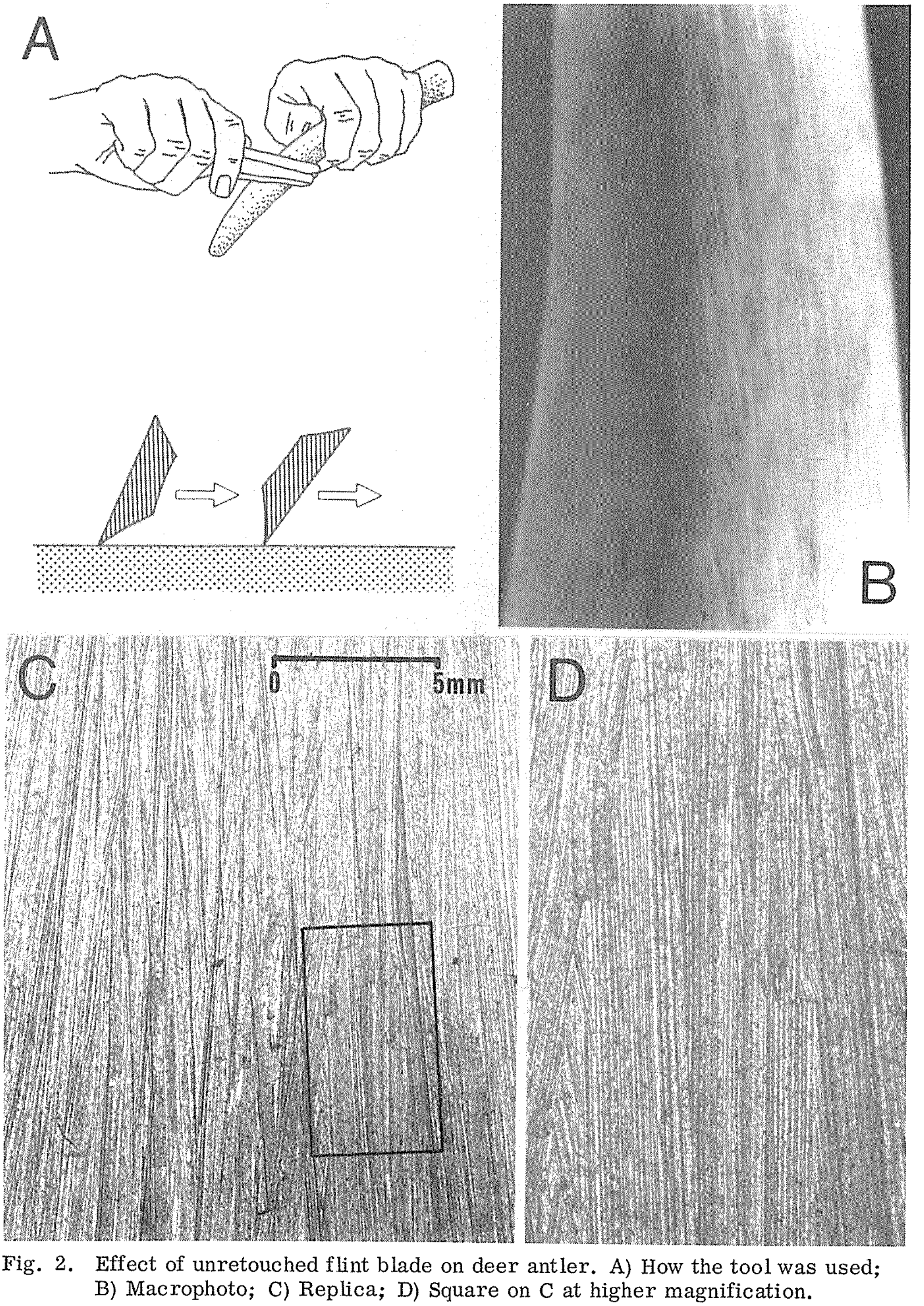

Fig. 2. Effect of unretouched flint blade on deer antler. A) How the tool was used; B) Macrophoto; C) Replica; D) Square on C at higher magnification.

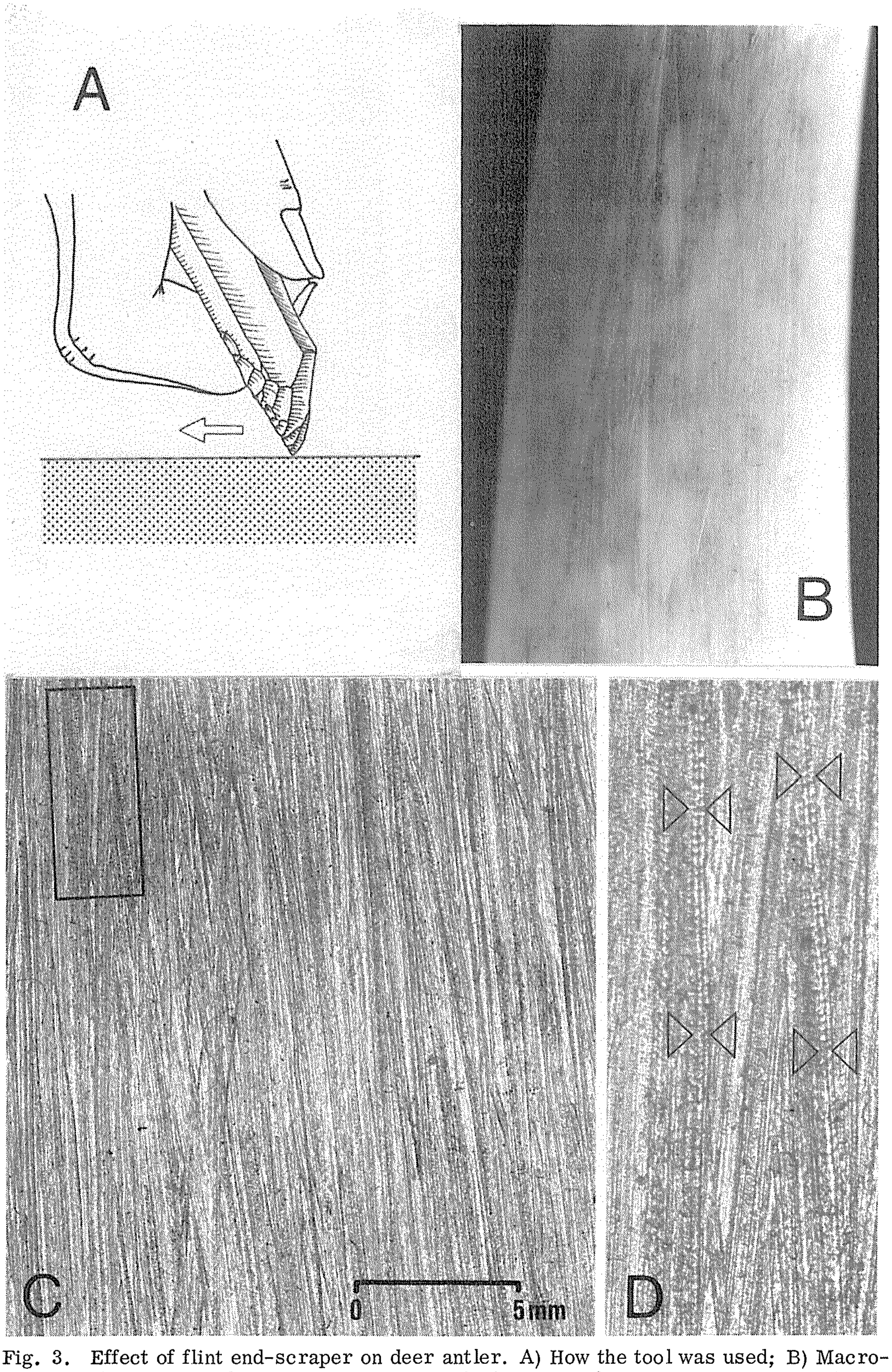

Fig. 3. Effect of flint end-scraper on deer antler. A) How the tool was used; B) Macrophoto; C) Replica; D) Square on C at higher magnification. The arrows indicate the "stepped" pattern described in the text.

in Fig. 3A. The striae it left were very pronounced (Fig 4A). The replica showed that they were arranged in wide, clearly distinguishable bundles, usually curved and partly overlapping (Fig. 4B). It was difficult to discern each area of contact between the tool and the bone, because several denticles worked in parallel, interspersed with very small or no contact areas. Once again, stepwise microwaves could be seen between the bundles (Fig. 4C). They were wider, less marked and sometimes crossed lengthwise by thin secondary striae probably attributable to micro-retouching of the denticle.

d) Crosswise scraping with a dihedral burin. A dihedral flint burin was used on deer antler as illustrated in Fig. 5A (for references on the possible uses of burins, see Pradel, 1973A and B). To the naked eye, the striae it left were thin. Much of their length was crossed by waves at right angles to the working direction of the tool (Fig. 5B). The replica showed that these striae were arranged in broad parallel bands (Fig. 5C). The shape of the striae was indicative of very superficial, rectilinear incisions. Each stria was not of constant width and its path was often clearly discontinuous. The waves were represented by irregularly distributed sets of transversal superficial notches (Fig. 5C and D), whose dimensions very likely corresponded to the width of the contact areas between the burin and the bone surface during the course of the working.

e) Incision with the edge of a burin. When used on a deer antler as shown in Fig. 6C, the edge of a dihedral burin produced a wide, deep groove whose walls were marked by parallel striae (Fig. 6A). These were very clear on the replica (Figs. 6B and D). They were straight in the central section of the groove, but wavy as they neared its ends, i.e. the points where the tool went in and out. Some striae in the bundle were deep, probably corresponding to the working points of contact of the surface of the edge of the burin. Outside the groove, and especially towards its end, there were deep, curved individual striae. These probably correspond to cases in which the tool slipped out of the groove. They are often V-shaped (Fig. 6B), suggesting an immediate return to the main working area.

f) Production of a hole with a borer and a burin. Holes in bone were usually made by prehistoric man with a borer and a burin (references in Bordes, 1969). The technique is illustrated in Fig. 7A. The first step in the working produces a tapered hole on one side of the bone only. When the hole has been made right through the bone, it is widened from the opposite side with both the borer and the burin to make a hole tapering outwards at each end. Both of these truncated-cone surfaces display striae made by the rotation of the tool (Fig. 7B). Their replicas, when detached from each other and turned back on the same plane (Fig. 7C) reveal distinct bundles of striae. These are usually sinuous, especially towards the narrower part of the cones, where they are thinner and generally intersect each other (Fig. 7D).

g) Polishing with sand. After rubbing a deer antler with a damp skin sprinked with sand (grain size: 50-500 µm), the surface displayed thick, parallel striae that were almost invisible to the naked eye and gave a slight sheen (Fig 8B). The replicas bore thick scratches of varying width (Fig. 8C). These were long and generally parallel, clearly distinguishable from each other, with a uniform distribution in which no bundles could be detected. The typical scratch was "comet-like", with an abrupt stop at the point where the greatest width and incisiveness were reached (Figs. 8C and D). It may be supposed that each grain did its work by making an increasingly deep furrow. At the point where the increase in friction coincided with the decrease in pressure from the skin pressed by the hand, the grain of sand leapt out of its furrow, giving the comet appearance described (Fig. 8A). The widened end of the furrow roughly corresponded to the impression made by the grain before it left the furrow.

h) Polishing with stone and sand. A fragment of horse long bone shaft was polished to make a spatula by placing sand between it and a sheet of sandstone. Very clear traces

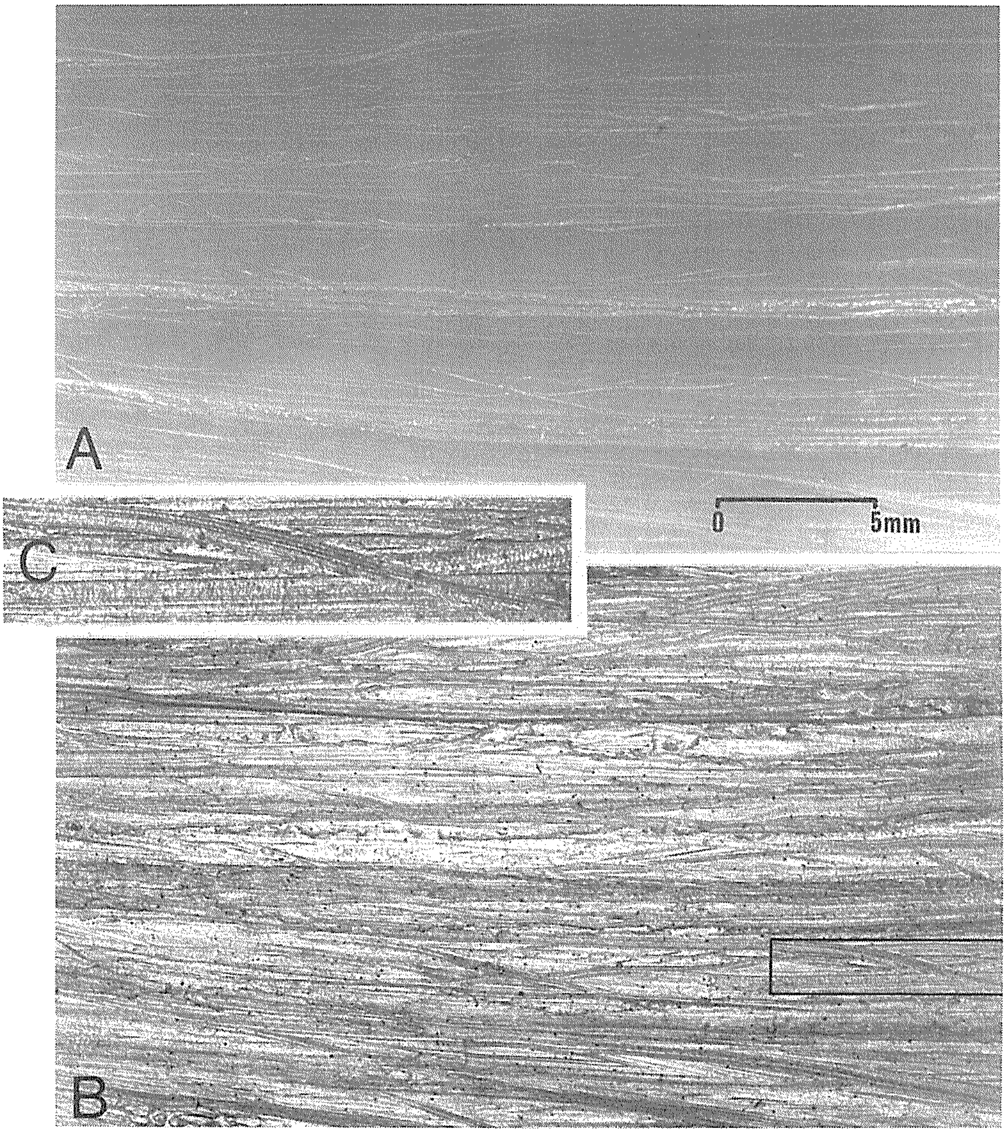

Fig. 4. Effect of flint denticulate end-scraper on horse long bone shaft. A) Macrophoto; B) Replica; C) Square on B at higher magnification.

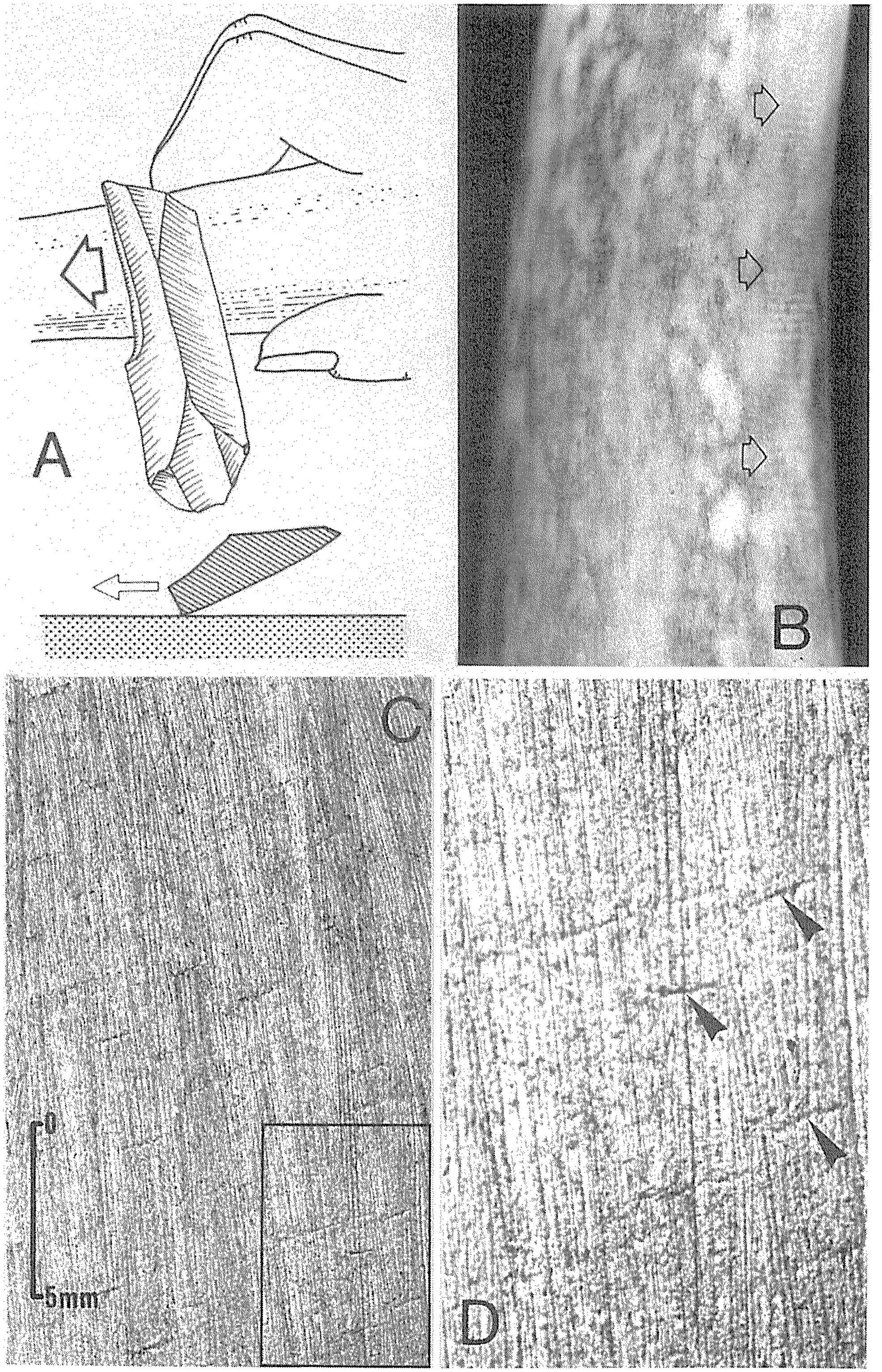

Fig. Effect of scraping deer antler with a burin. A) How the tool was used; B) Macro-photo (the arrows show the waves left by the tool); C) Replica; D) Square on C at higher magnification. The arrows show the typical crosswise notches mentioned in the text.

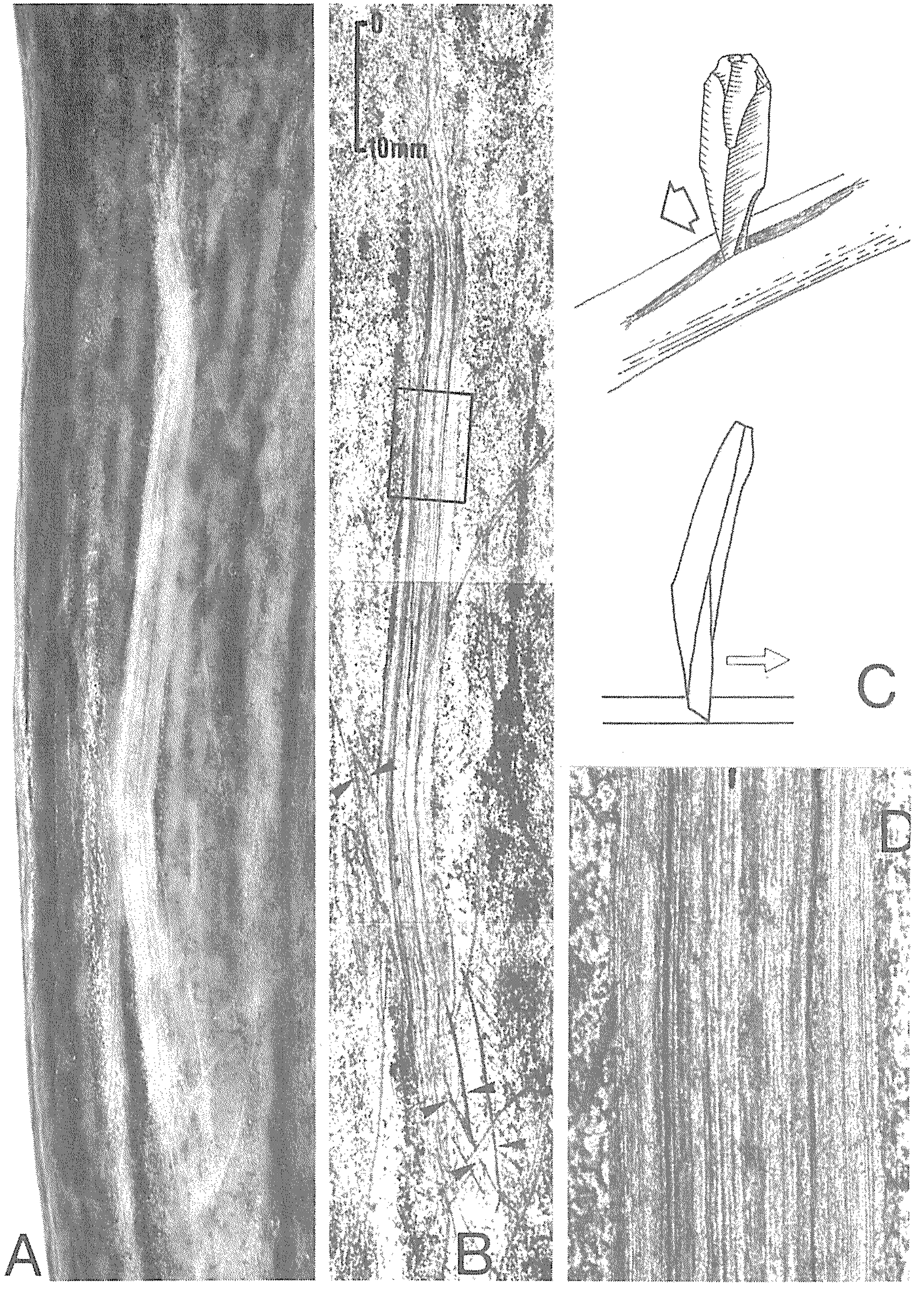

Fig. 6. Effect of engraving a deer antler with a flint burin. A) Macrophoto; B) Replica, the arrows indicate the V-shaped striae made when the tool came out of the groove (see text); C) How the burin was used; D) Square on B at higher magnification.

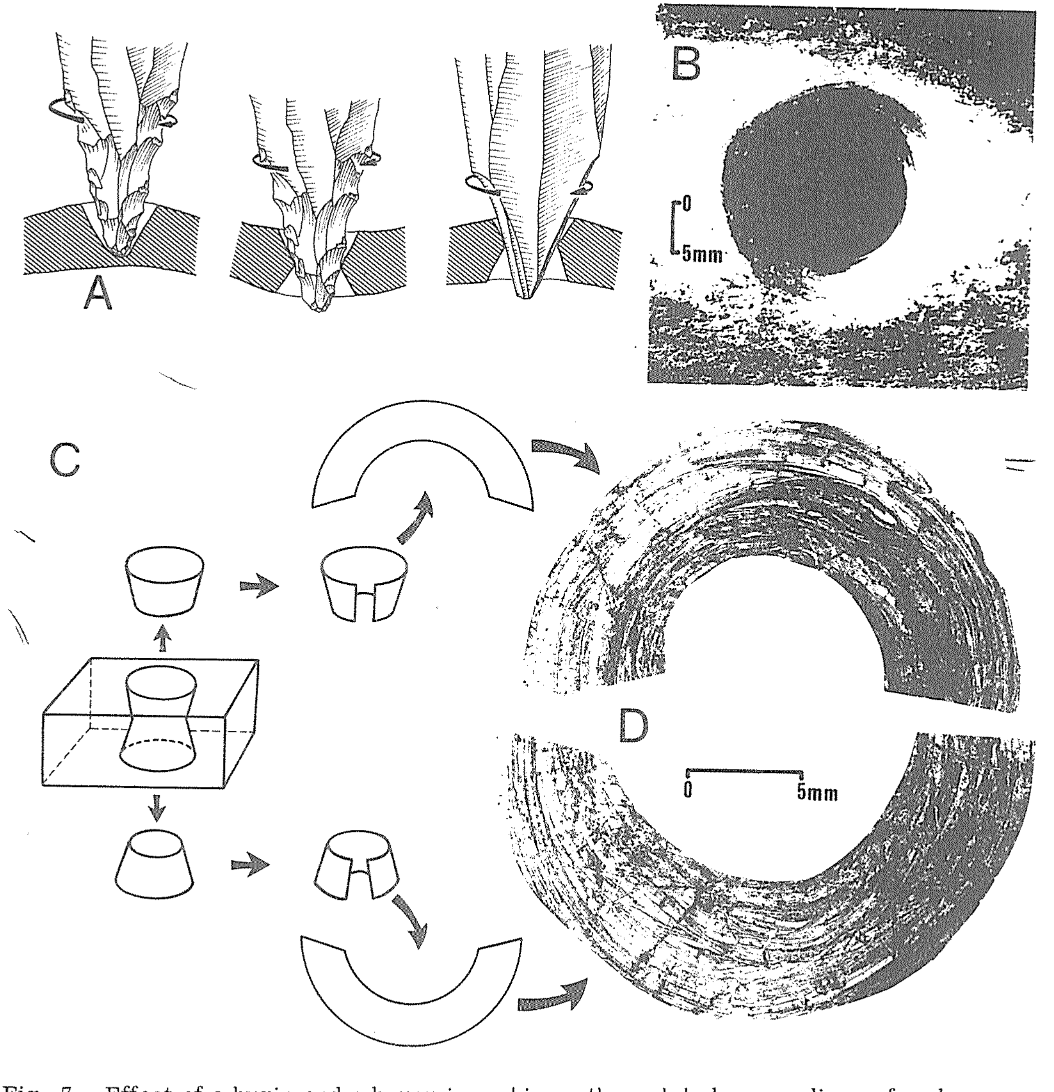

Fig. 7. Effect of a burin and a borer in making a through hole on a sliver of ox bone. A) How the tools were used; B) Macrophoto of the hole; C) How the replicas were taken and unrolled; D) Replicas.

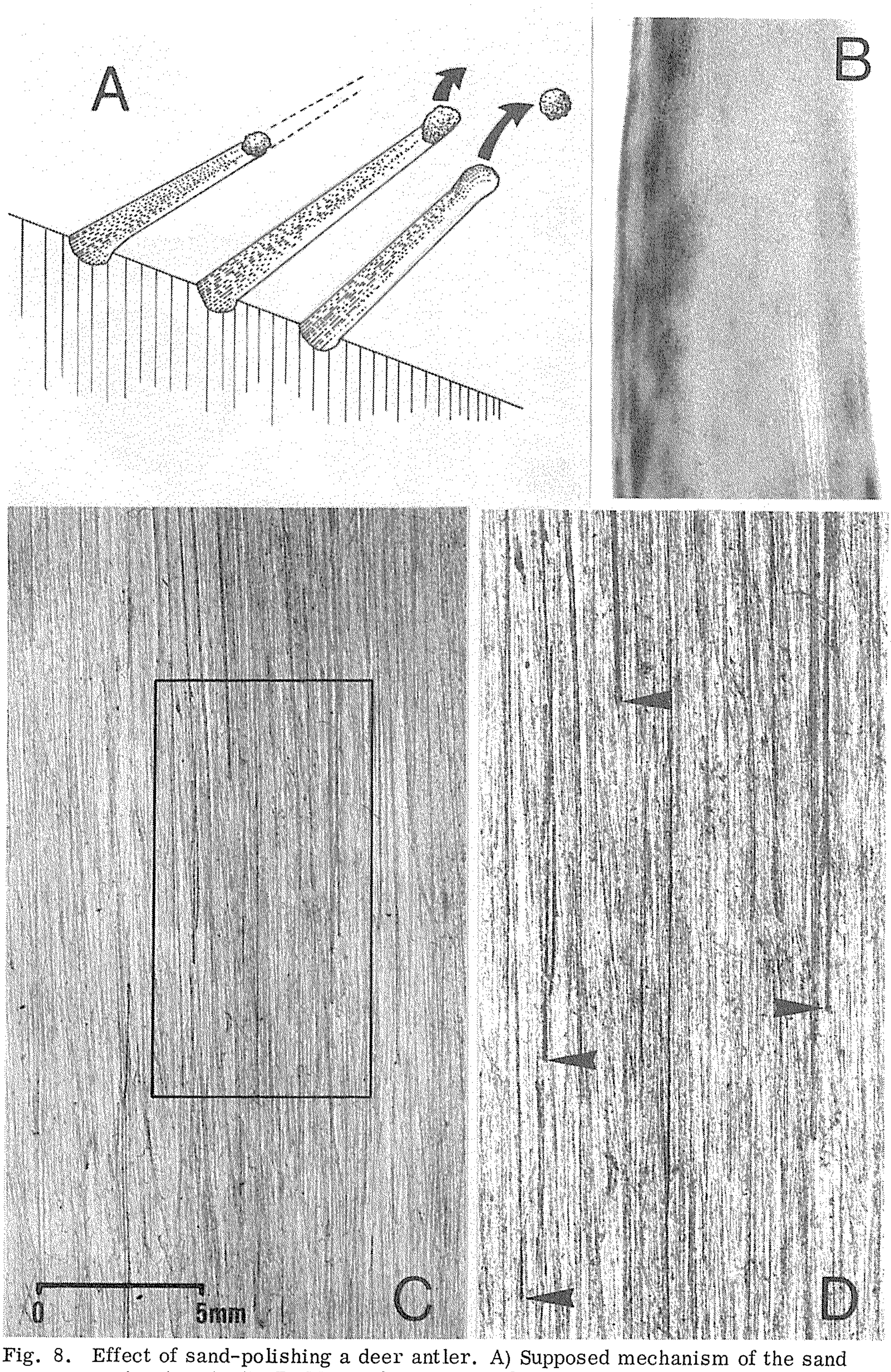

Fig. 8. Effect of sand-polishing a deer antler. A) Supposed mechanism of the sand grains (see text); B) Macrophoto; C) Replicas; D) Square on C at higher magnification showing the "comet" pattern (arrowed) described in the text.

were left on the surface of the bone (Fig. 9B). The replica presented short, long striae, not exactly parallel but arranged in groups, sometimes superposed and slightly overlapping (Fig. 9C). Individual striae (Figs. 9C and D) displayed a "spindle" shape, with a deep incision at the centre and indistinct at the start and the end. Differences in stria width were related to the presence of an abrasive matrix composed of different grain sizes (50-500 μm). The contact area between the bone surface and the abrasive matrix can be seen as slight facetting of the bone. On the replica, these facets are observed as areas formed of the association of subparallel striae. A schematic illustration of the action of the abrasive grains is given in Fig. 9A. Both the entrance and the exit of the grain from its groove are gradual, giving rise to the spindle appearance described. This is referable to the combined effect of the pressure exerted on the bone by the block of stone and the small amount of movement of the single grains of sand almost entrapped in the roughness of its surface.

i) Rubbing on sandstone. The replica of a deer antler rubbed on a piece of sandstone shows short, subparallel and shallow striae (Fig. 10A and B), usually arranged in short, small bundles. These bundles lie in the same general direction, but are unevenly distributed over the surface.

j) Polishing on sand after working with a stone tool. Polishing makes surfaces worked with various stone tools more uniform and shinier. The striae left by such tools become fainter and almost disappear as polishing proceeds. The result is similar to that in Fig. 8. One difference is that the discontinuities left on the surface by stone tools reduce the travel of the sand grains, so that the "comet" scratches are shorter. Slight polishing does not cancel the typical marks made by individual stone tools (e.g. scraping with a burin followed by sand-polishing in Fig. 11).

Observations on prehistoric artifacts

The replica method also gave good readings when used on prehistoric bone artifacts. A detailed account of some prehistoric bone industries will form the subject of further papers. We here offer some examples of replicas from prehistoric materials for comparison with the experimental results described above, and as an initial attempt to determine the technique used in their manufacture.

Fig. 12 shows a fragment of an oval-section Magdalenian ivory stick from the Petite Grotte de Bize, Aude, France (see Sacchi, 1977). The two main faces are shown in Fig. 12A, while their combined replica at the same magnification is illustrated in Fig. 12B. The striae on the object are clearly visible on the replica. They suggest that two forms of action took place. There are straight, though sometimes arched lengthwise striae, clearly distinct from each other and not arranged in bundles. Some of them show the point of entry and exit of the tool. There are other striae made when the tool accidentally slipped out of its groove. Their V-shape is comparable with that made by a burin (Fig. 6B). It may thus be suggested that the striae were made by the edge of a burin. The crosswise notches in the centre (clearly visible on the macrophotograph in Fig. 12A) are less easy to explain. It may be supposed that they were caused by the pressure of a stone tool against the surface.

The side edge of a bone plaque from the same source is shown in Fig. 13. It bears thin, curved striae arranged in bundles (replica in Fig. 13B). There are clear breaks in these bundles corresponding to points where the stone tool went in and out of the surface. The general shape of the bundles and the transverse microwaves within them (Figs. 13 C and D) point to the working of the edge with an end-scraper.

The tip of a Magdalenian bone point (same provenance) is shown in Fig. 14A. Its section is polygonal and its surface is covered with thin, straight lengthwise striae. These are also evident on the replica in which the whole face of the conical-pyramidal tip is spread over the same plane (Fig. 14B). Owing to the lack of distinctive features of the striae, it may be assumed that the point was worked with an unretouched or little retouched blade. On one sector, there are long cavities corresponding to boundary cavities

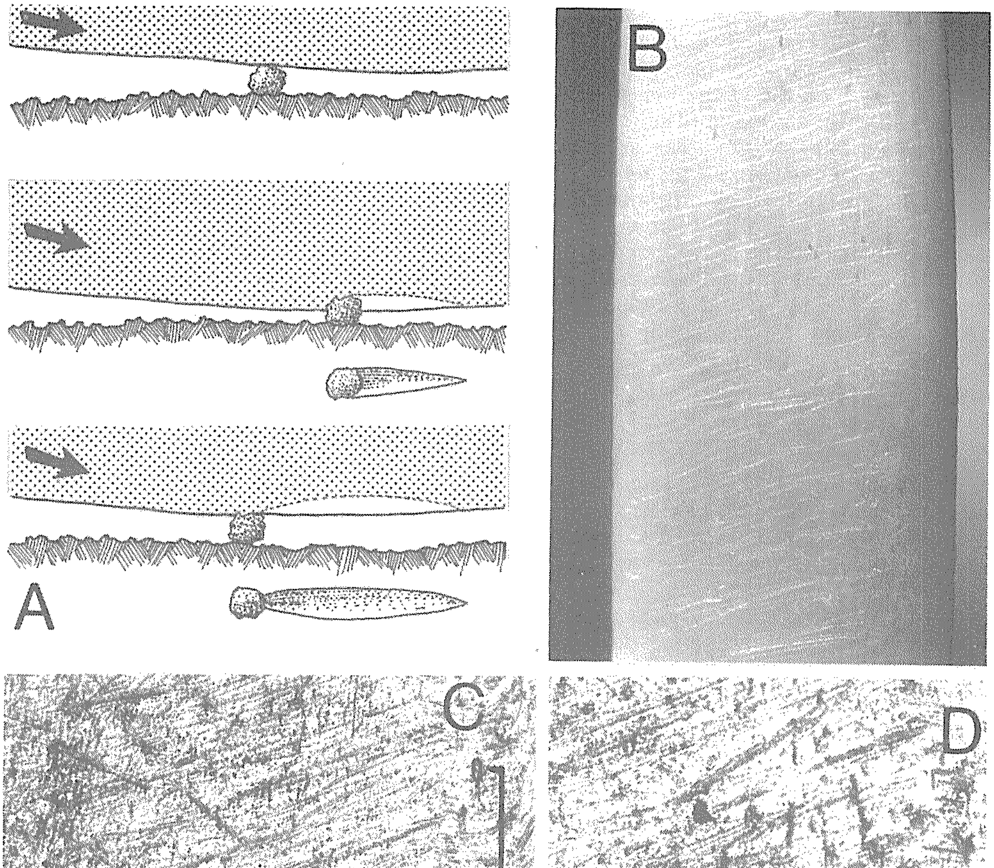

Fig. 9. Effect of polishing horse bone shaft with stone and sand. A) Supposed mechanism of the sand grains between the stone and the bone surface (see text); B) Macro-photo; C) Replica; D) Square on C at higher magnification, showing the typical "spindle" striae described in the text.

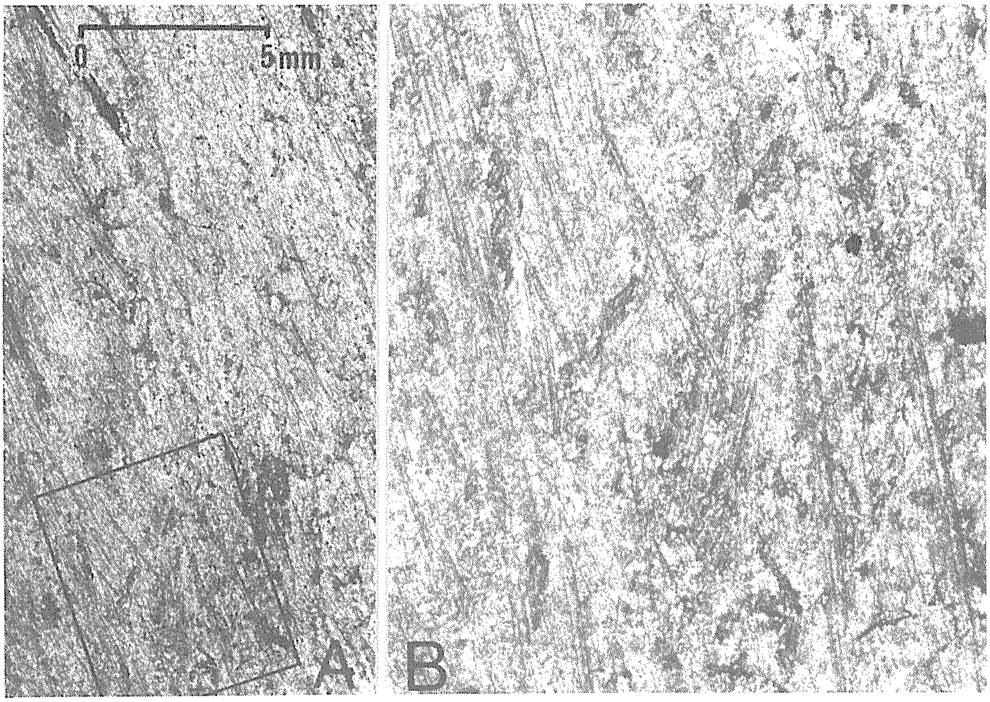

Fig. 10. Effect of polishing horse long bone shaft on sandstone. A) Replica; B) Square on A at higher magnification.

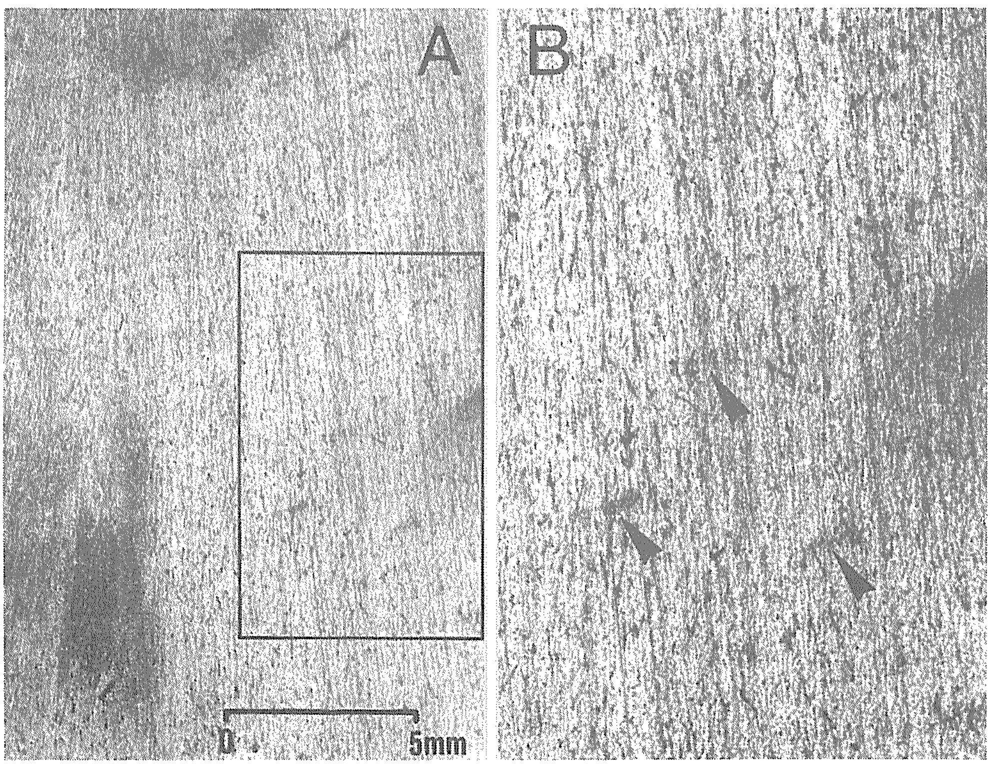

Fig. 11. Effect of polishing with sand after scraping with a burin (cf. Fig. 5). A) Replica; B) Square on A at higher magnification. The arrows show the typical crosswise notches left by the burin and their partial removal by polishing.

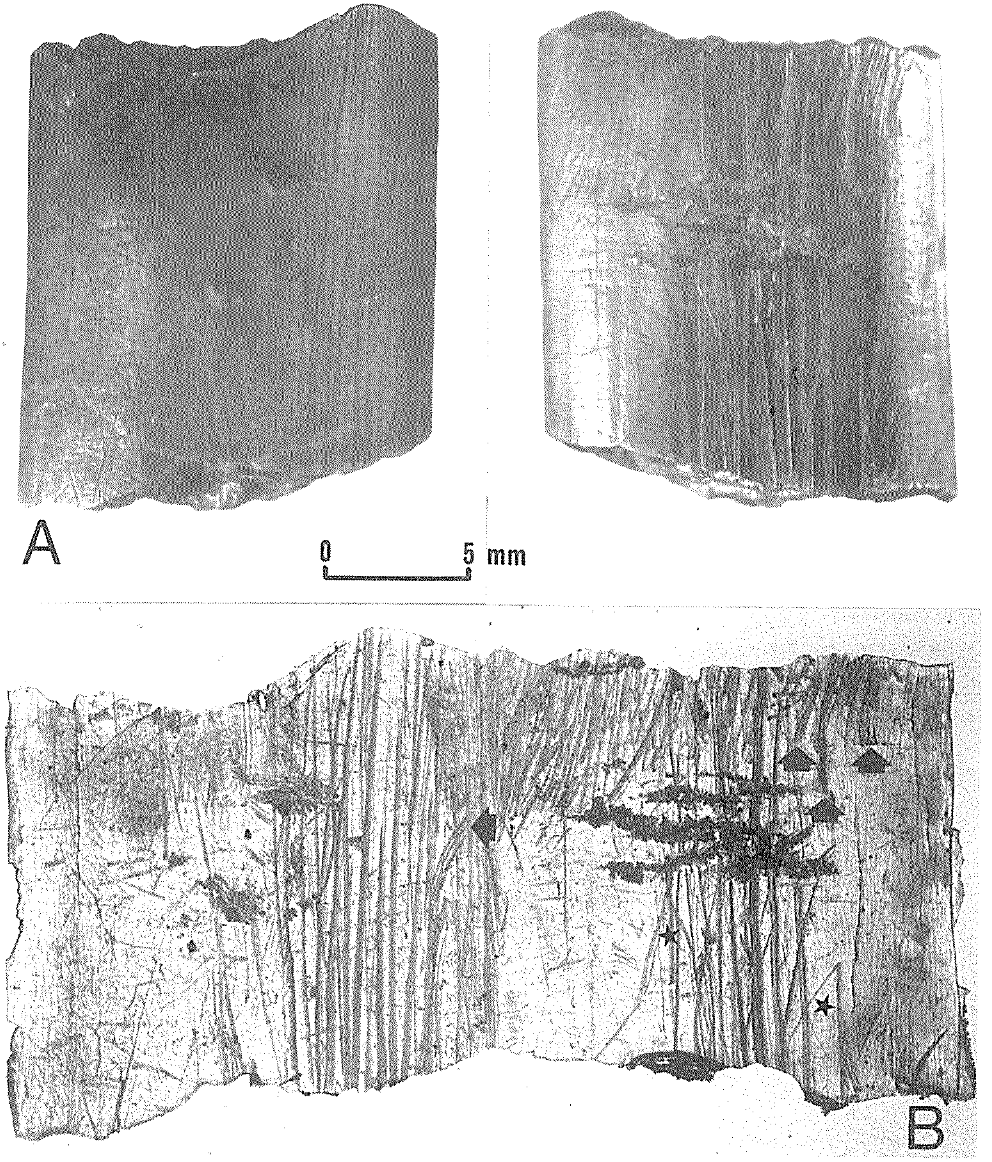

Fig. 12. Fragment of Magdalenian ivory stick (Petite Grotte de Bize, Aude, France). A) Macrophoto of the two faces; B) Replica of the entire surface. The asterisks show typical V-shaped striae left by the burin edge (cf. Fig. 6). The arrows show where the burin began to work.

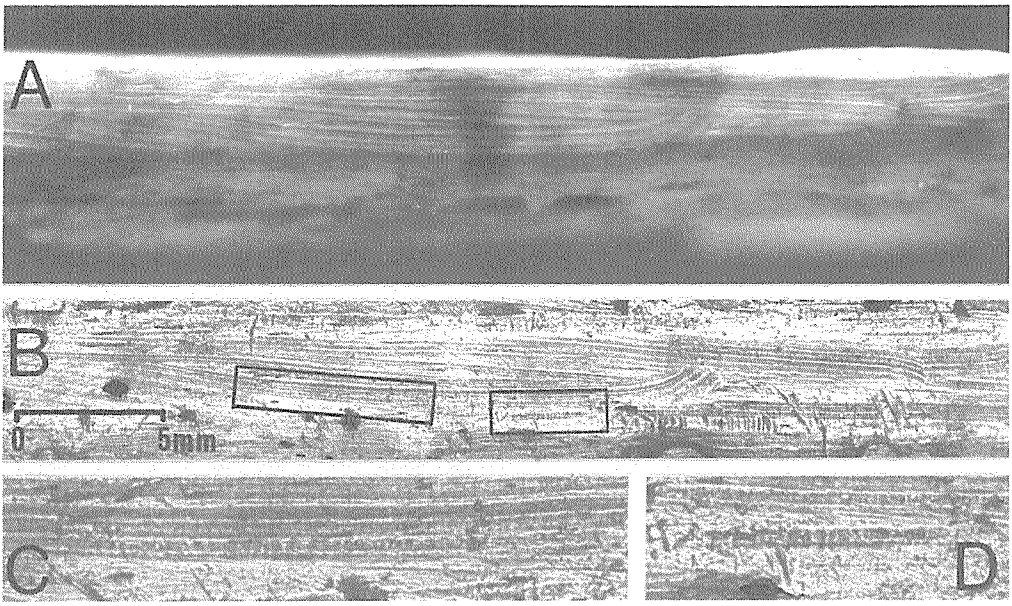

Fig. 13. Back of a Magdalenian bone plaque (Petite Grotte de Bize, Aude, France). A) Macrophoto; B) Replica; C-D) Squares on B at higher magnification showing the stepped pattern described in the text (cf. also Fig. 3).

between the compact and spongy bone of the reindeer antler from which the point was made.

A Bronze Age bone point from Southern Italy is shown in Fig. 15A. It is very much facetted at the tip. These facets are covered with thin, oblique striae, partly visible to the naked eye. The single-plane replica (Fig. 15B) makes it clear that they are arranged in parallel groups obliquely to the axis of the artifact. The striae on a facet may sometimes be crossed by others at a different angle (Fig. 15C). The shape, association and direction of the striae are very reminiscent of those produced by polishing with sand and stone (Fig. 9). The presence of facets is in line with this interpretation. It may be supposed that the object was made in stages, the tip being rubbed on the abrasive matrix at different angles.

Bone surfaces smoothed by the action of natural forces are illustrated in Fig. 16. These are pseudo-artifacts from Würmian deposits in Alpine Caves (Sambughetto grottoes, Novara, N. Italy). Charriage à sec caused by the trampling of cave bears has given them the appearance of tools made by smoothing with sand (see Jéquier, 1975). The striae on the replica, however, even though they sometimes have the comet form shown in Fig. 8, have an overlapping pattern. The direction taken by individual striae or bundles of a few subparallel striae is purely random (Fig. 16B). Where the "polishing" action has been slight (Fig. 16A), there are few striae and one can clearly see the outlets of tightly packed parallel vascular channels representing the passage of vessels from the periosteum.

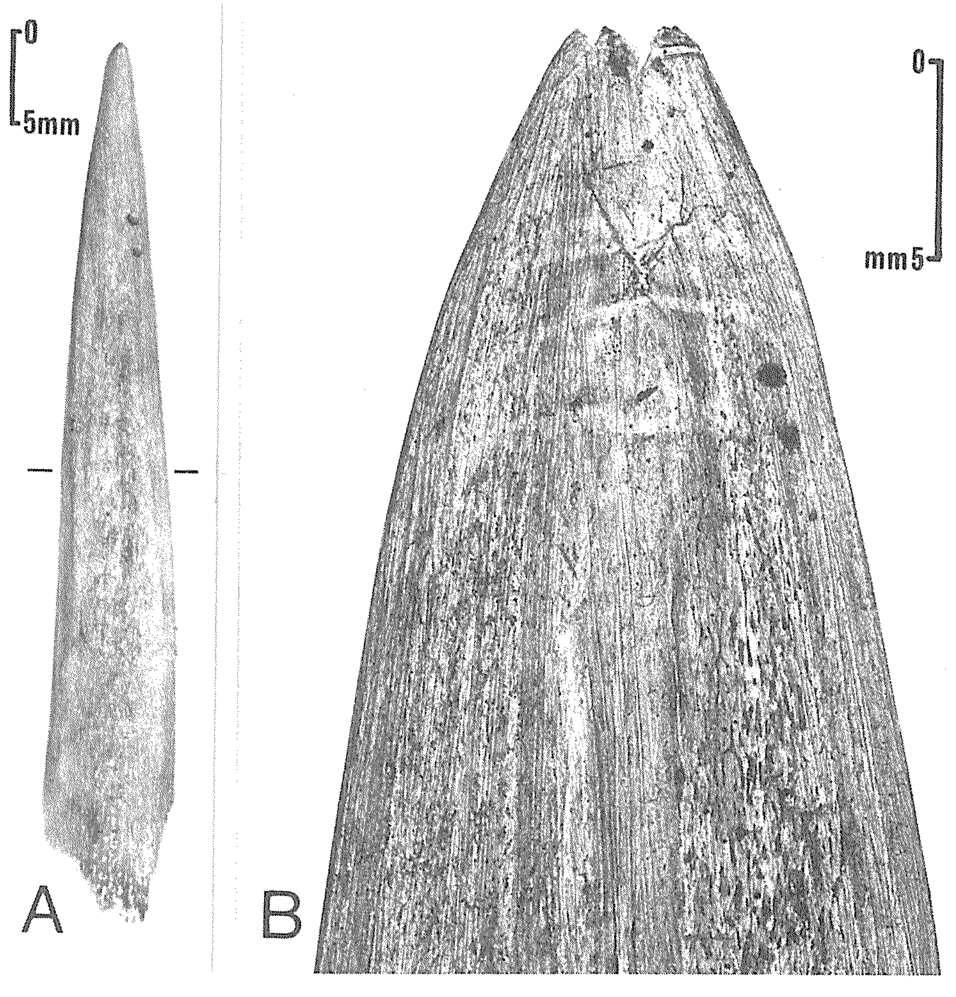

Fig. 14. Tip of Magdalenian bone point (Petite Grotte de Bize, Aude, France). A) Macrophoto; B) Replica taken between the tip and the lines shown on A and unfolded on a single plane.

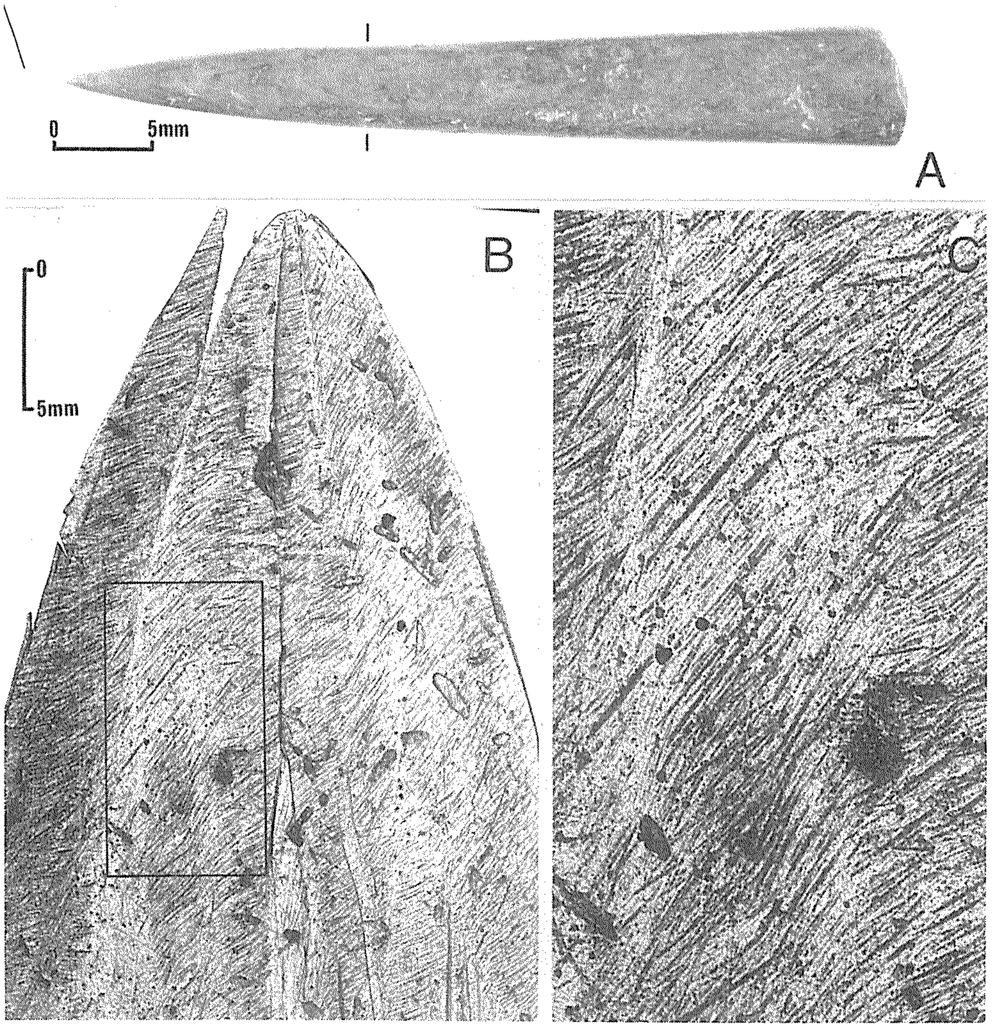

Fig. 15. Bronze Age bone point (S. Italy). A) Macrophoto; B) Replica taken between the tip and the lines shown on A, and unfolded on a single plane; C) Square on B at higher magnification showing the "spindle" striae described in the text (cf. also Fig. 9).

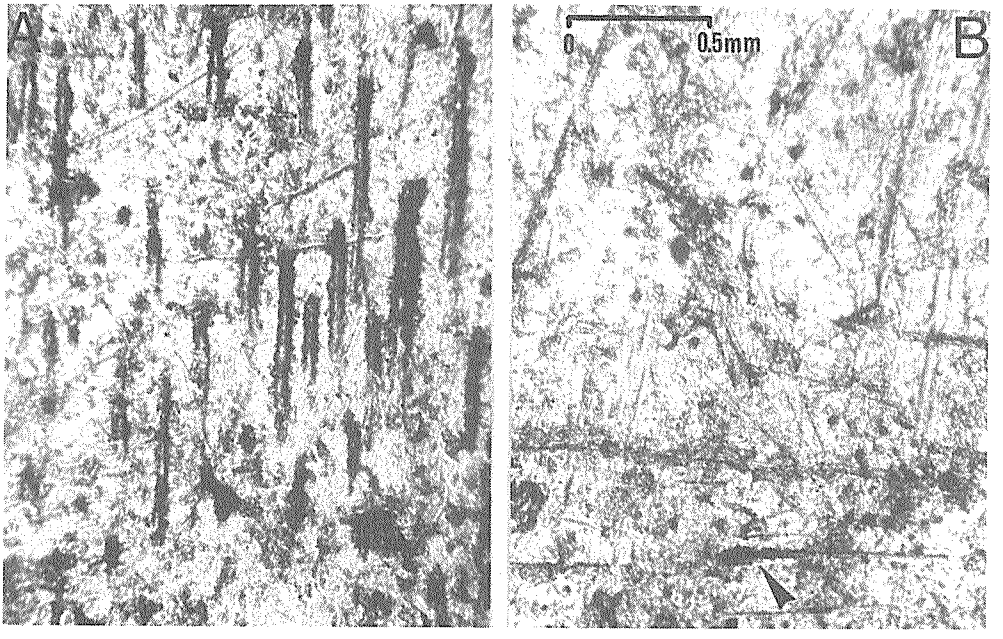

Fig. 16. Replicas of bone surfaces worn down by charriage à sec (Würmian deposits from the Sambughetto grottoes, Novara, N. Italy). A) Natural surface of long bone shaft fragment showing the mouths of vascular channels and a few overlaid striae due to trampling; B) Criss-crossing of the surfaces by striae caused by trampling.

Discussion

Determination of the techniques used in making bone artifacts

Our experimental results suggest that stone tools and the techniques with which they are employed leave characteristic striae on bone. These can be rendered particularly clear and exhaustively read by means of the replica method.

Some replicas of worked bone surfaces presented stria shapes, sizes and arrangements that were closely referable to the use of well defined techniques: working with a burin or scraper, polishing on sand and on sand and stone. On other occasions, the absence of distinctive features meant that determination was partly based on the exclusion of those typical of other techniques (use of an unretouched or poorly retouched blade, polishing on stone).

The prehistoric bone artifacts displayed the same types of marks as the surfaces worked experimentally. Clear reading and recognition of such marks obviously depend on the state of preservation of the surface. Examination of replicas will in many cases provide a reasonably definite clue to the technique or succession of techniques employed. It also enables fairly reliable differentiation of intentional polishing (e.g. with sand) from that due, for example, to charriage à sec.

A systematic study now being made of abundant collections of materials of uniform age, provenance and state of preservation will provide further evidence for the identification of techniques, and the frequency of their spread from one culture to another in the light of the typological percentage composition of the lithic industry in a given horizon.

Final reflections on the replica method

We feel that the replica method described here can be an important source of information, as well as being an advantage to use in several ways. Worked, three-dimensional and often curved bone surfaces are reduced to a two-dimensional, transparent form with no loss of detail. They can thus be examined, even at high magnification, under an ordinary direct-light microscope. The replica eliminates many problems of illumination, shading and depth of field, particularly at high magnification. Large surfaces can thus be examined on replicas spread over the same plane, and photographed with high resolution of even their smallest particulars. Moreover, a replica does away with the difficulties raised by some bone surfaces, such as translucency and patches of colour, so that striae are easier to read.

Very often the shape and size of an object to be examined and the state of preservation of some of its areas make observation in a SEM impossible, while the prolonged handling needed for complete reading under the stereoscopic microscope is also problematical. A varnish replica overcomes these difficulties, since it permits repeated observation with no further treatment of the original. Comparative examination of worked bone surfaces can be carried on replicas in laboratories far from where the objects themselves are located. The technique also permits the formation of files of replicas mounted on slides for easy storage and comparison under the microscope.

By comparison with direct observation by SEM, our method is both simple, quick and decidedly inexpensive. Even large worked areas can be examined as a whole, whereas in direct SEM the field is relatively limited. If metallisation is made of the specimen, it is irreversible (see discussion in Bouchud, 1977). Furthermore, vacuum is difficult to obtain when working with porous and large objects, and causes cracks and fractures in some materials. SEM can be performed on the replicas. The originals need not be metallised and the degree of precision offered by varnish replicas is distinctly better than that of double-impression resin casts. The observation of wear is easier than direct observation, due to the angle of electron incidence necessary to observe the shape of the damage (SEM does not give pictures with normal incidence).

The method also helps to determine the experimental steps in the process used to work bone. A succession of replicas can be made of different stages, such sand polishing after working with a burin (Figs. 5 and 11). Stereomicrophotography, hitherto used to evidence successive experimental actions exerted on materials, obviously does not offer the same preservation of different working stages.

Experience has suggested that certain limits must be placed on the choice of objects and their parts from which to take replicas when studying prehistoric bone artifacts. Fragile or altered surfaces must be avoided, since there is a risk of removing small pieces or even areas of the surface when the varnish is peeled off. Consolidation with cellulose acetate will prevent this form of damage, but at the same time interferes with the accuracy and validity of any examination of signs of working. Some surfaces, such as through holes in teeth, bone beads, eyes of needles, and very porous areas, do not lend themselves to the making of replicas. They are, of course, only partly reachable by other methods. The varnish in these cases is difficult to remove, or even impossible without tearing the replica. Generally speaking, what is obtained is insufficient for the purpose of the examination.

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The Skeleton of a Prehistoric Cow with Characteristics of both Primigenious and Brachycerous Cattle

ALICJA LASOTA-MOSKALEWSKA

OSSA

This study deals with the skeleton of a cow from an animal grave dated at the end of the Neolithic. The morphological analysis has been carried out by a point score method, which is a new technique in the field of archaeozoology: this makes it possible to compare objectively different bone dimensions. The analysis has shown that the skeleton possessed characteristics of both primigenious and brachycerous cattle, providing grounds for the hypothesis that this cow represented an intermediate link between these two types of cattle. This would tend to confirm the theory that evolution of brachycerous cattle from primigenious cattle took place in central Europe among other areas.

Keywords: Neolithic - Point score method - Cattle evolution.

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Two types played a vital role in the development of prehistoric domestic cattle. The first, Bos taurus primigenious, was long-horned, morphologically primitive and was directly descended from its wild ancestor, the aurochs. In earlier epochs, for example in the Neolithic, this type had been numerically clearly predominant in Europe. It had probably developed as a result of local domestication of the aurochs in all the areas where it occurred that had conditions favouring domestication. At present the majority of archaeozoologists working on the evolution of cattle support this thesis (a bibliography is given by Epstein 1964 and Bökönyi 1974). The second type is Bos taurus brachycerous, which was short-horned and considerably smaller than the former; it first appeared in Europe on a mass scale at the end of the Bronze Age. Opinions differ as to whether this latter type represented a continuation of the process of domestication of the first type, or had developed from some other form of wild ancestor. In the present state of knowledge, archaeozoologists are inclined to believe that the Bos taurus brachycerous type of cattle evolved from the Bos taurus primigenious type. Epstein (1964) claims that brachycerous cattle had developed to the point of forming a separate type by c. 3000 B. C. in Asia Minor. The question of how this type appeared on a mass scale in Europe is however controversial: did it result from immigration from Asia accompanying post-Neolithic population migrations, or from local evolution of primigenious cattle. Summing up the arguments on this point, Bökönyi (1984, p. 100) writes "Whether brachycerous cattle were the result of local domestication or had found their way there from other places remains an open question".

Numerical analysis of the ratio of brachycerous to primigenious cattle in Poland has shown that predominance of bulks of the first type occurred earlier than cows (Lasota-Moskalewska, 1980). This suggests local evolutionary changes rather than immigration, since due to greater reactivity of the organism, males undergo morphological change earlier.

However, skeletons which could represent an intermediate link between the two types of cattle are described rather rarely. Bökönyi (1974, p. 120) mentions skulls of this type, referring to finds on the Great Hungarian Plain, published earlier, which had been dated to the Lengyel Culture. The difficulties in describing whole skeletons result from the character of archaeozoological materials, which usually consist in single bones, on the basis of which a given specimen is identified as belonging to the primigenious or brachycerous type.

This study describes a whole skeleton of a cow (from an animal burial) in which a mixture of the characteristics of the two types of cattle has been observed. Bone dimensions have been evaluated by use of a point score, which makes possible more objective comparative analysis of the various bones and their various dimensions.

The material

The subject of this study is a cattle skeleton found during excavations at Wojciechowice, Tarnobrzeg voivodeship (in southern Poland), carried out by the State Archaeological Museum, Warsaw. The skeleton was lying in a grave pit dated to the Neolithic Globular Amphora Culture, with various additional Mierzanowice Culture materials dating from the early Bronze Age (Babel, personal information). The arrangement of the skeleton (Fig. 1) suggests that the cow was slaughtered at the site of the burial. The preservation of the anatomical bone lay-out, and absence of signs of blows, cutting, the effect of high temperatures etc. suggest that this specimen was placed in the earth together with the flesh. The only trace of human activity is to be found in the breaking off of the horn core a few centimetres from the skull. This procedure is fairly common in burials of horned animals and in the specialist literature is treated as a ritual practice (Zimmerman, 1970; Wegrzynowicz, 1982). No pathological changes were found in the bones of the skeleton.

Methods used

Bone measurements were taken in accordance with current international standards (von den Driesch, 1976). The sex of the specimen was established through simultaneous analysis of the length of the metapodial part of the limbs and the index values of width of the diaphysis in correlation fields (Całkin, 1960). Age was determined on the basis of the degree of obliteration of the cranial sutures, the degree of epiphyseal fusion in long bones, and the extent of tooth wear (Chaplin, 1971). In evaluation of the size of individual bones, a point score method has been used; since this is an innovation in archaeozoology, it will be discussed in detail. It is based on the conversion of individual bone dimensions into the appropriate number of points on a scale from 0 to 100. This makes it possible to make direct comparisons between dimensions, irrespective of which bone a given dimension is taken from, and irrespective of whether it is the length, width or circumference of the bone. The point scale was constructed separately for each dimension, based on the series of bone dimensions for cattle from the whole area of Poland taken from archaeozoological literature, used in a comprehensive study of the evolution of domesticated cattle from the Neolithic to the early Iron Age (Lasota-Moskalewska, 1980). These series of dimensions are given in Table I. The smallest size of a given dimension is treated as 0 points, and the largest as 100 points.

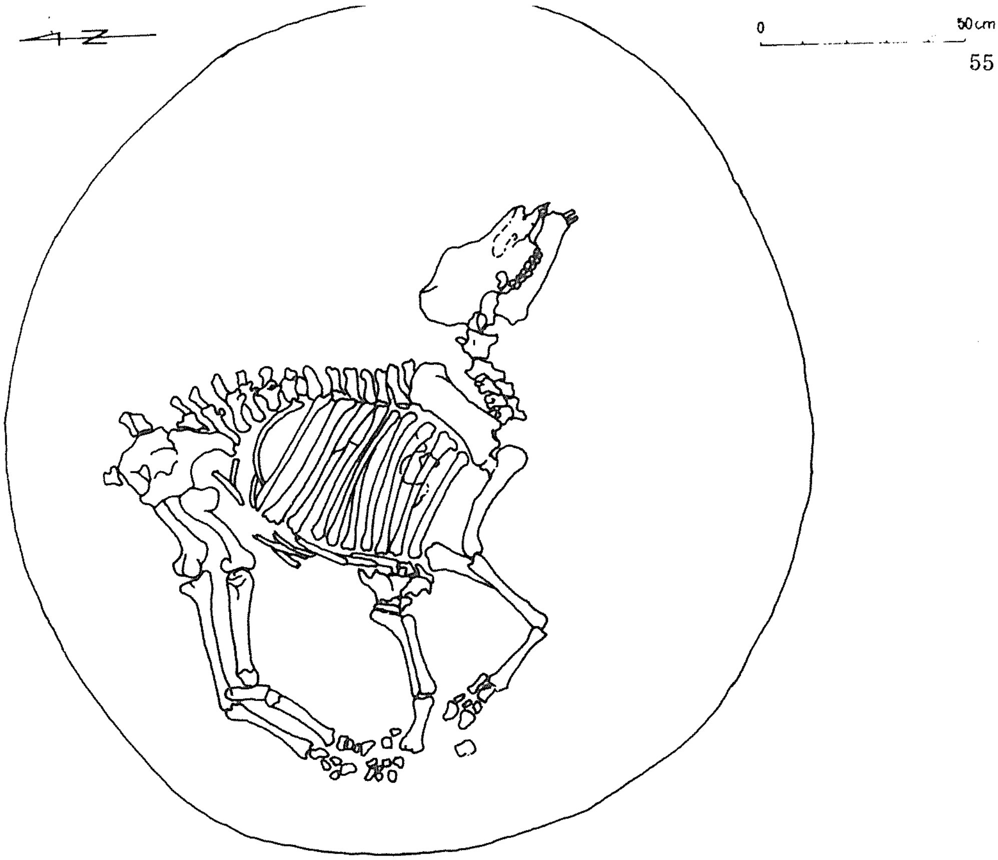

Fig. 1. Field plan of the cow skeleton (by K. Kowalski).

Where material classified earlier as to sex or type of cattle was available, and in the case of series where there was a bimodal, an attempt was made to delimit the range of points for the sexes and types of cattle (Table II). If the curve is the single mode, it was possible to assume that the sexual dimorphism of these dimensions was small, with insignificant typological differences. However, in making use of the point scale, it is necessary to remember these two factors conditioning the position of a given dimension on the scale. The point score for the various bone dimensions is given in Figures 2 to 12. In all the figures, the first left-hand column of figures represents the points on the scale, and the succeeding columns to the right show the scale of variability in the particular dimensions.

The withers height of the animal was calculated on the basis of the length of several long bones and the length of the talus. The following coefficients were used:

Humerus (greatest length)	4.14	Matolcsi (1970)
Humerus (length from caput)	4.77	"
Femur (greatest length)	3.23	"
Femur (length from caput)	3.47	"
Radius (greatest length)	4.30	"
Tibia (greatest length)	3.45	"
Metacarpus (greatest length)	6.00	Fock (1966)
Metatarsus (greatest length)	5.35	"
Talus (side length)	18.30	Całkin (1970)

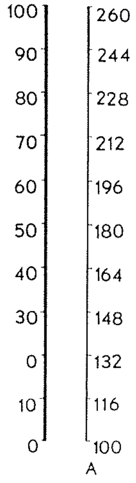

Fig. 2. Horn core (A - basal circumference).

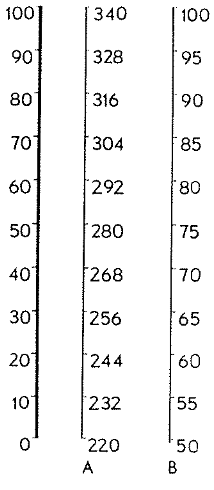

Fig. 4. Humerus (A - greatest length from caput, B - breadth of the distal end).

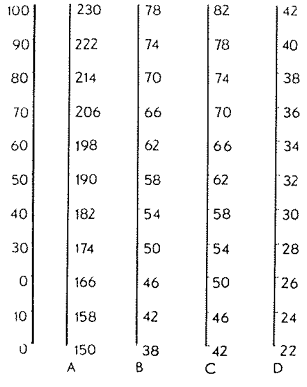

Fig. 6. Metacarpus III + IV (A - greatest length, B - breadth of the proximal end, C - breadth of the distal end, D - smallest breadth of the diaphysis).

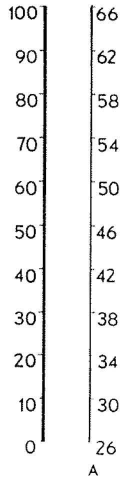

Fig. 3. Scapula (A - smallest length of the collum scapulae)

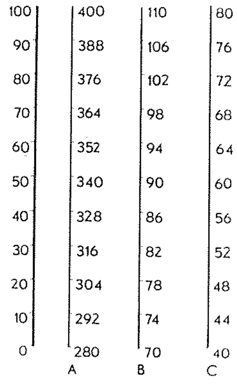

Fig. 5. Radius (A - greatest length, B - breadth of the proximal end, C - breadth of the distal end).

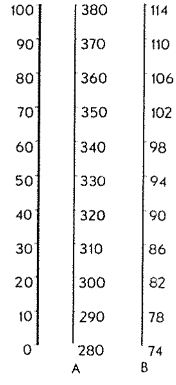

Fig. 7. Femur (A - greatest length from caput, B - breadth of the distal end).

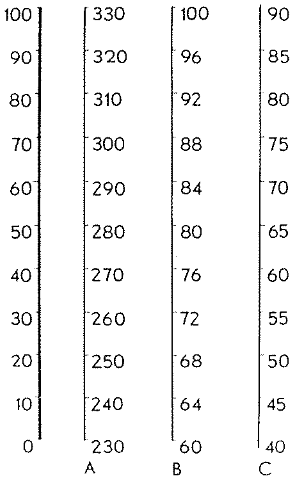

Fig. 8. Tibia (A - greatest length, B - breadth of the proximal end, C - breadth of the distal end).

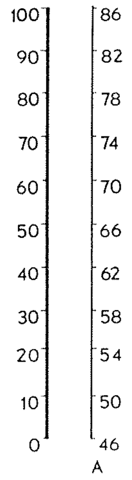

Fig. 9. Talus (astragalus) (A- greatest length of the lateral half).

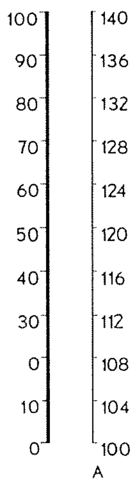

Fig. 10. Calcaneus (A - greatest length)

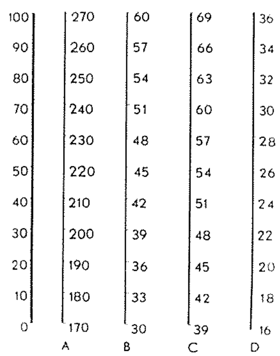

Fig. 11. Metatarsus III+IV (A - greatest length, B - breadth of the proximal end, C - breadth of the distal end, D - smallest breadth of the diaphysis).

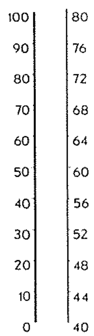

Fig. 12. Phalanx I (A - greatest length).

For the radius, coefficients have been suggested calculated on the basis of primigenious cattle occurring in Polish Neolithic materials. The coefficient value is 4.3 for cows and 3.9 for bulls (Lasota-Moskalewska, 1977, p. 118). The exceptional degree of accordance between the coefficient proposed by Lasota-Moskalewska for cows and that calculated by Matolcsi for both sexes is striking.

Results of morphological analysis

The specimen dealt with in this study was a cow aged c. 10 years. The partly preserved skull is marked by a fairly narrow forehead with slightly prominent orbits. The furrows over the orbits are deep, wide, long and convergent (Fig. 13). The frontal bone is almost straight in profile. The line between the horns is fairly straight. The horncores leave the skull as an extension of the line between the horns (Fig. 14). The horncore basal circumference is 170 mm. These characteristics indicate similarity between the skull under discussion and the skulls of primigenious cattle (Bogolubski, 1968).

The dimensions of the skeleton of the Wojciechowice cow are shown in Table III. Some dimensions have been evaluated on the point score. The dispersion of points attained by the various dimensions is fairly great: from 8 points in the case of length of the humerus, to 55 points in the case of the length of the Collum scapulae. Considering that this beast was a female, it would seem justified to expect to find its dimensions in the lower half of the point score scale. We may take it that a number of points below 30 indicates small dimensions, from 30 to 40 indicates medium size, and a number of points above 40 indicates large dimensions. According to these criteria, the following dimensions can be classified as small: length of the humerus, length of the femur (both measurements from the caput), greatest length of the tibia, and greatest length of the radius. The following dimensions can be classified as medium: breadth of the proximal end of the femur, breadth of the distal end of the radius, all dimensions of the metacarpus, greatest length and breadth of the proximal end of the metatarsus, and length of the phalanx I. The following dimensions can be classified as large: breadth of the proximal end of the radius, breadth of the distal end of the tibia, breadth of the distal end and breadth of diaphysis of the metatarsus, length of the calcaneus, length of the talus, length of the Collum scapulae, and horncore basal circumference.

Analysis of the average number of points of all the dimensions of a given bone shows that the femur is of smaller dimensions than the humerus, the tibia than the radius, while the metatarsus is of slightly larger dimensions than the metacarpus (Table IV). It is therefore possible to conclude that the bones of the hind limbs are relatively smaller than the bones of the fore limbs in two anatomical sections: the stylopodium and zeugopodium. More detailed analysis (Table V) indicates that this result was determined by the relatively smaller dimensions of the breadth of the proximal ends of the bones of the hind limbs. The dimensions of the breadth of the distal ends exhibit the converse tendency, being relatively larger in the bones of the hind limbs. Because of the absence of these dimensions in the stylopodial part of the limbs, it is only possible to say that this last observation is applicable to the zeugopodial and metapodial parts. Analysis of table V suggests one further conclusion: that in the stylopodial and zeugopodial parts of the limbs, the bone length dimensions are relatively smaller than the breadth dimensions.

The withers height attributed to this animal is between 102.4 and 119.0 cm (Table VI). The range in height is wide over 16 cm. The lowest value is arrived at by calculating height on the basis of the greatest length of the femur, and the greatest on the basis of the talus.

Discussion of results

The point score analysis of the size of particular elements of the skeleton of this cow was carried out within the context of the diminution of cattle bone dimensions from the early

Fig. 13. Cranium of cow, dorsal view (photograph by T. Biniewski).

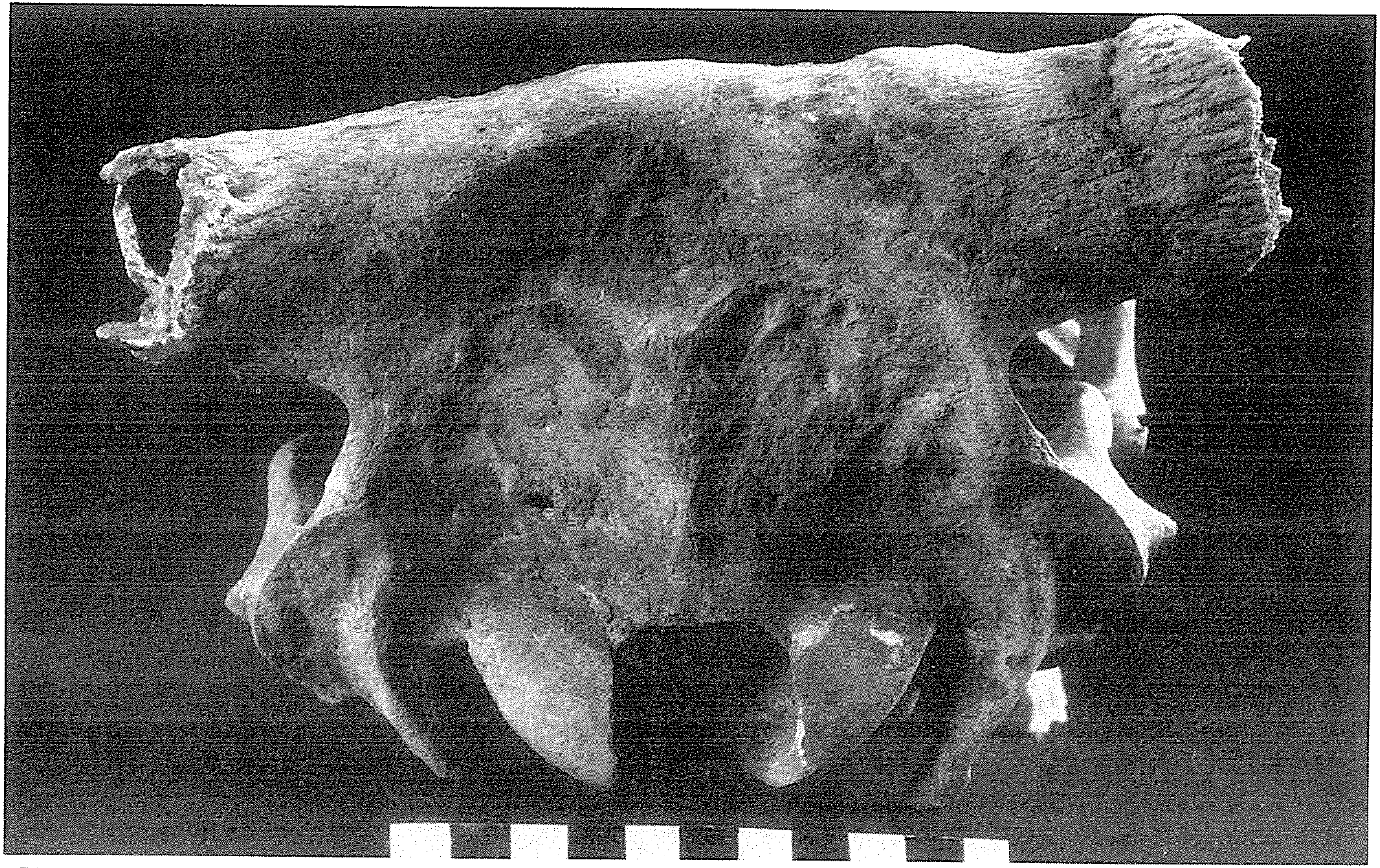

Fig. 14. Cranium of cow, nuchal view (photograph by T. Biniewski).

stage of domestication in the Neolithic to the stage of advanced cattle breeding in the early Iron Age. Over this period, the phenotype of cattle occurring in the Polish territories changed evidently (Lasota-Moskalewska, 1980). Neolithic cattle were predominantly of the primigenious type (Bos taurus primigenious). With time, and progress in the domestication process, the number of primigenious cattle was reduced and smaller specimens, with a more delicate skeleton, occurred ever more frequently; the latter were of the brachycerous type (Bos taurus brachycerous). During the period of Roman influence, almost 100% of cattle bones are of this type. As we have already mentioned in the introduction, the problem of the mechanisms determining this change is still the subject of controversy. The essential fact in this case is that the specimen was placed in the ground in this entirety, which makes it possible to evaluate the morphotype of the whole beast. The skull of this specimen has many of the characteristics of primigenious cattle; both descriptive characteristics and the dimensions of the horncore basal circumference. La Baum (1909) states that the upper limit in this dimension for brachycerous cattle is 150 mm. The horncore basal circumference of the specimen under discussion is 170 mm, and considering that it is a female this dimension may be classified as an attribute of primigenious cattle. The postcranial skeleton exhibits a mixture of the characteristics of primigenious and brachycerous cattle. For measurable characteristics, the criterion for classification as one of the cattle types is bone size. Therefore dimensions attaining more than 40 points on the point score can in the case of a female skeleton be treated as primigenious characteristics, dimensions attaining fewer than 30 points as brachycerous characteristics, and dimensions attaining between 30 and 40 points as a size intermediate between the two types. On this basis, we can conclude that the multiform bones like the calcaneus and talus represent, in view of their greatest length, the primitive type of cattle, while the long bones rather represent the brachycerous type.

A specimen whose skeleton exhibits mixed characteristics of the two cattle types could have been formed as an effect of the following combinations:

a) crossbreeding of an aurochs and brachycerous type beast
b) crossbreeding of a primigenious type and brachycerous type beast
c) local evolution of primigenious type cattle, in which case it would form a link intermediate between the two types.

In the first two cases (a and b) we must consider the problem of the inheritance of skeletal characteristics in the crossbreeding of wild or primitive animals with types which are at a more advanced stage in the domestication process. Unfortunately, in the case of domestic cattle, direct observation is impossible. It is only possible to draw indirect conclusions on analogy with other species. We may expect that in the crossbreeding of forms which are at very different stages in the domestication process, the heterosis effect will occur in their offspring, manifested mainly in increased height. This effect is widely known and occurs in crossbreeds at various degrees of affinity, for example: domestic cattle and bison, domestic cattle and yaks, bactrian cammels and dromedaries (Bogolubski, 1968). This phenomenon is so widespread in the animal world that it is justifiable to expect that the offspring of crossbreeding of domestic cattle with their wild forebears, or with various types of domesticated cattle, would also exhibit great height. The relatively low height of the cow under discussion suggests that it was not of the F_1 generation of this type of crossbreeding. We must then consider whether it could have been the result of a further stage of crossbreeding. Experimental research in crossbreeding bison with domestic cattle has shown that offspring with 3/4 to 7/8 cattle blood are ever closer to cattle in height (Krasińska, 1971). However, in these cases, the size and shape of the head are also increasingly similar to those of cattle. We should therefore on analogy expect that the skull of the cow under discussion would be of dimensions corresponding to those of the skulls of brachycerous cattle. In fact, however, the primitive characteristics of the skull force us to consider the third point (c) - that is, that the cow was an intermediate link in the process of a natural evolution of cattle in conditions of domestication. As is widely known, the size of cattle decreased as a result of the domestication process, with a consequent diminution in the individual parts of the skeleton. This diminution did not necessarily take place harmoniously. Those elements of the skeleton marked by greater conservatism gave way to change later than the more labile elements. Craniometric characteristics are among the most conservative in morphology. In the long bones, breadth dimensions are more conservative than length dimensions. Similarly, the distal elements of limbs are subject to deformation later than the proximal elements. It is generally accepted that those parts of the skeleton which are most highly developed in the prenatal stage exhibit greater resistance to morphologically formative factors. In the cow under discussion, the bones from the stylopodial parts of the limbs are relatively smaller, while the bones from the autopodial parts are the largest. Breadth dimensions are moreover relatively larger than length dimensions. The overall size of the bones from the stylopodial and zeugopodial parts of the limbs is relatively smaller in the hind limbs than the fore limbs. This last fact can also be explained by the greater reactivity of limbs playing a motor role in the organism to morphologically formative factors - a well-known phenomenon in biology. In cattle it is the hind limbs that play this role, while the fore limbs play a supporting role (Poplewski, 1948).

The above arguments suggest the likelihood that the cow under discussion was an intermediate form in the process of the evolution of cattle, bringing about the formation of new morphological types in conditions of domestication. In this way, the Wojciechowice cow may lead to the confirmation of the thesis that not only local domestication of primigenious cattle took place in central Europe, but also the forming of morphotypes which led to the development of brachycerous cattle. We should therefore remember when we have at our disposal only individual bones from various skeletons that it is safer to state the percentage share of cattle typological elements in the population, rather than the number of animals belonging to particular types. This has already been practiced for many years in populational anthropology.

We may now hope that analysis of skeletons from other burials will make it possible to discover various intermediate forms, representing the different stages of cattle evolution.

Summary

The mass appearance of brachycerous cattle in Europe in the Bronze Age represents a problem which continues to arouse controversy. Archaeozoologists cannot agree on whether it was an immigrant from Asia, or was the product of the evolution of local primigenious cattle. Finds of skeletons which by reason of their morphological features can be treated as intermediate links between these two types of cattle are therefore of exceptional importance in throwing light on this question.

This study describes the complete skeleton of a cow, found in an animal burial, which exhibits characteristics of both brachycerous and primigenious cattle.

The convenient point score method has been used to evaluate bone dimensions, providing an objective scale of comparison of various bones and their various dimensions. The transposition of these dimensions into points on a scale from 0 to 100 gives uniform rank to the various dimensions (length, width, circumference) which indicate the degree of size change of a particular characteristics in the process of diminution of the cattle skeleton under condition of domestication.

The skeleton under discussion was found in a grave at Wojciechowice, Tarnobrzeg voivodeship, which has been dated to the Neolithic Globular Amphora Culture, with some admixture of objects from the early Bronze Age. Many of morphological characteristics and the skeleton dimensions, indicated similarities between this specimen and primigenious cattle. In the post-cranial skeleton some bones like scapula, talus and calcaneus were of large dimension. The long bones of the limb showed lack of harmony in the process of dimension diminution. The width of the epiphyses was relatively great, but in

length the bones were of relatively small dimensions. The smallest bones were those of the stylopodial and zeugopodial part of the limbs. The bones from metapodial sections and the phalanx were of dimensions intermediate between the smallest and largest. The withers height, calculated on the basis of the length of the various bones was between 102.4 and 119.0 cm. The lowest value resulted from calculations based on the length of the femur, and the highest from calculation based on the length of the talus.

The analysis indicated that the characteristics recognised in morphology as most conservative were relatively greater, while the labile characteristics were more advanced in the general process of diminution of cattle skeleton. This provides grounds for suggesting that this skeleton of a cow represents an intermediate form between large and small cattle, and thus probably between primigenious and brachycerous cattle. If it is accepted as an intermediate link, it provides further evidence to support the thesis that brachycerous cattle developed locally in Europe due to natural changes taking place in primigenious cattle as a result of domestication.

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TABLE 1. Distribution of various cattle bone dimensions occurring in Polish territories in the period from the Neolithic to the beginning of the Iron Age (all dimensions in mm) f = frequency

Horn core, basal circumference

Class	100-115	116-131	132-147	148-163	164-179	180-195	196-211	212-227	228-243	244-259	260-275
f	8	12	7	13	10	11	6	2	3	3	1

Scapula, smallest length of the Collum scapulae

Class	26-29	30-33	34-37	38-41	42-45	46-49	50-53	54-57	58-61	62-65	66-69
f	1	1	1	10	15	16	6	-	-	1	1

Humerus, greatest length from caput

Class	220-231	232-243	244-255	256-267	268-279	280-291	292-303	304-315	316-327	328-339	340-351
f	2	6	7	3	1	2	-	1	-	1	1

Humerus, breadth of the distal end

Class	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100-104
f	1	2	7	21	35	28	15	15	1	4	2

Radius, greatest length

Class	230-239	240-249	250-259	260-269	270-279	280-289	290-299	300-309	310-319	320-329	330-339
f	4	3	4	3	3	4	4	2	2	1	1

Radius, breadth of the proximal end

Class	60-63	64-67	68-71	72-75	76-79	80-83	84-87	88-91	92-95	96-99	100-103
f	3	17	21	16	14	10	9	3	3	3	1

Radius, breadth of the distal end

Class	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94
f	2	-	2	6	22	12	15	5	3	4	2

Metacarpus III + IV, greatest length

Class	150-157	158-165	166-173	174-181	182-189	190-197	198-205	206-213	214-221	222-229	230-237
f	2	7	34	34	23	19	19	13	4	2	2

Metacarpus III + IV, breadth of the proximal end

Class	38-41	42-45	46-49	50-53	54-57	58-61	62-65	66-69	70-73	74-77	78-81
f	2	6	25	36	42	19	10	11	3	2	1

Metacarpus III + IV, breadth of the distal end

Class	42-45	46-49	50-53	54-57	58-61	62-65	66-69	70-73	74-77	78-81	82-85
f	2	22	30	29	33	15	9	10	6	2	1

Metacarpus III + IV, smallest breadth of the diaphysis

Class	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-39	40-41	42-43
f	6	19	22	22	26	21	10	12	8	9	4

Femur, greatest length from caput

Class	280-289	290-299	300-309	310-319	320-329	330-339	340-349	350-359	360-369	370-379	380-389
f	1	1	1	3	3	2	-	-	-	1	1

Femur, breadth of the distal end

Class	74-77	78-81	82-85	86-89	90-93	94-97	98-101	102-105	106-109	110-113	114-117
f	2	-	3	3	4	1	1	-	-	1	1

Tibia, greatest length

Class	280-291	292-303	304-315	316-327	328-339	340-351	352-363	364-375	376-387	388-399	400-411
f	2	5	1	6	9	2	-	1	-	1	1

Tibia, breadth of the proximal end

Class	70-73	74-77	78-81	82-85	86-89	90-93	94-97	98-101	102-105	106-109	110-113
f	1	1	-	2	5	6	5	1	1	-	3

Tibia, breadth of the distal end

Class	40-43	44-47	48-51	52-55	56-59	60-63	64-67	68-71	72-75	76-79	80-83
f	1	3	19	35	39	20	3	2	3	2	1

Talus, greatest length of the lateral half

Class	46-49	50-53	54-57	58-61	62-65	66-69	70-73	74-77	78-81	82-85	86-89
f	1	12	56	61	46	24	21	8	4	2	1

Calcaneus, greatest length

Class	100-103	104-107	108-111	112-115	116-119	120-123	124-127	128-131	132-135	136-139	140-143
f	1	-	4	4	4	5	10	1	1	-	1

Metatarsus III + IV, greatest length

Class	170-179	180-189	190-199	200-209	210-219	220-229	230-239	240-249	250-259	260-269	270-279
f	4	10	25	25	18	22	12	4	3	1	1

Metatarsus III + IV, breadth of the proximal end

Class	30-32	33-35	36-38	39-41	42-44	45-47	48-50	51-53	54-56	57-59	60-63
f	1	3	7	22	14	24	22	7	11	5	1

Metatarsus III + IV, breadth of the distal end

Class	39-41	42-44	45-47	48-50	51-53	54-56	57-59	60-62	63-65	66-68	69-71
f	1	9	20	17	20	16	13	7	4	12	1

Metatarsus III + IV, smallest breadth of the diaphysis

Class	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37
f	1	1	20	16	33	17	13	10	5	6	1

Phalanx I, greatest length

Class	40-43	44-47	48-51	52-55	56-59	60-63	64-67	68-71	72-75	76-79	80-83
f	3	10	60	100	67	36	10	6	-	5	1

TABLE II. Range of numbers of points typical for the sexes and different types of cattle (Btp Bos taurus primigenius; Btb = Bos taurus brachyceros)

Measurement	Males		Females	
	Btp	Btb	Btp	Btb
Horncore basal circumference	80-100	24-36	40-70	0-25
Metacarpus III + IV				
a) greatest length	56-100	0-56		
b) breadth of the proximal end	65-100	30-65	35-50	0-35
c) breadth of the distal end	60-100	25-60		
d) smallest breadth of the diaphysis	65-100	10-65	35-60	0-35
Metatarsus III + IV				
a) greatest length	50-100	0-50	50-60	0-50
b) breadth of the proximal end	67-100	40-67	47-67	0-47
c) breadth of the distal end	76-100	30-76	40-77	0-40
d) smallest breadth of the diaphysis	40-100	40-100	0-60	0-60

TABLE III. Dimensions of bones of Wojciechowice cow

Measurement	in mm		Number of points
Cranium			
a) Ectorbitale-Ectorbitale	196		
b) Ectorbitale-Entorbitale	58		
c) Least breadth between the bases of the horncore	153		
d) Horncore basal circumference	170		44
Mandibula			
a) Gonion caudale-Infradentale	332		
b) Gonion ventrale-highest point of the condyle process	145		
c) Gonion ventrale-Coronion	186		
d) Length of the cheektooth row	113		
Scapula			
a) Height along the spine	315		
b) Dorsal length	155		
c) Smallest length of the Collum scapulae	48		55
d) Length of the glenoid cavity	52		
e) Breadth of the glenoid cavity	48		
Humerus			
a) Greatest length	260	260	
b) Greatest length from caput	230	230	8
c) Breadth of the distal end	78	77	55
Radius			
a) Greatest length	258	258	28
b) Breadth of the proximal end	75	75	37
c) Breadth of the distal end	66	67	53
d) Smallest breadth of the diaphysis	37	36	
Metacarpus III + IV			
a) Greatest length	178	178	35
b) Breadth of the proximal end	51	51	32
c) Breadth of the distal end	54	54	30
d) Smallest breadth of the diaphysis	29	30	39

cont.

Measurement	in mm								Number of points
Femur									
a) Greatest length	317								
b) Greatest length from caput	304								24
c) Breadth of the distal end	87								32
Tibia									
a) Greatest length	297	297							14
b) Breadth of the proximal end	89	89							47
c) Breadth of the distal end	57	56							40
d) Smallest breadth of the diaphysis	37	36							
Talus = astragalus									
a) Greatest length of the lateral half	65	65							47
b) Greatest length of the medial half	56	55							
c) Breadth of the distal end	38	39							
Calcaneus									
a) Greatest length	120	121							54
Metatarsus III + IV									
a) Greatest length	202	202							32
b) Breadth of the proximal end	43	43							42
c) Breadth of the distal end	43	43							32
d) Smallest breadth of the diaphysis	25	25							45
Phalanx I									
a) Greatest length	53	53	53	55	55	56	56	56	32-40
b) Breadth of the proximal end	27	27	27	27	26	25	25	25	
c) Breadth of the distal end	25	25	26	25	25	24	26	25	
Phalanx II									
a) Greatest length	36	37	37	37	38	38	38	38	
b) Breadth of the proximal end	26	27	27	27	26	28	25	25	
c) Breadth of the distal end	24	23	22	23	22	23	22	22	
Phalanx III									
a) Diagonal length of the sole	57	57	66	67					
b) Length of the dorsal surface	43	45	49	49					

TABLE IV. Average number of points calculated from all the dimensions of a given bone for the Wojciechowice cow

Bone	$\bar{X}$
Humerus	31.5
Femur	28.0
Radius	39.3
Tibia	33.7
Metacarpus III + IV	34,0
Metatarsus III + IV	37.8

TABLE V. Comparison of size of the various dimensions of the limb bones in the Wojciechowice cow (point score)

Anatomical part of limbs	Forelimb	Hind limb
	Length	
Stylopodium	8	24
Zeugopodium	28	14
Metapodium	35	32
	Breadth of the proximal end	
Stylopodium	-	-
Zeugopodium	37	47
Metapodim	32	42
	Breadth of the distal end	
Stylopodium	55	32
Zeugopodium	53	40
Metapodium	30	32

TABLE VI. Withers height of Wojciechowice cow calculated from the length of various bones

Calculation basis	Withers height in cm
Humerus (greatest length)	107,6
Humerus (greatest length from caput)	109,7
Femur (greatest length)	102,4
Femur (greatest length from caput)	105,5
Radius	110,9
Tibia	102,5
Metacarpus III + IV	106,8
Metatarsus III + IV	108,1
Talus (astragalus)	119,0

To Settle a Controversy

EMERIC LAX, GRIGORE STANCIU and VERA LEIBOVICI

OSSA

A case strikingly similar of the skeletal findings from Paucancarcha in 1915 is presented as endothelioma thus confirming earlier opinions of P. Weiss and G. Ramsey.

Keyword: Endothelioma.

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In 1915 in Paucarcancha in a cave under the ruins of this old Inca locality, the scientific explorers of Yale University and the National Geographic Society found a well preserved skull belonging to a primitive man with a peculiar massive bony exrescence of the parietal bone (Fig. 1).

The fossil was considered to represent a man in his sixties, the bony mass was thought to be an osteosarcoma. Later the diagnosis of osteosarcoma was contested and the probable diagnosis of meningeoma was made (6).

In 1964 we reported a case of arachnoendothelioma with a prolonged clinical evolution (4), with a radiological picture strikingly similar to that of the fossil (Figs. 2 and 3). The similarity of the radiological pictures, the interesting clinical observations and the histological studies have led us to support the conclusions of P. Weiss and G. Ramsey.

Meningeomas are most commonly detected in the middle decades of life, with clear predominance in women. In childhood and adolescence they form 3 to 4 per cent of all intracranial tumours (1). In children these are apt to prove malignant. They are slowly growing tumours and probable as many as five or more years elapse before there is even suspicion of its existence. The reported longest period from the time of the onset of symptoms to the date of the operation was seventeen years (2).

The primary intradural tumour may be either spherical and embedded in the cerebral substance with a variable extent of the attachment to the dura, or rarely may appear as a meningeoma "en plaque", or flat meningeoma, with a broad attachment to the dura. This type produces hyperostosis more frequently and of more extensive nature than the spherical meningeomas.

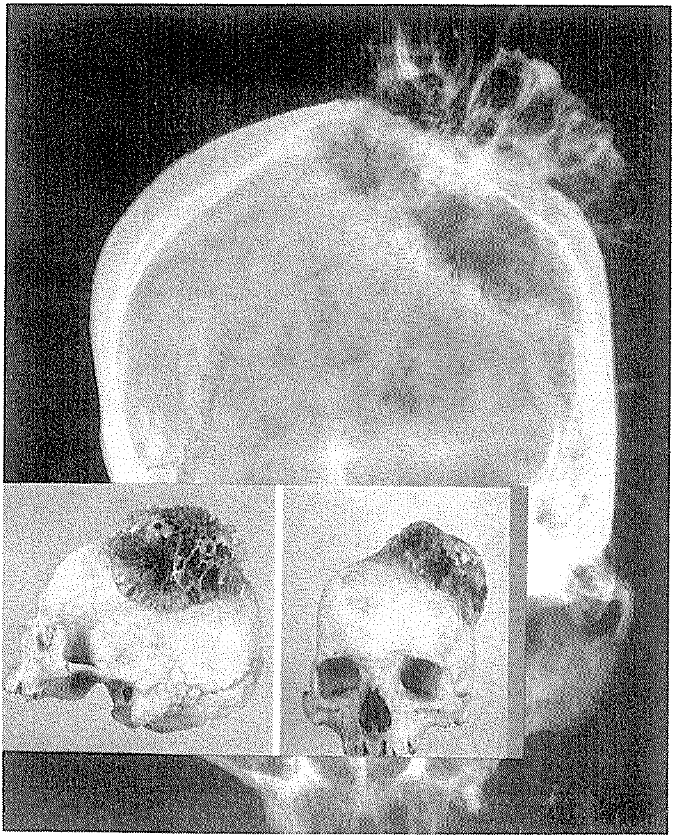

Fig. 1. The radiograph and photograph of the fossil of Paucaracancha (with permission from Med. Radiography on Photography).

The changes in the bone are explained by the tendency of meningeomas to squeeeze into small crevices and spaces enlarging them and at the same time stimulating the bone to proliferation. We see spicules, slender columns of new bone perpendicular to the surface of the normal bone, frequently imitating an osteogenic sarcoma. The direction of their deposit is apparently determined by the radiating vascular arrangement in the meningeal tumour. The precise mechanism whereby bone formation is increased has been longly debated. Some authors claim that the tumour cells are directly responsible for forming new bone (3). This type of invasive meningeoma is most often of the sincytial or endotheliomatous type as it was in our case, so that the radiological picture of the typical bony reaction one may allow a histological diagnosis. Certain meningeomas, probable those with more rapid growth appear to be osteolytic: they may erode or even perforate the skull. Five main histological types of meningeoma occur: 1) sincytial (endotheliomatous) with polygonal cells arranged in sheets; 2) transitional (psammomatous); 3) fibroblastic (dural fibroblastoma; 4) angioblastic (leptomeningeoma) and 5) sarcomatous. It is well established that certain of these tumours prove malignant either in the character of their local behaviour and cytological changes or in respect of metastasis. The angioblastic meningeoma and especially its hemangiopericytic variant has long been recognised as a tumour with a potential of rapid growth and sarcomatous transformation. In our case only a minimal number of mitotic figures were demonstrated

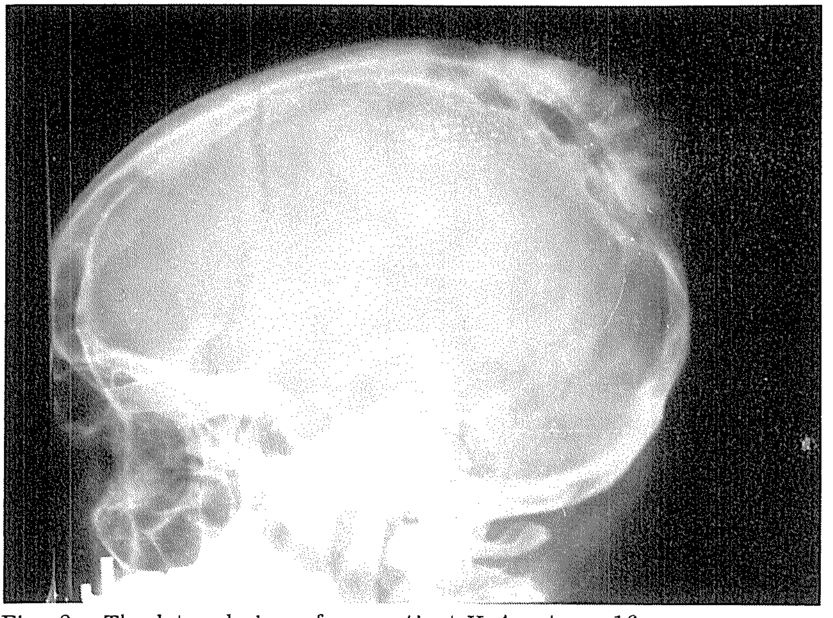

Fig. 2. The lateral view of our patient K. A. at age 16.

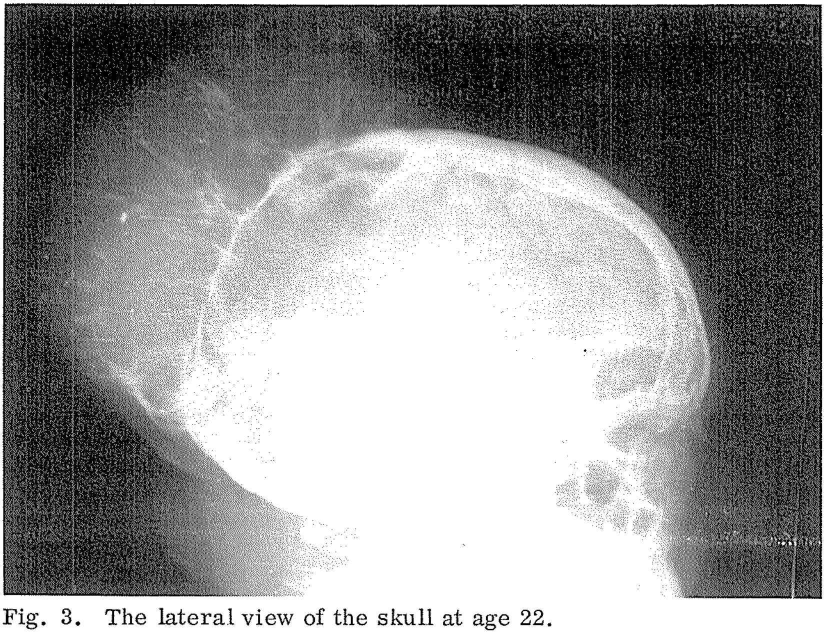

Fig. 3. The lateral view of the skull at age 22.

Fig. 4. K.A. after radiotherapy.

but the clinico-pathological correlations confirmed the aggressive behaviour of this tumour. In our case the parents observed the bony growth of the calvaria in the first months of the life. This grew very slowly. The first radiograph was made at age of sixteen. At this time there were no symptoms or neurological changes. A hard, fixed non tender fist-sized mass was palpated on the left side of the head. It was covered by normal hair. Exploration and plastic surgery was attempted. The hard bleeding bony mass originating from the dura could not be resected. Three years later the mass, blindness, ataxia and headaches appeared. There was evidence of post-papillitis optic nerve atrophy. The sella turcica was markedly enlarged and the dorsum sellae erroded. Conventional radiotherapy through a grid was administered in single doses of 3000 rads (180 kV, 10 mA, 50 cm. FSD) repeated three times at intervals of 12 days, with a total surface dose of 9000 rads. Visibility improve for three months, the headaches and ataxia disappeared. Six years later she was doing well. It has to be mentioned that despite the huge dose the radiation didn't cause complete hairloss (Figs. 4 and 5). This was due to the special effect of the grid which maintained small areas of non damaged skin, which permitted revitalization (5) of the surrounding area. It is also to be mentioned that despite the huge number of therapeutic epilations for fungi performed in the

Fig. 5. K.A. after radiotherapy.

past, we didn't see this hyperostotic type of meningeoma as a postiradiation complication.

Summary

We have presented a case strikingly similar to the skeletal finding from Paucancarcha. Histologically it had a benign endotheliomatous character and despite the malignant behaviour we didn't encounter any sarcomatous elements. The radiological similarity between these two cases seems to confirm the opinions of P. Weiss and G. Ramsey.

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Pachydermoperiostosis (a case report)

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OSSA

Pachydermoperiostosis (PDP) has several synonyms: primary or idiopathic hypertrophic osteoarthropathy, generalised hyperostosis with pachydermia, pachydermia striata, cutis striata. PDP is a well known syndrome consisting of hyperthrophic osteoarthropathy of the extremities, coarse thickening of the skin of the face, especially the forehead and scalp, and excessive sweating, particularly of the hands and feet. The osteoarticular changes start in adolescence, with an insidious thickening of the fingers and toes, clubbing of the terminal phalanges, cylindrical thickening of the arms and legs, without pain. The skin shows deep transverse and vertical folds, the nasolabial folds become deep, the thickening of the scalp produces a corrugated surface, "bulldog scalp", and the face resembles the "leonine facies". The bony features of the syndrome are strikingly similar to those of secondary pulmonary osteoarthropathy, where the bony changes are associated with benign (bacterial endocarditis, congenital heart disease, achalasia, liver cirrhosis, intrathoracic suppurations, purgative abuse) or malignant (primary or metastatic lung, pleura or mediastinal tumours) conditions.

Keywords: Pachydermoperiostosis - Osteoarthropathy.

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Case report

A 20 year old Arab male was admitted for swollen joints, muscle wasting, and skin changes. His father, who died at the age of 70 years, had diabetes mellitus. The mother was well at the age of 53. They were not related. The patient was the third of 11 children. Two of his brothers had died in infancy of unknown causes. All other siblings were healthy. At the patient's birth his father was 56 years old.

At the age of 16 years, the patient had an umbilical hernia and suffered from acne. At the age of 19 a diverticulum of the urinary bladder was removed. The swelling of his legs, the coars wrinkles of his face, and the excessive sweating started one year prior to his hospital admission.

On examination he was thin, his stature 164.5 cm; muscle wasting, coarse horizontal wrinkles on the forehead, and deep nasolabial folds were noticed. There was scanty hair on the face, and hair was absent on the chest and axillae. The fingers and big toes

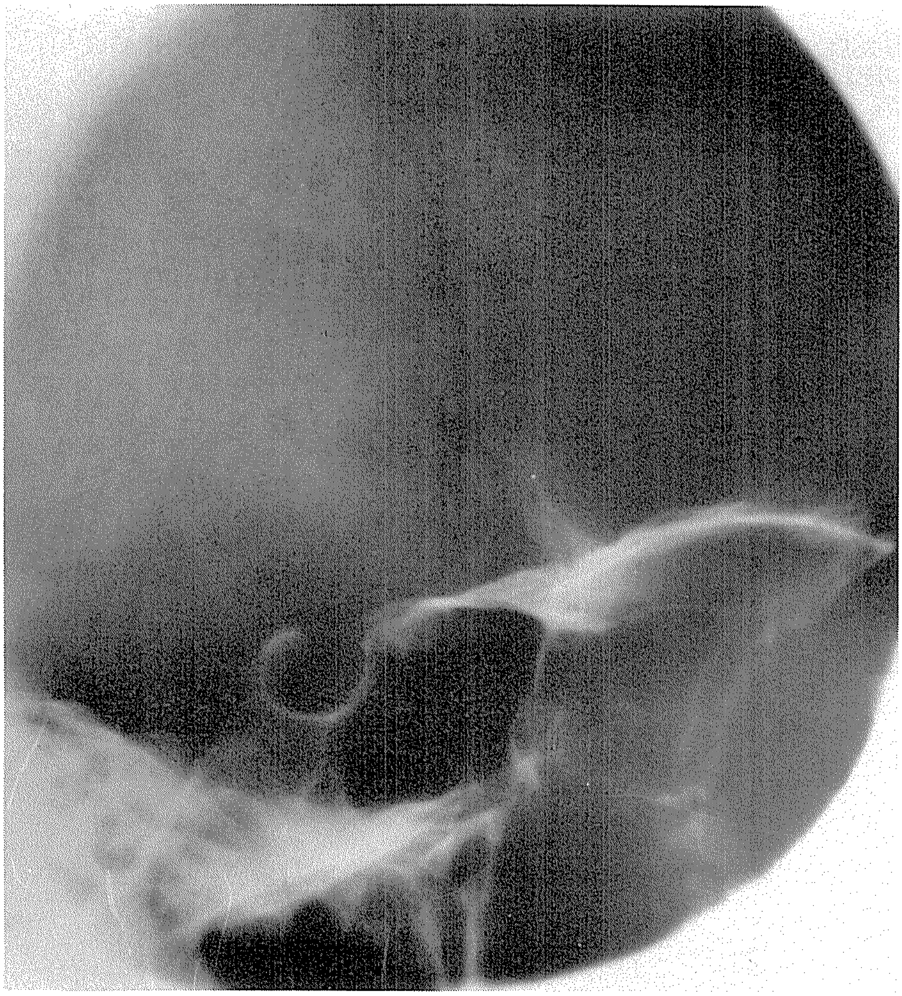

Fig. 1. The sella turcica is normal.

were thick, the knees and ankles were swollen. Serum phosphorus, calcium, chloride, glucose, urea, alkaline phosphatase activity, VDRL test for syphilis, blood gases, urine analysis, EKG, and sweat test were normal.

The radiological examination of the limbs showed thick tibiae and fibulae with coarse periostel apposition. The radii and the ulnae, the metacarpals, the metatarsals and the phalanges were coarsely englarged. The periosteal apposition blended into the cortex. The medullary spaces of the long bones were narrowed, indicating that the cortical widening is from both endosteal and periosteal origin. The bone-scan showed linear, marginal increased uptake, along the periosteal new bone formation. Thick knuckle pads, the hallmark of the generalized proliferative condition of the skin, are responsible for the soft tissue bulk surrounding the phalangeal bones.

Fig. 2. Thick radius and ulna.

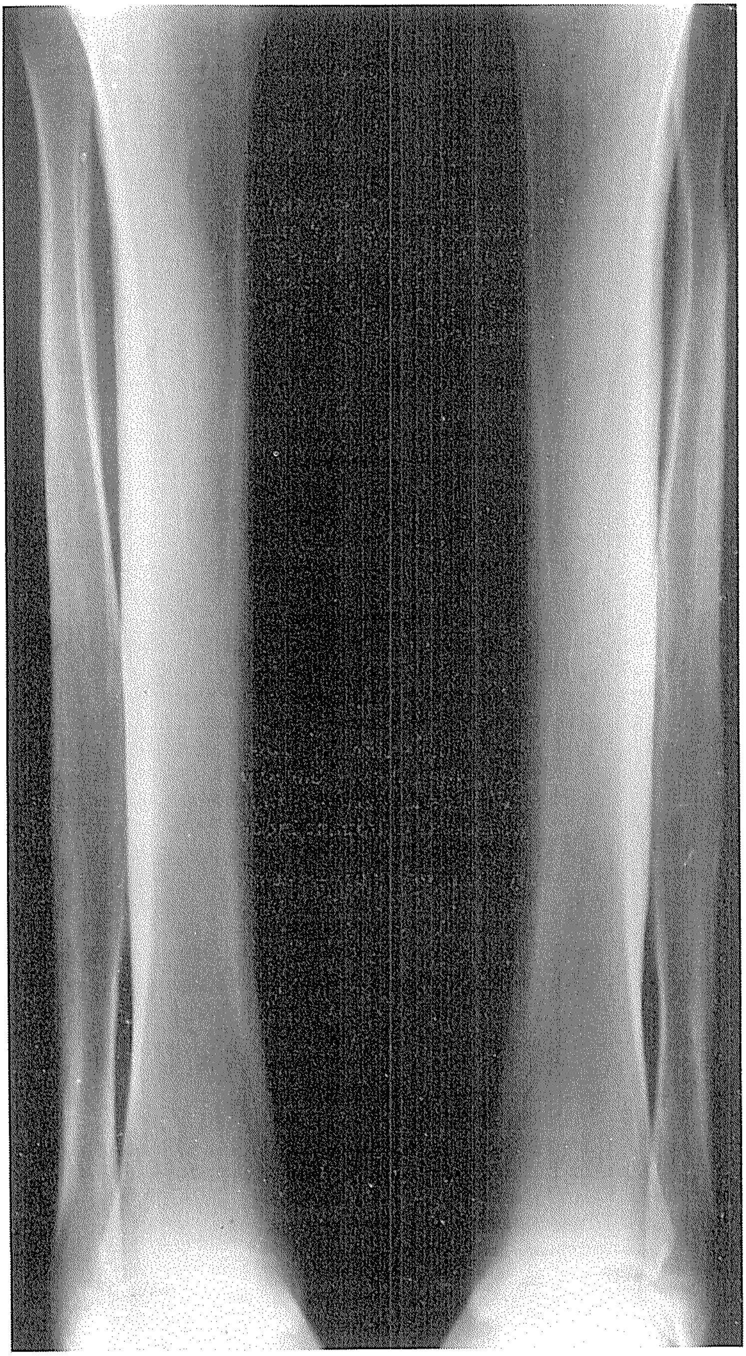

Fig. 3. Coarse periosteal deposition on the tibia and fibula.

Discussion

The pathologic changes in PDP involve both the skeleton and the skin. The bony changes are limited to the distal parts of the long bones, the metacarpals, metatarsals and phalanges. There is a diffuse irregular periosteal thickening. In severe cases all the bones of the body are affected. The bones are coarsely thickened, their surface is irregular due to periosteal apposition, extensive ossification of ligaments, tendons or inter-osseous membranes (6, 7). Histologically there is periosteal proliferation with focal round cell infiltration. Initially there is a thin layer between the cortex and periosteum consisting of irregular trabecula and highly vascular marrow spaces. The wall of the nutrient vessels show hypertrophy of the muscularis. Later, the cancellous cortex becomes more compact with a dense concentrical lamellar structure (2, 3, 5, 9).

The skin histology is characterised by hyperplasia of the connective and elastic fibers. The sebaceous and sweat glands are enlarged, and the secretory ducts are dilated (2, 3, 13).

The symptoms appear in adolescence, rarely in childhood. Males are most frequently affected, but in the same families (1, 3, 9) females were also reported. The familial occurrence, the juvenile onset, and the painless character of the arthropathy have to be emphasized for differentiation from similar condition such as: acromegaly, Paget' s-osteitis deformans, syphilitic periostosis or leprosy. In pulmonary or secondary osteroarthropaty, the bony changes are more acute, and they are painful, disabling the patient, with frequent joint effusions (4). The periosteal apposition is seen as a separate layer and does not blend into the cortex as in the PDP (12). Sometimes the similarities are so striking that definite diagnosis is not possible until the causative factor of the secondary pulmonary osteoarthropathy is found.

Even though we did not find affected relatives in the family of our patient, many examples of linear descent of the disorder, reported in the literature, support an autosomal dominant inheritance (3). If we accept the so called form fruste incomplete forms of the disease, such as cutis verticis gyrata without periostosis, periostosis without pachydermia, familiar or hereditary simple clubbing without periostosis or skin anomalies, as monosymptomatic forms of the PDP, then the hereditary character of the disease is certain. The increased incidence of these affections among family members of patients with PDP seems to confirm the autosomal dominant mode of inheritance. No racial preponderance was documented.

Different theories tried to explain the bony changes. Turner et al (3) found decreased blood flow in the fingers. Mendlowitz found the opposite (2, 12). increased blood flow and blood pressure in the clubbed digits. Angiography showed segmental arterial narrowing, vascular stasis and tortuous vessels in the affected digits (3). Endocrine etiology was implicated by the pubertal onset, male predominance, and the acromegalic features. Neurocirculatory etiology seems to be supported by the benefit of patients with pulmonary osteoarthropathy from thoracal vagotomy, tumour excision, radiotherapy, intercostal nerve dissection and pulmonary artery ligation (10, 11, 12, 13, 14).

Summary

A patient with pachydermoperiostosis is reported and the rare syndrome of PDP is reviewed. The relationship between the incomplete forms of the syndrome was emphasized.

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Thoracic-Pelvic-Phalangeal Dystrophy: A Case report in an Adult

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OSSA

Thoracic-Pelvic-Phalangeal Dystrophy is an autosomal recessive disorder in which severe ventilatory difficulties are common and related to the small thoracic cage. Renal dysfunction may occur later in childhood. The clinical course and the prognosis cannot be predicted in relation to thoracic capacity. Nevertheless, if the affected person reaches late childhood without respiratory or renal disease, his prognosis is good.

Keywords: Bone dysplasia - Small thoracic cage - Asphyxia.

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Thoracic-Pelvic-Phalangeal dystrophy (TPPD) is a rare skeletal dysplasia, usually recognized at birth. It was first described by Jeune et al. in 1954 as a polychondrodystrophy with a small thorax, familial occurrence and fatal outcome. This dysplasia has many synonyms, the most common in use are: Jeune's disease and asphyxiating thoracic dystrophy. This last name was given in view of death in early infancy from respiratory insufficiency related to the associated hypoplastic lungs. Patients who survive the neonatal period may develop a lethal renal disease and die before reaching late childhood and adulthood.

The purpose of this paper is to present the case report of a young adult with typical TPPD with no pulmonary and renal disabilities.

Case Report

S.A., the third child of unrelated parents, was born at term in 1962 after normal gestation and delivery. He was noted to have a strikingly narrow chest. He did not suffer from major respiratory problems throughout his childhood. At the age of 15, he was evaluated for stubby hands and feet. The physical examination revealed short stature (141 cm), narrow elongated chest and stubby fingers and toes. The radiologic evaluation confirmed the long narrow thoracic cage, the ribs were horizontal having peculiar

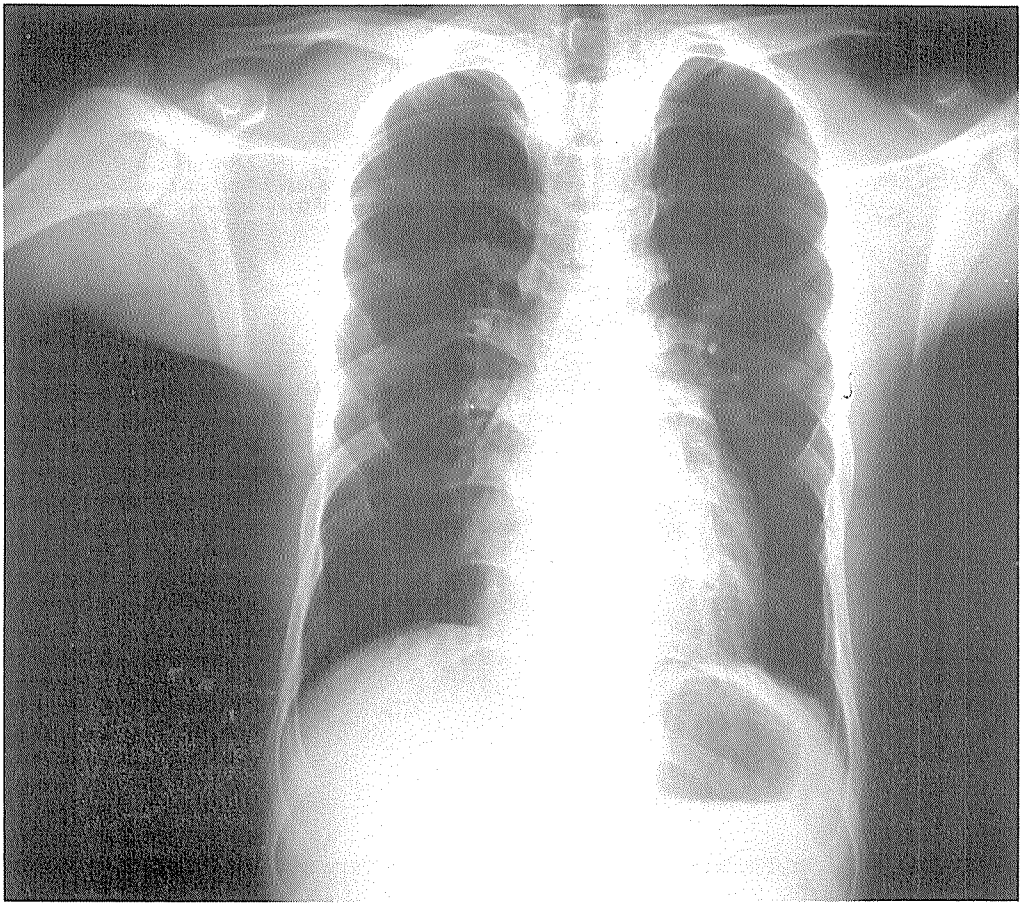

Fig. 1. The thorax is long and narrow. The ribs are short with "U"-shaped anterior margins. The clavicles are high.

"U"-shaped anterior margins, and bulbous medial ends (Fig. 1). The transverse diameter of the thorax measured 16.4 cm and the antero-posterior diameter 13 cm (Fig. 2). The clavicles were high but otherwise normal, the skull, thoracic and lumbar spine were normal. The pelvis was shortened cephalo-caudally, the iliac wings were shortened and broad resembling "elephant ears", and the greater sciatic notches were slightly narrowed (Fig. 3). The acetabular rooves were normal. The upper and lower limbs were proportionately shortened. The configuration of the hands was peculiar, with short and slightly broad distal and middle phalanges, with cone-shaped epiphyses. Early epiphyseo-metaphyseal fusion and epiphyseo-metaphyseal invagination of the mid-phalanges were visualised. The distal phalanges of the thumbs and great toes were broad-based and bulky (Figs. 4 and 5). The hamate bones had a triangular shape and overlapped the capitates in dorso-volar projection, without fusion. A supranumerary bone (parastyloid) was demonstrated. Standard laboratory, renal function tests and repeated intravenous

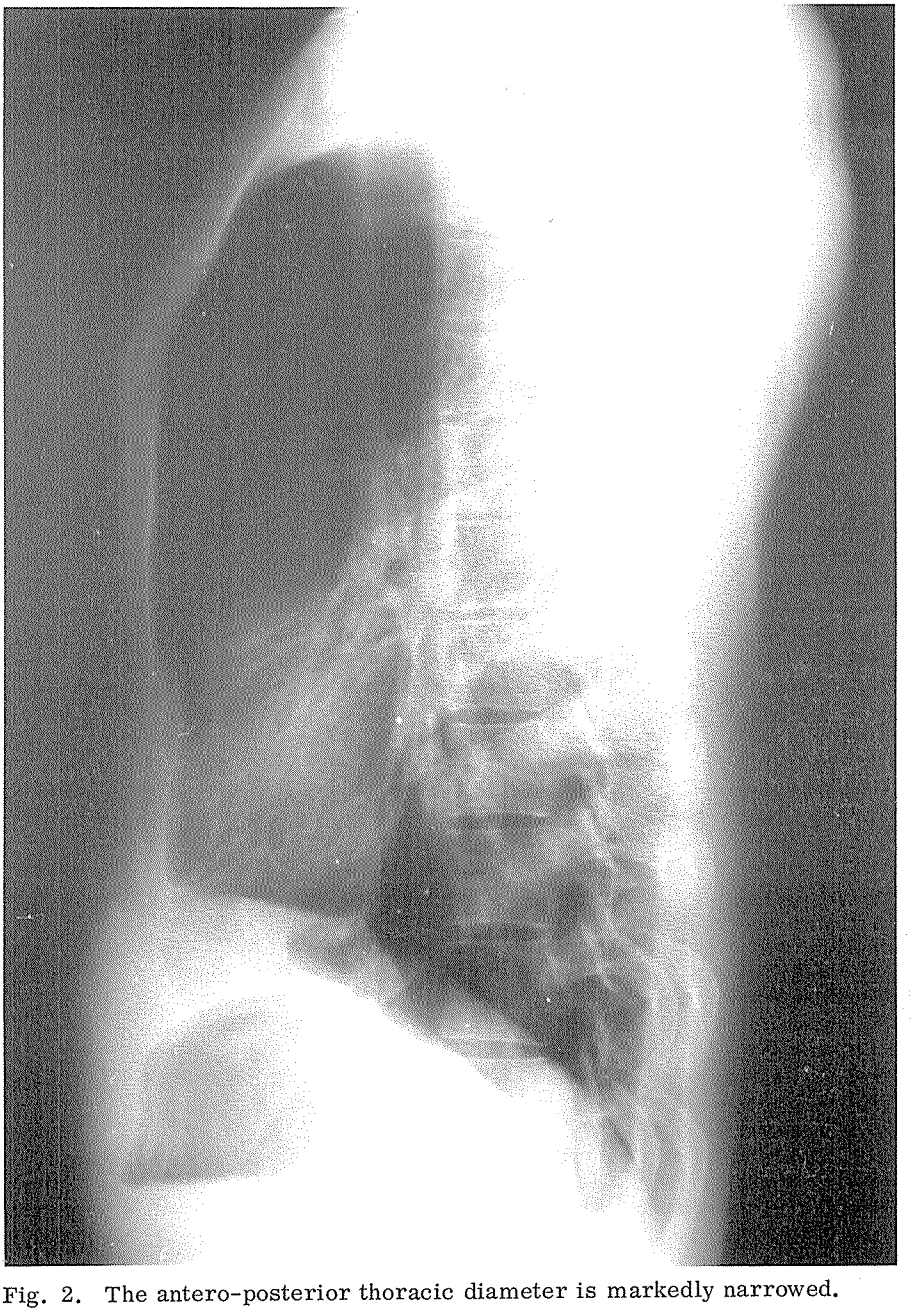

Fig. 2. The antero-posterior thoracic diameter is markedly narrowed.

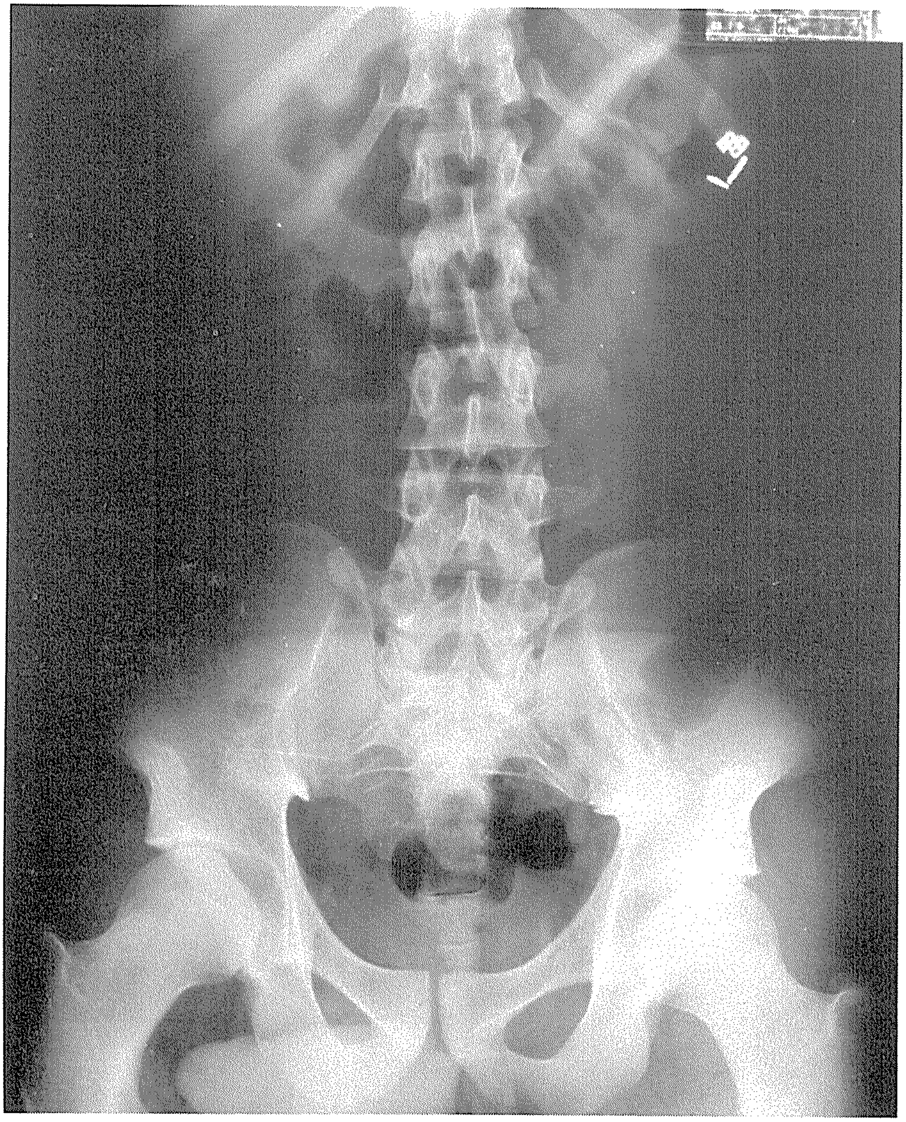

Fig. 3. The pelvis is shortened cephalo-caudally: the iliac wings resembling "elephant ears"; and the sciatic notches are narrow.

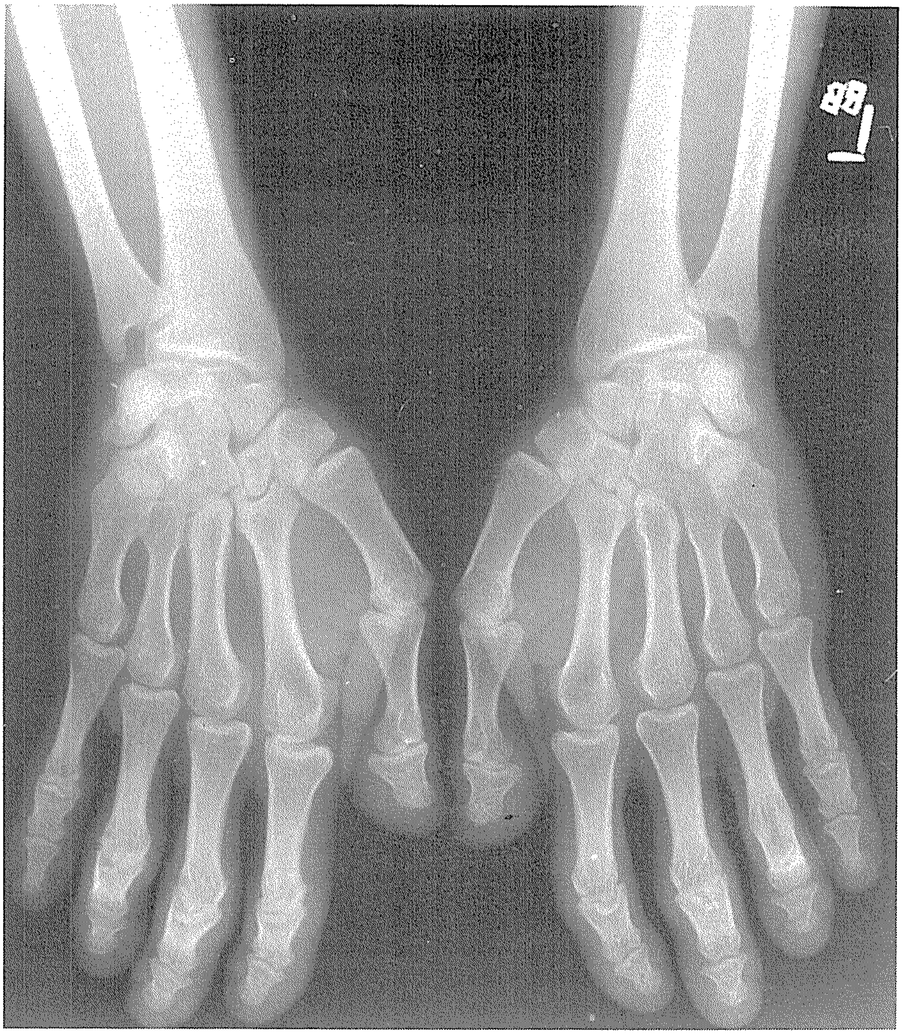

Fig. 4. Hands: short distal and middle phalanges, cone-shaped epiphyses, early epiphyseo-metaphyseal fusion in mid-phalanges and epiphyseo-metaphyseal invagination. The distal phalanges of the thumbs are broad-based and bulky.

urography and ultrasound examinations of the kidneys were normal. Thorough genetic evaluation did not reveal similar cases in the family.

Discussion

The two main clinical features in our patient beside the small stature were small chest and stubby hands and feet. There are numerous conditions in infancy and childhood characterized by a small chest cage. Hypophosphatasia with low serum alkaline phosphatase levels and osteomalacia are easily ruled out in our case. Achondroplasia associated with a relatively small thorax has typical skeletal changes which were lacking in our case. The thorax in hypochondroplasia is not severely narrowed as in our case and

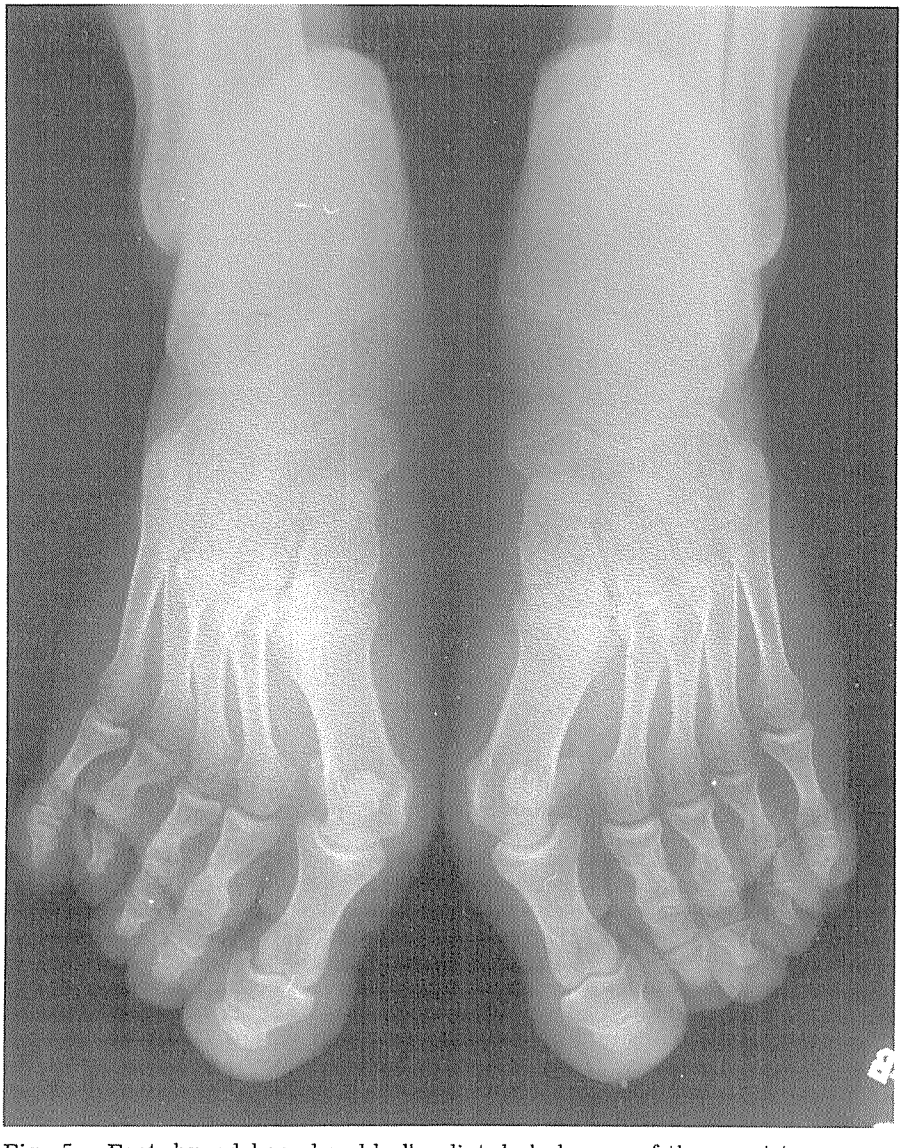

Fig. 5. Feet: broad-based and bulky distal phalanges of the great toes.

there are usually similar cases in the family. The absence of neuro-muscular abnormalities excludes conditions such as Werdnig-Hoffman syndrome where the small thorax is a feature (Hanissian et al., 1967). The main differential diagnosis is with the Chondro-Ectodermal Dysplasia (CED) or the Ellis van Creveld syndrome which, beside a small thorax, has a pelvis configuration indistinguishable from that of TPPD. The hands are quite similar, but polydactyly which is very rare in TPPD is always present in CED (Poznanski, 1974). In CED there is fusion of the capitate and hamate, not present in TPPD. Langer (1968) described a peculiar configuration of the proximal tibial metaphyseal line in TED, which slants cephalad in an arcuate manner. In the newborn period in both CED and TPPD there is a premature epiphyseal ossification at the proximal humerus and femur. Renal disease never develops in CED. There are some ectodermal defects in CED, such as hypoplasia of the nails, short fused upper lip which is attached by multiple frenula to the maxillary gingiva, never seen in TPPD. Cardiac anomalies are not seen in TPPD, but are frequent in CED.

The features present in the hands in our case especially the cone-shaped epiphysis are similar to those in trycho-rhino-phalangeal dysplasia, a condition with thin hair, bulbous nose tip, cone-shaped phalangeal epiphyses, but normal thoracic configuration (Langer, 1968). A patient with the features of TPPD was clinically and karyotypically identifiable as a case of trisomy, most likely D/C translocation, while another patient showed a mosaic trisomy pattern (Kohler and Babbitt, 1970). No chromosomal abnormalities were present in TPPD. The diagnosis in our case is therefore TPPD.

In TPPD there are two clinical presentations: a major and a minor form. In the major form the chest is narrow and rigid. A prominent rosary sign is frequent (Jequier et al., 1973). The high "bicycle-handle"like clavicles give the impression of a short neck. Respiration is solely disphragmatic. Cyanosis may appear hours or days after delivery, almost always when crying or feeding. The clinical evolution is quite variable and does not depend on the chest circumference alone; although there are no survivals described with a circumference at birth below 28 cm (Jequier et al., 1973). Asphyxiating attacks during meals make feeding difficult and repeated pulmonary infections cause death. In the minor form pulmonary ventilation is sufficient at rest, and there is improvement of respiratory capacity with age. If the patient lives through the first year his survival chances rise rapidly. In childhood the tendency to improve is more evident, however, thoracic measurements remain below normal. Short stature is more prominent in this period. Our case belongs to the minor form. The syndrome has an autosomal recessive type of inheritance. The frequency in parents and siblings is 30%, corresponding well to the recessive inheritance mode. It is possible that heterozygous carriers show only mild deformity of chest, hands and pelvis (i. e. minor or latent forms); only homozygotes suffer the full-fledged asphyxiating (major or severe) form (Shokeir et al., 1971).

Death secondary to pulmonary complications was common in young infants while fatal renal complications were seen in the older age group (Langer, 1968; Spranger et al., 1974; Oberklaid et al., 1977; Shokeir et al., 1971; Herdman and Langer, 1968). Table 1 summarizes the age of death and the mortality rate in 48 cases out of 90 reported cases in the literature (Langer, 1968; Cortina et al., 1979; Kohler and Babbitt, 1970; Kozlowski and Masel, 1976; Cremin, 1970; Combe et al., 1969; Leclerc et al., 1969; Oberklaid et al., 1977; Shokeir et al., 1971; Herdman and Langer, 1968; Neimann et al., 1963; Jequier et al., 1973; Kaufman and Kirkpatrick, 1974).

Very few cases of TPPD reached adulthood. In 1973 Jequier et al. stated that the oldest reported patient was 11 years old. The adult case of Barnes et al. (1968) and the relatives of the first case of Wendler and Rossipal (cited in Jequier et al , 1973) seem to be the only reported adult cases. Barnes et al. (1969) described the mother of an infant who died of asphyxia due to a small chest cage; she had no record of respiratory infections, her chest was small in proportion to her height, her ribs were horizontal and her pelvis was narrowed, similar to that of achondroplasia. No changes in her hand bones were noted. Kaufmann and Kirkpatrick (1974) reported two cases of

TPPD patients diagnosed at age 11 and a half and 15 and a half years, both with renal failure requiring hemodialysis. Langer (1968) reported an asymtpmatic 9-year-old girl, with typical bony changes but with proteinuria. Jequier et al. (1973) reported a six-year follow-up of a patient until age 6 and-a-half. Herdman and Langer (1968) reported the follow-up of a girl with a minor form from age 7 until 9. Pirnar's (cited in Combe et al., 1969) oldest patient was 7 years and Hanissian et al. (1967) reported a case with a 10 years' follow-up til age 11.

As we stated previously, our case seems to belong to the minor form of TPPD with no apparent pulmonary or renal disabilities.

It seems to us that a third category in classifying TPPD is in order as suggested by Combe et al. (1969): the "forme fruste" or minimal form. The incidence of this form is unknown because very few cases are described. If one would follow the classification of TPPD into three forms, one would classify the present case into the minimal form. It seems logical to assume that patients reaching adulthood with no apparent pulmonary or renal abnormalities are not at risk later on.

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TABLE 1.

	Diag. made at birth or within first month	Diag. made between 2 months and one year	Diag. made between ages 2-5 years	Diag. made after age 6 years
Number of patients	41	28	13	8
Percent	45	31	15	9
Number of deaths	30	12	5	1
Mortality rate (%)	73	42	38	12

Inherent Deficiencies in Cortical Bone Microstructural Age Estimation Techniques

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In the last 20 years physical anthropologists have turned to cortical bone microstructure in a serious effort to satisfy a need for a reliable and accurate technique for deriving age at death estimates for adult human skeletons. Extrinsic limiting factors in the subject skeleton's context and condition have since been identified. This paper examines critically the four available methods themselves, and finds serious intrinsic deficiencies present in all. The combination of intrinsic and extrinsic limitations forces the conclusion that these particular histological age estimation techniques do not possess a measure of confidence which would justify their continued use.

Keywords: Age estimation - Cortical bone microstructure - Intrinsic limitations.

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In the last 20 years, four techniques for estimating age at death from cortical bone microstructure of unknown human skeletons have been published: Kerley (1965), Ahlqvist and Damsten (1969), Singh and Gunberg (1970) and Thompson (1979). All estimate age at death from the examination and quantification of the histological structures, i.e. Haversian systems, of cortical bone when viewed in transverse thin sections microscopically. Each of these techniques operates on the major premise that the apparent changes in cortical microstructure are, in fact, age-dependent.

Recently, the widespread application of these methods has been criticised from a number of different perspectives. Sources of difficulty include normal interpopulation variation in bone remodeling rates (Ubelaker, cited in Pfieffer, 1980; Thompson and Guiness-Hey, 1980); environmental influences on skeletal physiology (Martin, Goodman and Armelagos, 1981) and on preservational quality (Stout, 1978; Ortner and Putschar, 1981); and effects resulting from various disease processes (Thompson, 1981). Inclusively, these may all be deemed secondary or extrinsic considerations. The following critique focusses on primary, intrinsic concerns inherent in the methods themselves, and not associated with any particular population or ecological paramenters. These intrinsic considerations will militate irrespective of the origin and/or the condition of the remains to which the methods are to be applied. Two areas are examined: 1) sample size and constitution; and 2) variable definition and measurement.

TABLE 1. Sample size and distributional data, by method and bone.

Study	Bone	n=	Mean Age	Range
Ahlqvist and Damsten	femur	20	55.45[a]	4 - 89[a]
Kerley	fibula	25	34.48[a]	0 - 83[a]
	tibia	33	?	?
	femur	67	41.55[a]	0 - 95[a]
Singh and Gunberg	femur	33	62.333 +/- 10.80	?
	tibia	33	62.333 +/- 10.80	?
	mandible	52	64.250 +/- 12.14	?
Thompson	l. femur	91		
	r. femur	113	males:	
	l. tibia	112		
	r. tibia	113	71.48 +/- 12.90	30 - 97
	l. humerus	29		
	r. humerus	31	females:	
	l. ulna	31		
	r. ulna	31	71.94 +/- 13.81	43 - 94

a. Data from Bouvier and Ubelaker (1977).

Samples

The size of sample used and the age distribution within each sample is of concern. Table 1 gives the available sample size and distributional data for each method, by bone. Bouvier and Ubelaker (1977) have discussed the effects of sample size and skewness in their comparison of Kerley's femoral regression with Ahlqvist and Damsten's linear regression. Small sample sizes tend to reduce the standard error associated with the regression estimate and, indeed, Kerley's lowest standard error accompanies his smallest sample, i.e., n=25 for fibulae. Similarly, Ahlqvist and Damsten's reported standard error of +/-6.71 years is suggested to be an artifact of their sample of only 20 femora. Bouvier and Ubelaker re-calculated a standard error for Ahlqvist and Damsten's method using a sample of 40 of Kerley's original femora, arriving at a value of +/-11.65 years.

Skewness is a measure of deviation of a distribution from standard normal. Statistically, skewness affects differentially the accuracy of a predictive model. Positively skewed distributions will generate models which estimate younger age categories more accurately; negatively skewed likewise for older aged groups. This was demonstrated by Bouvier and Ubelaker (1977), and the effect is also reported by Stout and Gehlert (1980). Unexpectedly, in their test of these two techniques they report greater accuracy in the older age group for Kerley's fibular formulae. For Kerley's femoral formulae, expectations were confirmed: greater accuracy resulted in the younger age group (13-51 years), less in the older (60-102 years). Figure 1 depicts the distribution of Kerley's samples within 10 year age intervals. All are positively skewed, tibia and fibula significantly so. Ahlqvist and Damsten's sample, also illustrated, depicts a significant negative skewness. The sample distributions for Singh and Gunberg (1970) and Thompson (1979) are not avail-

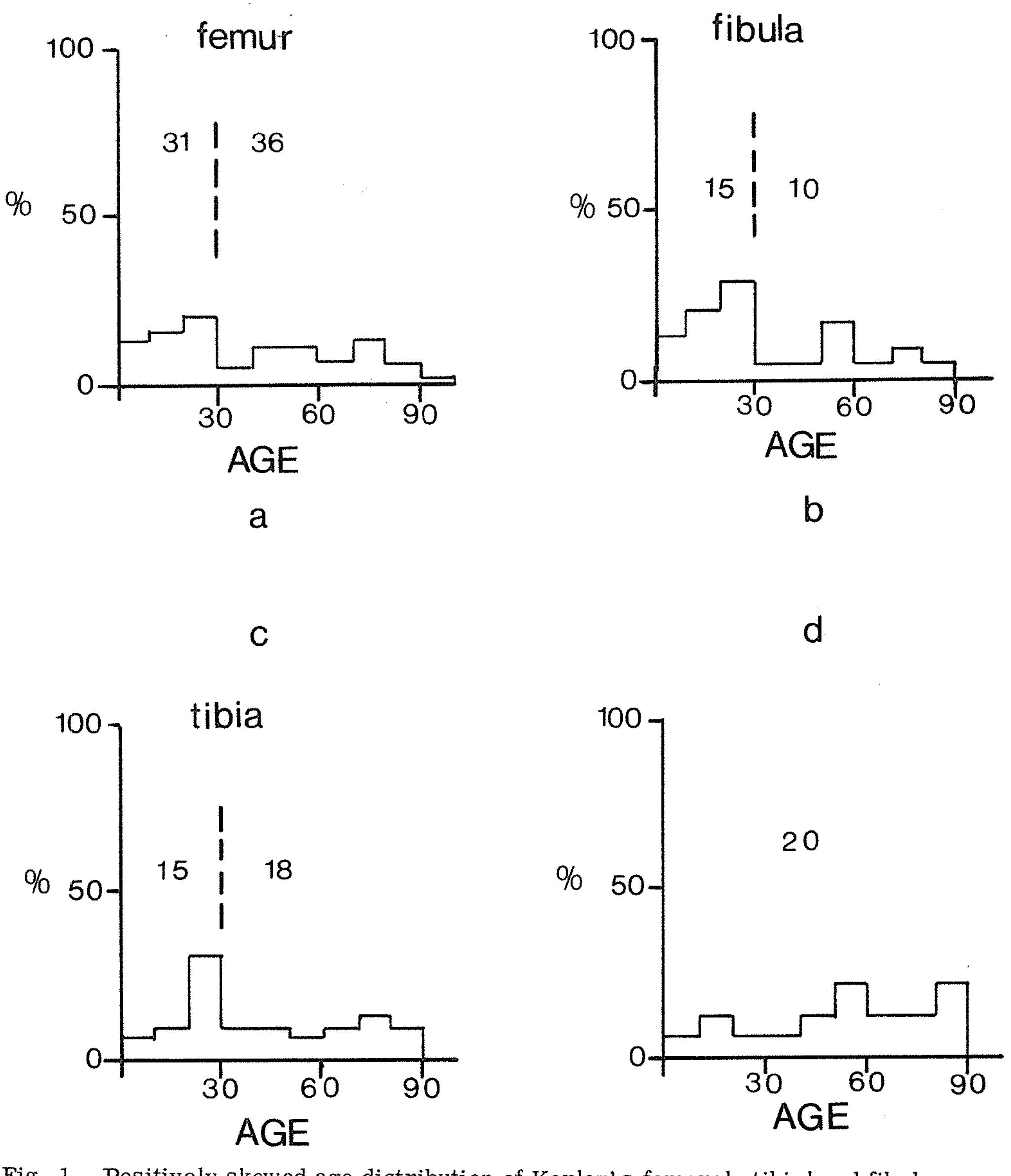

Fig. 1. Positively skewed age distribution of Kerley's femoral, tibial and fibular samples (a-c); and the negatively skewed distribution of Ahlqvist and Damsten's femoral sample (d).

able from published sources. However, reporting sample characteristics in terms of mean age at death and the standard deviation around the mean presumes a normal distribution, though this cannot be verified.

An additional note should be made with regard to Kerley's technique. Ostensibly, cortical remodeling age estimation methods are significant for their purported ability to age adult skeletons in older age groups. Ortner and Putschar (1981:31) even go so far as to say, with specific reference to Kerley, "this is the only method currently available that allows age estimation for skeletons over 50 years of age". However, as Figure 1 shows, in all cases 46% to 60% of Kerley's samples are less than 30 years of age. Sample sizes of relevance to the problem of aging adult skeletons reduces to 36 femora, 18 tibiae and 10 fibulae.

Variables

All four methods use the Haversian system, or secondary osteon, as the microstructural unit of measurement. Kerley and Thompson additionally use other purportedly age-related factors. The Haversian system, however, remains the basic unit, and these methods utilize frequency, size and proportional evaluations of it in their analyses. Inherent difficulties arise concerning three aspects of Haversian systems: definition, relevance, and measurement.

When using these techniques one must feel confident that the variables being measured agree, by definition, to those the original investigator chose to work with. A legitimate question to ask here, then, is what exactly is a Haversian system? This is particularly important for methods such as Kerley's which deal in both 'whole' and 'fragmentary' Haversian systems. Stout and Gehlert (1980) list a number of definitions which have appeared in the literature, ranging from "completely unremodeled" (Wu et al., 1970) to "intact Haversian canal" (Ortner, 1970). For Kerley, a secondary osteon which is 80% or more complete is equivalent to 'intact'. Without considerable modification to method, such an assessment must be purely subjective, engendering a source of error which will vary from investigator to investigator, and with the acquisition of experience.

Ahlqvist and Damsten provide what seems a plausible solution in their consideration of whole and fragmentary osteons as a single composite variable - 'remodeled bone'. However, this solution is at best only a partial answer. Remodeled bone is differentiated from unremodeled bone, or circumferential lamellar bone. Their approach requires estimating the proportions of each in a field 1 mm^2 comprised of 100 squares of equal size. Remodeled bone is the variable of interest, and an individual square is classified as such if it is 50% or more filled with this type of bone. Again, such an assessment is subjective in itself. However, the major difficulty arises on definition, for microstructural variation consists of more than remodeled and unremodeled bone. How are we to assess to occurrance of resorption spaces and forming osteons, in which the central vascular canal - essentially a void viewed in cross-section - may occupy several grid squares? On assumption we should classify these as remodeled since they are part of the remodeling process, though we are not told how to deal with them explicitly.

Not one of the four techniques approach the question of osteon relevancy. In fact, I am aware of but one study (Vincentelli, 1978), biomechanical in aspect, which considers and attempts to control for this seemingly obvious source of error. Haversian systems are produced through a process of removal and subsequent replacement of bone matrix. The average life span of an osteon - its persistence prior to being remodeled itself - will be a function of the rate of bone turnover within the region of bone in question. For some bones, and some regions, osteons may persist for a considerable period of time (Jowsey, 1966), twenty years being a not unreasonable figure (Frost, 1980). Ortner and Putschar (1981) report that long bone cortices have relatively slow turnover rates. To characterize variable states representative of a given age it stands to reason that the investigator must measure the Haversian systems formed at that age, and not several years previously. Since the age-related changes in osteonal parameters are directional (e.g., 'less' to 'more'; 'smaller' to 'larger'), the effect of not differentiating relevant from non-relevant osteons will be to shift the mean value for each individual studied to that more in keeping with a younger age, and increase the variance associated with that deceptive mean. That is, if we measure 20 osteons in a section taken from a 50 year old person, and 15 of these had been formed between 35 and 40 years of age, our mean value will be more reflective of the younger age than of the true age at death.

In 1978, Kerley and Ubelaker published a short revision to Kerley's original method. At this time new regression equations were provided to replace originals, several of which would give wholly unreasonable estimates. It was also reported that the field diameter of Kerley's original microscope was greater than his published 1.25 mm; in fact, being closer to 1.62 mm. Field size is an important consideration. A larger or smaller field of view increases or decreases the area available for evaluation, which will be affect the scores obtained for certain characterizations, i.e. frequencies and proportions, of Haversian systems.

The effect of using non-equivalent field sizes has been treated by Stout and Gehlert (1982). Generally, non-significant results were obtained, but they did recommend using a combination of ocular and objective lenses giving a field size more closely approximating Kerley's estimated original. Their study also questioned the validity of using correction factors to compensate for differences in field size. I would like to expand on this aspect here. Kerley and Ubelaker suggest a ratio of the area of the field of the microscope in use to 2.06 mm^2 as an appropriate correction factor. Stout and Gehlert have previously used such a factor (1980). At that time they also made the following statement: "Since our grid measured 1 mm^2, as did Ahlqvist and Damsten's, a field size correction factor was not necessary." Such correction factors, however, can be shown to be neither used, nor formulated, for use with these techniques.

Kerley and Ubelaker's suggestion provides a single correction factor to be applied across all variables assessed in each of four different fields-of-view (with the exception of the variable: total circumferential lamellar area). This approach assumes that the occurrance of whole osteons, fragmentary osteons and non-Haversian canals is proportional within any given area of bone. Proportionality applies only across the entire cross-section being examined - it would be possible to determine, theoretically, the ratios which obtain between these variables. However, we have no reason to believe that these ratios would be transferable to sub-samples of the cross-section, as represented in the microscope fields, nor that these ratios would be maintained in sub-samples of different absolute sizes. The assumption in question is founded on the erroneous belief that Haversian systems are distributed uniformly throughout the cortex of bone. This is not the case, a fact Frost (1969) first made explicit and which Stout and Gehlert recognized (1980, 1982). That Haversian systems are not distributed uniformly, and consequently that sub-samples of various sizes will most likely not reproduce variable scores in proportion to area evaluated, is predicted by Martin and Burr's (1982) theory of bone remodeling dynamics. Their model views the secondary osteon as a structural unit responding to microdamage within the cortex which thereby increases the fatigue life of the area of bone in question. This theory has received recent experimental confirmation (Burr et al. n.d.). To argue that the ratio of Haversian systems to other microstructural units is a constant, and a function of area, would suggest that all regions of bone are structurally and functionally homogeneous, a proposition which a survey of the biomechanical literature (e.g., Burr, 1980) would quickly refute.

Deriving a correction factor for Ahlqvist and Damsten's method presents a somewhat different problem. Figure 2a illustrates my argument. Their technique is based on measuring the percentage of remodeled bone within a gridded area of 1 mm^2. Grids of a larger or smaller size cannot be used. This is because the size of any histological structure is fixed at the level of the section, not at the level of the eyepiece which contains the gridded reticule. At any given magnification, a single osteon will contribute more area of remodeled bone if the grid is less than 1 mm^2; less if the grid is greater than 1 mm^2. Furthermore, their method requires placement of the grid such that one side borders along the periosteal margin of the bone section. Therefore, larger or smaller

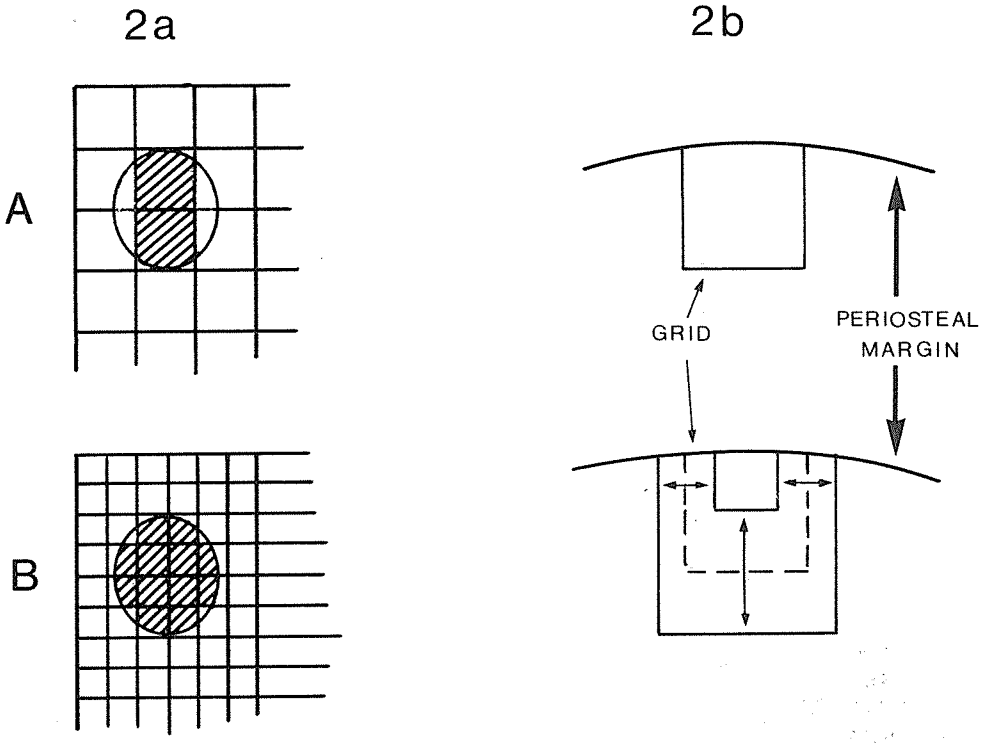

Fig. 2. a) An effect of variation of grid size for the use of Ahlqvist and Damsten's method. A) Part of a 100 square grid = 'x' mm on a side. The shaded areas are 50% or more filled with remodeled bone and contribute 2% to the total value for this variable. B) Partial grid = 'x/2' mm on a side. The same sized osteon now contributes 12% to the total value for remodeled bone - a six-fold increase. Thompson's method also employs a grid, using principles of stereology - i.e., the point-count method - to evaluate the observed variation. Principles of stereology will permit the alteration of grid size independently of image magnification, while the Ahlqvist and Damsten method will not.

b) The Ahlqvist and Damsten method requires placement of one of the grid sides against the periosteal margin of the bone section. Increasing or decreasing grid size results in a non-uniform alteration to the sampling universe in the two-dimensional space. Variation characteristic of the middle of the cortex (i.e., between periosteal and endosteal margins) will contribute more if the grid is larger than 1 mm on a side; less if it is smaller.

grids will not alter the area evaluated uniformly, but in only three directions (Fig. 2b). This result subjects the grid method to the same objections raised against the use of microscopes with different field-of-view areas.

Discussion

In the preceding critique I have attempted to identify, and elaborate upon, deficiencies perceived in the bone-based histological age estimation techniques presently available. These deficiencies originate with the methods themselves and are not derived from the context or condition of any particular human remains to which they might be applied. Five areas of deficiency were identified: sample size, sample distribution, variable definition, osteon relevancy, and correction factor use. This list is not exhaustive, as other inherent weaknesses have been recognized, such as field shape (i. e., circular versus square grid) and field location (i. e., the inappropriateness of standard body orientations - anterior, posterior, medial and lateral - for bones such as tibia and fibula which have asymmetrical and variable mid-shaft cross-sectional morphology). These latter two points have been discussed by Stout and Gehlert (1980), among others.

Table 2 lists all points discussed, including the last two mentioned, and indicates which of the four methods could be considered deficient in each category. Table 2 also assesses these techniques under the rubrics of parsimony (including economy of technique, expertise required and so on) and confidence (a qualitative judgement regarding the reliability, precision and accuracy to be expected given these inherent deficiencies). Ahlqvist and Damsten's method is most parsimonious, requiring little equipment, effort or expertise. This is followed by Kerley, Singh and Gunberg and Thompson. Thompson's method is highly sophisticated both in terms of section preparation and data acquisition. A high level of knowledge of both microscopic technique and of bone remodeling phenomena would be required for successful application of this method. With the exception of Thompson, confidence is negative in all cases. Thompson is excepted given that it 'fails' in only one major category - osteon relevancy - although sample distribution is questionable. The question mark under Thompson in the category of Confidence indicates only that the actual degree cannot be assessed, even subjectively.

This paper has dealt primarily with Kerley's and Ahlqvist and Damsten's technique. The latter is an explicit modification of Kerley. Singh and Gunberg's technique calls for a random selection of two microscope fields from appropriate bone mid-shafts. Given the inhomogeneity of microscopic variation within bones discussed above, this does not seem a viable approach. Thompson's method uses a square grid system, and is therefore subject to the same comments directed towards Ahlqvist and Damsten, particularly with regard to formulating correction factors. Kerley's technique 'fails' in most areas, a finding which may be accounted for by the fact that this approach is the oldest of the four. Knowledge concerning bone remodeling activity which would have proved useful to Kerley was not available at the time of his study. Still, it is necessary to recognize these inherent shortcomings, particularly with regard to Kerley's method if for no other reason that it so often seems that his technique is consistently cited by others as 'the' histological approach to age at death estimation from cortical bone.

Conclusion

Histological age estimation techniques utilizing bone do not seem able to provide estimates in which a researcher can invest a great deal of confidence. Reports of qualified success notwithstanding (Thompson, 1981), the combination of limitations deriving from the nature of the bones to be aged and those inherent in the techniques themselves should be sufficient enough argument, at this time, for discontinuing use of these methods.

TABLE 2. Summary of deficiencies.

Category	Kerley	Ahlqvist and Damsten	Singh and Gunberg	Thompson
Sample size	*	*	*	*
Distribution	*	*	?	?
Definition	*	*		
Relevance	*	*	*	*
Correction factors	*			
Field shape	*		*	
Field location	*	*	*	
Parsimony[a]	2	1	3	4
Confidence[a]	no	no	no	?

a. See text for an explanation of these terms.

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About the Dead Bodies of two Buddhist Monks Preserved in the Form of Statues at the Dau Pagoda

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OSSA

Two bodies, preserved as statues from the Dau Pagoda in the Nguyen Trai Village of the Thuong Tin district, Ha Son Binh province, in Vietnam are described and pictured.

Keywords: Bodies preserved as statues - Early and mid-XVIIth Cy - Vietnam.

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Dau pagoda, with other names as Phap Vu pagoda or Thanh Dao pagoda, is situated at Nguyen Trai village, Thuong Tin district, Ha Son Binh province, 23 km south of Hanoi. It was built during the Ly dynasty XIth-XIIth centuries. But the present structure as well as other articles in the pagoda such as stone stelae, bell, "khanh" (musical stone), stone pedestal, bronze book... all bear the imprint of the Le and Nguyen dynasties (XVII or XVIII century). In the pagoda, there are 2 statues which, according to local version, were the dead bodies of two Buddhist monks native of Gia Phuc hamlet, Nguyen Trai village, of early and mid-XVIIth century, who succeeded each other as Superiors of Dau pagoda.

Recently, the Institute of Archaeology, with the assistance from the Culture and Information Service of Ha Son Binh province and the local authorities, has started initial studies on these two monks' bodies.

The first statue (which was said to be Superior Vu Khac Minh) is in sitting position with folded body; his head leaning a bit forward, his two hands put against his belly, the right one outside, the left one inside. The height of this statue is 57 cm. Through a 2 mm wide crack at his head and face, we found that deep inside is the skull, then an empty space, then a 2 mm - 4 mm thick cover-layer. The material forming this layer is soft earth mixed with crude paint and powdered saw-dust. Then comes a 0.5 mm thick layer of resin, brownish colour, which was in-laid when still fresh with very thin silver sheet (0.1 mm thick), still shining in certain parts. The extreme outer layer is a coat of oil paint. This technique of making cover-layer has normally been used to cover the surface of wooden boards and parallels in Vietnam.

Fig. 1.

With the help from Dr Dan Van An, Director of X-ray Department of Bach Mai hospital, we got 7 films of Superior Vu Khac Minh's body. From out study, it has been found that all bones, particularly 8 at the wrists and 7 at ankles coincided and adjusted very well anatomically. The entire vertebrae from the neck to the waist, ribs, clavicles, collar-bones... has been separated and collapsed, tupsy-turvy in the abdomen cavity. But the finger-joints and toe-joints are normal, which reveal that there was nothing like joined with one another by any gum or skeleton. So, the bone frame, once becoming statue, was intact from the dead and not re-arranged. The angle of the pubis is acute, which shows that this is a male statue, conforming to legend. Also through X-ray, we find that the entire skull-box is safe. The nose cartillage and the occipital bone were not perforated like the mummies of the Pharaohs whose brains had been removed to fill up

Fig. 2.

with scented oil. We may therefore conclude that: the monk's brain was not taken out from the skull. It is likely that after his death, people covered his body immediately, then painted it with red and silver paint, with oil-paint coat outside. Its total weight is 7 kg. Thus, as time passed, it is possible that the water from his body has been evaporated through the cover-layer which was like a box and a frame to preserve the body-shape. However, what is important is that this anonymous popular artist was so qualified that the monk's face looks very "alive".

The second statue (which was said to be Superior Vu Khac Truong) is painted white, with red lips, eye-brows and eyes decorated, his legs crossed, in straight position, and according to local version, this statue was similar to the first one, but later on, after a big flood, the statue got damaged and had been retouched. Through a crack on the left knee, we clearly see the femur and the tibia. X-ray method cannot be applied yet due to light obstruction of the material. Dr Le Nguyen Soc of the Institute of Chemical Industry analyzed the cover material by Ultraviolet Emission Spectroscopy which revealed the

Fig. 3.

components of the elements (chiefly metals) in the specimen; X-ray diffraction revealed the crystallization. Results of analyses showed that the material forming the cover-layer of the 2 monks were completely different.

So far, only the two statues of Superiors Vu Khac Minh and Vu Khac Truong remain unique for studies on this very original craft of making statue and on the customs, belief and civilisation of the Le dynasty.

Fig. 4.

Craniosynostosis in a Prehistoric Aboriginal Skull: A case report

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OSSA

Premature fusion of one or more cranial sutures is a relatively common condition. Myrianthopoulos (6) found an incidence of 1 in 1900 in a prospective study of more than 50,000 pregnancies, and in South Australia, a retrospective study (2) has shown an incidence of not less than 1 in 4,000 births. Many cases of craniosynostosis are asymptomatic, or evident only as an unusual head shape. Cases with signs of raised intracranial pressure are relatively rare and almost always show premature fusion of multiple sutures, causing reduction in cranial capacity (craniostenosis). We report such a case: a South Australian Aboriginal child who was confirmally born before Europeans came to this part of Australia.

Keywords: Craniosynostosis - Prehistory - Australian aboriginal archaeology.

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Case report

One of us (M. P.) is studying osteological material (9) from a prehistoric Aboriginal open air settlement at Roonka, 8 kms. north of Blanchetown, South Austrialia (34° 21' S, 139° 36' E). The investigations (8) have been under the direction of another of us (G. P.). The principal stratified site is a dune resting on an ancient river terrace, whose elevation has protected it from floods (Fig. 1). This has preserved a sequence of three phases of prehistoric settlement commencing 18,000 years ago and extending to the onset of European settlement at this spot (150 years ago). The picture now emerging shows the site as under continuing occupation by hunter-gatherers relying upon hunting, fishing and collecting wild foods. Analysis of the associated burials and their furnitures suggests a rich and evolving ritual life. Radiocarbon dates at present suggest that use of the site for burial begins during Roonka Phase II about 8,000 years ago and continues through Roonka Phase IIIa and IIIb to the onset of European settlement.

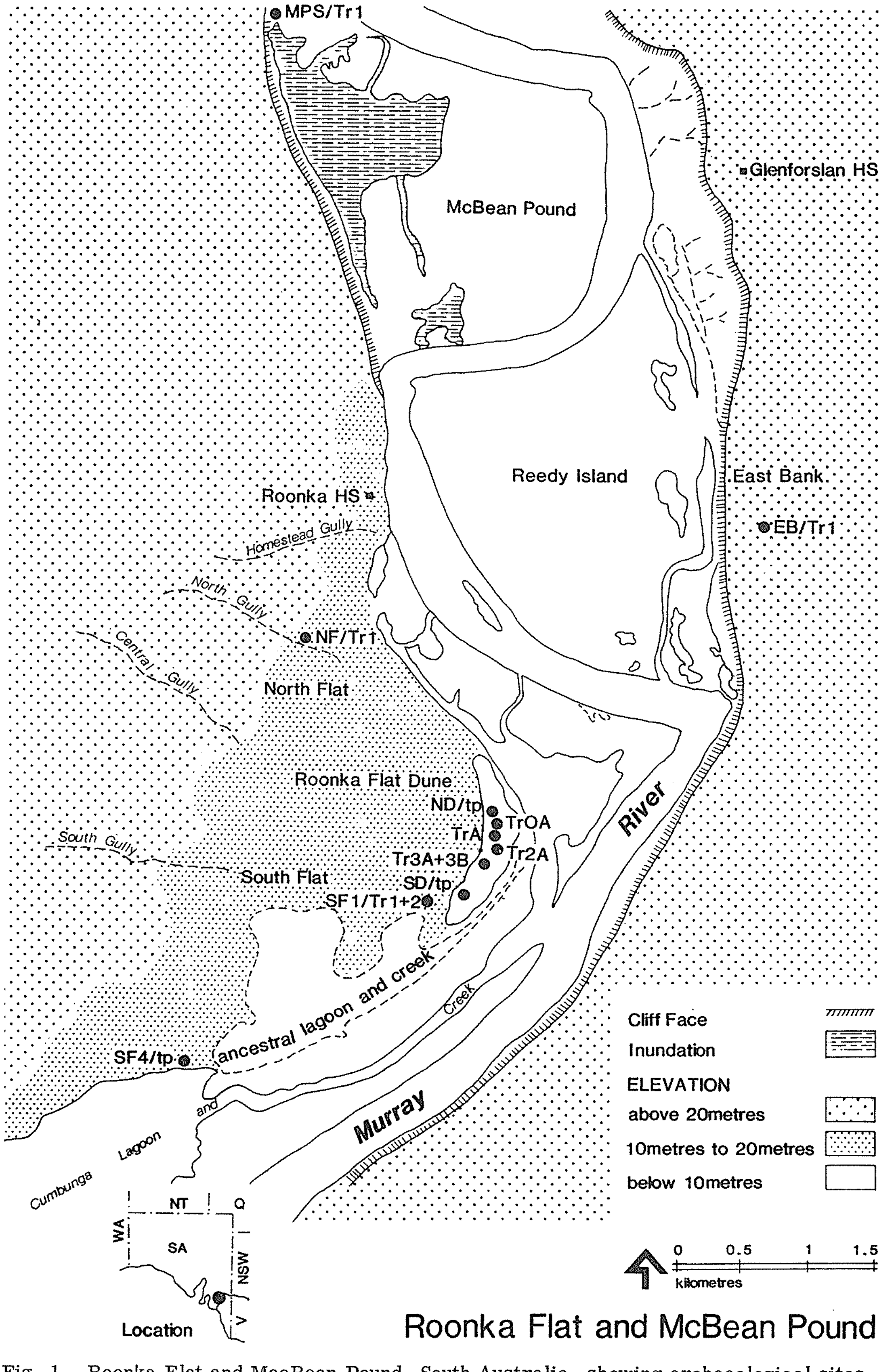

Fig. 1. Roonka Flat and MacBean Pound, South Australia, showing archaeological sites investigated by the South Australian Museum (1962-1977).

Our subject is from tomb 77 in Trench A, Roonka Flat Dune. It is the complete skeleton of a child about five years old. It has been assigned by the excavator to the most recent cultural phase, IIIb, and a radiocarbon age determination, courtesy of H. A. Polach (ANU Radiocarbondating laboratory), has fixed its age as 220 $\pm$ 80 BP (ANU 3262). The dated sample has been derived from sealed contemporary vegetation surrounding the bones and supports the tomb as being of recent age but prior to European settlement.

The skull, which is light brown in colour, shows obvious deformities (Fig. 2): there is a smooth bulge in the region of the bregma, the so-called "clown's cap" deformity (2), and the occipital condyles are asymmetrical. The frontal and parietal tuberosities are prominent, giving a pentathoid shape when viewed from above. There is fine osteopathic pitting of the surfaces of the parietal bones, especially on the right side.

The sagittal and lambdoid sutures are completely fused. The left coronal and right squamosal sutures are fused; the right coronal suture is fused medially but open in its lateral part. The left squamosal suture is patent. Transillumination shows several areas of marked thinning (craniolacunia) in the calvarial bone.

Cranial measurements, taken according to anthropometric standard procedures (4, 5, 9) are given in Table 1. For the present purpose, it is chiefly of interest to note that the cranial index $\left(\frac{\text{breadth x 100}}{\text{length}}\right)$ is 75.3, which would be within the normal range in a west-European population; Australian Aboriginals, however, tend to have elongated (dolichocephalic) heads, and this skull is mesocranic compared with other skulls from the excavation. Expressed in percentages, if the adult female mean cranial index in the Roonka skulls is 100, then this skull has a cranial index of 109.30%.

Radiography (Fig. 3) confirms the diagnosis of multiple craniosynostosis. Convolutional markings are rather prominent, suggesting raised intracranial pressure, but the sella turcica is normal and there is no erosion of the posterior clinoid processes. The orbits, facial skeleton and dentition appear within normal limits.

Radiographs of the long bones (Fig. 4) suggests a bone age of three to five years. There is irregular sclerosis of the diaphysis of the tibia, extending into the metaphyseal region and proximal tibial epiphyses; there is some diaphyseal sclerosis in the fibula, radius and ulna, but not in the humerus or femur. The metaphyses are well mineralised and there is nothing to suggest a metabolic bone disease such as rickets.

Comment

Craniosynostosis is usually seen as an idiopathic condition, sometimes showing Mendelian inheritance, but more commonly sporadic (2). Occasionally the condition results from metabolic disturbances such as hyperthyroidism (7), rickets (8) and mucopolysaccharidosis. In our case, the abnormalities in the long bones do not seem definite enough to establish a diagnosis of metabolic craniosynostosis; a multifocal low grade inflammatory process could be responsible, or even yaws. It seems more likely that our case was an example of idiopathic craniosynostosis. The bulging in the bregmatic region suggests onset in infancy. The areas of calvarial thinning, though not gross, suggest that there was at some time raised intracranial pressure. There is nothing to say whether there would have been any symptoms such as headache or failing vision from papilloedema.

Craniosynostosis has been seen in contemporary Australian Aboriginals (2), and was reported by Fenner (3) in five Aboriginal skulls of varying origins; these all showed premature fusion of the sagittal suture, and two showed additional fusion of other sutures. The condition has been reported in other archaeological material, notably a grave in Nubia (1) dating from early Christian times. We report our case because of its intrinsic historical interest, and, more importantly, to emphasise that whatever the causes of craniosynostosis may be, they are not peculiar to modern civilisation.

Fig. 2. Skull of an Aboriginal child aged about five years:
(a) left lateral view: shows fusion of coronal suture, and "clown's cap" bulge at bregma (outlined by arrows). The squamosal suture is patent.
(b) right lateral view: shows fusion of squamosal suture and partial fusion of coronal suture; the lateral segment of the coronal suture is open, though this may be a postmortem fracture
(c) basal view: note the asymmetry of the occiptial condyles and foramen magnum.

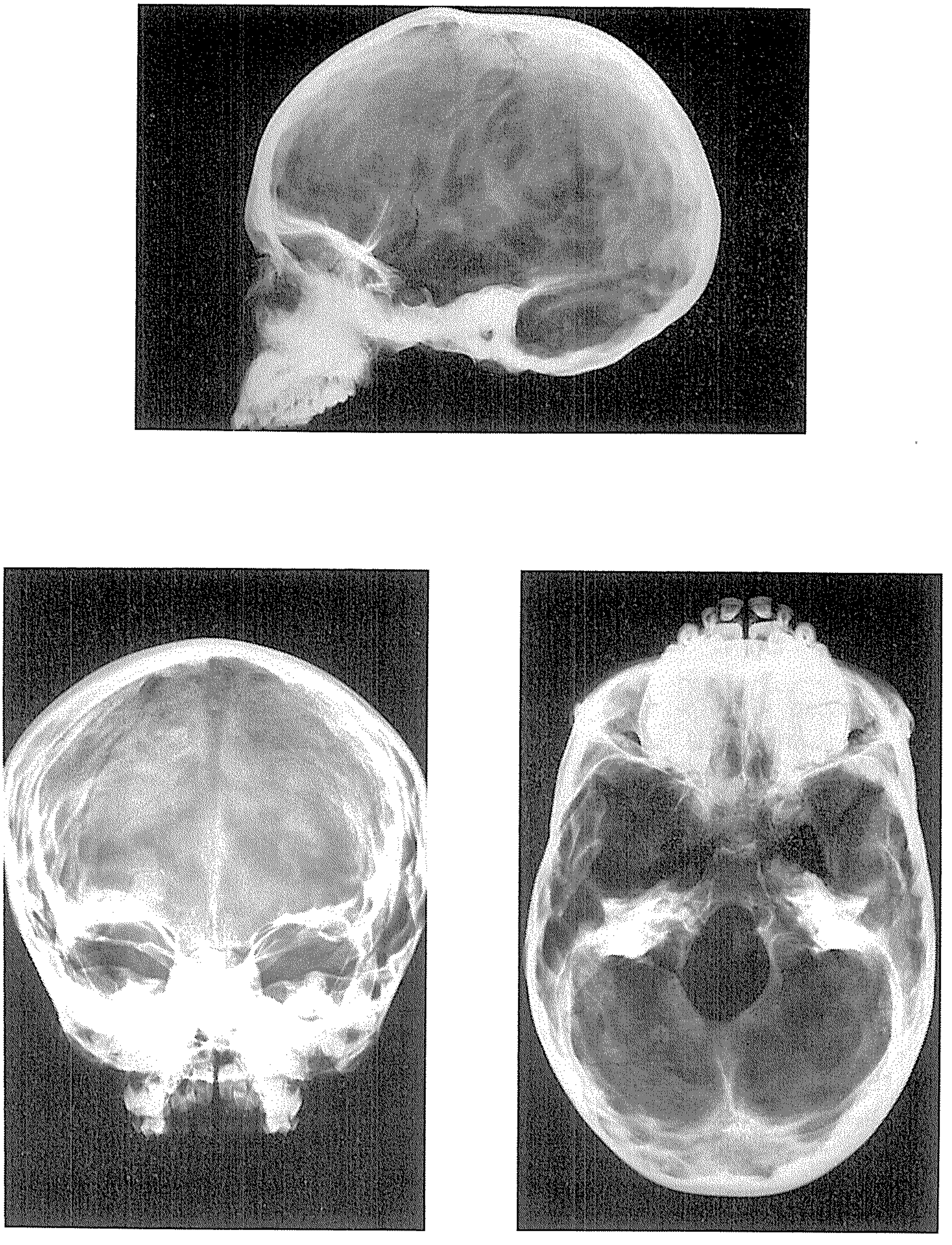

Fig. 3. Radiographs of the same skull:
(a) lateral view, showing fusion of coronal and lambdoid sutures; the apparent patency of one coronal suture is probably a fracture and extends into the skull base. The convolutional markings are increased.
(b) frontal view: the sagittal suture is fused.
(c) basal view: there are no major abnormalities in the synchondroses but the foramen magnum and the petrous bones are asymmetrical presumably as a result of the plagiocephaly.

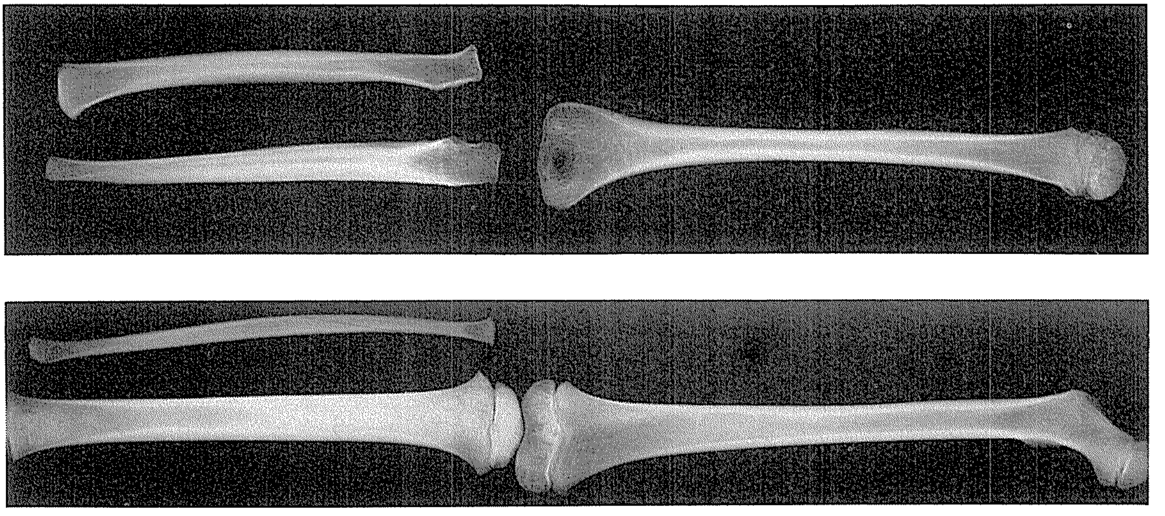

Fig. 4. Radiographs of long bones, suggesting a bone age of three to five years. There is some diaphyseal sclerosis, but nothing to suggest rickets.

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TABLE 1. Anthropometric measurements of Roonka skull No. 77

No.	Measurement	In % of adult female
1.	Maximal length	166 mm
2.	Maximal breadth	125 mm
3.	Basion-bregma height	125 mm
4.	Cranial index	75.3
5.	Mean height index	85.9
6.	Cranial module	13.9
7.	Total facial height	92 mm
8.	Upper facial height	54 mm
9.	Max. facial breadth	98 mm
10.	Facial index total	93.9
11.	Facial index upper	55.1
12.	Basio-alveolar diameter	88 mm
13.	Basion-nasion	91 mm
14.	Basion-subnasal point	86 mm
15.	Facial angle	76°
16.	Alveolar angle	76°
17.	Height of symphysis	28 mm
18.	Orbital mean height	31 mm
19.	Orbital mean breadth (4)	38 mm
20.	Mean orbital index (4)	81.6
21.	Nasal height	37 mm
22.	Nasal breadth	23 mm
23.	Nasal index	62.2
24.	Palatal length	47 mm
25.	Palatal breadth	60 mm
26.	Palatal index	127.7 mm
27.	Bi-auricular breadth	90 mm
28.	Prosthion subnasale height	16 mm
29.	Bizygomaxillar breadth zm-zm	75 mm
30.	Minimal frontal breadth ft-ft	97 mm
31.	Palatal height	7 mm
32.	Interorbital breadth mf-mf	25 mm
33.	Foramen magnum length	27 mm
34.	Foramen magnum breadth	26 mm
35.	Nasion-bregma chord	100 mm
36.	Bregma-lambda chord	120 mm
37.	Lambda-opisthion chord	82 mm
38.	Nasion-bregma arch	112 mm
39.	Bregma lambda arch	135 mm
40.	Lambda-opisthion arch	97 mm
41.	Nasion-opisthion arch	344 mm
42.	Porion-bregma-porion arch	291 mm
43.	Porion-bregma left arch	143 mm
44.	Porion-bregma right arch	148 mm
45.	Porion-bregma left chord	119 mm
46.	Porion-bregma right chord	122 mm
47.	Circumference glabella opisthion	475 mm
48.	Processus mastoid height	22 mm
49.	Processus mastoid length	22 mm
50.	Processus mastoid breadth	9 mm
51.	Height of vault	107 mm
52.	Nasion-metopic angle	86°

cont.

No.	Measurement	In % of adult female
53.	Total profile angle	85^{o}
54.	Nose profile angle	87^{o}
55.	Alveolar profile angle (ns-pr)	75^{o}
56.	Frontal angle (nasion-bregma)	57^{o}
57.	Supra-orbital (bitragone) breadth	100 mm
58.	Bimastoideal breadth	73 mm

Analysis of some Human Femora from a Medieval Charnel House at Rothwell Parish Church, Northamptonshire, England

CHARLOTTE A. ROBERTS

OSSA

This paper describes the analysis of 500 femurs from a bone crypt in Northamptonshire. A summary of the history of the bone collection is given and previous work undertaken. Computer application of information retrieved from the material is discussed and results summarised. Attention is also paid to palaeopathological aspects of the bones.

Keywords: Medieval - Crypt - Femurs - Anthropology - Palaeopathology - Computer - Platymeria.

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Introduction

Rothwell is situated very close to Kettering in Northamptonshire, England (Fig. 1). A bone crypt underneath the Parish Church houses a considerable collection of human femurs and skulls (Plate 1) dating from the early 13th century. According to documentary evidence, the bones derive from parts of the churchyard which have now been built upon (Sharp, 1970). As is widely known, the custom in the Medieval period was to exhume bones from areas of proposed building and deposit them in an underground purpose built building. At Rothwell, two periods of deposition have been isolated, the first in the 13th century when the chancel of the church was lengthened, and the north and south aisles were extended into the surrounding churchyard. The second was in the 16th century when the Jesus Hospital was built over part of the graveyard. However, this dating is only tentative and is based on artefactual evidence and cannot therefore be regarded as very accurate.

Previous work

Since the crypt's discovery in about AD 1700 (Cypher, 1849. 39), the arrangement of the bone collection has undergone modification. Restacking in 1912 has contributed to a deterioration in the condition of the bones and dampness has accelerated their decay. Previous work on parts of the collection has resulted in occasional but inadequate publication.

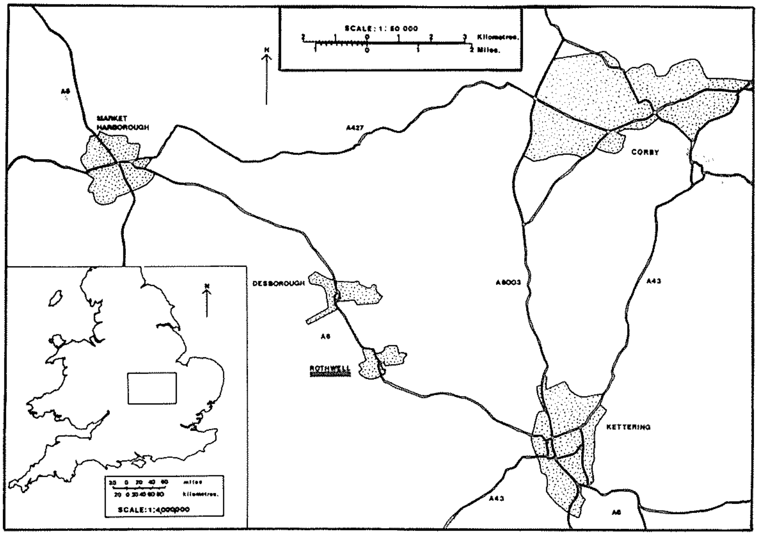

Fig. 1. Rothwell Location Map.

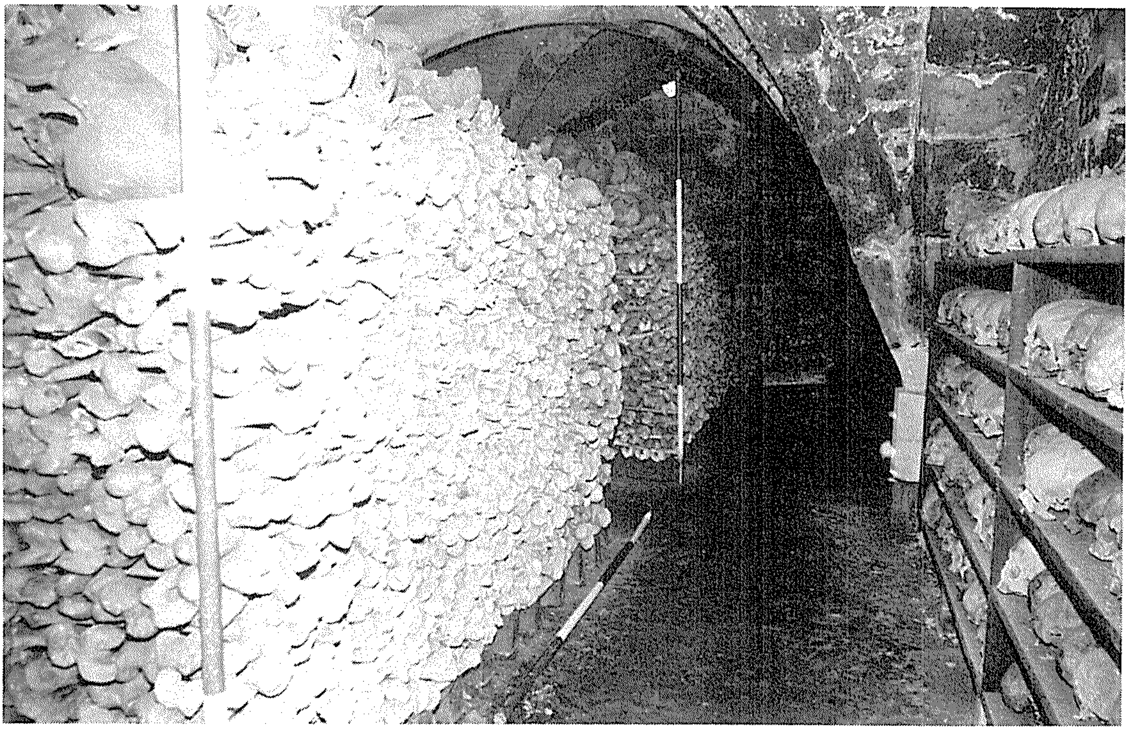

Plate 1. The bone crypt at Rothwell Parish Church.

Some femurs and crania were used by Professor F. G. Parsons for 2 papers (1914, 1927). Later on this century, Dr. J. C. Trevor made several studies of the material but never published reports, the work he did being preserved in the Cambridge University's Manuscripts Rooms. More recent work by Calvin Wells was concerned with the palaeopathological evidence present. Finally, Bryan Doughty (1977) analysed the blood groups of some of the crania.

A general survey of the literature about the bones revealed a lack of any systematic study. This present paper was undertaken as part of an undergraduate degree with the aim of:

1) Providing a critical review, based on computer analysis, of the validity of femoral osteometric data.
2) Giving a broad picture of the Medieval population at Rothwell.

Format of the project

Consideration of the femurs was felt to be a priority due to the lack of work by previous people. In addition, time was a limiting factor and concentration on one part of the collection was seen to be potentially more valuable.

Due to time limitations, it was only possible for random selection of 500 femurs for study, therefore any conclusions should be regarded as tentative and specific to this sample. This study encompassed two areas of human osteology:

1. Anthropology

Femoral measurements were taken (according to Brothwell, 1972. 85 f) with the aim of recording on computer. It was hoped that these variables would ultimately help in the determination of sex, stature and platymeria, and, by cluster analysis, particular group characteristics in the bones. In addition, comparison with other human bone collections was deemed useful. It should be noted that each bone was considered an individual. Pairing was not feasible. Abbreviations for measurements used in the text are as follows:

FeL1	Maximum length of femur
FeL2	Oblique length
FeL3	Trochanteric length
C	Circumference of mid-shaft
FeD1	Sub-trochanteric antero-posterior diameter
FeD2	Sub-trochanteric medio- lateral diameter
FeD3	Mid-shaft antero-posterior diameter
FeD4	Mid-shaft medio-lateral diameter
FeD5	Maximum longitudinal diameter of femoral head

2. Palaeopathology

The bones were examined to assess their general condition and to isolate specimens displaying pathological features.

Computer Application

The femoral measurements with sex and side of each bone were recorded and stored on computer at the University of Leicester. They were analysed using the S. P. S. S. package (Statistical Package for the Social Scientists - Nie et al, 1975). This package was useful because of its ability to select, transform and combine appropriate variables. Variables with missing values could also be omitted from specific calculations if required. Sexing was based on measurements and the general appearence of each bone. Bones with a robust appearence and prominent attachment areas for muscles (such as the linea aspera) were considered male. This procedure was carried out as carefully as was possible. Without doubt the lack of skulls or pelves made this more difficult.

(i) Histograms

Histograms were plotted to show the range and frequencies of specific male and female variables. Figures 2 and 3 illustrate some of the variables plotted (FeL1, FeL2, FeL3, C and FeD5) and they display the obvious bi-modal distribution of the bones presumably indicating the sexes. It becomes clear that there are fairly large areas of overlap between the two groups in each histogram. Obviously there are certain ranges of measurements which can encompass both male and female bones alike. It would naturally be hazardous to try to sex a random bone by consulting these histograms. However, it would be possible to determine the likelihood of a bone being male or female by consulting the frequencies for a particular measurement and each sex.

(ii) Procedures

The following procedures were carried out:

a) Statistical descriptions of variables for both sexes were plotted. Tables 1 and 2 describe them.

TABLE 1. Statistical Description of Variables (Male) Measurements in millimetres

	FeL1	FeL2	FeL3	C	FeD1	FeD2	FeD3	FeD4	FeD5	Stature	Platymeria
Mean	460.1	455.2	437.3	101.1	31.5	30.4	29.7	35.9	49.0	1722.2	83.5
Std.Dev.	19.7	20.6	18.3	5.8	2.6	2.3	2.5	3.6	3.4	45.6	10.6
No. of Cases	173	173	179	225	255	225	220	220	170	173	220

TABLE 2. Statistical Description of Variables (Female) Measurements in millimetres

	FeL1	FeL2	FeL3	C	FeD1	FeD2	FeD3	FeD4	FeD5	Stature	Platymeria
Mean	421.5	416.5	400.5	90.9	28.0	27.4	26.6	32.7	42.8	1582.1	81.6
Std.Dev.	21.7	22.0	19.5	6.2	2.7	2.1	2.9	2.6	3.8	53.6	10.6
No. of Cases	156	157	139	250	251	250	241	240	176	156	240

b) The following more complex procedures were carried out to determine any significant groupings in the data obtained:

(i) Principal Components Analysis

Principal Components Analysis, a multivariate technique, aims to find a new set of orthogonal axes with the same origin which have certain desirable properties (Doran & Hodson, 1975.190). The first new axis is along the direction of greatest spread of the point scatter and the second along the direction of the greatest remaining spread, and

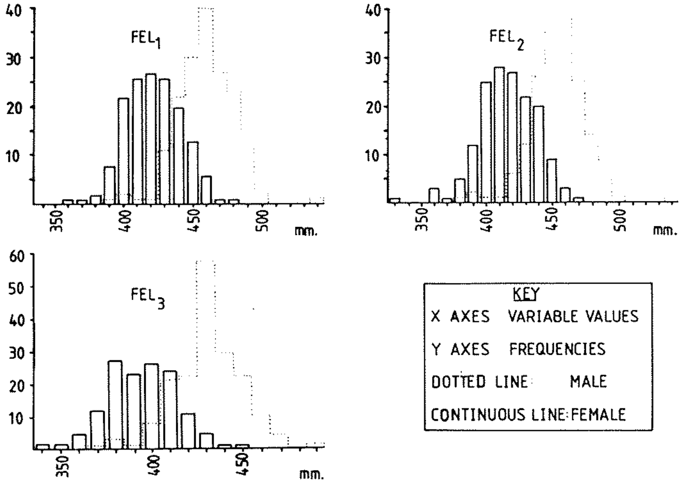

Fig. 2. Histograms of FeL1, FeL2, and FeL3.

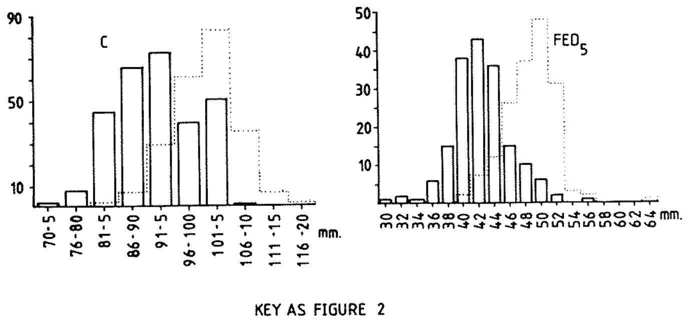

Fig. 3. Histograms of C and FeD5.

so on until the whole population is covered. The new axes are called Components and the resulting scatter of points represents the variables which best describe the form and structure of, in this case,the sample of bones. Often the points can be accommodated in the space defined by the first one or two components, the contribution of the remaining components being minimal. It was considered useful to subject the data to this analytical technique to show how much the original variables contributed to the variation in the sample. It was found that Principal Components 1 and 2 contributed most of the percentage variation as indicated below.

TABLE 3. Principal Components

	% Variance	Cumulative Variance
Principal Component 1	66.21	66.21
Principal Component 2	12.61	78.81

78.81% of the variation in the data was explained by two variables instead of the original nine measurements taken. The 1st Component was seen to be related markedly to FeL1, FeL2, FeL3 and C. The 2nd Component was related mainly to FeL1, FeL2, and FeD3. These two Components reflected the thickness and length of the bone, the most important variables being length, mid-shaft circumference and diameter. It becomes clear that certain variables were not very informative as measurements.

It these results are compared to the resultant three clusters of the Cluster Analysis procedure a similar picture is found. The variables which are diagnostic of the clusters tend to be the ones which contribute most to the Principal Components Analysis. As Cluster Analysis has separated the bones into groups of a particular sex it appears reasonable to suggest that the variables FeL1, FeL2, FeL3, C and FeD3 may be sufficient for sexing of femurs. A further point to bear in mind is the especial significance of C and FeD5. In males a pronounced linea aspera will naturally have some effect on the variables measured over it. In addition, the usefulness of the femoral head diameter should not be overlooked in the question of sexing.

To test the importance indicated in Principal Component 1 of FeL1, FeL2, FeL3 and C and in Principal Component 2 of FeL1, FeL2 and FeD3, scatter diagrams were plotted with regression lines. Close correlations were observed between FeL1, FeL2, FeL3 and C (See Figs. 4, 5 and 6). They seem to indicate a relationship between bone length and circumference of femur. As C increases bone length rises in proportion.

(ii) Cluster Analysis

Cluster Analysis, or the use of a numerical procedure to divide a given group of units into homogenous sub-groups, was carried out (Cowgill, 1968. 370). Each bone is assigned to a current cluster to which it is most similar at a similarity level indicated by the coefficient. Analysis was carried out using the Clustan 1B Package at the Northwest Regional Computing Centre's CDC computer at Manchester (Wishart, 1979). There are several techniques of cluster analysis and, in all, there is a possibility of different results with the same data. Therefore methods should be tested against each other.

Male and female data was analysed together and 270 cases were computed ie. those with full sets of the 9 variables recorded.

Initially, Iterative Relocation was used. It starts off with a random classification of all cases into clusters and relocates individuals to the group with which they are most similar, to produce the desired number of clusters. The procedure works on the error sum, which means the total sum of the squared distance from each object to the centroid of its parent cluster.

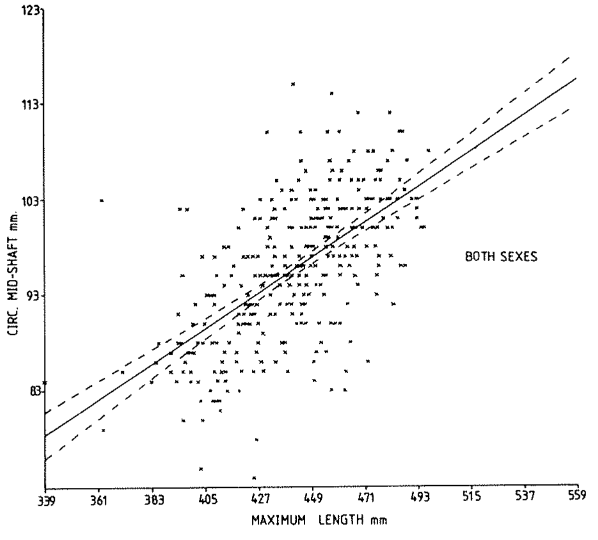

Fig. 4. Scatter Diagram of FeL1 and C.

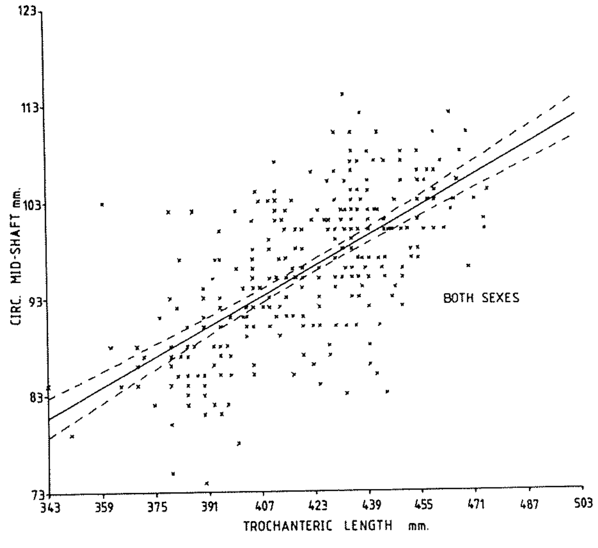

Fig. 5. Scatter Diagram of FeL2 and C.

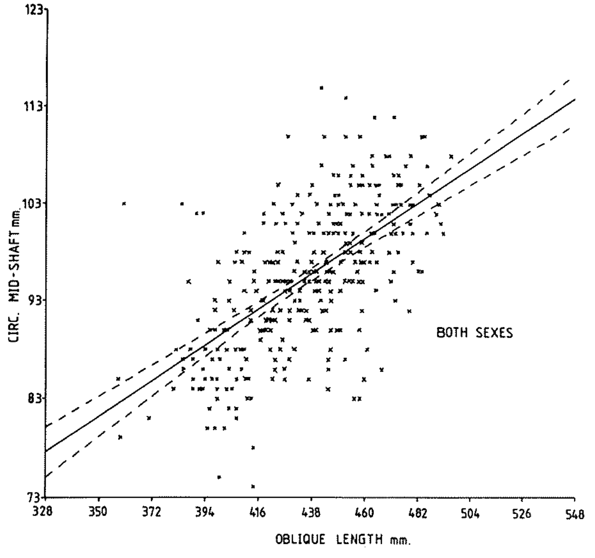

Fig. 6. Scatter Diagram of FeL3 and C.

Cluster 1 showed the predominance of larger than average males. Cluster 2 included a virtually equal distribution of males and females very close to the population mean and Cluster 3 was dominated by smaller than average females. It is suggested that Cluster 2, being made up of male and female bones, may be a group of small boned males and large boned females. Statistical description for the 98 cases in Cluster 2 showed this hypothesis to be correct.

Ward's Method of hierarchical fusion (Ward, 1963) was then used to check the results of Iterative Relocation. It uses a similarity co-efficient of squared euclidean distance between individuals ie. taking the geometric distance between two points in multi-dimensional space. Ultimately it fuses the bones into two terminal groups. The 3 clusters produced showed similarities to the previous method. Cluster 1 comprised males with larger than average bone dimensions. Cluster 2 was made up of females with smaller than average bones and Cluster 3 was predominately of females with even smaller bone measurements.

Diagnostic statistics were computed for each method and all clusters. They showed little variation within the clusters. Comparison between the clusters and Principal Components 1 and 2 show that the variables which best describe both, appear to be the same- FeL1, FeL2, FeL3, C and FeD3. F-Ratios, which indicate how good the cluster is when compared to 1.0, were observed. Low variation within a cluster means it is diagnostically good. Variations for F-Ratios in each cluster and for both methods are small which shows that the variables are good diagnostics for the clusters.

The computer was also used ultimately to describe other features of the bones.

Platymeria

It has been shown that in the proximal part of the femur there are often obvious differences in shape between populations. Many authors have tried to understand what the presence of platymeria actually means. Brothwell (1972. 20) summarises their thoughts.

The recording of platymeria involves the measurement of the sub-trochanteric antero-posterior and medio-lateral diameters (in this case FeD1 and FeD2) and their incorporation into the following formula:

$$\frac{100 \times FeD1}{FeD2}$$ To give the femur shaft index.

There seems to be some dispute as to what femur shaft index denotes a platymeric bone. Brothwell (1972. 89) considers an index of < 84. 9 to be platymeric, while Parsons (1914. 256) considered bones with indices of < 75. 0 (which Wells & Clayton, 1980. 255 consider to be hyper-platymeric). Yet Townsley (1946. 85) regards a platymeric bone to be one with an index of <80. 0.

It is perhaps more relevant to be studying the relative degrees of antero-posterior flattening in populations rather than trying to define a dividing line for platymeric variation.

460 platymeric indices were calculated, the remaining 22 of a possible 482 cases being absent through missing values for FeD1, FeD2 or sex and, of those, 305 were less than 84. 9 (Brothwell's division for platymeria), that is 66. 3% of the population.

The indices computed are represented in the following table:

TABLE 4. Platymeric Indices

	Mean	Std.Dev.
Male	83.5	10.6
Female	81.6	10.6

and their values displayed in the histogram in Figure 7. 60. 1% of the male bones (137 of 228 in the sample) and 66. 1% female bones (168 of 254) were platymeric. As a comparison, the platymeric indices from St. Helen-on-the Walls cemetery at York (Dawes & Magilton, 1980. 29) showed 84% males and 89% females to be platymeric. Yet at North Elmham Park (Wells & Clayton, 1980. 255), 96. 5% of the males and 100% females appeared platymeric (for both cemeteries the definitive index was < 84. 9). Both cemeteries showed appreciably more platymeric bones than at Rothwell.

Results from the present analysis indicate that platymeria is slightly more common in female bones than in male and in left more than right bones (168:137). Parsons (1914) as mentioned above, restricted his platymeric bones to those below an index of 75. 0 but he still found a marked swing of platymeria to left and female bones.

There is a need for platymeria to be assessed for more skeletal populations so that results can be collated and perhaps a comparative study done on modern human bones would help in relating platymeria to disease.

Stature

Stature was calculated for the sample under consideration. The maximum length (FeL1) was used in the regression equation devised by Trotter & Gleser (1952, 1958). As no similar equations exist for British populations it was felt appropriate to use Trotter & Gleser's formulae as follows:

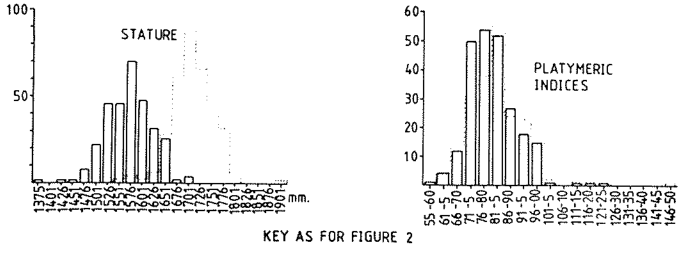

Fig. 7. Histograms of Stature and Platymeric Indices.

Male	2.32 X FeL1 + 655.3
Female	2.47 X FeL1 + 541.0

Allowing for missing values for FeL1, there were 173 male cases and 156 female. The following table describes the statures:

TABLE 5. Stature

	Min.Stat.	Max.Stat.	Mean	Std.Dev.
Male	1.57m	1.91m	1.72m	45.6
Female	1.38m	1.71m	1.58m	53.6

and Figure 7 visually displays the variation. Comparison with other populations of a similar date (based on the same formulae) shows the following:

TABLE 6. Stature. St. Helen-on-the-Walls, York (Dawes & Magilton, 1980.28)

	Min.Stat.	Max.Stat.	Mean
Male	1.54m	1.84m	1.69m
Female	1.45m	1.73m	1.69m

TABLE 7. Stature. North Elmham Park (Wells & Clayton, 1980.254)

	Min.Stat.	Max.Stat.	Mean
Male	1.62m	1.80m	1.72m
Female	1.42m	1.69m	1.57m

Stature for the Rothwell bones does not seem to differ much when compared to the above populations and is certainly not very different to the present day. However, the difference in male and female stature means compared to modern populations is rather greater. This suggests that there are probably genetic or environmental factors which affect stature.

Palaeopathology

To conclude the study, the bones were subjected to examination for evidence of palaeopathological conditions. Unfortunately, due to the nature of the bone deposit,the femurs could not be related to the rest of the skeleton and therefore are isolated. Bones displaying some affliction were X-Rayed and recorded by photography. Examples of some of the more severely affected bones will be described:

No. 443 (Plate 2) Lesion on the posterior aspect of the proximal shaft in the area of the iliacus muscle insertion. This could be due to muscle strain and subsequent haemorrhage under the periosteum.

No. 420 Lesion on the anterior aspect of the lateral condyle appearing in the form of a lip of extraneous bone. This could be secondary to an old haemarthrosis of the knee.

No. 442 (Plate 3) Head and neck are deformed. There was possibly some injury to the soft tissues around the hip joint and subsequent thickening of the bone in the neck region.

16 possibles cases of degenerative joint disease were found in the sample. The more severe ones were X-Rayed and photographed.

No. 5 (Plate 4) In this grossly deformed case, the head and neck are badly affected and do not appear delineated from each other. X-Ray (Plate 5) shows areas which indicate severe infection and inflammation.

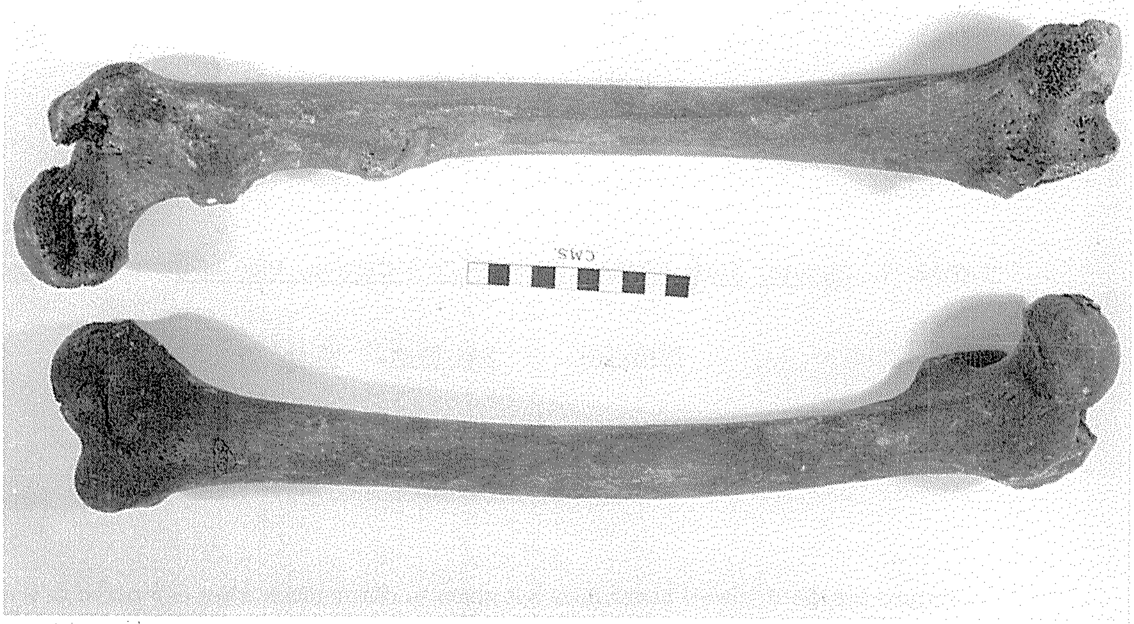

Plate 2. Lower: No. 443. Sub-periosteal haematoma possibly following injury.

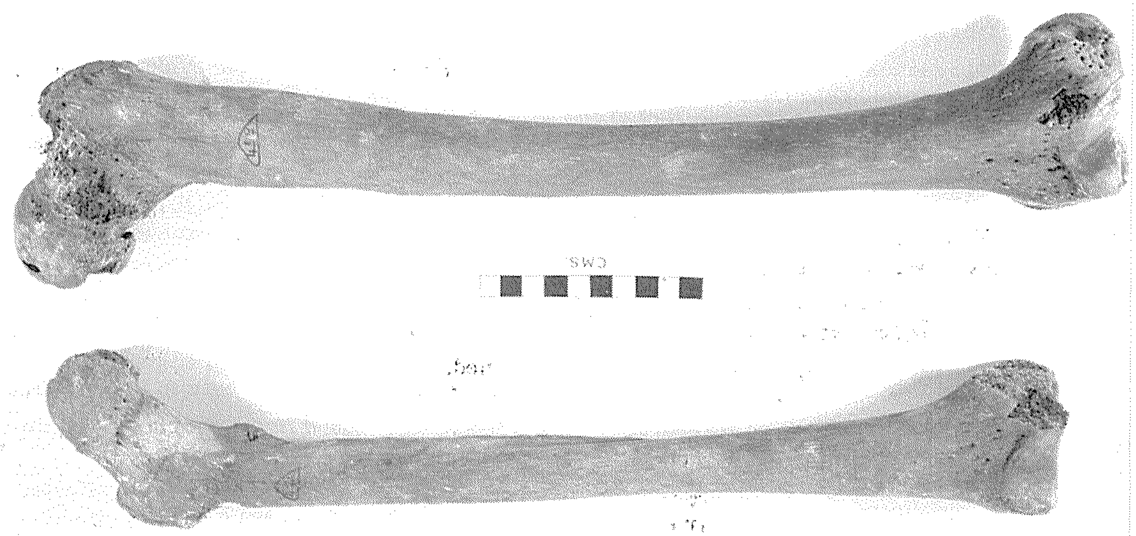

Plate 3. Upper: No. 442. Injury to soft tissues around the hip joint.

Plate 4. No. 5. Degenerative joint disease of the hip (possibly tuberculous).

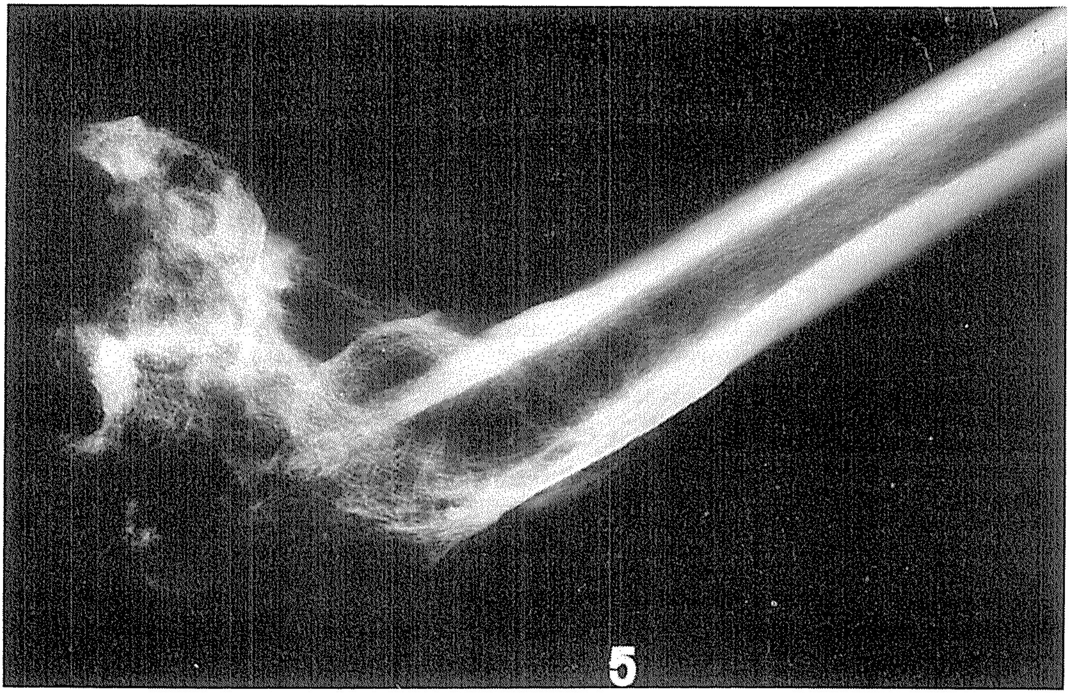

Plate 5. No. 5. X-Ray of proximal femur.

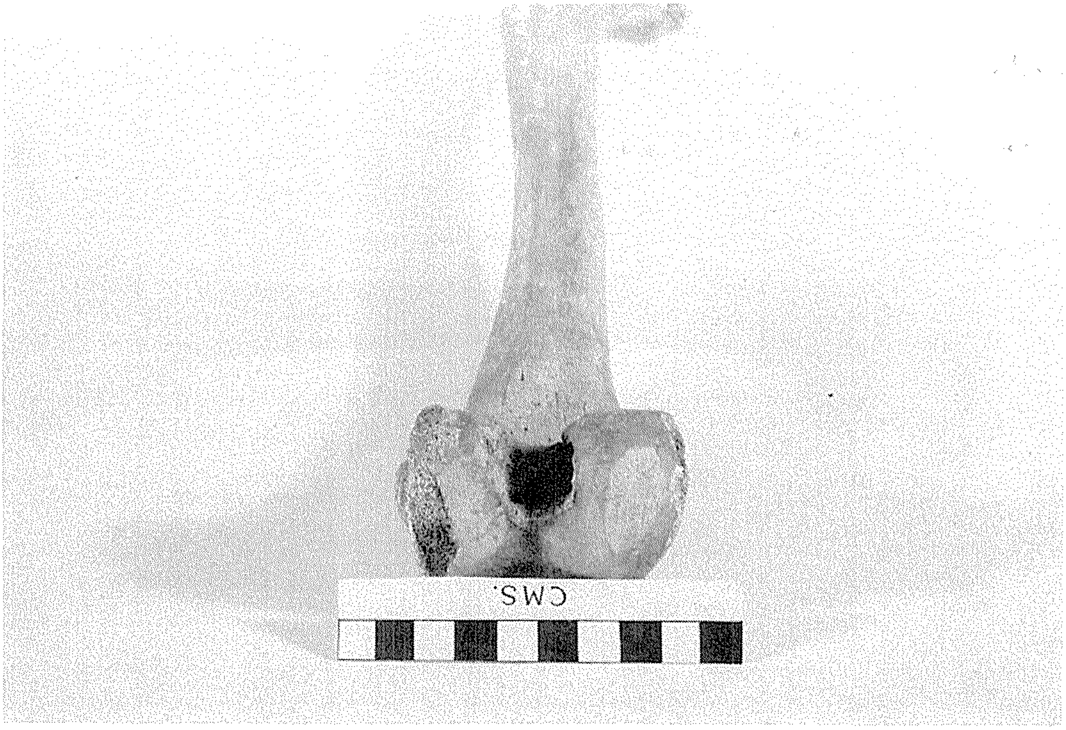

Plate 6. No. 431. Eburnation of the distal condyles.

No. 431 (Plate 6) Eburnation of the distal condyles of the femur.

No. 460 Degeneration of the head and considerable osteophytic lipping and deformity of the head and neck.

No. 461 Severe deformity, rougheningand lipping of the femoral head. This could also be a case of congenital acetabular dysplasia.

2 possible cases of Paget's Disease (osteitis deformans) were found.

No. 30 (Plate 7) The whole shaft is obviously thickened along its length and X-Ray showed an obliteration of the medullary cavity and replacement with new spongy bone.

No. 60 The femur is bowed and thickened and there is little delineation between the medullary cavity and the cortex of the bone.

Other palaeopathology present included periostitic lesions, possible cases of osteochondritis dessicans and osteoporosis. In general the population at Rothwell, assessed on femurs alone, was quite healthy and well nourished. Diseases present were those which still affect modern populations. The relatively high incidence of degenerative joint disease and injuries shows that the population was probably carrying out strenuous work causing wear and tear on the joints. The presence of one well aligned and healed fracture in the sample indicates the possibility of splinting as a treatment available at that time.

However, it should be recognized that all conclusions can only be tentative. Without whole skeletons to work on the pathological picture will be incomplete.

Plate 7. Lower: No. 30 Paget's Disease of femur indicated by thickening of shaft and confirmed by X-Ray.

Conclusion

The study of the Rothwell bones was a useful exercise. It brought to light many aspects of the study of ancient skeletal material which still await resolution. To summarise thoughts on some of the above, the following points should be made:

1. A revision of measurements taken on bones should perhaps be made. Principal Components Analysis clearly showed that some of the variables used here were of no use. Before measuring bones, objectives should be stated and collaboration with other workers in the field should be carried out so that useful comparative work can be made between populations.

2. It was found that the condition of the bones often masked much of the information or prevented some measurements being made. Pathological conditions may be missed or, on the other hand, could be simulated by post-mortem effects in the ground. Care in diagnosis is evidently needed in these circumstances.

3. There is obviously dispute on the subject of platymeria in human bone analysis. A decision has to be made as to whether it really means anything or even if it is worth recording.

4. There is a need for regression equations for stature to be calculated for European populations so that accurate stature estimations can be made.

5. It is without doubt that some of these problems may well be resolved in the near future as more workers endeavour to process human skeletal material from archaeological sites.

Acknowledgements

I would like to thank Dr. Keith Manchester for reading the preliminary manuscript of paper and giving constructive criticism. I would also like to thank the Photography Department at the University of Bradford for reproducing the photographs and diagrams for publication, Roger Martlew of the University of Leicester for all the initial help he gave in the computing aspects of this study and the Rev. J. C. Cocks and Church Council for their permission to study the bone collection at Rothwell.

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Trephination in Ancient Egypt and the Report of a new Case from Dakleh Oasis

MOHEB M. SHAABAN

OSSA

A true healed trephination on the right parietal bone in a skull of a 12-13 year old child is described. The skull came from a tomb at the eastern part of Dakhleh Oasis and dates about 500-400 B.C. The reason for the trephination was therapeutic, to alleviate depressed fracture. The operation was successful and the patient survived the event for some time. Current evidence supports the view that trephination was occasionally practiced in Egypt. The motive for the operation appears to be therapeutic rather than ritualistic or magic.

Keywords: Trephination - Bakhleh Oasis - Egypt - 27th Dynasty.

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Trephination, the process of making a hole in the skull without damaging the dura mater, has been known to have been practiced since the Neolithic time in Europe (Horsley, 1888; MacCurdy, 1905; Ruffer, 1918; Moodie, 1923; Sigerist, 1951). Indeed, it is highly likely that the operation was performed even earlier in Mesolithic times (Wells, 1964). Trephination has also been documented from many parts of the world especially in Peru (Moodie, 1927; Popham, 1954; Stewart, 1958). A variety of motives for the operation have been suggested (Parry, 1931; Wells, 1964; Liskowski, 1967). Undoubtedly, at least one motive for performing trephination is to treat a depressed fracture (Malcolm, 1934; Daland, 1935; Popham, 1954; Stewart, 1958; Wilkinson, 1975; Manchester, 1983).

Instances of cranial trephination are not common among the ancient Egyptians. A search of the literature provides only eight cases. Table 1 summarizes, chronologically, the foregoing cases. Because of the meager evidence of such operations in Egypt, this new case is of special interest. The find is from southwestern Egypt, and will be discussed in the wider context of such operations in ancient Egypt.

Material

The specimen under study came to light during the fifth season of work in Dakhleh Oasis 1982-1983. It consists of a cranium only. Neither the mandible nor any infracranial bones could be associated with the cranium with any degree of certainity. The cranium was exhumed from a cemetery located in the eastern part of the Dakhleh Oasis. The archaeological analysis has determined the tomb to date between 500-400 B. C. i. e. the 27th Dynasty (Millet, 1983). State of preservation is excellent, however, both zygomatic arches are damaged and all front teeth and premolars have been lost post-mortem.

The spheno-occipital synchondrosis suture as well as all cranial sutures do not show any signs of obliteration. All permanent teeth are fully erupted except the third molars. The second molars show evidence of attrition, which is limited to slightly blunted enamel of the cusps. These features suggest that the cranium is that of a person whose age at death was 12 to 13 years.

Description

The cranium shows a wound associated with an irregular opening about midway on the right parietal bone and 10 mm lateral to the sagittal suture (Fig. 1). The opening measures about 20 mm in diameter in a plane parallel to the mid sagittal suture and about 14 mm at right angle to that plane. Tracing the extension of the original borders of the opening suggests that the opening originally was oval and measures about 34 mm by 21 mm. Because the oval is bevelled, a wider circular area about 41 mm in diameter is involved. The edges of the original opening are smooth and distinctly bevelled, and there is much evidence of healing and subsequent remodelling (Fig. 2). The process of generation had proceeded far enough to have approximately one fourth of the original aperture filled with new bone. The osseous growth proceeded irregularly from the margins of the opening toward the center. A mild case of infection seems to have followed the wound as evidenced by the small pitting around the opening. Two curved cuts or scratches with short radii are visible on the outer table of the medio-posterior and medio-anterior borders of the wound. Two remnant cracks or fissures measure about 5 mm and 3 mm in length, and radiate from the lateral margins of the wound. There is nothing to indicate a disease condition of the bone, except that the parietal bones and the roof of the orbits show mild case of spongy hyperostosis and cribra orbitalia, respectively (Figs. 3 and 4).

Diagnosis

It has been repeatedly demonstrated that several conditions may procedure holes in the skull that can be mistaken for a trephination. According to the characteristics of the wound, conditions such as enlarged parietal foramina (Goldsmith, 1945; Hoffman, 1976), cranial disraphism (Steward, 1975), biparietal osteoporosis (Lisowski, 1967), cranial injury (Cybluski, 1977) and osteolytic disease, e.g. infectious diseases and tumours (Steinbock, 1976) can be easily ruled out. The size and shape of the opening, the presence of well defined wide bevelled borders associated with cut or scrap like-grooves (Daland, 1935; Wilkison, 1975), evidence of advanced bony regrowth (Roger, 1939; Ortner and Putschar, 1981) and signs of bone osteitis surrounding the opening (Stewart, 1956) suggest that the wound resulted from a trephination.

Discussion

There can be little doubt about the authenticity of this trephination, as it shows all the characteristic marks. It lends an additional support to the existence of a true surgical custom in ancient Egypt as far back as 400-500 B. C. An inspection of the details of the wound indicates that a combination of two techniques were probably used. The wide bevelled borders of the area involved suggests scraping, while the curved grooves suggests cutting (Wilkinson, 1975). The advanced healing of the wound and the minimal expression of infection verify a successful operation with no complications and prolonged survival of the patient (Ortner and Putschar, 1981). The likelihood that this operation had been conducted to alleviate a depressed fracture is suggested by the nature of the posterior border

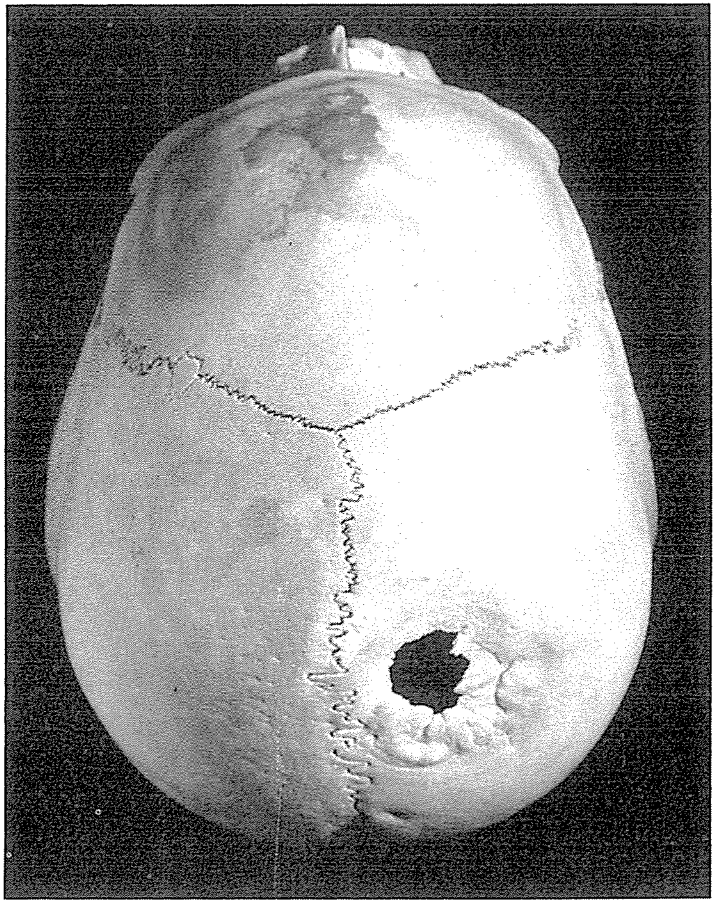

Fig. 1. Calvarium in norma verticalis.

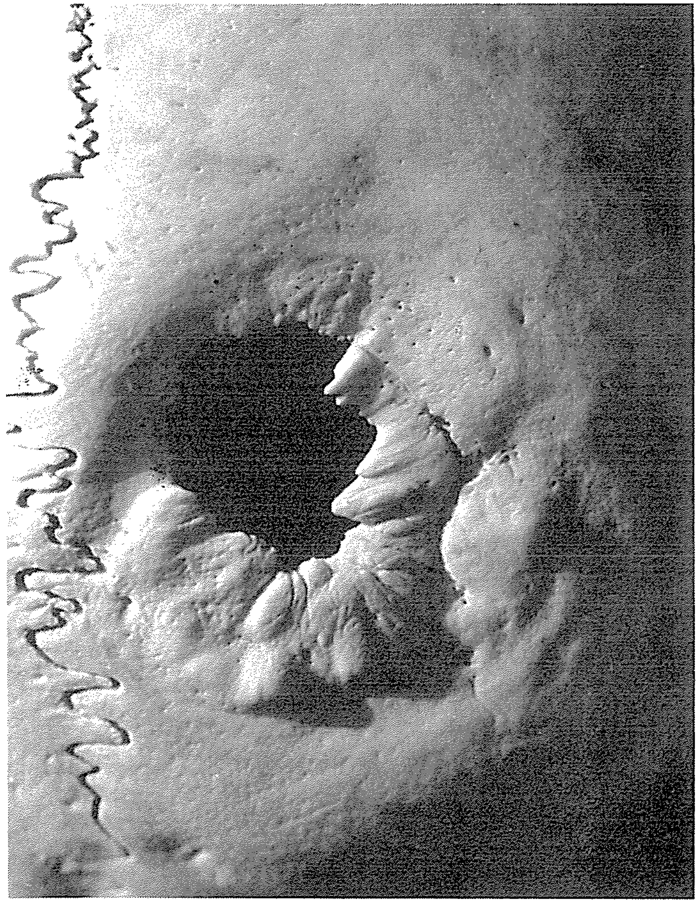

Fig. 2. Close up showing detail of the lesion.

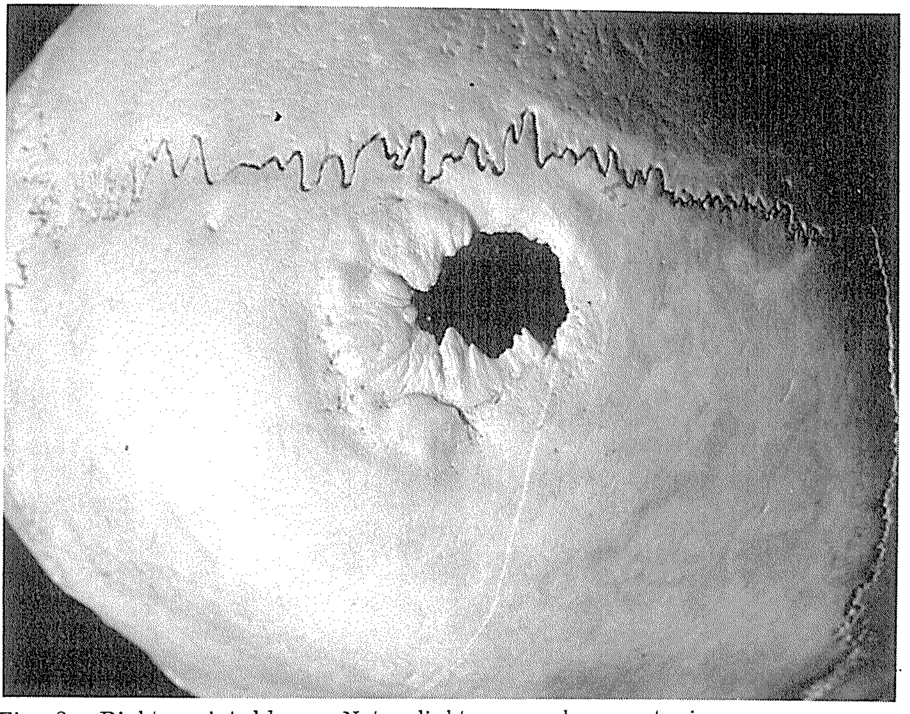

Fig. 3. Right parietal bone. Note slight spongy hyperostosis.

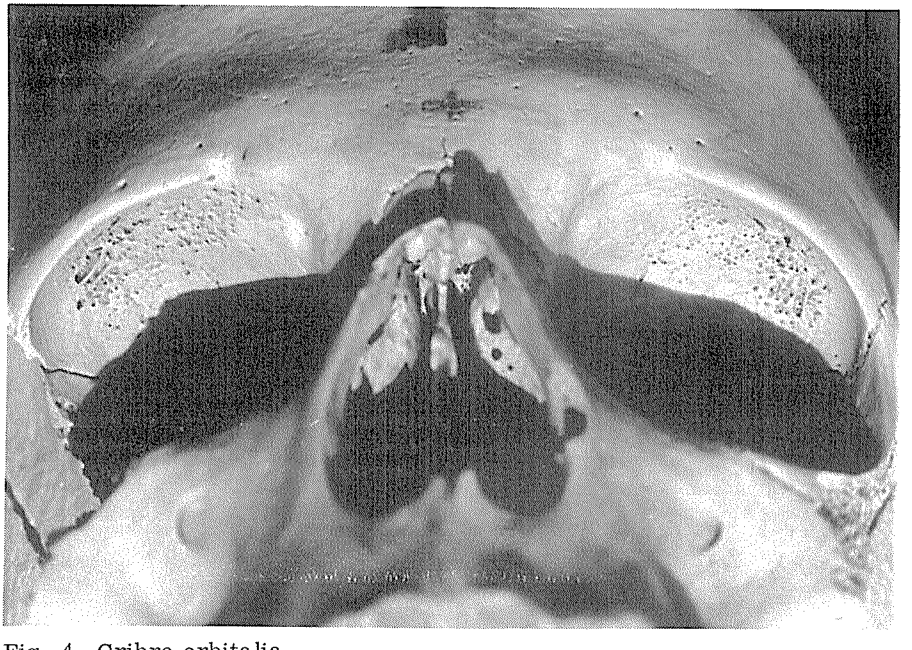

Fig. 4. Cribra orbitalia.

of the opening, which shows elevation of portion of the bone, and the presence of two remnant cracks radiating from the lateral border of the defect. It is highly probable that the positive indication of trauma may have been further obliterated by the process of healing.

Evidence for the practice of trephination among the ancient Egyptian is scarce. Only eight cases have been reported among thousands of skulls recovered throughout the last century. This rarity leads some workers, to conclude that the operation has never been practiced in Egypt (Smith and Jones, 1910; Derry, 1919; Moodie, 1919, 1920, 1923; Janssens, 1970). The presence of trephination in Egypt has not been documented on philologic grounds (Ghalioungi, 1963). However, more conclusive evidence is the demonstration of the operation in several skulls (Table 1). This unfortunate paucity of skull surgery in ancient Egypt provides considerable difficulty to an adequate analysis of the procedure. However, taking this fact into consideration, some interesting observation can be inferred.

The practice of trephination has considerable time depth in Egypt. The oldest skull showing artificial openinghas been reported by Brothwell (in Oakley et al., 1959) and dated back to the early dynastic time. Table 1 reveals that all reported cases of cranial trephination; including the present case, show evidence of osseous regeneration. This is a definite indication that the operation in all cases had been performed antemortem and that each individual survived the event. This suggests a 100% survival rate, which may be related to the fact that the ancient Egyptians had considerable knowledge of human anatomy (Gordon, 1949; Reid, 1970) and traumatic surgery (Breasted, 1930; Hussein, 1949). The operation does not appear to be an age or sex related procedure as trephination was conducted on males, females and children. The trephined holes described among all skulls share striking characteristics; edges bevelled and oval or circular in shape, which indicate that scraping and/or cutting in circular fashion was employed. This method is common in the ancient time (Parry, 1931; Stewart, 1959; Lisowski, 1967; Wilkinson, 1975) and proved to involve minimal risk to the dura mater (Parry, 1931; Ortner and Putschar, 1981; Manchester, 1983). The reasons why trephination was practiced in ancient Egypt is difficult to judge from our scanty examples. However, it seems highly probable that four cases out of the nine represent surgical intervention for therapeutic purposes. The association of the operation with sinusitis problem; mastoid sinus infection in case of Tharkan skull (Brothwell, in Okley et al., 1959) and with maxillary sinus inflamation in Pahl's case (1980), together with evidence of fracture in the present case and Parry's (1923) strongly favour of the idea that the procedure was therapeutic rather than retualistic or magic.

The practice of trephination among the ancient Egyptians is troublesome. One can not refrain from asking why only nine cases have turned up among all the thousands of skulls exhumed in Egypt? Certainly, skull surgery was not frequently practiced in ancient Egypt. It is to be hoped that more recovery of new cases will help us to a better understanding of the procedure in ancient Egypt.

Acknowledgements

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TABLE 1. **Cases of Skull Trephination from Egypt.**

Location	Time Period	Sex	Age	Position	Shape & Size	Evidence of Healing	Author
Nubia	Byzantine 395-641A.D.	F	Adult	R.parictal	Circular	Present	Jones(in Smith& Jones 1910),Parry 1923)
Nubia	Meroitic	F	25Y.	R.anterior angle of frontal bone	circular, 30mm.diam.	Present	Batrawi(1935)
Alexan-dria	Roman 200A.D.	—	—	R.parietal	—	—	Ruffer(1918)
Sakkara	Ptolemaic 332-31B.C.	—	Adult	2.R.&L. parietals	Oval	Present	Lisowski(1967)
Dakhleh Oasis	27th Dynasty 500-400B.C.	?	12-13Y.	R.parietal	Oval,34mm. by 21mm.	Present	Shaaban
Sakkara	25th Dynasty 767-656B.C.	F	Adult	R.frontal	Circular 10mm.diam.	Present	Salib(1962, Ghalioungi(1963)
—	New Kingdom?	M	Adult	L.fronto-parietal	Oval 20mm. by 15mm.	Present	Phal (1980)
Tarkhan	Early dynastic	—	Adult	L.parietal	Oval,Max. diam.23mm.	Present	Brothwell(in Oakley et al. 1959)
—	—	?	Child	Frontal	Circular, 10mm.diam.	Present	Ghalioungui (1963)

Domestic Violence in Two Skeletal Populations

STEWARD SHERMIS

OSSA

Most skeletal trauma goes unaccounted for. By comparing documented cases of domestic violence with patterned fractures as seen in two skeletal populations, it is perhaps possible to account for some of these fractures.

Keywords: Skeletal violence - Domestic - California and South Dakota.

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The distributions of traumatic lesions in a skeletal population generally follows a pattern (Wells, 1964) as they often reflect specific cultural practices. Inasmuch as the range of behavioral practices in prehistoric populations is often unknown and at best inferred or extrapolated, many skeletal collections go uninterpreted so far as cultural causes of fractures are involved.

Two skeletal populations of which the author has had experience, 4-SJO-17 from the Central Valley in California and 39-CO-9 from South Dakota presented the usual mix of healed and incompletely healed fractures. The California skeletal sample came from Mormon Slough and is attributed to the Middle Horizon which, in California, dates from around 1, 500 B. C. to A. D. 300. The South Dakota sample passed out of existence around 1830 (Thwaites, 1904) from the onslaught of several kinds of infectious diseases, the most common and lethal being smallpox. The South Dakota skeletal population was very likely related to the historic Arikara Indians of about the same region.

The Mormon Slough sample numbered 223 burials with only 132 of these skeletons sufficiently complete to be used for research. Of those burials which could be sexed, there were slightly more males than females (Table 1). Nevertheless, there are 15 healed fractures among the females as opposed to nine in the males (Table 2). In the South Dakota population there were 285 burials with only 102 available for investigation. Of the latter, were two more males than females (Table 3). The South Dakota sampling has 16 healed and incompletely healed fractures, 11 male and 5 female (Table 4).

No cohesive pattern presented itself until the fractures were drawn into composite skeletal figures distinguished by sex. The distribution of fractures in both skeletal populations then had similar characteristics (Figs. 1 and 2; Figs. 3 and 4).

In both skeletal populations there was a preponderance of vertebral fractures to be found in the male skeletal material while lower limb long bone fractures are encountered

TABLE 1. Age and sex distribution of skeletal population from 4-SJO-17, Mormon Slough, California.

SEX-AGE DISTRIBUTION	NUMBER	PER CENT OF TOTAL
Male Adult	70	31.4
Female Adult	62	27.8
Indeterminate Sex, Adult	10	4.5
Subadult	61	27.3
Indeterminate Age and Sex	20	9.0
	223	100.0

TABLE 2. Trauma distribution and description in skeletal population from 4-SJO-17, Mormon Slough, California.

SEX	BONE	SIDE	DESCRIPTION
female	sternum		healed
female	clavicle	left	healed
	rib	left	healed
female	2nd phalanx pedal	right	healed offset
female	humerus	left	healed
female	clavicle	left	healed
female	2nd phalanx pedal	left	healed, displaced
male	tibia	right	healed, comminuted
	fibula	right	healed, compression
male	vertebrae T-4, T-6		Fx through centrum
female	radius	right	healed, displaced
	clavicle	right	healed
	rib	right	healed
male	ilium	right	healed
male	rib	left	healed
female	ulna	right	healed
male	ulna	left	pseudoarthrosis
female	rib	right	healed
female	rib	right	pseudoarthrosis
male	vertebra L-2		compression Fx
female	vertebra L-5		compression Fx
female	rib	right	healed
male	phalanx proximal manual	left	healed with offset

TABLE 3. Age and sex distribution of skeletal population from 39-CO-9, South Dakota.

SEX-AGE DISTRIBUTION	NUMBER	PER CENT OF TOTAL
Male Adult	52	18.2
Female Adult	50	17.5
Indeterminate Sex, Adult	13	4.6
Indeterminate Subadult	170	59.6
	285	100.0

TABLE 4. Trauma distribution and description in skeletal population from 39-CO-9, South Dakota.

SEX	BONE	SIDE	DESCRIPTION
male	scapula	right	overriding Fx through blade
male	clavicle	right	healed, near center
	clavicle	left	healed, near proximal end
	radius	left	Colles' healed
female	nasal	left	slight deflection, rt.
male	frontal	left	depressed into orbit
male	vertebrae L2, L-3		healed
male	vertebrae T-5, T6		fused
male	talus	right	anterior border, healed
female	maxilla	right	healed, but not fully bridged
	ulna	left	unhealed with pseudo-arthrosis
female	coccyx		healed
	rib	left	two fractured, healed
male	femur	right	healed badly

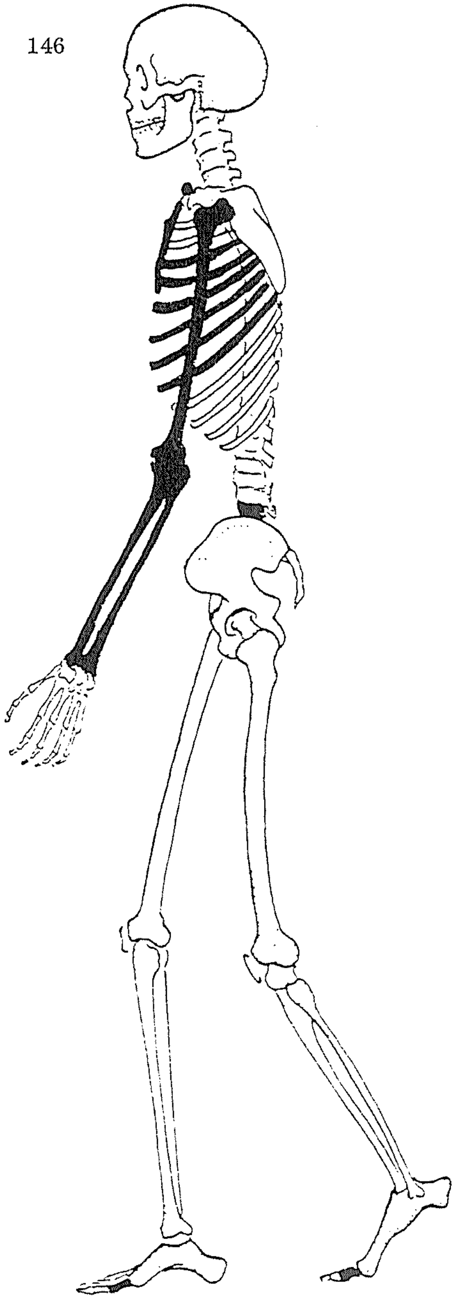

Fig. 1. Composite of all fractures found in the female skeletal population from 4-SJO-17, Mormon Slough, California. Most of the fractures are confined to the arm and ventral surface of the thorax.

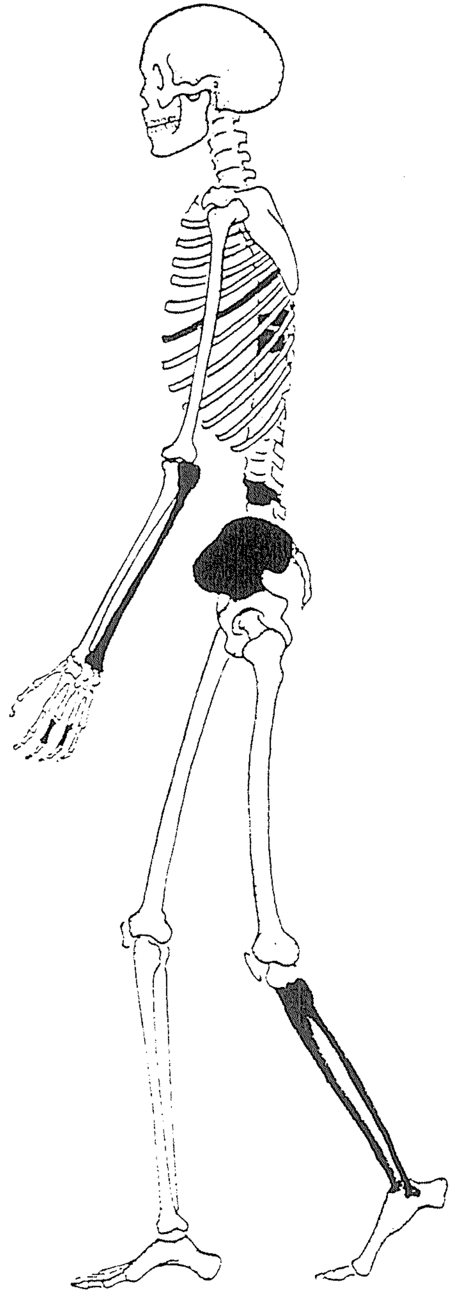

Fig. 2. Composite of all fractures found in the male skeletal population from 4-SJO-17, Mormon Slough, California. Fractures are disseminated throughout the body and are not those normally associated with simple assault.

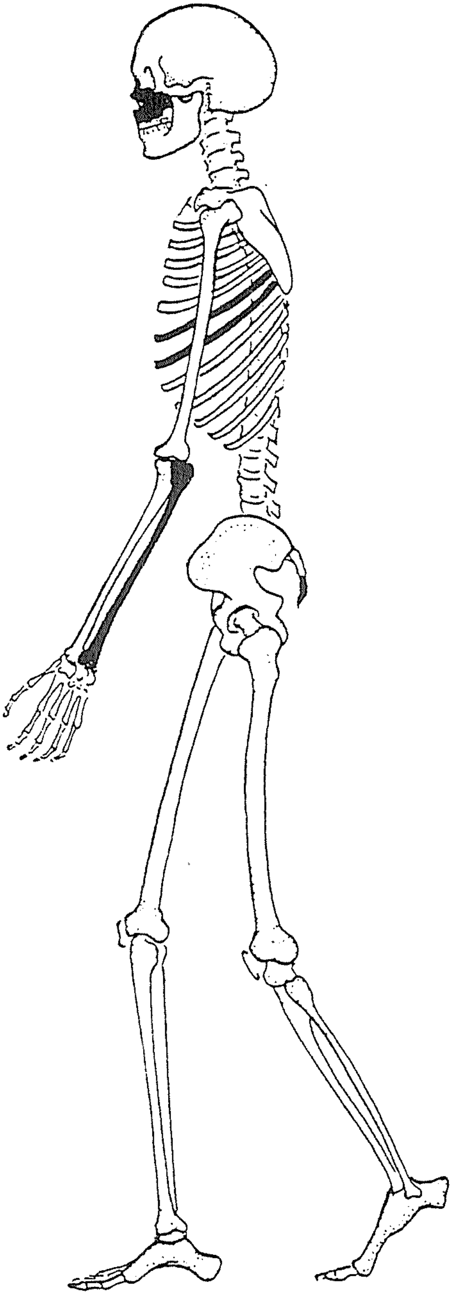

Fig. 3. Composite of all fractures found in the female skeletal population from 39-CO-9, South Dakota. Fractures of nasal, maxilla, ribs and ulna are consistant with the pattern found in cases of contemporary wife-beating.

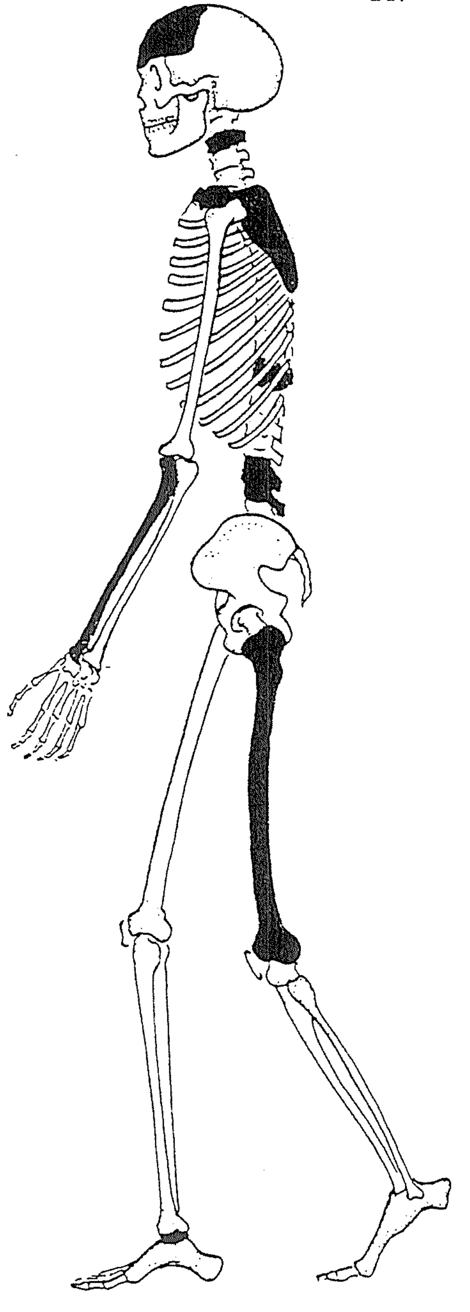

Fig. 4. Composite of all fractures found in the male skeletal population from 39-CO-9, South Dakota. For the most part, fractures are in bones with heavy muscle overlay or thick cortical surfaces.

only in males. In both populations, the broad, irregular bones are fractured, the ilium in the California sample and the scapula from South Dakota.

The females of both prehistoric Amerind groups had more costal fractures than the males and more upper limb bone fractures. Where the thin, lower facial bones are fractured, nasal and maxilla, they are encountered in a female population. The thicker frontal bone is seen fractured in a male skeletal population.

Impressive in both female skeletal populations was the appearance of trauma to the upper ventral aspect of the females, fractured ribs and sternum. It was this which suggested the idea that the females sustained these lesions in domestic violence. To verify this impression, I enlisted the assistance of the intake case worker in a refuge for battered women in Long Beach, California. On a single sheet of paper were two outlines of a female form, ventral and dorsal. The instructions accompanying these forms were for the traumatised women to place a dot at the exact area of the body struck and a cross where it was a particularly hard or painful blow. The rationale behind this dichotomy was that the harder or more painful blows would translate into potential fractures. This is not necessarily airtight logic but contact with these battered female residents was restricted to no interviews and the most minimal of requests. Of the forms distributed, 51 were returned of which 32 were filled out correctly. The composite results are illustrated in Figure 5.

Discussion

Examination of the composite results indicate that the largest number and the more painful blows were located on the ventral surface. Both the face and the thoracic region received most of the more painful trauma followed by the arms. As both these regions are thinly overlain with soft tissue, trauma to the unerlying bone structure is more probable than in the more heavily muscled parts of the body. The findings of facial, thoracic and limb trauma correspond to those observed by Fonseka (1974). It is likely that the arms incurred part of the more severe trauma in an attempt to shield the face and body. Three forearm fractures are noted in females of both skeletal populations as well as a healed fracture of the humerus. These could well be parry fractures. There are also more clavicular fractures in the female population.

The fractures in the male skeletal material in this sampling, while in part overlapping the female, do not suggest coherent patterning nor tight clustering. Several of the male would not fracture easily in simple assault. I believe it is significant to note that there is a distinction in patterning between wife-beating and assault with the latter showing greater dissemination on the trunk, arms and legs (Fig. 6).

In as much as wife-beating is widely distributed throughout the world (Lewis, 1965; Read, 1965) and wife-beating documented in historic ethnographies for North America (Llewellyn and Hoebel, 1941; Dorsey, 1884; Redfield and Rojas, 1934) it is not unreasonable to attribute most of these ventral and limb fractures to domestic violence.

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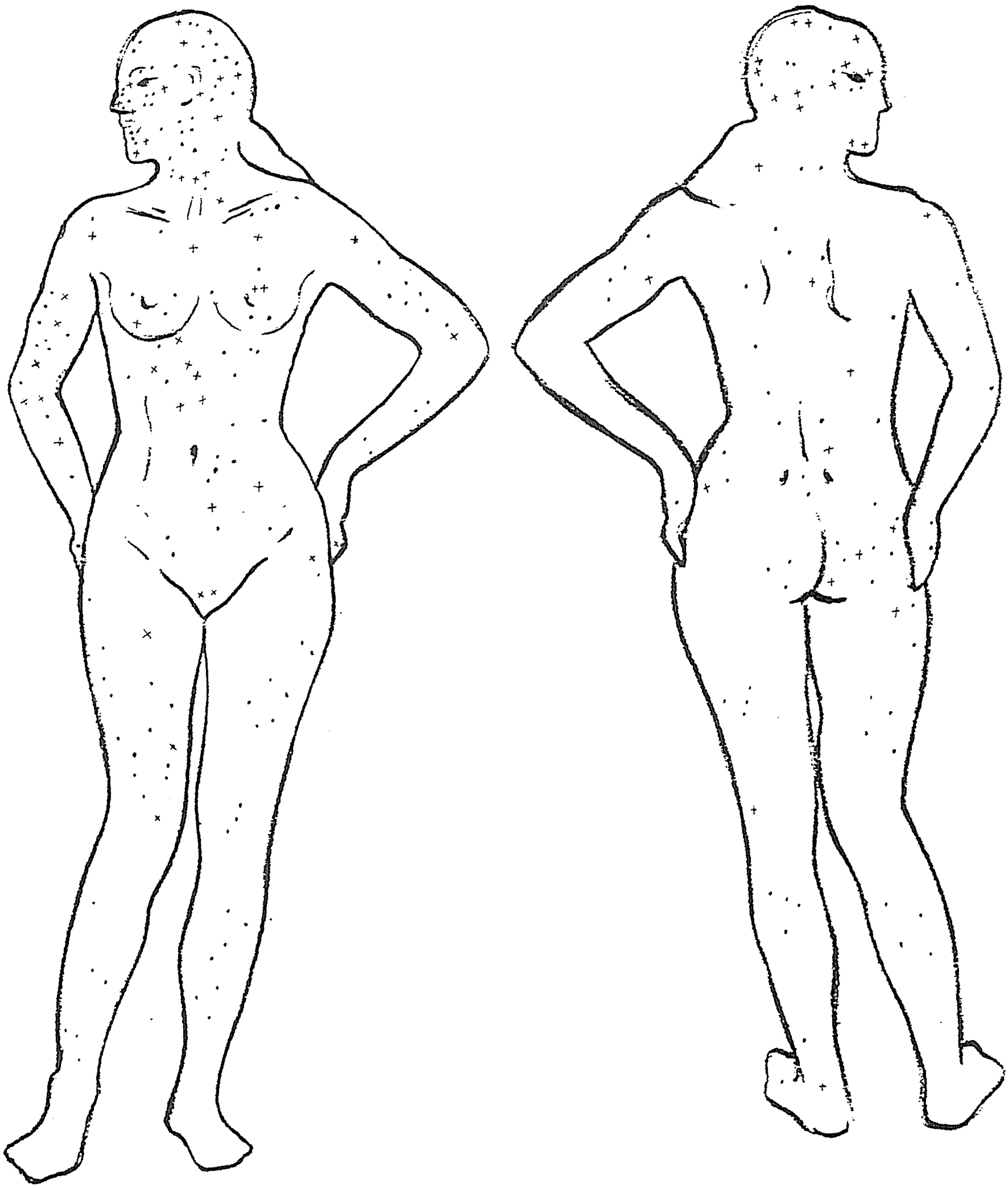

Fig. 5. Composite of blow distribution in 32 women at a woman's shelter in Long Beach, California. Dots refer to location of blows; crosses refer to blows of strong intensity. Note that the largest number of heavy blows fall on the face, thorax and arms on the ventral surface.

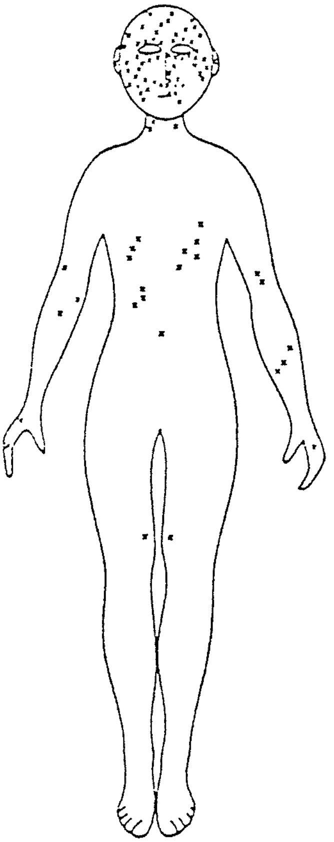

Fig. 6. Pattern of soft tissue trauma in physician documented cases of wife-beating. Distribution of injuries corresponds to that in Figure 5 (After Fonseka, 1974).

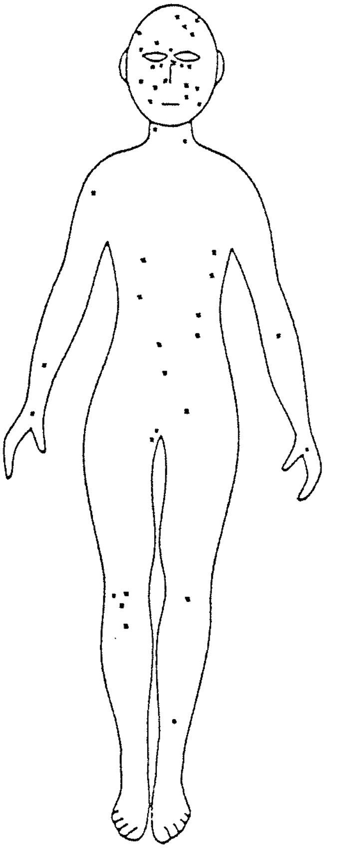

Fig. 7. Pattern of soft tissue injury in physician documented cases of assault. Blows are more widely scattered over thorax, abdomen and legs.

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Paleopathological Study on Osseous Syphilis in Skulls of the Ainu Skeletal Remains

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OSSA

Palaeopathological study of the osseous syphilis based on the gross examination was carried out on 139 skulls of the Ainu skeletal remains.

Two demonstrable cases, two possible cases, and four questionable cases of osseous syphilis were described according to their pathological changes of the cranium.

The sexual differences, age distribution and the location of syphilitic lesion were discussed in comparison with those of the Japanese.

Using the incidence of the demonstrable cases, palaeoepidemiological analysis revealed that a high prevalence of syphilis occurred among the Ainu population as well as among the Japanese during the Edo and early Meiji period, which was supported by a few old documents concerning the epidemic of syphilis among the Ainu population.

Keywords: Palaeopathology - Osseous syphilis - Ainu cranium.

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Introduction

As to the origin of syphilis in Japan, based on the study of medical history (Fujikawa, 1904; Dohi, 1921), it was within a few years following 1510 that the vicious veneral disease was transmitted into Japan from the east coast of China (the Canton district) and suddenly disseminated itself among the people in epidemic proportion in this country.

Syphilis in its tertiaty stage characterized by gumma, frequently involves the skeletal system, usually known as osseous syphilis. Gumma of the bones may cause peculiar pathological changes in the dried skeleton such as osteolytic destruction, irregularity of bone surface with stellate scars, and hypertrophy with sclerotic bone changes.

In the osseous syphilis, the bones most frequently affected are the skull, tibia, clavicla and femur. In particular, the frontal and parietal bone of the skull should be the most commonly involved lesion (Kobayashi, 1981). Thus, such peculiar gross-pathological changes of the bones can be sometimes easily discovered among the ancient human skeletal remains, in particular in the case which shows the typical and/or demonstrable changes of osseous syphilis in the cranium.

Several palaeopathological studies of osseous syphilis in the earlier human skeletons have so far been presented by some authors (e.g. Goff, 1967; Steinbock, 1976; Zimmerman & Kelly, 1981; Suzuki, T., 1984a).

In Japan, Suzuki (H., 1963) reported that three out of twenty-three skulls of the Muromachi period (1338-1573 A. D.) excavated from Kaji-bashi in Tokyo showed the characteristic features of osseous syphilis. Recently, the author (Suzuki, T., 1984a) has studied the prevalence of syphilis among the people of the Edo period (1603-1867 A. D.) using 923 isolated adult skulls excavated from various sites of Edo city (old Tokyo), and elucidated that the incidence rate of syphilis among the adult population could be estimated statistically being from 39.4 percent to 69.7 percent at the level of 95 percent confidence limits and 54.5 percent on the average. Furthermore, the author (Suzuki, T., 1984b) has found out the case of typical osseous syphilis in the medieval (late Muromachi period) human skeletal remains excavated from Hokkaido, most northern part of Japan, which might be the evidence of the serious and persistent epidemic of syphilis in every part of this country.

In the present study, the author would like to describe the evidences of osseous syphilis in the human skeletal remains of the Ainu population of the Edo and early Meiji period and to elucidate and compare the prevalence of syphilis with the Japanese population of the same period.

Materials

The materials used in this study consist of 139 human skeletal remains of the Ainu population which are now stored in the Department of Anatomy, University Museum, The University of Tokyo. These Ainu skeletal remains almost of which were excavated and collected by Professor Koganei in 1888 and 1889 from various sites in Hokkaido and Kuril Islands totally amount to 166 individual skeletons. An anthropological description of these skeletons was published by Koganei (1894) in detail.

In the present study, the adult skulls selected were relatively well preserved with a minimum loss of bones so that it would be possible to observe the pathological changes and to compare the results with those of the author's previous data on the Japanese.

The sexing and age estimation on all of them were made according to the manner corresponding to general anthropological inspections (e.g. Hanihara, 1952; Brothwell, 1972; Krogmann, 1973; Workshop of European Anthropologists, 1980). In the cases of whole skeleton, such morphological traits of the pelvis as the greater sciatic notch and the pubic symphysis provide reliable information for sexing and age estimation. However, in the cases of isolated skull, sexing of the cranium should be based on the general shape and stautness of the skull, the swelling of the superciliary arch and development of the mastoid processes and of the external occipital protuberance. The age estimation of the cranium is somewhat more difficult. Important points such as the morphology of the endocranial suture closures, the condition of ossification of synchondrosis spheno-occipitalis in the cranial base, suture closure between the bones in orbit and attrition pattern of the teeth with the grade of resorptive atrophy in the alveolar region were emphasizingly observed as age indicators.

Finally, the skulls used here were roughly classified into three age groups, i.e.

(1) Young age group (-ca 20 years old),
(2) Adult age group (ca 20-45 years old),
(3) Mature and Senile age group (ca 45+ years old).

The skulls grouped into "Young" showed a clear opening of the three main sutures, incomplete ossification of the spheno-occipital synchondorosis and little attrition of the teeth. The skulls estimated as belonging to "Mature and Senile" showed, on the contrary, complete obliteration of the main endocranial suture closure, considerable fusions among the intraorbital sutures, and apparent dental wear with bone resorption and atrophy in the alveoral region.

The results of the sex determination and age estimation on 139 individual adult skulls are given in Table 1.

TABLE 1. Materials used.

Age \ Sex	Male	Female	Total
Young	12	7	19
Adult	42	37	79
Mature & Senile	24	17	41
Total	78	61	139

Methods - palaeopathological diagnosis of osseous syphilis in the cranium

Because neither microscopic nor roentgenological approach reveals very much in diagnosis of osseous syphilis in the cranium, macroscopic observation was emphasized to provide the basic direction for the diagnosis of the pathological changes in the present study (see Goff, 1967; Morse, 1978; Gregg et al., 1982).

However, in fact, the syphilitic changes in the cranium vary from simple to complicated or from atypical to typical or from doubtful to certain in gross pathology. With regard to the cases of typical or certain syphilitic cranium, the pathological changes frequently consist of the following three characteristic features (triad; Suzuki, T., 1984a).

1) Diffuse and multi-focal lesions: Syphilitic lesions produced by the formation of gummatous areas are usually diffuse and multifocal over the entire cranium.

2) Various morphological features: Syphilitic lesions frequently show such various morphological features as osteolytic destruction, resorptive bone changes, crater-like depressions, sclerotic clumps of bone, stellate scars, and an overall worm-eaten appearance.

3) Healed processes: Syphilitic lesions commonly consist of reactive and irregular new bone formation which sometimes gives the vault a folded or wrinkled appearance.

In this study, the palaeopathological diagnosis of osseous syphilis in the cranium was made on the basis of these three morpho-pathological characteristics (triad).

Due to the lack of existance of non-venereal treponemal infections such as yaws, pinta and bejel at anytime in Japan, the diagnosis of osseous syphilis may be obtained with ease and certainty in the typical cases. The differential diagnosis, however, between osseous syphilis and other bone pathological changes should be carefully carried out with sufficient knowledge concerning such bone diseases as non-specific infections and malignant bone tumours which were already pointed out and discussed by many authors (e.g. Goff, 1967; Steinbock, 1976; Cook, 1980; Gregg et al., 1982; Suzuki, T., 1984a). Actually the diagnosis of cranial syphilis in the present study should be weighted and then classified into the following three categories according to the certainty of the syphilitic lesion as the author carried out previously.

1) Cases of "Demonstrable" osseous syphilis:
The cases diagnosed as demonstrable should necessarily fulfill the three morpho-pathological characteristics (triad) of osseous syphilis. They should be clearly differentiated from other bone diseases. The demonstrable cases of course are the most reliable among the three categories.

2) Cases of "Possible" osseous syphilis:
The cases diagnosed as possible should fulfill at least two characteristics of the triad, and may be differentiated from other bone diseases under careful examination.

3) Cases of "Questionable" osseous syphilis:
The cases diagnosed as questionable are defined as the cases which consist of atypical or weak lesions such as a single small bone depression or slight bone surface irregularity and therefore cannot be determined with certainty whether the cranial lesions were caused by syphilis or other bone pathologies.

Result

Gross pathological examination on the 139 adult skulls of recent Ainu revealed that there were two demonstrable cases and two possible cases and four questionable cases of osseous syphilis. Sex and age distribution of the cases diagnosed as osseous syphilis is given in Table 2.

TABLE 2. Sex and age distribution of the osseous syphilis in the recent Ainu cranium.

Diagnosis / Age \ Sex	Demonstrable		Possible		Questionable	
	M	F	M	F	M	F
Young	-	-	-	-	-	-
Adult	1	1	1	1	1	2
Mature & Senile	-	-	-	-	-	1

Here the author would like to describe the pathological changes in the skull of each case in detail (in particular demonstrable and possible cases).

1) A-1350 (Male, Adult, "Demonstrable", Fig. 1).

This is an almost complete skeleton including skull and main long bones which are preserved in good condition. Koganei (1894) described the morphology of this specimen with pathological changes in the skull and left femur as follows; "--Schädel. Mittelgross, weisslich, etwas leicht, am l. Scheitelbein u. bes. an der Stirnbeinschuppe viel Narben (Syphilis), übrigens gut erhalten. --- Femora: L. aspera schwach; oberes Viertel nicht abgeplattet; im unteren Drittel des l. Femur eine unvollkommen geheilte Fraktur mit osteoporotischem Callus. ---"

This case surely showed such typical and pathological changes of osseous syphilis as diffuse osteolytic destructions, many stellate scars with considerable bone sclerosis and partially irregular new bone growth, which could be seen in the frontal, both parietal bone and even in the orbital region. In the postcranial skeleton, severe gummatous osteolytic destructions were recognized in the head of humerus on both sides. The left femur, as pointed out by Koganei, had a deformed fracture with great hyperostosis and syphilitic periostitis could be seen in the shaft.

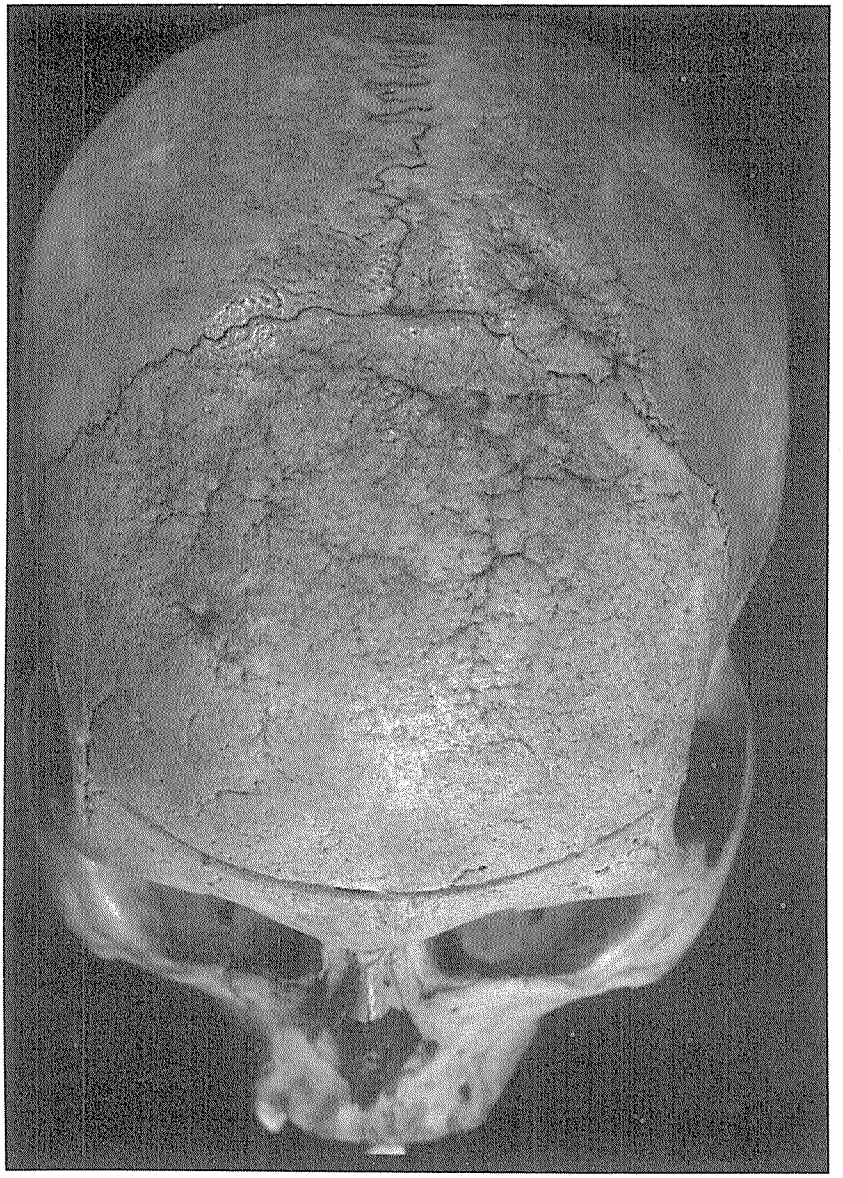

Fig. 1 a. A case of demonstrable osseous syphilis in the crania (A-1350, male, adult). Note the diffuse and multifoci of the syphilitic lesions.

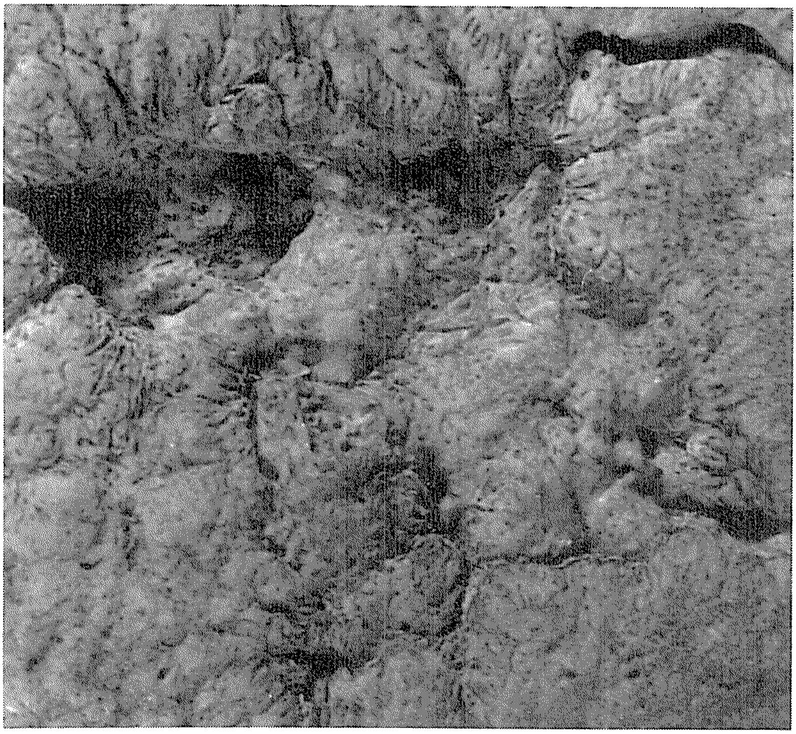

Fig. 1b. Close-up view of the same case. This illustrates several characteristic pathological changes of the cranial syphilis such as gummatous desctruction, stellate scars with bone sclerosis and irregular new bone production. The feature as a whole has a "worm-eaten" appearance in the lesion.

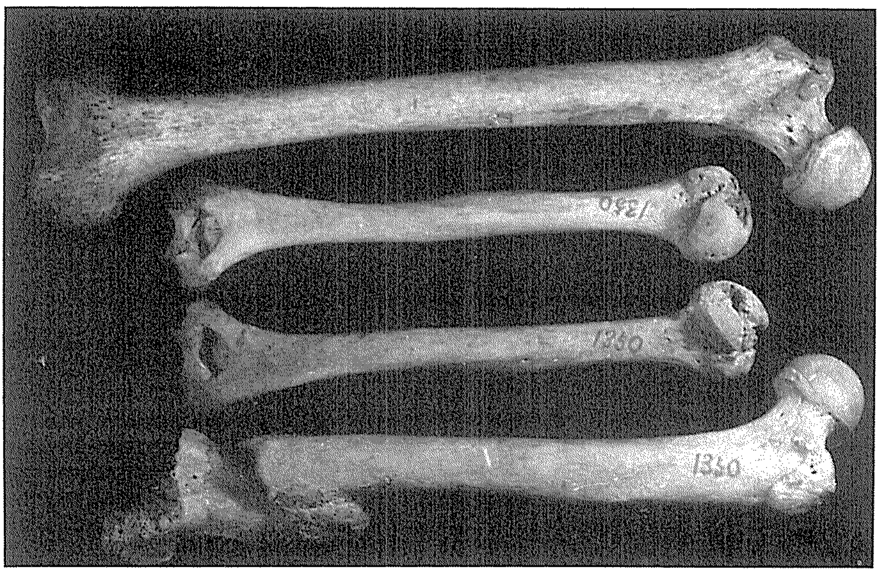

Fig. 1 c. Postcranial skeleton of the same case shows the gummatous destructions in the humeral head and the healed fracture in the left femur.

2) A-1404 (Female, Adult, "Demonstrable", Fig. 2)

This is an isolated skull specimen with obviously pathological changes which, however, was not described by Koganei at all. In the frontal, parietal and occipital bone, the lesion which could be diagnosed as demonstrable osseous syphilis consisted some stellate scars or crater-like depressions with marginal bone sclerosis, osteolitic destruction and partial healing processes with hyperostosis.

3) A-1353 (Female, Adult, "Possible", Fig. 3)

In the center of the frontal bone, one large depressive lesion having a 2.5 cm diameter could be seen. Sclerotic changes could also be seen around the margin of the depression. There was a partial hyperostosis in the bottom which seems to be the "reactive-inflammatory change" of the bone and which made the bone surface irregular.

There were no abnormal finding in the postcranial skeleton of this individual.

4) A-1400 (Male, Adult, "Possible". Fig. 4)

This is an isolated skull specimen which showed the pathological changes in right mastoid area and palatine bones. In the frontal bone there were small and coalesced depressions with smooth bone surface.

In the right mastoid region, osteolytic destruction with bone sclerosis was clearly recognized, but didn't seem to be of acute pyogenic mastoiditis which usually showed a widespread erosion without any signs of healing as stated by Elliot Smith & Dawson (1924). In the palatine region, there were two clear perforations in the palatine process of maxilla with little inflammatory erosion. There were no pathological changes such as ostitis in both the nasal cavity and maxilloalveolar region.

This case, however, consisted of considerable pathological changes which might be caused by syphilis, could not be diagnosed as demonstrable osseous syphilis owing to the unusual distribution and uncertain morphology of the lesions.

5) Questionable cases: The description of each case is given in the Table 3.

TABLE 3. The cases of questionable osseous syphilis.

designation	sex	age	location of the lesion	pathological changes
A-1383	Female	Adult	r.parietal bone	wide and shallow depress with slight osteoporosis. irregular bone surface of the depressive bottom.
A-1390	Male	Adult	r.parietal bone	single depression with partial bone sclerosis (Fig.5)
A-2186	Female	Mature	l.parietal bone	single lesion, irregular bone surface with porotic change
A-2412	Female	Adult	frontal bone	shallow depression with slight sclerosis in the bottom.

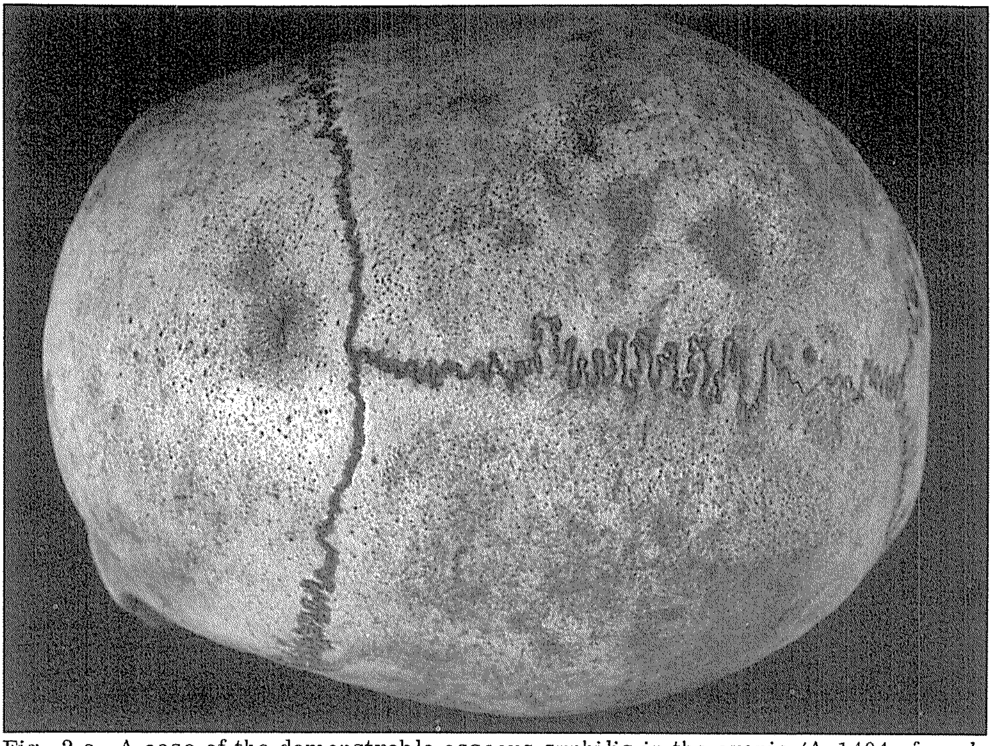

Fig. 2 a. A case of the demonstrable osseous syphilis in the crania (A-1404, female, adult). The syphilitic lesions can be seen widely in the entire skull.

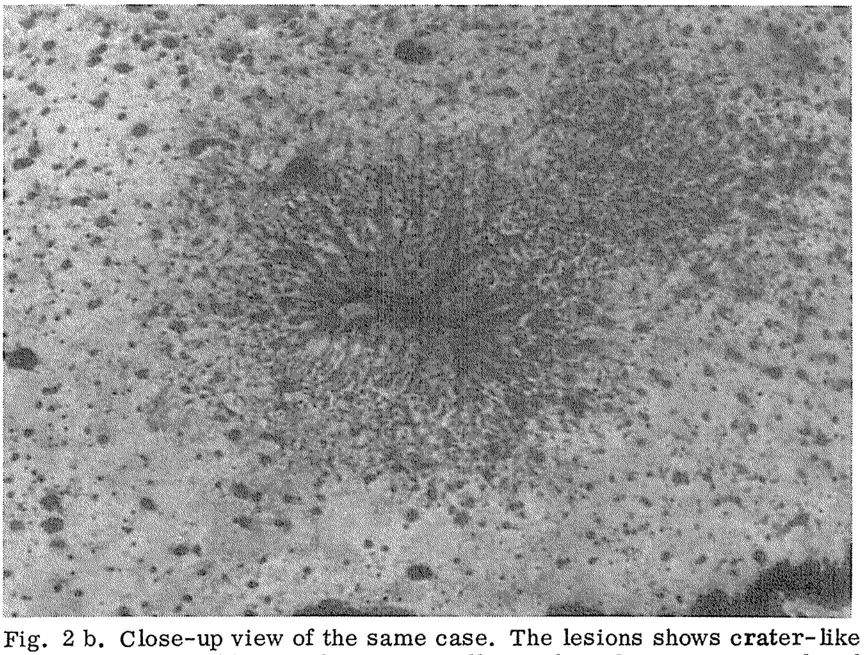

Fig. 2 b. Close-up view of the same case. The lesions shows crater-like depression with marginal bone sclerosis. Small osteolytic destructions can be also recognized.

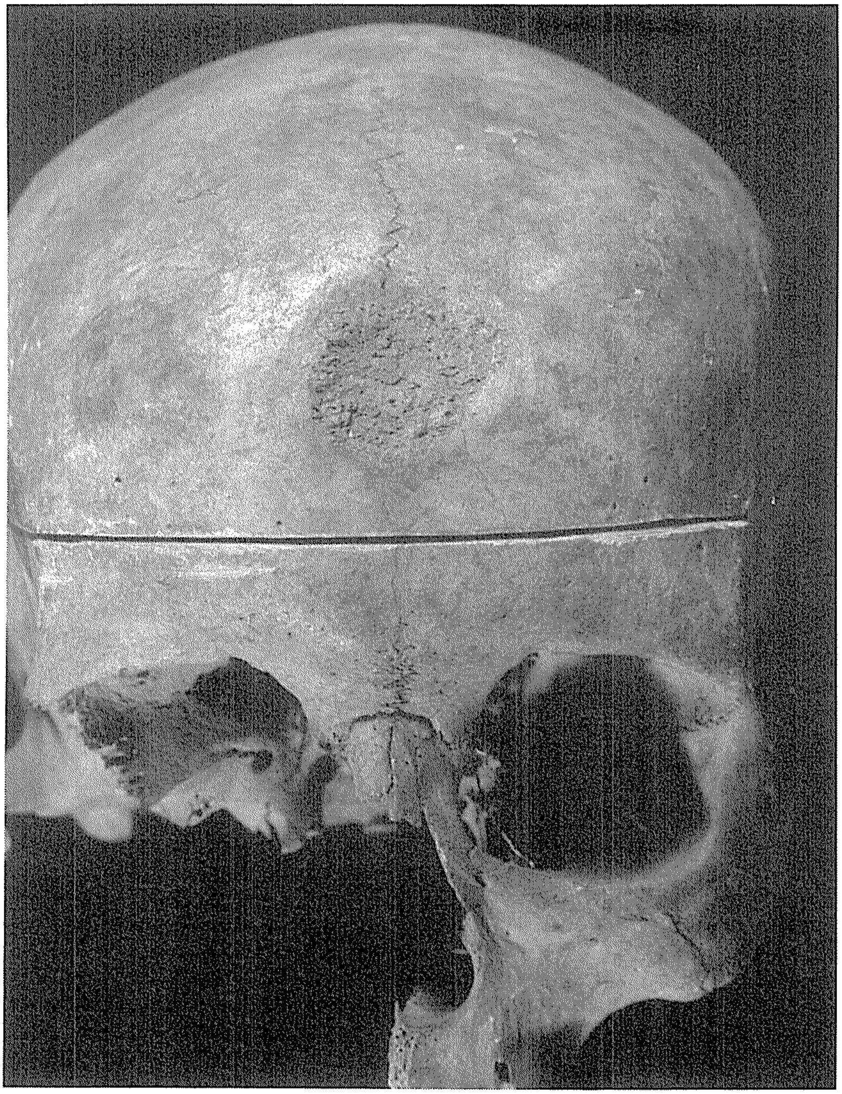

Fig. 3. A case of the possible osseous syphilis in the crania (A-1353, female, adult). A large depressive lesion with irregular new bone formation in the bottom can be seen. Sclerotic bone changes exist around the margin of the depression.

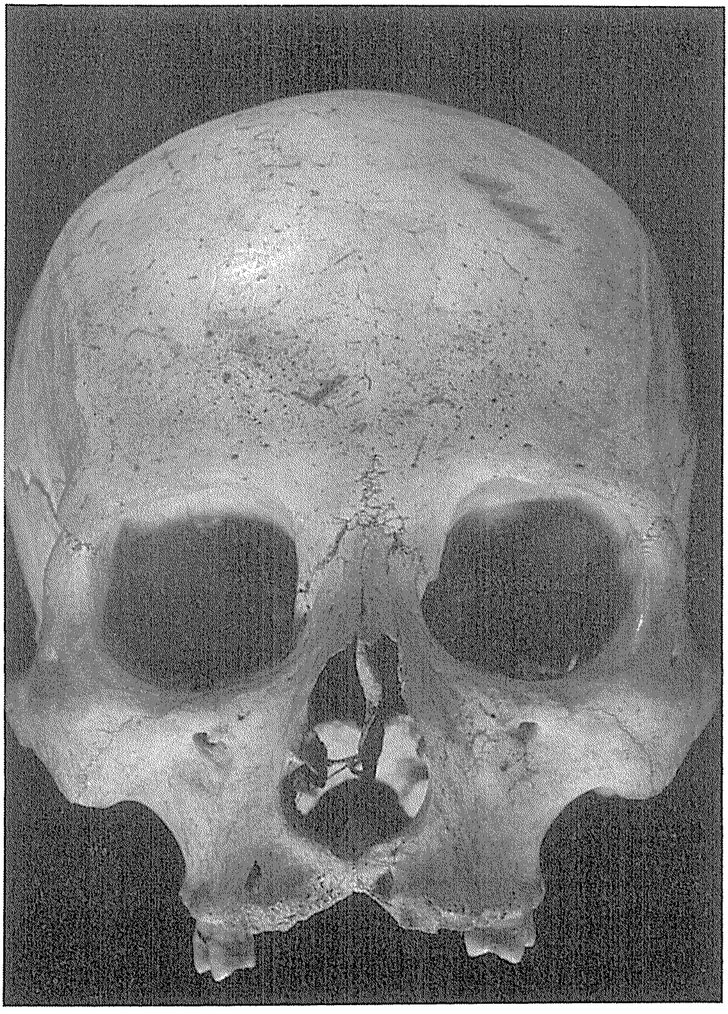

Fig. 4 a. A case of the possible osseous syphilis in the crania (A-1400, male, adult). There are some small depressions in the frontal region.

Fig. 4 b. Close-up view of the same material. Osteolytic destruction and depressive stellate scars are visible at the posterior area of the right external acoustic meatus.

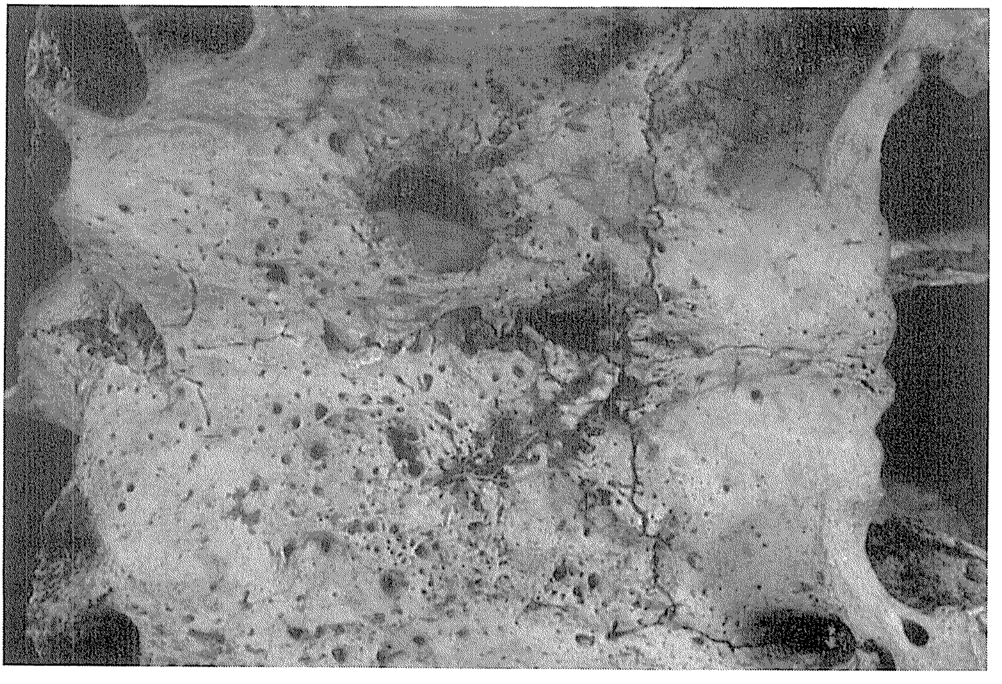

Fig. 4 c. Close-up view of the same material. Some smooth-margined perforations and irregular bone surface can be seen in the palatine process of maxilla. The antemortem atrophic and resorptive bone changes are also visible in the anterior area of the alveolar process for incisors.

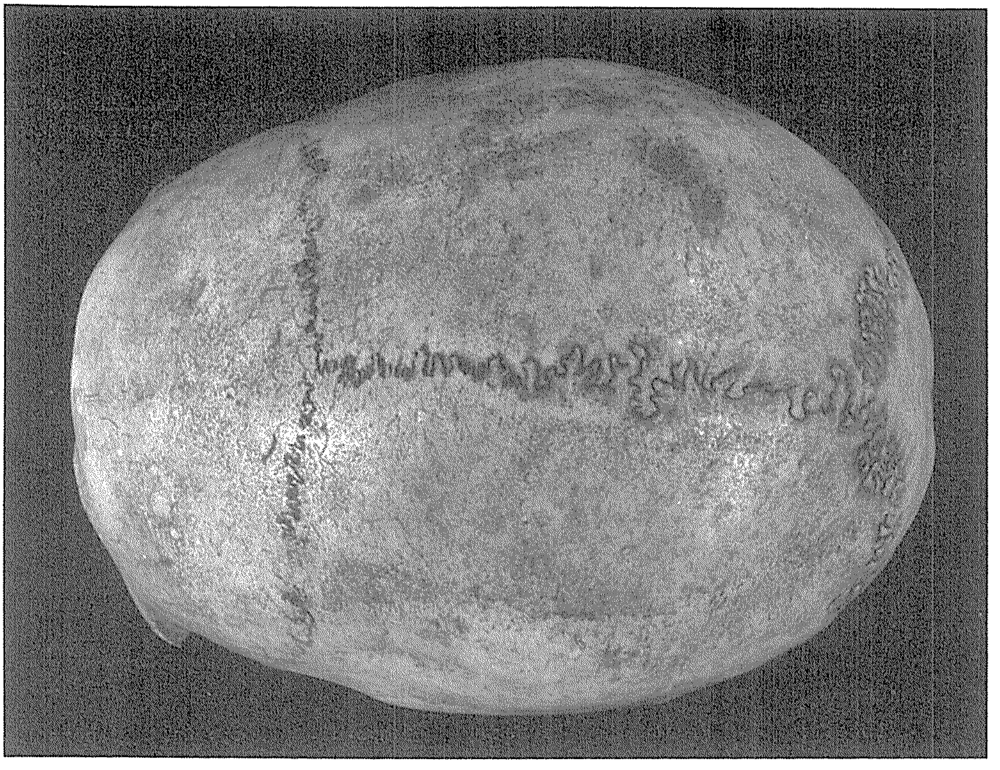

Fig. 5. A case of the questionable osseous syphilis in the crania (A-1390, male, adult). Single and shallow depression with partial bone sclerosis is visible in the right parietal bone.

Discussion and Summary

As previously mentioned, there were two demonstrable cases, two possible cases and four questionable cases of osseous syphilis among 139 adult skulls of the Ainu population. It is, however, not possible to make an exact distinction between demonstrable cases and possible cases or between possible cases and questionable cases because of the continuity and variability of the syphilitic lesions in gross examination. And with regard to the questionable cases, they showed weak and atypical pathological features which were naturally less reliable than those of demonstrable and possible cases. Therefore the discussions on the epidemic of syphilis comparing with those of the author's previously studied (Suzuki, T., 1984a), should be weighted on the cases only diagnosed as demonstrable and possible osseous syphilis in the present study.

1) Sex difference in the incidence of cranial syphilis

Using the demonstrable and possible cases, the incidence rate of cranial syphilis was 2.6 percent (2/78) for males and 3.3 percent (2/61) for females. There are no statistically significant differences between the incidence of syphilis with regard to sex (χ_c^2 =0.58), which was the same result as the incidence of the Edo population reported previously.

According to Sekiba (1896) who reported some valuable clinical data on many diseases including syphilis among the Ainu population during the Meiji period, there were seventeen male patients and twenty female patients out of thirty seven syphilitic Ainu patients in his clinic. In this context, this vicious epidemic of syphilis struck the Ainu people without distinction to sex as well as striking the Japanese people.

2) Age distribution of cranial syphilis

All four cases which were diagnosed as demonstrable and possible osseous syphilis belonged to the adult age group. And among the adult age group, the incidence of cranial syphilis comprised 5.1 percent (4/79) in the present study for the Ainu and 8.7 percent (53/606) in the previous study for the Japanese.

Furthermore, the frequency of the adult cases among all cases of the osseous syphilis showed 100 percent (4/4) in this study and 73 percent (53/73) inthe previous study, which indicates that the highest incidence of osseous syphilis existed in the "Adult" age group of all three age groups. Thus, during the period without any effective drugs or medical therapy for syphilis, the people who were involved by the disease seemed to be not able to survive to reach a mature or senile age and seemed to have died of the various symptoms and many causes related directly or indirectly to syphilis in his relatively early life time.

3) Incidence of the location of syphilitic lesion in the cranium

Syphilitic lesions are widely seen throughout the entire skull, and in particular, the bones most frequently involved are the frontal and parietal bone in the cranium.

In the present study, as shown in Table 4, similar frequencies were obtained. Of the four crania of the demonstrable and possible, three cases exhibited the lesions in the frontal bone and three in the parietal bone. Only one case (A-1350) had the typical syphilitic changes in the left orbit and another (A-1400) showed the lesion in the palatine process of maxilla.

TABLE 4. The location of bone lesions in the skull of osseous syphilis.

Location / Diagnosis	Frontal	Parietal		Temporal		Occipital	Others
		r	l	r	l		
Demonstrable & Possible	3	2	1	1	-	-	2
Questionable	2	2	1	-	-	-	-
Total	5	4	2	1	-	-	2

In the present study, however, there were no cases which presented the syphilitic deformity in the nasal bone called the saddle nose in the life time.

4) Palaeoepidemiological analysis

Using the demonstrable cases alone which, of course, must be the most reliable in diagnosing the materials, an epidemiological approach was done to elucidate the prevalence of syphilis among the recent Ainu population in comparison with the epidemiological analysis for the Japanese population during the Edo period.

The proportion of the osseous syphilis among all the Ainu materials obtained from the demonstrable cases alone was 1.4 percent (2/139), which showed no statistical significant difference with the proportion of 5.4 percent (50/923) in Japanese materials ($Zc = 1.83$ or $\chi^2c = 3.30 < P\ 0.05$). And in the comparison of the incidence of the demonstrable plus possible cases, there was also no statistical significant difference between the Ainu proportion (2.9 percent) and the Japanese (7.9 percent) $\chi^2c = 3.83 < P0.005$).

With regard to the palaeograph, unfortunately, there are few old documents reporting the exact prevalence of syphilis among the Ainu population. Sekiba (1896) described that the epidemic of syphilis during Meiji period was very serious among the Ainu people who called this vicious venereal disease as "Wen-tashum" at that time. He also described that patients of tertiary syphilis who suffered from gummatous erosive ulcers and necrotic or rotting tissues appearing in the head, hip and lower extremities were commonly seen.

According to Takahashi (1936), who reviewed the prevalence of small pox and syphilis among the Ainu people from the view point of medical history, estimated that the syphilis might be transmitted from the Kinki district during the Tensho period (1573-1592 A.D.) when an active movement of people engaged in coastal trade and fisheries between Hokkaido and Honshu took place. He also presented a syphilitic skull with osteoloytic defect which was found in the Yakumo Ainu skeletal remains.

As to the demographical problem of the Ainu population in ancient Hokkaido (Yezo), Takakura (1943) stated that the remarkable decrease of the Ainu population occurring during the Edo period may have been caused by the terrible prevalence of syphilis among the people as well as small pox, measles and tuberculosis. The cause of such prevalence of syphilis, as Takakura pointed out, might be induced by the large number of prostitutes who lived in the small port towns along the south-west coast of Hokkaido who suffered from the afflictions of their way of life and from the virulent venereal disease at that time.

Anyway, it seems to be natural that the persistent epidemic of syphilis prevailed in every part of this country immediately after the transmission of this disease during the late Muromachi period and inevitably struck the Ainu people without distinction as to age and sex as well as the Japanese people.

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Diminution of the Dentition with Age. A survey on 500 Dry Skulls of Bantu-Speaking South African Blacks

HAIM TAL and SHMUEL TAU

OSSA

Five hundred skulls of Bantu-speaking South African blacks equally distributed over the third and seventh decades of life were examined for the presence of dental units. Analysis of the diminution of teeth showed significant decrease in retained dental units with increasing age with similar trends in the maxillae and mandibles. More dental units were retained in the mandibles (p=N.S.) and more maxillae were edentulous ($p < 0.05$). No edentulous specimens could be found before the age of 41 years but these were common (19-30%) later. The specimen were obtained from people who did not have preventive or conservative dental treatment and it is therefore believed that the diminution rate described here is 'natural' and relatively little influenced by professional dental considerations.

Keywords: Dentition - Tooth loss - Tooth retention - Tooth mortality.

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Introduction

Dental surveys of tooth loss provide useful information on the manner in which the reduction of the dentition is related to the age of a population. The ultimate condition of the dentition of a population is best investigated in the longest surviving population group. But the ideal would be to carry out a longitudinal study from youth to old age. A reasonable compromise which can make available a good deal of information is the study of dentitions at various ages.

Various studies have dealt with the causes of tooth loss: caries, periodontal disease, trauma, severe attrition, surgical, orthodontic, prosthodontic and cosmetic considerations (Allen, 1944; Andrews & Krogh, 1961; Lundqvist, 1967). It has been shown that in most populations, dental caries is the major cause for tooth loss up to the age of 30 years; periodontal disease becomes the predominant reason during the fourth to fifth decades of life and in some populations reaches a peak later.

Material and methods

Five hundred skulls equally distributed over the 5 decades of life from the third to the seventh, were selected from the Raymond Dart collection of skeletons in the Department of Anatomy, University of the Witwatersrand, Johannesburg. All skulls were obtained from cadavers of South African blacks of known sex, tribe and stated age. None of the specimen showed any sign of conservative dental treatment. Because the more recent additions to the Raymond Dart collection were more fully documented as to tribe, sex, and stated age (Tal & Tau, 1983) we decided to accumulate our research material by working backwards, seriatim from the most recent specimen. Table 1 shows the distribution of the selected skulls by age, sex and tribe.

The presence of dental units was recorded in each of the 1000 jaws. The term dental unit is taken to include intact teeth, roots left after destruction of the crown by caries, attrition or trauma, and sockets left by postmortem loss of teeth. Roots or sockets of birooted teeth were treated as single dental units. The study ignores any clinical value that these dental units may once have had.

Maxillae and mandibles were grouped under four groups according to the number of dental units present. These groups are as follow:

1. 13-16 dental units present; representing complete or almost complete dentition.
2. 9-12 dental units, representing mild loss of teeth.
3. 5-8 dental units, representing moderate loss of teeth.
4. 0-4 dental units, representing severe loss of teeth or edentulous dentition.

The data were recorded on special charts, computed and analysed statistically with the use of the Statistical Analysis System (Barr et al, 1979).

Results

The experimental sample comprised 1000 dry jaws (500 mandibles and 500 maxillae). These were equally distributed between the five decades from the third to the seventh; one hundred pairs in each age group. The minimum age was 21 years and the maximum was seventy. The mean age was 46.5 years and the median age 47. Three hundred fifty eight skulls were of males (71.6%) and 142 (28.4%) of females. The specimens were distributed among 22 different tribes, the largest of which are listed in Table 1. Comparison of the prevalence of dental units between males and females in each age group showed no significant difference between the two ($p > 0.1$) and these were therefore treated together.

The 500 mandibles carried a total of 5459 dental units (Table 2) and the maxillae carried a total of 5076 units (Table 3). The reduction in the number of dental units with age is shown in Fig. 1 and 2.

Retention rate of dental units in the mandibles was higher than in the maxillae (Mand. 68.2%; Max. 63.4%) when age groups were compared however, the difference between the prevalences of the retained dental units in the mandibles versus maxillae were not significant ($p < 0.1$).

The dimunition of the dentition with age is shown in Tables 4 and 5 and Figures 3 and 4.

Fifty-five out of the 100 mandibles in the age group 21-30 years (55%), and 45 (45%) in the age group 31-40 years had complete dentitions (16 teeth present). The frequency of complete dentitions decreased to 19%, 0% and 4% in the age groups 41-50, 51-60 and 61-70 years respectively. Edentulous mandibles were common among mandibles from the aged (19%-20% between the ages of 51-70 years), were less common in the 41-50 years age group (14%) and were absent in the 21-30 and 31-40 years age groups. None of the mandibles from the 21-30 year age group had less than 10 teeth (56-25%) present and none of the mandibles from the 31-40 year age group had less than 7 teeth (37.5%) present.

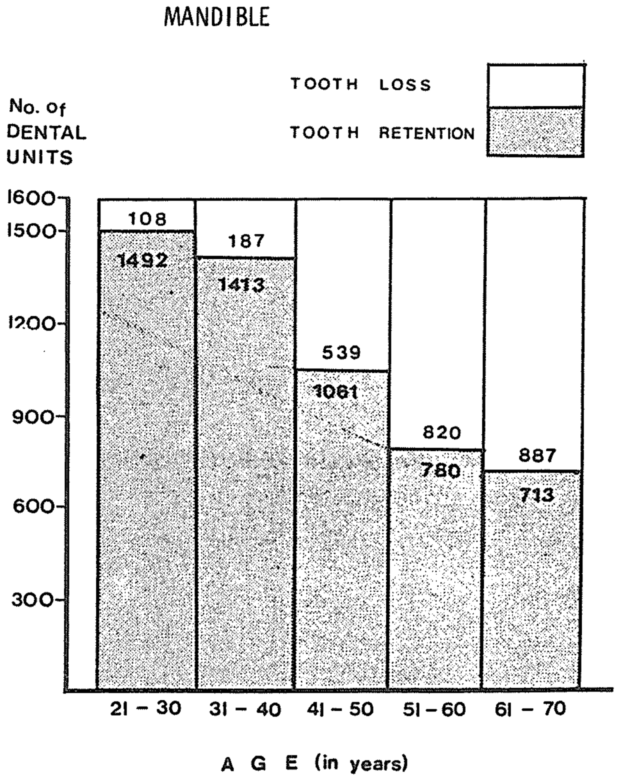

Fig. 1. Percentage of tooth loss and tooth retention in the mandibles.

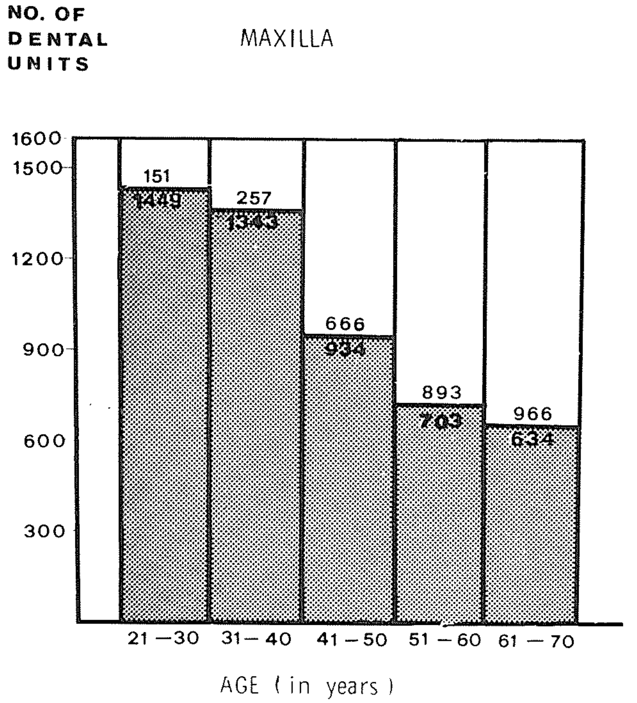

Fig. 2. Percentage of tooth loss and tooth retention in the maxillae.

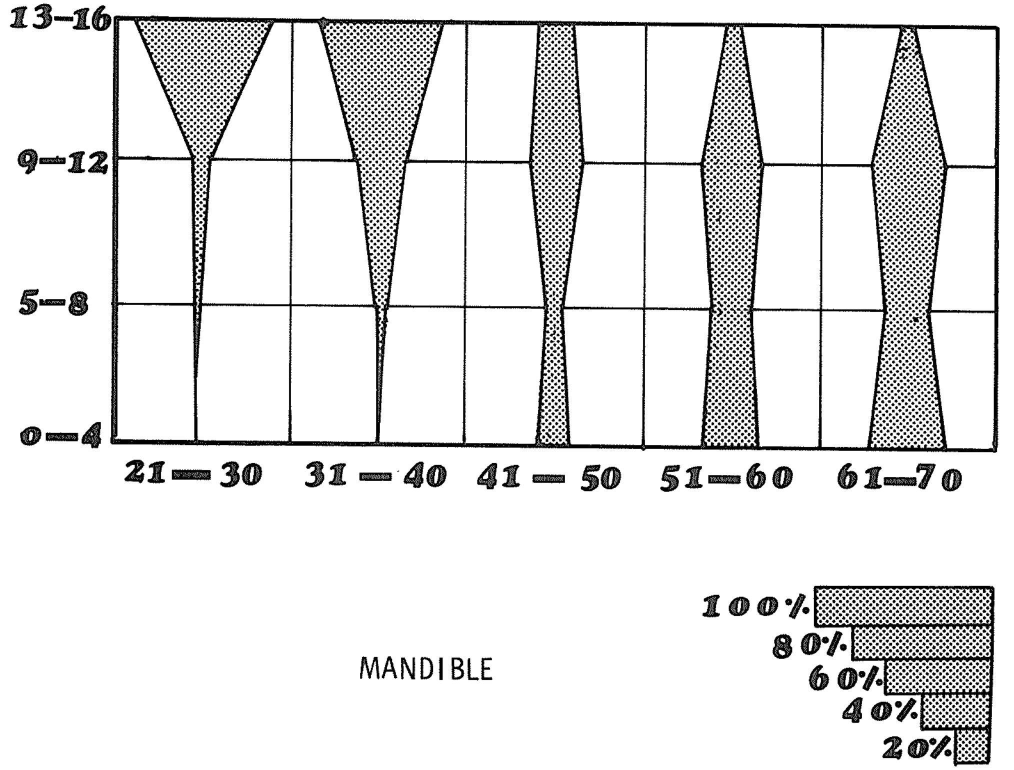

Fig. 3. Diminution of the dentition with increasing age: Mandibles.

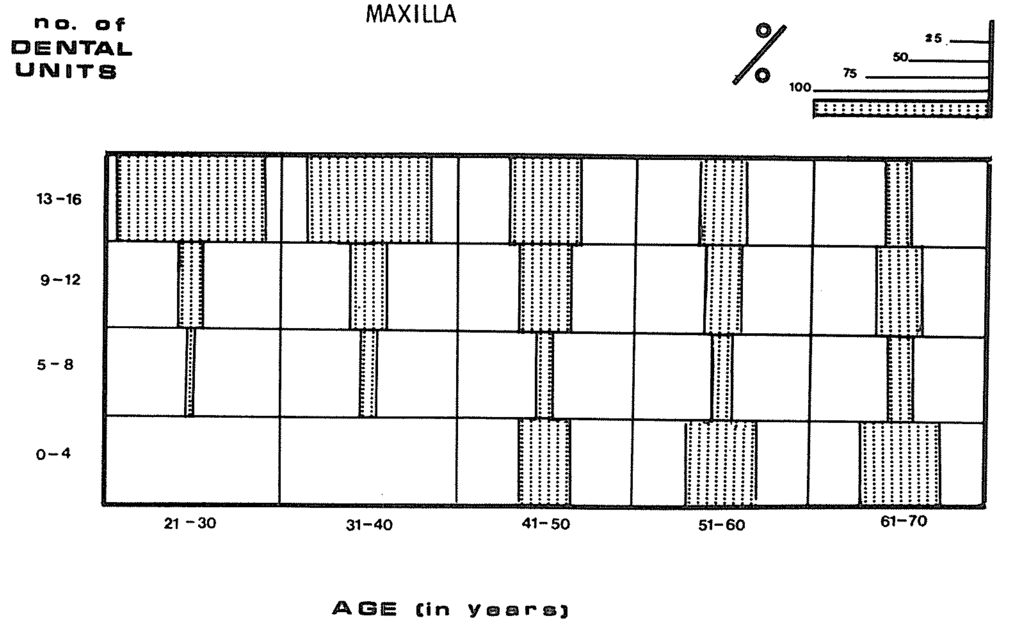

Fig. 4. Diminution of the dentition with increasing age: Maxillae.

Maxillary dentitions generally followed the same pattern. Complete dentitions were common in the two youngest age groups (46-51%) and were reduced to 5% in the oldest. Edentulous maxillae were however significantly more common than edentulous mandibles between the ages 41-70 years. There were no edentulous specimens in the 21-40 year age groups.

Discussion

The objective of this study was to evaluate the diminution of the dentition of a multitribal group of Bantu-speaking South African blacks. Unlike other studies in different populations, none of the specimen in our sample showed signs of conservative dental treatment, and it is assumed that only teeth which were severely affected by dental decay or advanced periodontal destruction were lost.

Various authors who surveyed tooth reduction with increasing age preferred different methods of data collection. Adler (1964; 1965) believed that the investigation of "tooth survival" is more valuable than the study of "tooth mortality" for the assessment of the efficiency of the impaired dentition. Langer, Michman and Librach (1975) felt that in actual dental practice, a knowledge of the number, type and distribution of surviving teeth is indispensible. Jackson and Murray (1972) considered tooth loss to provide valuable information for estimating the success of preventive and conservative dentistry. For the purpose of this study, data on tooth loss or tooth retention are of equal value.

In the present population 84% of the jaws retained some dental units. When the old (61-70 yrs. old) age group is considered separately, 81% of the jaws retained some dental units. The last figure is much higher than the 28% found by Langer et al. (1975) who surveyed an aged multicultural Jewish population in Israel; or by Martinello and Leake (1971) who found natural teeth in only 23% of their old population. The diminution of the dentition in Sweden is comparable to the present finding (Lundqvist 1967). While one would expect a Swedish population to exhibit a lower rate of tooth loss because of the advanced preventive dental services available to them, extractions for prosthetic reasons influenced the final figures.

The reasons for tooth loss in our population were not available. Several studies (Brekhus, 1941; Allen, 1944; Krogh, 1958) have demonstrated that the importance of caries as a cause for extraction continuously diminished from the twenties onwards while periodontal disease grew in importance from the early thirties, and in the Swedish population (Lundqvist, 1967) became equally responsible with caries, for tooth loss, in the fifties and later. To the best of our knowledge there is only one preliminary study on the reasons for extractions in South African blacks (Shakenovsky,1983); this study claims that in the younger age groups (21-40) dental decay is by far the predominant reason for tooth loss.

In the light of the available data it is therefore reasonable to assume that in our sample, like in other populations, the rate of tooth loss from periodontal disease increased with increasing age, and that during the fifth and sixth decades played a major role in the high rate of tooth loss.

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TABLE 1. Distribution of specimens by age, sex and tribe

Age Group		Sex Male	Sex Female	Tribe Zulu	Sotho	Xhosa	Swazi	Shanganaan	Tswana	Venda	Nuaza	Ndlebe	Pedi	Other	Total
21-30		65	35	25	23	13	8	7	4	2	7	1	2	8	100
31-40		67	33	31	18	7	8	3	5	4	7	3	1	13	100
41-50		76	24	29	17	23	2	4	4	4	4	3	3	7	100
51-60		74	26	24	20	12	8	6	5	7	2	5	3	8	100
61-70		76	24	24	16	17	7	8	7	3	-	3	4	11	100
Total	No	358	142	133	94	72	33	28	25	20	20	15	13	47	500
	%	71,6	28,4	26,6	18,8	14,4	6,6	5,6	5,0	4,0	4,0	3,0	2,6	9,4	100%

TABLE 2. Prevalence and frequency of dental units according to age.

Age Group	Prevalence Frequency	Dental unit 48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38	Total
21-30	No	86	86	83	93	100	100	100	99	99	99	100	98	94	84	86	85	1492
	%	17,2	17,2	16,6	18,6	20,0	20,0	20,0	19,8	19,8	19,8	20,0	19,6	18,8	17,0	17,2	17,0	18,65
31-40	No	73	82	87	92	95	97	94	88	88	93	97	98	95	85	86	63	1413
	%	14,6	16,4	17,4	18,4	19,0	19,4	18,8	17,6	17,6	18,6	19,4	19,6	19,0	17,0	17,2	12,6	17,66
41-50	No	52	62	67	74	78	81	65	55	57	64	77	82	76	60	56	55	1061
	%	10,4	12,4	13,4	14,8	15,6	16,2	13,0	11,0	11,4	12,8	15,4	16,4	15,2	12,0	11,2	11,0	13,26
51-60	No	29	39	50	59	62	65	49	44	42	47	64	67	55	47	33	28	780
	%	5,8	7,8	10,0	11,8	12,4	13,0	9,8	8,8	8,4	9,4	12,8	13,4	11,0	9,4	6,6	5,6	9,75
61-70	No	31	30	41	53	62	61	41	38	36	38	55	57	57	44	40	29	713
	%	6,2	6,0	8,2	10,6	12,4	12,2	8,2	7,6	7,2	7,6	11,0	11,4	11,4	8,8	8,0	5,8	8,91
Total	No	271	299	328	371	397	404	349	324	322	341	393	402	377	320	301	260	5459
	%	54,2	59,8	65,6	74,2	79,4	80,8	69,8	64,8	64,4	68,2	78,6	80,4	75,4	64,0	60,2	52,0	68,23%

TABLE 3. Comparison between the prevalence of retained teeth. Each pair of subsequent teeth is compared within age groups and in the sample as a whole.

Teeth compared	Chi square p 1 df	Age Groups 21-30	31-40	41-50	51-60	61-70	Total
38-37	X^2	5,47	8,277	28,571	25,974	36,336	152,28
	P	0,019	0,004	0,0000	0,0000	0,0000	0,00000
37-36	X^2	8,73	2,351	45,481	23,970	11,931	136,40
	P	0,003	0,125	0,0000	0,0000	0,0000	0,0000
36-35	X^2	1,42	2,589	47,136	6,134	23,527	115,69
	P	0,232	0,108	0,0000	0,013	0,0000	0,000
35-34	X^2	7,005	0,107	50,672	41,943	30,382	206,17
	P	0,008	0,743	0,0000	0,0000	0,0000	0,00000
34-33	X^2	-	0,063	63,266	51,010	26,379	236,86
	P	-	0,801	0,0000	0,0000	0,0000	0,00000
33-32	X^2	-	41,089	46,132	46,160	29,430	245,92
	P	-	0,0000	0,0000	0,0000	0,0000	0,00000
32-31	X^2	0,010	38,73	60,737	74,486	68,763	345,63
	P	0.919	0,0000	0,0000	0,0000	0,0000	0,00000
41-42	X^2	-	46,808	59,151	67,850	53,245	335,78
	P	-	0,0000	0,0000	0,0000	0,0000	0,00000
42-43	X^2	-	20,182	43,562	45,877	29,321	235,15
	P	-	0,0000	0,0000	0,0000	0,0000	0,00000
43-44	X^2	-	5,226	83,164	45,987	46,707	285,87
	P	-	0,022	0,0000	0,0000	0,0000	0,00000
44-45	X^2	-	1,029	61,763	41,721	44,387	225,56
	P	-	0,310	0,0000	0,0000	0,0000	0,00000
45-46	X^2	3,56	4,615	30,657	25,837	38,696	153,72
	P	0,059	0,031	0,0000	0,0000	0,0000	0,00000
46-47	X^2	1,54	1,650	34,779	15,174	31,750	127,70
	P	0,21	0,198	0,0000	0,0001	0,0000	0,0000
47-48	X^2	2,87	12,95	32,197	19,168	25,488	150,18
	P	0,09	0,0003	0,0000	0,0000	0,0000	0,00000

TABLE 4. Comparison of the prevalence of retained homolgous teeth between the subsequent age groups.

Tooth	Chi square p 1 df	Age groups compared 21-30/31-40	31-40/41-50	41-50/51-60	51-60/61-70
38	X^2	20,764	2,746	36,161	0,050
	P	0,000	0,098	0,000	0,824
37	X^2	0,000	74,751	23,926	2,216
	P	1,000	0,000	0,000	0,137
36	X^2	0,768	49,020	6,784	0,361
	P	0,779	0,000	0,009	0,548
35	X^2	0,211	76,000	17,818	0,162
	P	0,616	0,000	0,000	0,688
34	X^2	0,000	130,612	10,176	4,523
	P	1,000	0,000	0,004	0,033
33	X^2	abandoned	117,457	7,115	3,810
	P	1 cell, 2 freq.	0,000	0,007	0,001
32	X^2	5,530	129,186	11,602	3,252
	P	0,019	0,000	0,001	0,071
31	X^2	11,458	91,004	9,236	1,478
	P	0,001	0,000	0,002	0,224
41	X^2	11,458	103,125	4,911	1,461
	P	0,001	0,000	0,0027	0,227
42	X^2	abandoned	149,113	10,244	2,561
	P	1 cell, 2 freq.	0,000	0,001	0,110
43	X^2	abandoned	87,973	11,253	0,703
	P	1 cell, 2 freq.	0,000	0,001	0,402
44	X^2	abandoned	60,842	10,866	0,000
	P	1 cell, 2 freq.	0,000	0,001	1,000
45	X^2	0,136	44,022	9,301	1,488
	P	0,712	0,000	0,002	0,222
46	X^2	1,415	35,367	11,560	3,240
	P	0,234	0,000	0,001	0,072
47	X^2	1,084	27,100	22,236	3,405
	P	0,298	0,000	0,000	0,065
48	X^2	8,574	22,374	25,692	0,194
	P	0,003	0,000	0,000	0,659

TABLE 5. Distribution of specimens according to age and number of dental units present.
(Diminution of Dentition with increasing age)

Age		No of dental units in the mandible																	total dental units
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
21-30	No	-	-	-	-	-	-	-	-	-	-	1	3	7	8	9	17	55	1492 27, 33%
31-40	No	-	-	-	-	-	-	-	1	-	1	6	7	12	7	10	11	45	1413 25, 88%
41-50	No	14	-	1	1	2	-	2	2	4	4	8	5	7	13	8	10	19	1061 19, 43%
51-60	No	20	2	-	3	2	5	3	6	8	6	9	9	9	9	5	6	0	780 14, 28%
61-70	No	19	3	5	2	4	4	7	4	6	7	7	10	9	2	6	1	4	713 13, 06%
Total	No	53	5	6	6	8	9	12	13	16	18	31	34	44	39	38	45	123	5459
	%	10, 6	1, 0	1, 2	1, 2	1, 6	1, 8	2, 4	2, 6	3, 2	3, 6	6, 2	6, 8	8, 8	7, 8	7, 6	9, 0	24,6	100%

The Prevalence and Distribution of Periodontal Bone Loss in Dry Mandibles of Bantu-Speaking South African Blacks

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OSSA

Periodontal bone loss caused by periodontitis results in an increase in the distance between the cemento-enamel junction (CEJ) and the alveolar bone crest (ABC). The distances between CEJ and ABC were measured along the midvertical lines of 1106 teeth in 100 dry mandibles. There were equal number of mandibles from subjects in each of the 5 decades of life from the third to the seventh. Analysis of the distribution and frequency of the 4904 measurements taken, showed that in the youngest age group (21-30 years old) the CEJ to ABC distance was 1-3 mm in 75% of the measured surfaces. Between the fourth to sixth decades of life most of the measurements (56-67%) were 4-6 mm. The mean measurements increased with increasing age; but differences were significant only between the age groups 21-30 years and 31-40; and between the age groups 31-40 years and 41-50 ($p < 0.05$). It is speculated that after the fourth decade of life, teeth which were affected by extensive periodontal destruction were lost, thus decreasing the mean recordable bone loss.

Keywords: Periodontal bone loss - Alveolar bone loss.

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Introduction

The degree of root exposure from alveolar bone resorption has long been a major criterion for the detection of periodontal disease. Several methods have been used and several indices have been applied in the study of bone loss; radiographic estimation being the most common (Sheppard, 1936; Marshall-Day and Shourie, 1949; Shei et al., 1959; Waerhaug, 1966; Boyle et al., 1973; Markkanen et al., 1982). Many investigators believe that radiographs are inaccurate and permit estimations of interproximal bone loss only. Studies on dry skulls and autopsy material on the contrary permit direct measurements on all tooth surfaces, and should therefore be considered very accurate.

It has commonly been observed that the distance between the cemento-enamel junction (CEJ) and the alveolar bone crest (ABC) increases with increasing age (Belting et al., 1955; Davies and Picton, 1969; Lavelle, 1973) and that in health, the alveolar crest is parallel to, and perhaps determined by the position of the CEJ (Black, 1918; Ritchey and Orban, 1953; Wheeler, 1974).

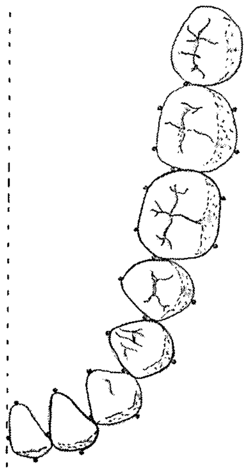

Fig. 1.
Schematic drawing of a mandibular dental arch (left half) showing the position of the vertical measurements from ABC to CEJ.

The purpose of this investigation is to study the prevalence and distribution of measured distances between CEJ and ABC in dry mandibles of South African blacks.

Materials and methods

One hundred mandibles of South African negroes were selected from the anthropological collection of skeletons, housed in the Department of Anatomy of the University of Witwatersrand, Johannesburg. For further information on this collection the reader is referred to Tal & Tau (1983).

Mandibles were selected according to the following criteria:

1. Tribe, sex and stated age should be known.
2. Stated age should not differ by more than 10 years from the estimated age using a calibrated attrition scale.
3. Mandibles should have at least one tooth present.
4. Mandibles should not show any obvious postmortem damage.

The 100 mandibles were so selected as to be equally distributed between the 3rd, 4th, 5th, 6th and 7th decades of life, 20 in each age group. Table 1 shows the distribution of specimens by age, sex and tribe.

The distance between CEJ and ABC was measured along the midvertical lines of the buccal, lingual, mesial and distal surfaces of each tooth. In view of the possibility that alveolar bone destruction may occur separately around each root of multirooted teeth, in these, measurements were made along the midvertical lines of the mesial and distal surfaces (Fig. 1).

Measurements were taken to the nearest millimeter with a fine periodontal probe with millimeter markings from 1 to 10 mm, checked for accuracy. All measurements were made under standard conditions of good illumination (Fig. 2).

The measurements were recorded on a special chart and analysed statistically.

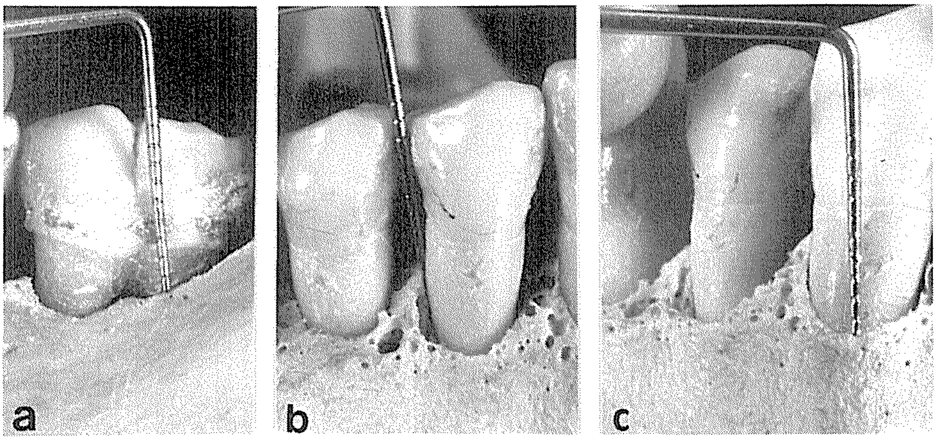

Fig. 2. The technique of measuring the CEJ-to-ABC distance with a calibrated probe.
A. Mesiobuccal surface - molar
B. Distal surface - premolar
C. Buccal surface - canine

Results

There were altogether 1106 teeth present in the 100 mandibles; 5012 surfaces were observed: 1764 on molars and 3248 on premolars, canines and incisors. 108 surfaces were excluded from the study because of root fractures or caries involving the CEJ, or because of alveolar dehiscences which precluded accurate measurements. The distribution of the 4904 measurements by age groups is shown in Table 2.

Table 3 and Figure 3 show the distribution of the frequencies of each measurement from 1 to 10 mm and more, by age groups. The frequency of each group of measurements was calculated as the prevalence of that measurement divided by the number of measured surfaces and multiplied by 100.

Since there was no difference between measurements obtained from mandibles of males and females ($p > 0.5$) these were studied together.

The measurements were further grouped under 3 groups: 1-3 mm represents no significant bone loss; 4-6 mm represents significant bone loss; and 7 mm or more represents extensive bone loss (Table 3).

In the youngest age group (21-30 years old) measurements of 1, 2 and 3 mm predominated, making up 75% of the measurements. The mean measurement in this group was 3.47 mm. In the age groups 31-40 years, 41-50 years, 51-60 years and 61-70 years, measurements 4, 5 and 6 mm predominated with frequencies varying between 56% and 67%. Measurements of 7 mm or more were least frequent (9-17%).

With the exception of the age group 51-60 years, measurements increased with age. When the differences between measurements were tested between age groups there was a significant difference between the age groups 21-30 and 31-40 years ($p < 0.05$), and between the age groups 31-40 and 41-50 years. There were no significant differences between the remaining age groups.

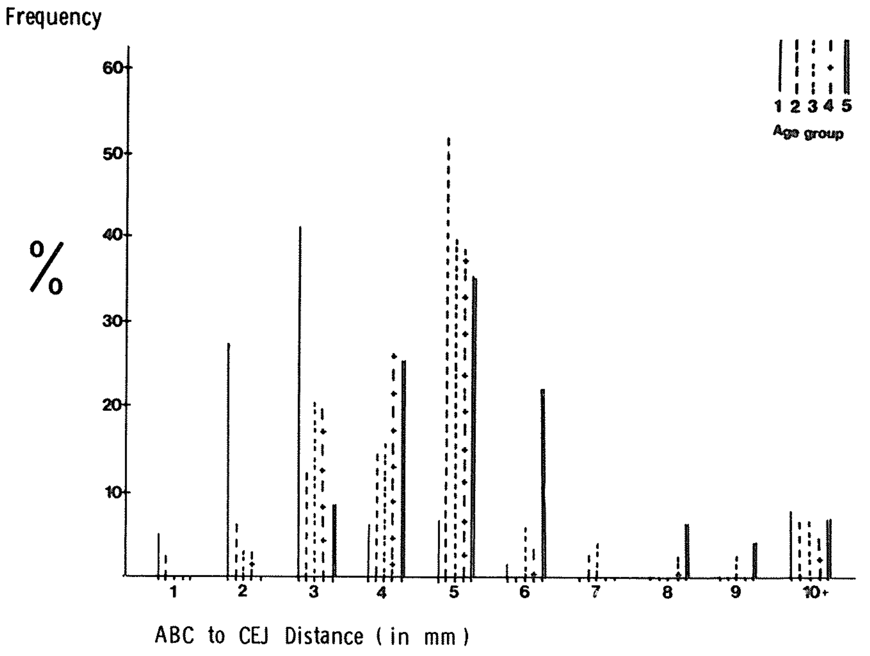

Fig. 3. Distribution of the percentage frequencies of measurements by age groups.
Age group 1: 21-30 years
Age group 2: 31-40 years
Age group 3: 41-50 years
Age group 4: 51-60 years
Age group 5: 61-70 years

Discussion

All the mandibles were obtained from cadavers of known sex, tribe and stated age. Previous studies have shown that South African blacks exhibit no major anthropometric, cultural, nutritional of health intertribal differences (Penrose,1954; de Villiers, 1968; Lestrade, 1937; Schapera, 1937; Hornle, 1937). For these reasons the mandibles were treated as an honologous group. The fact that the ages of specimens were known, puts this study at an advantage over other studies, in which the ages of specimens were estimated by suture closure, a method which has been shown to be unreliable (Stewart, 1979).

It may reasonably be assumed that none of the specimens were from people who had been exposed to oral hygiene education, and certainly none showed any evidence of dental treatment. The specimens studied were therefore from a population in which progression of periodontal destruction had not been affected by professional intervention.

The distance between ŒJ and ABC in health has never been agreed upon. Barker (1975) believed that the distance in the absence of periodontitis is 1.75 mm to 3.13 mm depending upon attritional wear. Baer and Morris (1977) regarded 1.86 mm as the normal distance. Any increase in the CEJ to ABC distance with increasing age has been regarded as strictly pathological by Bass (1946) and by Williams (1943). Gahan, Tal and Lemmer (1983) reported that the mean measured distance between the CEJ and the ABC in mandibles of South African juveniles, free of signs of periodontitis is 1.40 mm ($\pm$ 0.45).

In the present study a distance of less than 2.5 mm (recorded as 2 mm) is regarded as normal and the fact that the frequency of measurements of 1-2 mm was 33% in the third decade of life, less than 10% in the whole sample, and 3% or less after the age of 41 years supports this. These figures also suggest that although periodontal bone loss progresses with increasing age, it is not universal, and some teeth may never suffer significant bone loss.

The predominance of measurements 1-3 mm in the third decade of life is expected, and suggests that during this early period of life, 75% of root surfaces suffered little or no bone loss. In the fourth, fifth and sixth decades of life only 23-24% of root surfaces were free of, or affected by only slight bone loss, and in the seventh decade only 9%. Moderate bone loss (4-6 mm) was uncommon in the third decade of life (16%) but was predominant (56-67%) later.

The frequencies of extensive bone loss (7 mm or more) varied from 9% to 17% in different age groups, and scored the least frequency (7%) in the 51-60 years old age group. This unexpectedly low frequency, and the insignificant differences between mean bone loss in the fifth, sixth and seventh decades of life could result from loss of teeth which were affected by extensive bone loss. It has been shown that during the fourth and fifth decades of life periodontal disease exceeds caries as the main cause of tooth loss (Brekhus, 1941; Allen, 1944; Krough, 1958; Lundqvist, 1967). It may therefore be speculated that as people grew old, teeth which were lost were those with more severe periodontal breakdown, and this loss of teeth would decrease the recordable bone loss.

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TABLE 1. Prevalence and distribution of mandibles by age, sex and tribe.

AGE GROUP	SEX		TRIBE											
	MALE	FEMALE	MALAWI	PEDI	PONDO	SHANGAN	SOTHO	SWAZI	TONGA	TSWANA	VENDA	XHOSA	ZULU	TOTAL
21-30	8	12				2	7	1		2		2	6	20
31-40	11	9	1			3	2		1	3		2	8	20
41-50	19	1	1			1	4	1			1	5	7	20
51-60	16	4		2		1	6	1		1		4	5	20
61-70	16	4		2	1	2	5			3		5	2	20
TOTAL	70	30	2	4	1	9	24	3	1	9	1	18	28	100

TABLE 2. Distribution of teeth and measured surfaces by age.

Age (in years)	21-30	31-40	41-50	51-60	61-70	Total
No. of teeth present	235	233	228	222	188	1106
No. of Measured surfaces	1029	1042	1011	974	848	4904
No. of Excluded surfaces	27	8	15	38	20	108

TABLE 3. Distribution of the frequencies (in percent) of measurements and mean measurements by age.

Age	measurement in mm										Mean
(in years)	1	2	3	4	5	6	7	8	9	10+	Measurement
21-30	6	27	42	7	7	2	-	-	-	9	3.47 mm
31-40	3	7	13	15	52	-	3	-	-	7	4.15 mm
41-50	-	3	21	16	40	6	4	-	3	7	4.94 mm
51-60	-	3	20	28	39	3	-	2	-	5	4.57 mm
61-70	-	-	9	27	36	11	-	6	4	7	5.34 mm

Bone Core Analysis and Vertebral Pathologies in Sadlermiut Eskimo Skeletons

DAVID D. THOMPSON, SARA B. LAUGHLIN, WILLIAM S. LAUGHLIN and CHARLES MERBS

OSSA

Osteoporosis is found in high frequency in living Eskimos and in Eskimo skeletons. This study focuses on cortical bone variables associated with age-related bone loss (thin bone cortices and secondary osteons) in Sadlermiut Eskimo skeletons and compares these with results obtained from other Eskimo skeletal series reported elsewhere and from U. S. Whites. Also analyzed are the relationships between cortical variables and collapsed vertebrae and separate neural arches.

Bone cores from femora of 88 adult Sadlermiut (44 males and 44 females) Eskimo skeletons were removed with a high speed drill. Cortical thickness, core mineral content, and cortical bone density were assessed from intact cores. Thin sections were then removed from the cores and the secondary osteon number, area, and perimeter and Haversian canal area and perimeter were measured.

The results revealed that Sadlermiuts have thin femoral cortices and increased numbers of secondary osteons compared with U. S. Whites; results that are consistent with those obtained in other Eskimo skeletal series. Similar numbers of secondary osteons were found between Sadlermiut Eskimos and other Inupiaq Eskimos and between Yupik Eskimos. A high incidence of compressed vertebrae and low cortical thickness values reveals the high incidence of osteoporosis in Inupiaq Eskimos and this in spite of a reduced life expectance. No relationship between cortical bone variables and appearance of separate neural arches was detected in this study.

Keywords: Osteon - Cortical Thickness - Eskimo - Osteoporosis - Femur.

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Introduction

The discovery that Arctic Eskimos die at an earlier age than other populations, and that they age more rapidly than other related and unrelated populations, required some twenty years to demonstrate (Laughlin et al., 1979). The analysis of Sadlermiut Eskimo skeletons has played a key role in this development.

Hrdlicka remarked that it was noteworthy that none of fourteen adult Sadlermiut skulls were that of really aged individuals (Hrdlicka, 1910, p. 206). Laughlin and Merbs noted the absence of older persons in their larger collection of 1959 (Laughlin, 1963). They clearly comprise an especially informative series for the study of length of life, aging rates, and bone biology including bone mineral, osteoporosis and related pathologies.

Living Eskimos undergo an early onset and a rapid rate of age-related bone loss compared with U.S. White controls (Mazess and Mather, 1974, 1975). Inupiaq-speaking Eskimos, living at or above the Arctic Circle and distributed from Alaska to Greenland and presumably Sadlermiut Eskimos lose bone at a faster rate than Yupik-speaking Eskimos, living in Alaska below the Arctic Circle (Thompson and Gunness-Hey, 1981; Thompson et al., 1982). Eskimo skeletons also reveal a high frequency of collapsed vertebrae and separated neural arches (spondylolysis) (Merbs, 1969). Discerning the distribution and identifying the etiology of the unique pattern of age-related bone loss among the two Eskimo populations and the Aleutian Aleuts was the focus of attention of a multi-disciplinary investigation centered at the Laboratory of Biological Anthropology, University of Connecticut. This multidisciplinary investigation utilized both living Eskimos and skeletons of dead Eskimos. Research involving living Eskimos allows longitudinal measurement studies of bone loss by photon absorptiometry, with metabolic, genetic, and dietary factors examined simultaneously.

Studies utilizing Eskimo skeletons provide an important link with studies conducted in the living by adding a time depth to the analysis. For example, is the Eskimo bone loss pattern a recent post-European phenomenon or is it apparent in pre-European skeletons? Utilizing selected parameters applicable to both living and dead populations this question can be addressed. Also, multiple samples and x-rays and direct measurements and observations can be made on dry skeletons, unlike the work in the living where only a single scan is made, or single biopsy is removed.

The purpose of this paper is to describe cortical bone parameters and the relationship between these parameters and certain vertebral pathologies in a series of Sadlermiut Eskimo skeletons to elucidate patterns of aging. Also, the cortical bone parameters are compared with those obtained in other Eskimo skeletal populations.

Materials and methods

The skeletons used in this study consisted of 44 males and 44 female adult Sadlermiut skeletons from Southampton Island, Canada (Table 1). The collection used was excavated by Henry Collins in 1954 and 1955 and by a team headed by William Laughlin in 1959. The collections are housed in the Museum of Man, Ottawa, Canada, and the National Museum of Natural History in Washington, D. C. Age and sex determinations have been assessed by standard morphological indicators. Means of the age ranges assigned by the morphological methods were utilized in this study. The vertebral pathologies and anomalies included in this study were compressed vertebrae and spondylolysis.

Cortical bone cores, 0.4 cm in diameter, were removed from one femur of each individual included in this study. The site of core removal was the anterior midshaft region of the femur. The following variables were ascertained from each intact core: cortical thickness, cortical bone density, and bone mineral content index. Cortical thickness was measured with dental calipers and bone mineral content was measured with a Norland-Camerone Bone Mineral Analyzer. Cortical bone density was determined as the weight of the core per unit volume. Assessed from the 80 micron thick sections removed from each core were: secondary osteon area, secondary osteon perimeter, Haversian area and perimeter and secondary osteon number. The histological variables were assessed with the aid of a microprojector and a Numonics digital calculator. For a detailed discussion of the methods and the variables see Thompson (1979).

Results

Sadlermiut Eskimo femoral cortices are thin compared with similarly aged U. S. White femora and Yupik Eskimo femora, but similar to other Inupiaq Eskimo (Inuit) femora (Table 2). Sadlermiut males of Southampton Island had a mean anterior midshaft cortical thickness of 4.31 mm and females a mean cortical thickness of 3.47 mm. The mineral content index and cortical bone density of the Sadlermiut Eskimo femora did not differ from other Inupiaq femora, Yupik Eskimo or U. S. White femora (Table 3).

Sadlermiut femora contained secondary osteons of the same perimeter and area as other skeletal series examined. Mean male secondary osteon perimeter was 0.570 mm and 0.595 mm for females. Similarly, mean male secondary osteon area was 0.025 mm^2 and 0.028 mm^2 for Sadlermiut females.

The major histological distinction identified in Sadlermiut femora and consistent with that found in all Eskimo femora, including Yupik Eskimos, but contrasted with U. S. White populations is the increased number of secondary osteons per unit area in similarly aged individuals. Sadlermiut males of Southampton Island who had a mean estimated age of 32 years had a mean number of 13.31 osteons per mm^2 (Table 4). Sadlermiut females of Southampton Island with a mean estimated age of 35 years had a mean of 12.06 osteons per mm^2. This compares with a mean of 8.72 osteons per mm^2 for similarly age distributed U. S. White males and 6.06 osteons per mm^2 for U. S. White females (Table 5). Mean known age at death for U. S. White males was 36 years and 26 years for U. S. White females.

From the data on vertebral pathologies on the sample used in this study, 14 out of 44 males or 32 percent had collapsed vertebrae (Table 5). The mean age at death for the 14 males with collapsed vertebrae was 37 years while the "normal" unaffected male group was 29 years (n=30). Of the 44 females in this study, 14 or 32 percent had collapsed vertebrae. Mean estimated age at death for females with collapsed vertebrae was 32 years and 36 years for females who were unaffected.

No statistical differences were noted for the femoral variables between the males and females who had compressed vertebrae and males and females who were unaffected.

Of the 44 male skeletons in this study, 10 or 23 percent had spondylolysis. Of the 44 female skeletons, 9 or 20 percent suffered from spondylolysis. A further analysis also demonstrated no statistical differences for individuals with and without compressed vertebrae and spondylolysis and unaffected individuals.

As was the case with comparing individuals with and without compressed vertebrae, no statistical differences were found for the femoral variables for individuals with and without vertebral anomalies.

Discussion

Inupiaq Eskimos living at or above the Arctic Circle reveal a relatively short length of life, a high frequency of vertebral compression fractures, a high incidence of vertebral anomalies, and an increased number of secondary osteons per unit area compared with U. S. Whites. These conditions are prevalent in all Inupiaq skeletal populations examined to date, including skeletons from as long ago as 2,000 years B. P. to the present and extending from the U. S. S. R. to Greenland. The Sadlermiut Eskimos, and Inupiaq Eskimos in general, are similar to the Yupik Eskimos in the increased number of secondary osteons per unit area and the high incidence of vertebral anomalies, but are dissimilar in that Yupik Eskimos have thicker cortices and lower incidences of compressed vertebrae.

The results from analysis of living Eskimos show increased rates of age-related turnover among Inupiaq Eskimos compared with other Eskimos and U. S. Whites. Analysis performed on dry skeletons indicates a similar pattern of aging in skeletons compared with that found in the living and that thin cortices and frequency of compressed vertebrae compounded with, or a function of, the high rate of turnover identified in the living reveals a high frequency of osteporosis in Inupiaq skeletal populations. Additionally these conditions are of considerable antiquity, predating European contact.

In spite of high frequencies of vertebral disorders in Sadlermiut skeletons, i.e. collapsed vertebrae and spondylolysis, no differences were observed for the femoral variables collected from affected and unaffected individuals. While the magnitude of bone loss experienced by Inupiaq Eskimos does result in structural failure of the vertebrae in high frequency, a similar failure is not observed in the femur. The result of a high rate of bone loss in Inupiaq femora is a thinned cortex, but not a bone that is fractured in increased frequency. Hrdlicka (1945) remarked on the broad (platymeric) femur found in Eskimos compared to other populations. This structural difference may be providing Eskimos with some resistance to femoral fractures. Also, the mean age at death for Eskimos is low compared to other populations and the fact that onset of age-related bone loss is first observed in trabecular bone may further contribute to the higher incidence of vertebral fractures and lack of femoral fractures. In Inupiaq Eskimo populations, the people may not live long enough to experience sufficient cortical bone loss to experience significant numbers of femoral fractures.

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TABLE 1. Age and sex distributions of Sadlermiut skeletal series.

	n	MEAN AGE AT DEATH	SD
FEMALE	44	34.50	7.95
MALE	44	31.75	8.27

TABLE 2. Mean cortical thickness values for Inupiaq and Yupik Eskimos and U. S. Whites.

		SKELETAL SERIES	MALES n	MALES $\overline{X}$(mm)	MALES SD	FEMALES n	FEMALES $\overline{X}$(mm)	FEMALES SD
ESKIMO	YUPIK	ST. LAWRENCE IS.	21	4.73	(0.93)	32	4.16	(0.73)
ESKIMO	YUPIK	KODIAK ISLAND	53	5.17	(0.91)	39	4.39	(0.66)
ESKIMO	YUPIK	TOTALS	74			71		
ESKIMO	INUPIAQ	BAFFIN ISLAND	24	4.09	(0.88)	20	3.34	(0.85)
ESKIMO	INUPIAQ	SOUTHAMPTON IS.	44	4.31	(0.93)	44	3.47	(0.98)
ESKIMO	INUPIAQ	TOTALS	68			64		
U.S.	WHITES	FORENSIC	18	5.42	(1.39)	10	4.57	(0.86)
U.S.	WHITES	CADAVER	64	4.99	(1.20)	52	3.60	(1.18)
U.S.	WHITES	TOTALS	82			62		

TABLE 3. Secondary osteon area and perimeter for Sadlermiut femora.

	SECONDARY OSTEON AREA (mm^2)			SECONDARY OSTEON PERIMETER (mm)		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD
MALES	44	0.025	(0.009)	44	0.570	(0.095)
FEMALES	44	0.028	(0.007)	44	0.595	(0.081)

TABLE 4. Mean secondary osteon number and perimeter values of Inupiaq and Yupik Eskimos and U. S. Whites.

		SECONDARY OSTEON NUMBER						SECONDARY OSTEON PERIMETER					
		MALES			FEMALES			MALES			FEMALES		
	SKELETAL SERIES	n	$\bar{X}$(mm)	SD	n	$\bar{X}$(mm)	SD	n	$\bar{X}$(mm)	SD	n	$\bar{X}$(mm)	SD
ESKIMO YUPIK	ST. LAWRENCE IS.	21	11.54	(4.79)	32	9.55	(4.32)	21	0.594	(0.076)	32	0.580	(0.074)
ESKIMO YUPIK	KODIAK ISLAND	53	13.40	(5.20)	39	12.68	(4.00)	53	0.614	(0.144)	39	0.624	(0.078)
ESKIMO INUPIAQ	BAFFIN ISLAND	24	11.25	(4.89)	20	12.42	(4.32)	24	0.592	(0.080)	20	0.587	(0.073)
ESKIMO INUPIAQ	SOUTHAMPTON IS.	44	13.31	(4.99)	44	12.06	(3.63)	44	0.570	(0.095)	44	0.595	(0.081)
U.S. WHITES	FORENSIC	18	8.72	(5.80)	10	6.06	(4.45)	18	0.570	(0.071)	10	0.572	(0.075)
U.S. WHITES	CADAVER	64	18.40	(4.33)	52	17.40	(3.73)	64	0.562	(0.059)	52	0.578	(0.050)

TABLE 5. Vertebral compression fractures Sadlermiut femora cortical bone

	n	MEAN AGE AT DEATH (yrs)	CORTICAL THICKNESS (mm)	CORE MINERAL INDEX (gm/cm^2)	CORE DENSITY (gm/cm^3)	OSTEON AREA (mm^2)	OSTEON PERIMETER (mm)	OSTEON NUMBER ($\#/mm^2$)
		$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD
MALES NORMAL	30	29.48 (7.46)	4.275 (1.02)	0.324 (0.04)	1.929 (0.09)	0.025 (0.01)	0.570 (0.01)	12.989 (5.16)
VERTEBRAL COMPRESSION FRACTURES	14	36.57 (7.83)	4.125 (1.15)	0.331 (0.04)	1.884 (0.11)	0.022 (0.01)	0.527 (0.18)	13.071 (5.84)
FEMALES NORMAL	30	35.59 (8.29)	3.435 (1.19)	0.300 (0.05)	1.886 (0.13)	0.029 (0.01)	0.608 (0.08)	12.277 (4.04)
VERTEBRAL COMPRESSION FRACTURES	14	32.23 (6.93)	3.523 (0.69)	0.304 (0.04)	1.875 (0.12)	0.026 (0.01)	0.570 (0.09)	11.384 (2.61)

TABLE 6. Sadlermiut femoral variables on vertebral pathologies.

	n	MEAN AGE AT DEATH (yrs)	CORTICAL THICKNESS (mm)	CORE MINERAL INDEX (gm/cm^2)	CORE DENSITY (gm/cm^3)	OSTEON AREA (mm^2)	OSTEON PERIMETER (mm)	OSTEON NUMBER ($\#/mm^2$)
		$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD	$\overline{X}$ SD
MALES								
NORMAL	31	31.96 (8.49)	4.273 (0.94)	0.329 (0.05)	1.917 (0.10)	0.025 (0.01)	0.564 (0.09)	13.145 (5.20)
SPONDYLOLYSIS	10	31.00 (8.21)	4.255 (1.41)	0.314 (0.04)	1.917 (0.12)	0.024 (0.01)	0.548 (0.22)	11.667 (6.27)
SPINAL BIFIDA	1	27.00 (0.0)	2.500 (0.0)	0.301 (0.0)	1.933 (0.0)	0.018 (0.0)	0.469 (0.0)	17.670 (0.0)
CENTRUM	2	38.00 (7.07)	4.250 (0.21)	0.349 (0.0)	1.869 (0.07)	0.022 (0.0)	0.523 (0.02)	15.335 (0.47)
FEMALES								
NORMAL	30	35.39 (8.18)	3.338 (1.12)	0.300 (0.05)	1.895 (0.13)	0.029 (0.01)	0.603 (0.08)	11.822 (3.72)
SPONDYLOLYSIS	3	31.25 (7.80)	3.811 (0.49)	0.305 (0.06)	1.864 (0.12)	0.027 (0.01)	0.606 (0.06)	12.110 (4.24)
SPINAL BIFIDA	1	38.00 (4.00)	2.850 (0.0)	0.314 (0.0)	1.843 (0.0)	0.025 (0.0)	0.511 (0.0)	10.330 (0.0)
CENTRUM	4	25.00 (0.0)	3.800 (0.44)	0.308 (0.05)	1.844 (0.05)	0.023 (0.01)	0.529 (0.11)	14.167 (0.43)

Book Review:

By GARY HEATHCOTE

MARGARET M. WADDINGTON: Atlas of The Human Skull: Academy Books, Rutland, Vermont, U.S.A. – (US $ 85) ISBN 0-914960-36-9

OSSA

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It is commonplace that physical anthropology or human biology teaching laboratories are equipped with human skeletons which are less-than-ideal demonstration specimens. Such collections, especially the skulls, are often moderately to badly damaged as a result of their sustained use over a number of years by hundreds of grasping and probing digits, not to mention abuse by illicit pens and pencils and occasional drops on hard surfaces. Certain normal and variational anatomical features are sometimes not observable on the specimens themselves. Often, for historical reasons if nothing else, the skull receives a disproportionate amount of attention. This "craniology" bias in our discipline makes it especially important to have good visual aides on craniofacial anatomy.

The intended audience for Waddington's atlas is medical students, neuro-scientists and surgeons. My critique, however, focuses on the atlas's serviceability to students of physical anthropology and archaeology. Additionally, this review contrasts the present atlas with a selection of other publications on the skeletal anatomy of the skull. These comparative resources have been found to be particularly useful in teaching craniofacial anatomy within the context of a laboratory course on human osteology.

Atlas of the Human Skull is organized into four parts: Skull, Facial Bones, Cranial Bones and Infant Skull at Birth. The first part covers the craniofacial complex, its various standard views and regional anatomy. Both photographs and line drawings are employed, the latter maintain a uniform colour coding scheme for individual bones throughout the atlas. Craniometric landmarks and reference lines are also depicted. The second and third parts cover the anatomy of individual facial and neurocranial bones in either greater detail or in sectioned views. Throughout the first three parts, notably useful features are the use of coloured rods to illustrate the anatomical relations of foramina and canals and illustrations of muscle attachment areas. The last part on the infant skull is the only weak one, a seeming afterthought. Presented are a mere five renderings of a newborne's skull. Curiously absent is even a single illustration of the cranial base. The atlas includes an expansive (30 page) glossary and a listing of the craniofacial muscles which includes information on origin, insertion, innervation and action.

The atlas is generally well-illustrated; while some line drawings are a bit crude, the photographs are excellent. In concept and execution it deserves fairly high marks, but it now remains to consider a selection of the competition. While Waddington's atlas naturally conveys more information in 147 pages of illustrations than R. M. H. McMinn and R. T. Huchings (Color Atlas of Human Anatomy) do in a 24 page section on cranial anatomy, the fact is that not much more is offerred by the atlas under review. McMinn and Hutchings' more economical treatment practically matches Waddington on detailed skeletal anatomy and muscle attachment sites, and their colour photographs are even better. J. H. Scott and A. D. Dixon's (Anatomy of Students of Dentistry, 3rd ed.) text goes beyond Waddington's mere (albeit vivid) illustration of coloured rods coursing through foramina and canals -- they tabularize the vascular and nerve contents of same. Surely this information would have enhanced an atlas intended for clinicians and surgeons. Another contrast of note is that J. E. Anderson's (Grant's Atlas of Anatomy, 7th ed.) general anatomy atlas has a better section on the osteology of the newborne (as well as child) skull. Another favourable aspect of Anderson's atlas is that is not, like Waddington's and so many others, a "bare bones" atlas virtually devoid of text. Anderson's atlas features notes and commentary which make it apparent why certain anatomical features, or regions or "anomalies" have been selected for illustration.

Not unexpectedly, Waddington makes no mention of the skull's variational anatomy, i.e. discrete or nonmetrical variants. Indeed, few anatomical atlases or texts do. Anderson's atlas and M. Trotter and R. R. Peterson's (Morris' Human Anatomy: A Complete Systematic Treatise, 12th ed.) text chapter are among the notable exceptions to this generalization. Given the recent upsurge of interest in the analysis of nonmetrical cranial traits in comparative skeletal population studies, this omission certainly lessens the value of Waddington's atlas to physical anthropology students. In fairness, it must be conceded that good illustrations of these traits are hard to come by. Two secondary sources worthy of mention, here, are D. R. Brothwell's (Digging up Bones, 3rd ed.) and M. Y. El-Najjar and K. R. McWilliams' (Forensic Anthropology) texts. However, the best photographs and descriptions of nonmetrical cranial variations must be culled from primary sources such as H. de Villiers' (The Skull of the South African Negro) monograph and an article by N. S. Ossenberg (American Journal of Physical Anthropology 45(3) Part II:701-715, 1976).

In summary, Waddington's atlas is a worthy one but its high cost and limited scope make it a less essential addition to a human osteology teaching laboratory than such general anatomy atlases as McMinn and Hutchings' and Anderson's. Certainly, however, it deserves a place on the shelves of university libraries. Were its cost halved, I could also recommend its purchase by individual researchers.

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Illustrations should be reducible to a maximum size of 14.0×20.3 cm or less. It is recommended that figures be constructed *either* for the entire width of the type area (14.0 cm) *or* for the column width of 6.7 cm. If possible, avoid figures *between* 10.4 and 14.0 cm. On all figures should be the author's name and the figure number. Do not attach captions to the figure. Photographs are to be clear, sharply contrasted, and printed on white paper with glossy finish. Figures may be composed of several quadrangular units separated by 1 mm broad spaces. The items in composite figures should be similar to each other in tone. If the natural background is to be deleted, blackening is preferred.

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