

A method for investigating bone fragmentation and anatomical representation

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Summary

This paper describes and discusses a method for investigating bone fragmentation and anatomical representation by means of a Fragmentation Index. This index is calculated using fragment size and is felt to be of potential use for investigating relative degree of fragmentation in different anatomical elements for different taxa and sites.

It has become apparent in recent years that quantifying bones is not a simple matter of counting or weighing fragments. Over the past two decades a number of papers and bone reports have given space to the consideration of how to calculate anatomical frequency in archaeological samples. These have ranged from simple, but effective methods such as that of Grant (1975) who advocated the 'epiphysis count', and that of Watson (1979) who was one of the first to advocate 'zone' counts, to extremely complex methods based upon recognition of a multitude of characteristic zones (Dobney and Rielly 1988). Methods for quantifying bones continue to proliferate. In some respects this seems to add to the confusion, but it does serve to show that analysts continue to actively question their methods and design new ones to cover new circumstances.

Some workers have taken the view that the method they are advocating is the best option, whilst others have taken the view that different situations call for different solutions, and that a particular method may be appropriate in one case but not necessarily in another. The latter is the view supported here. After all, a prehistoric hunter-gatherer settlement bears little resemblance to a medieval waterfront. The former site can reasonably be expected to reflect the activities of the inhabitants in a fairly straightforward fashion: the bones were the remains of meals and secondary usage (bone working, hide preparation, etc.); the latter may contain deposits that

did not originate from the site but which were brought in as rubbish from elsewhere, and even the point of origin of the rubbish may have represented the end point of a complicated series of events that began with raising the animals at some remote location, included droving and marketing, then butchery and retailing, and finally domestic consumption. Clearly the questions posed in any analysis of anatomical elements will depend upon the type of deposit, and it follows that the method of analysis will in turn be dependent upon those questions. It should never be said that any one method is the best, and it may often be appropriate to use several methods in a single report. So long as the way in which the calculations are made is clearly defined, and the raw data are available (though not necessarily in the published report), there should be no restraint upon the analyst in using 'non-standard' methods, or in creating new ones.

The aim of this paper is to put forward a method of calculating anatomical frequency that the author has found to be useful on a number of urban sites and also on a range of high status medieval sites (abbeys, castles, etc.). The intention is not to propose that this method is better than any other, but simply to add to the suite of tools of analysis. The method is not entirely new or entirely original, but is a refinement of methods that have been described elsewhere. It evolved from the use of the Ancient Monuments Laboratory

(AML) coding for fragmentation of bones (Jones *et al.* 1980). The analytical software provided with the AML system did not support analysis of anatomical representation using the fragmentation codes, except in a very basic and 'raw' state which still required a large amount of manipulation. It was felt, therefore, that a method for dealing with the data generated by the use of the coding was needed.

Methods described by O'Connor (1984), Payne (1979) and Watson (1979) provided the basic idea, i.e. that bone counts can be standardised for skeletal frequency and account can be taken also of fragmentation (Watson's 'zones'). The present method employs a modification AML fragmentation scoring rather than the diagnostic 'zones' of Watson. An example of Watson's method is that, for a longbone such as a humerus, there are four zones: 1—right humerus (head), 2—left humerus (head), 3—right humerus (distal) and 4—left humerus (distal) (Watson *op. cit.*, table 1). In some respects this resembles the epiphyses counts of Grant (1975), though there are differences, particularly in the zones of non-long bones, and zones may be defined that use shaft fragments without epiphyseal parts present.

Payne's approach, which he called MINDEX and used for his analysis of bones from Towcester, was to use finer basic units with a built-in correction factor for fragmentation (Payne *op. cit.*).

The AML method subdivides a bone into the following fragmentation categories: <25% complete, 25%, 25–49%, 50%, 51–74%, 75%, 75–99% and 100%. These eight divisions can be supplemented with a coding for proximal end present (P), distal end present (D) and midshaft (M).

In a recent paper O'Connor rightly criticised some of the methods of quantification, particularly those based upon pairing of elements (O'Connor 1985). Quite apart from the problems he discussed, such methods seem inappropriate for sites with complex stratigraphy and which are themselves part of a more complicated economic framework (e.g. urban sites in particular). Elements from single individuals may become widely dispersed, and only some of them may be represented on the site. A good example of

this is the specialised processing of animals in Exeter (Levitan 1989). Furthermore, butchery and other processes can result in differential fragmentation of bone elements, so that simple counts, for example, would be biased in favour of the more fragmented bones.

Fragmentation Index: method of recording

The method is actually a system for providing a measure of the degree of fragmentation in an element. It is not primarily a means of calculating anatomical frequency (though see below), and is not intended as a replacement of other methods which address that need (eg the zone count and epiphysis count methods). It has, therefore, been named a Fragmentation Index (FI). This involves recording the proportion of the bone that is present. It is scored on a five-point scale that is rather subjective, but which is wide enough for the overlap not to be significant. The five-point scores are based on the AML method summarised above, but have been simplified into five categories rather than eight:

1—less than a quarter of the bone represented (<25% complete);

2—between a quarter and a half complete (25–49% complete);

3—between a half and three-quarters complete (50–74% complete);

4—three-quarters or more complete, but not complete (75–99% complete);

5—complete (100% complete).

The scoring is subjective in that a bone that is close to the border between one score and another may be placed in the wrong category. It is difficult to see, however, how this can be overcome. Absolute size does not provide an answer because without knowing the size of the whole bone it would be impossible to weight the measurements, and two fragments of equal size may not represent equal proportions of the bones. It is the opinion of the author that the 'bias' of wrongly recording some bones using the subjective scoring will not be great. In any

case if a bone is close to the borderline between scores, then it probably does not matter too much which score it is given as the *FI* itself is only an approximation.

Fragmentation Index: calculation

Having recorded the bones in this manner, the *FI* for a particular element may then be calculated using the following formula:

$$FI = (n_2/4 + n_3/2 + n_4 + n_5)/NE (\%)$$

where $n_{2..5}$ = total number of specimens for that element in fragment categories 2...5 and

$$NE = n_1 + n_2 + n_3 + n_4 + n_5.$$

Score 1 (<25% complete) is not included in the first part of the index because the factor for division is so uncertain, fragments may be nearly 25% complete, or only 10% complete, etc. For this reason, a separate index for this score (FI^P) is calculated, this being a simple percentage based on the total number of fragments for that element:

$$FI^P = n_1/NE (\%).$$

For example, two sets of 150 humeri with the following scores: (a) 66 score 1, 53 score 2, 20 score 3, 10 score 4, 1 score 5; (b) 42 score 1, 20 score 2, 17 score 3, 28 score 4, 43 score 5 may be calculated:

$$(a) \quad (53/4 + 20/2 + 10 + 1)/150 (\%) \\ = FI \quad 22.8\%$$

$$66/150 (\%) \\ = FI^P \quad 44.0\%$$

$$(b) \quad (20 + 17 + 28 + 43)/150 (\%) \\ = FI^P \quad 56.3\%$$

$$42/150 (\%) \\ = FI^P \quad 28.0\%.$$

If all the bones were complete, an *FI* of 100% would result; thus the smaller the *FI*, the greater the degree of fragmentation. The two *FIs* give an obvious indication of the relative fragmentation in the two examples. In the first case FI^P is low, indicating that most of the humeri were very fragmented; the FI^P is quite high. In the second case, the FI^P is low and the FI is high (this is not to suggest the cor-

relation of FI and FI^P is always of this kind). Whilst these results are self-evident before calculation, it would not be so obvious in larger and more diffuse assemblages which occur in the real world. It will be obvious from the formula applied above that the index is only approximate. For instance, bones in score 2 are assumed to be about a quarter complete and thus are divided by 4; similarly bones in score 3 are assumed to be about a half complete and so are divided by 2. For the present purpose, it does not really matter that this index is not a precise measure of fragmentation because what it does is provide a standardised method of assessing relative fragmentation across the skeleton and, for any one element, across the site. In recording the bones, the scoring method also employs some measure of 'zone' by adding the suffix *P* if the proximal end is present, *D* if the distal end is present and *M* if the middle part only is present (*P* and *D* are also used for cranial and caudal respectively). Thus the method can easily be used for the 'epiphysis' count advocated by Grant (*op. cit.*), whilst a simple summation of all the bones (the *NE* of the formula) provides a simple fragment count of the elements. The method described above is the result of a process of evolution through work on bones from several sites analysed by the author which have all referred to the present paper as 'forthcoming'. The appendix lists those sites where this method has been employed so that the reader may look at some real data and real cases in order to form a more complete opinion of this method, though it should be noted that previous versions of this method differed slightly in detail (though not intention—in the main, the differences relate to the definition of the fragment classes): e.g. Levitan (1987); Rielly (1988).

Uses of the Fragmentation Index

(i) the FI^P is only a single measure of overall fragmentation in an element, but it does serve as a useful tool for intra- and inter-site comparisons. In a series of reports on sites from the Upper Thames valley, Wilson has commented on the fact that some sites display distinct patterning in fragmentation (see, in particular, Wilson (1978) and Wilson and Levitan (forthcoming)). Unfortunately Wilson did not use

the method described above, but employed a cruder fragmentation index. Had the present method been used, a far more detailed picture might have emerged.

(ii) in addition to using this method in terms of the FI , the individual fragmentation scores could be used in the way the FI is calculated, and distribution maps produced for each score. This would produce a far more precise and detailed way of mapping fragmentation than the FI .

(iii) the FI can be used as a sort of anatomical frequency indicator, although it should be employed alongside other methods of calculation in such cases (Levitan 1987; 1989). Used in this sense it is particularly useful because it reduces all elements and all taxa to indices which are directly relatable. When used in this sense, the formula given above is modified to the extent that the '/NE (%)' factor is removed. In the examples given, the results would be: 34.3 and 78.0 respectively. The raw fragment counts indicate that both sets of humeri are the same, but the FI counts indicate that the second set potentially represents a greater number of complete humeri. The greater degree of fragmentation in example (a) has led to the same number of fragments which may have originated from a smaller number of bones than example (b). In such cases it is often important to quantify the bones in two ways—one to show the main zones of fragmentation, since these relate to the processes which preceded deposition and, in part, led to the fragmentation pattern (e.g. butchery), and one to compensate for the degree of fragmentation. The former can be tackled using Watson's zones, as O'Connor has shown (1984), and he is presently working on further refinements of this idea (T. P. O'Connor, pers. comm.). The present method is an attempt to deal with the latter problem. It reduces the fragments to indices calculated for each body element, i.e. as if they are 'whole bones', and allows direct comparison of these across a site, or between sites, as well as comparisons between species.

(iv) the fragmentation indices described above may also be used to calculate the relative abundance of the species, the individual anatomical indices simply being summed (the indices being used without

being transformed into percentages). An example of this is given in Levitan (1987, figure 7). These results may be presented as individual percentages or as aggregate counts (*ibid.* 67, 69). The aggregate method is useful because it provides a direct view of how the species inter-relate.

Discussion

Is there really a place for yet another method of anatomical analysis? Clearly the author feels there is otherwise this paper would not have been written! The method presented here is felt to be a valid one because it addresses anatomical representation from a different viewpoint to the papers cited above. Normally the analysis is trying to reconstruct the patterns of anatomical representation in order to discover whether certain elements have been selected rather than others; from such patterns, conclusions about butchery and animal by-products, such as horn-working, can be made. The present method, however, is more concerned with patterns of fragmentation. The indices produced give a measure of how fragmented different elements have become. The indices can be used to compare fragmentation in a single element in several different locations, or overall patterns for different taxa, and so on. Not only is such information of intrinsic value in certain circumstances (e.g. for the Thames valley sites quoted above), but it may also be of facility in helping to understand anatomical representation in the first sense above. Something of this can be seen in the third of the applications described.

'Worked examples' were given in two papers by Levitan (1987, 65–9; 1989, 163–5, 174–8). The reader may like to refer to these papers (which used an older version of the FI formula) and consider the following points. Three obvious problems with this method are:

(i) epiphyses and symmetry are ignored;

(ii) it is not sufficiently precise in weighting for fragments of scores 2 and 3;

(iii) small fragments <25% complete are not included in the FI , yet these often form the bulk of the sample.

Table 9: Anatomical representation for the major domesticates from Narrow Quay, Bristol (AD 1580-1600).

Key: SKL = skull, JAW = mandible, HC = horncore, CAR = carpus, TAR = tarsus, MC = metacarpus, MT = metatarsus, PHAL = phalanges, RIB = ribs, VERT = vertebrae, SCAP = scapula, PEL = pelvis, HUM = humerus, RAD = radius, ULN = ulna, FEM = femur, PAT = patella, TIB = tibia, FIB = fibula; N = number of fragments, R = rank; %P = proportion of epiphyses (proximal and distal) which are proximal.

Anatomy group	N	FF ¹	FF ²	R	%P (of P+D)
Cattle:					
SKL, JAW	222	20.17	69	9	
HC	-	-	-	-	
CAR, TAR	51	16.73	14	11	
MC, MT	200	57.17	24	4	22,45
PHAL	73	9.01	1	14	
RIB	696	2.94	68	19	
VERT	411	7.95	61	16	
SCAP, PEL	386	35.62	60	7	
HUM, RAD, ULN	633	113.92	26	1	36,62,-
FEM, PAT, TIB	407	57.75	32	3	48,-,46
Sheep/Goat:					
SKL, JAW	172	26.67	49	8	
HC	6	2.00	33	21	
CAR, TAR	4	0.88	0	23	
MC, MT	106	37.46	5	6	47,54
PHAL	-	-	-	-	
RIB	845	8.11	23	15	
VERT	94	4.49	26	17	
SCAP, PEL	250	70.21	18	3	
HUM, RAD, ULN	285	110.79	3	2	19,74,-
FEM, PAT, TIB	262	53.46	15	5	55,-,40
Pig:					
SKL, JAW	110	13.50	68	12	
CAR, TAR	5	1.88	0	22	
MC, MT	21	2.54	0	20	-,50
PHAL	-	-	-	-	
RIB	46	0.65	26	24	
VERT	72	4.16	21	18	
SCAP, PEL	47	10.30	13	13	
HUM, RAD, ULN	43	12.05	19	12	67,50,100
FEM, PAT, TIB, FIB	61	19.42	13	10	29,-,45,100

To deal with these points:

(i) Epiphyses counts may be utilised by calculating the proportions of proximal epiphyses out of the proximal plus distal total. This may be used as an additional indication of intra- and inter-species variation. The example given by Levitan (1989, table 8) of a group of late 16th century AD bones from the site of St Nicholas' Priory, Exeter, illustrates that the FI^2 values may be ranked to show their relative abundance between, as well as within, species. The skeletal elements have been lumped into groups (similar to those of O'Connor (1984)), and it should be noted that ideally the indices should also be given for each skeletal element separately. The table also gives the FI^2 results as <25%. A useful addition would be proportions of proximal epiphyses present (out of total epiphyses per element). An example of this is given in Table 9, which shows the results from a late 16th century deposit from the site of Narrow Quay, Bristol. Thus, for example, cattle have low proportions of proximal metacarpals and high proportions of proximal metatarsals, but in sheep (where the proportions of proximal metapodia are higher) the pattern is reversed. The problem of ignoring symmetry is felt to be less important as in a complex urban deposit, for example, there is little chance of paired elements occurring on a regular basis (O'Connor 1985).

(ii) In the case of a lack of precision for the 2 and 3 scores it was felt that the rather subjective nature of assigning degree of completeness to a bone is not sufficiently precise for the formula to take account of fragments which are, for example, 33% complete. To divide the scores into finer fractions would introduce spurious accuracy into a method which mainly seeks to provide standardisation for the FI^2 rather than precision.

(iii) In the case of fragments less than 25% complete, it is clearly impossible to assign a reasonable weighting factor. One possible way of including these fragments is the weight method of quantification, but this method is not in common usage and has many problems attached to it. In order to include some indication of the representation of this size fraction, the FI^2 is employed. It is then possible to gain an

impression of which body-parts might still be under- or over-represented. In the example in Table 9 the FI^2 results are given. Here, for instance, it can be seen that fragmentation of skull was greater for cattle and pig than for sheep, so the relatively higher FI^2 obtained for sheep may be something of an over-representation. In conclusion, this method should be useful in mapping fragmentation patterns across sites, and in helping to understand anatomical representation patterns.

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Appendix

List of sites where the Fragmentation Index has been employed:

(a) Sites analysed by the author (np = not published):

Hazleton, Gloucestershire (Levitan 1990a)

St Katherine's Priory, Exeter (np, but see Levitan 1987; 1989)

St Nicholas' Priory, Exeter (np, but see Levitan 1989)

Narrow Quay, Bristol (np, but see Table 9)

Brean Down, Somerset (Levitan 1990b)

(b) Other sites:

The Ditches, Gloucestershire (Rielly 1988)

Potterne, Wiltshire (A. Locker) (np)

Wroxeter, Shropshire (B. Meddens) (np)