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Comparative Radiographic Study of Human and Animal Long Bone Patterns

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ABSTRACT: The objective of this study was to test the hypothesis that certain radiographic features can be found to distinguish between human and animal long bone fragments, and therefore would be useful as an adjunct in forensic science identification. Using proposed radiographic criteria, 13 archeologists and 12 dentists were asked to identify 20 radiographic samples as representing human or animal bone. Results showed that archeologists correctly identified 86.8% of the samples, and dentists correctly identified 81.9%. Based on the results of this study, it was concluded that radiographic interpretation of long bone fragments may be a useful aid in a forensic science investigation of human and animal remains.

KEYWORDS: physical anthropology, X-ray analyses, musculo-skeletal system, human identification

In forensic science identification, instances may arise in which only the midshaft or diaphysis of certain bones may be recovered. Determination of human versus animal bone, in such cases, may be made on the basis of histologic appearance [*1*].

Several texts dealing with animal bone identification are available to the archeologist and anthropologist [*2–4*]. These texts are also of value to the forensic anthropologist in that fragmentary animal bone remains encountered during a forensic science investigation may provide useful information to the forensic science specialist. Cornwall [*2*] compared the gross anatomical differences between human and various wild animal bones. He reported that bones are often identified by "the form of their articulations" and consequently, it is impor-

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tant to recover the articular surfaces. Recovery of shaft fragments are also important, however, because these fragments may retain certain features which lead to identification of bone and species. "Shaft-fragments should, therefore, be examined for excrescences, pits, ridges, grooves, foramina, etc., which may betray their nature directly or enable a match to be found among the comparative material" [2].

Olsen [3] and Gilbert [4], using drawings and diagrams, depicted the differences between gross anatomic forms of long bones of various mammals. Gilbert [4] provided useful information on species distribution by including range maps of different mammals of North America. He reported that most human bony elements have counterparts in various animals. "Form and function of bones are sufficiently similar among groups that identification is not difficult" [4].

Stewart [1], however, has commented on the difficulty in determining human and animal origin from bony fragments, particularly diaphyses, citing several instances involving incorrect determinations [5,6]. He suggested that the texts described above are of "limited use" to the forensic science specialist in that they deal mainly with a selection of bones from wild animals. Stewart [1] cautioned against erroneously identifying skeletal material of small animals uncovered in forensic science cases as human. Microscopic examination of bony fragments may also leave doubt concerning species identification. At present it is difficult to determine which animal or human bony fragments can be accurately differentiated microscopically [1,7].

Although several texts are available to aid in the comparison and identification of gross fragments of human and animal bones, there may be considerable uncertainty, both grossly and microscopically, in the identification of small bony fragments. Fragments from the midshaft of bones seem to be especially difficult in terms of species determination. Also, the above mentioned authors seem to rely on gross and microscopic appearance and rarely mention the possible usefulness of radiographs in the identification process. The objectives of this study are (1) to propose certain differences in the radiographic appearance of the midshaft of human and animal bones, and (2) to determine whether these radiographic differences are useful as an additional method of forensic science identification.

Materials and Methods

The radiographic appearance of human and animal long bones was compared using the following method. Radiographs of the midshaft area of the femur, humerus, tibia, fibula, and radius were taken in anatomic position using standard occlusal film on a sample of human and nonhuman animal bones. Animal bones used in this study were procured from the Center of Archeological Research, The University of Texas at San Antonio, and included those of white-tail deer, juvenile deer, jack rabbit, bobcat, badger, puma, and peccary. The bones were selected on the basis of similarity in midshaft size and shape to that which may be found among human long bones.

Initially, 50 human long bones, obtained from The University of Texas Health Science Center at San Antonio Medical School, were radiographed in the lateral and anatomic positions to determine which position most consistently demonstrated characteristic radiographic features. It was determined by the authors that the anatomic view (anterior-posterior) showed the most consistent pattern of bone with respect to the spongy bone and cortex. The terms "cortex" and "spongy bone" will be used throughout this paper to designate the areas of dense compact bone and interiorly surrounding trabeculae, respectively [8]. The human bones used in this study included 10 samples of each of the following: humerus, radius, femur, tibia, and fibula. Twenty animal long bones were also radiographed. The midshaft area of these bones was radiographed with standard occlusal film (Kodak, Rochester, NY, DF-50) and an Intrex dental X-ray unit (S. S. White, Philadelphia, PA). Bones were placed on a dental chair, with X-ray film positioned under the bones in the midshaft area (Fig. 1). The X-ray beam was directed perpendicular to the film, and the cone positioned 10 cm from the film. Exposure factors were standardized (65 kvP, 10 MA) to achieve optimum radiographic density for diagnostic purposes. X-ray film was developed using a Phillips (Model 810) automatic developer. Comparisons of the human and animal midshaft radiographs identified certain features, or combinations of features, which characterized each group.

In evaluating radiographs of *human* long bones, two characteristics were noted:

1. The spongy bone in the midshaft area often showed a pattern of circular or oblong trabeculae (Fig. 2*a* and *b*). The spongy bone of the radius often had a more homogeneous appearance (Fig. 2*c*) with a similar, yet more sparse trabecular pattern.
2. In many instances, there was not a sharp line or border delineating the internal aspect of the cortex from the spongy bone in the midshaft area (Fig. 2*c*).

In evaluating radiographs of *animal* long bones, four characteristics were noted:

1. The trabecular pattern of the spongy bone in the midshaft area was more homogeneous in appearance (Fig. 3*a*) and, generally, did not show the characteristic pattern observed in human long bones. In some cases, the trabecular pattern exhibited a more dense or granular appearance (Fig. 3*b*).

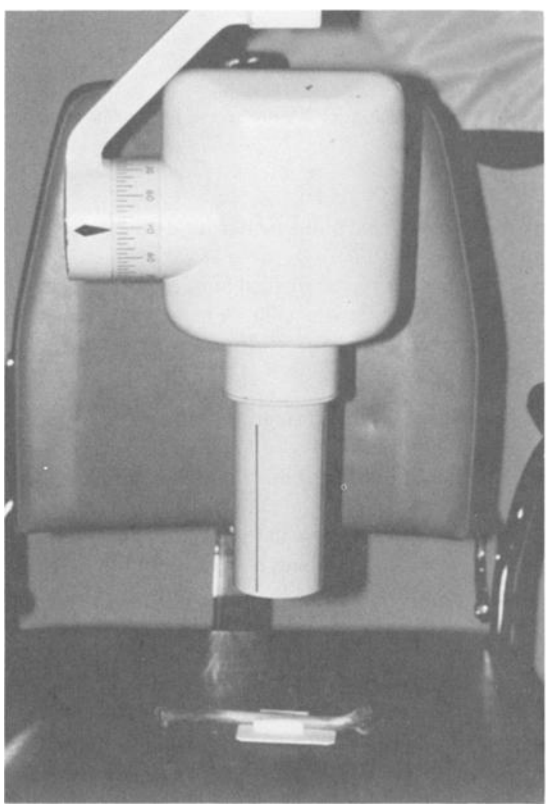

FIG. 1—*Bone placed on dental chair, with X-ray film positioned under specimen. The X-ray beam is directed perpendicular to film.*

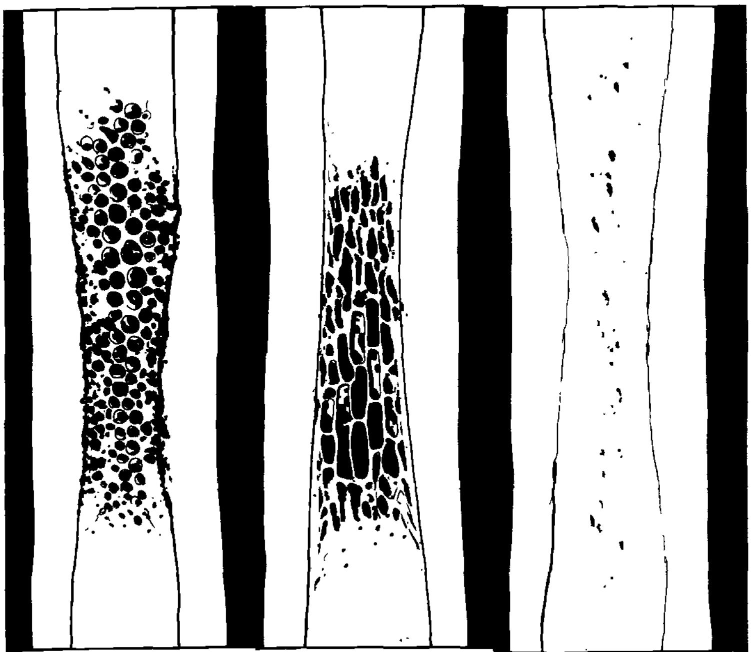

FIG. 2—*Schematic drawing showing radiographic appearance of spongy human bone in midshaft area. Note* (a) *the circular trabecular pattern,* (b) *the oblong trabecular pattern, and* (c) *the more homogeneous appearance of the spongy bone, with a more sparse trabecular pattern.*

2. In many cases, there was a sharp line or border delineating the internal aspect of the cortex from the spongy bone (Fig. 3*b*).
3. Small, spicule-like invaginations of cortical bone may appear to extend from the cortex into the spongy bone in the midshaft area (Fig. 3*c*).
4. The presence of nutrient canals extending into the midshaft area may be noted (Fig. 3*d*).

Figure 4 provides comparison of the radiographs of a human (Fig. 4*a*) and a nonhuman animal (Fig. 4*b*) long bone midshaft.

Comparisons of the human and animal midshaft radiographs led to the hypothesis that radiographic differentiation is possible in many cases utilizing the characteristics mentioned. To test the usefulness of the criteria in forensic science analysis, 24 raters were asked to determine human from animal long bones from a randomly selected sample of 20 radiographs. Animal radiographs are described by bone element and animal group in Table 1.

Raters included 13 dentists (faculty and postdoctoral students) from The University of Texas at San Antonio Dental School and 11 archeologists (faculty and postgraduate students) from The University of Texas at San Antonio. All of the dental participants and none of the archeologists had received advanced training in dental radiology. Raters were asked to read a short narrative describing the proposed radiographic characteristics of human versus animal long bones similar to that described above. They were also referred to 2 diagrams (Fig. 5) that further illustrated the radiographic differences between bones. After reading the narrative and studying the diagrams, raters were shown radiographs of long bones, one at a time, using a cutout which exposed only a small portion (3 by 4 cm) of the midshaft area. Raters were asked to categorize each radiograph as human, animal, or difficult to distin-

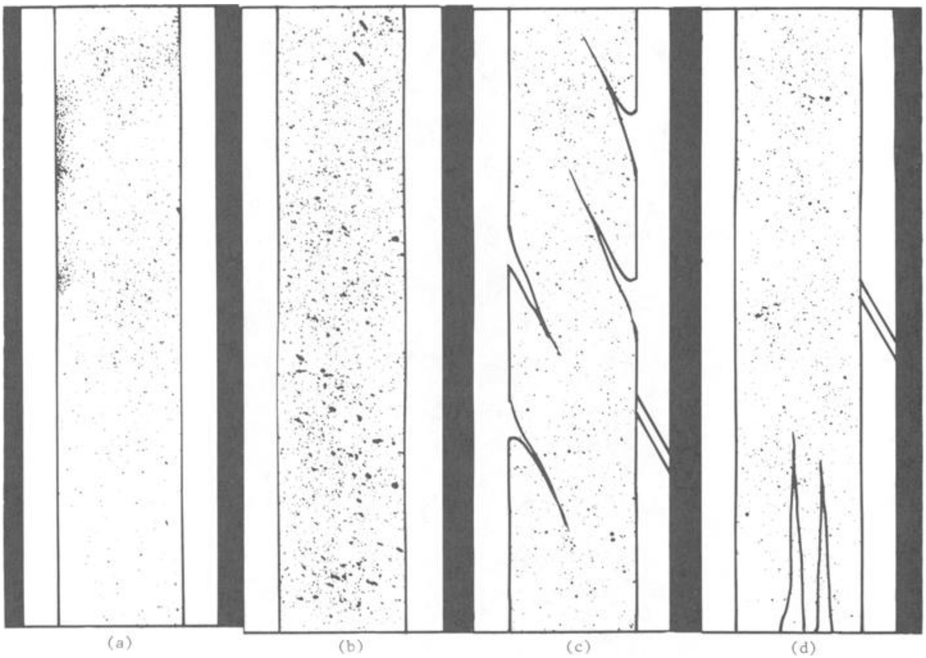

FIG. 3—*Schematic drawing of midshaft of an animal long bone. Note* (a) *the more homogeneous appearance of spongy bone,* (b) *the sharp line or border delineating the internal aspect of cortex from spongy bone,* (c) *the small, spicule-like invaginations of cortical bone extending from cortex into spongy bone in midshaft area, and* (d) *the presence of nutrient canals extending into midshaft area.*

guish. If the radiograph was difficult to distinguish, raters were asked if enough diagnostic information was evident to venture a guess. If so, raters were asked to guess whether the radiographic appearance resembled that of human or animal long bones. Each rater was shown the 20 radiographs in the same order, and no time limit was imposed to respond. Raters were allowed to view radiographs a second time before completion of the procedure.

Statistical Methods

The number of correct answers, incorrect answers, and samples difficult to determine were summarized for human and animal bones and for dentists and archeologists. The Kappa statistic [*9,10*], a measure of agreement, was calculated for each of these combinations. The Students t test was used to test for significant differences in the correct classification between archeologists and dentists [*11*]. The Wilcoxon two-sample nonparametric test [*12*] was used to determine significant differences between archeologists and dentists in the number of correct responses for guesses.

Results

For each bone, the number of raters who responded correctly, incorrectly, or difficult to determine were calculated (Table 2). Overall, the number of correct responses (mean = 15.9) for all professionals (dentists and archeologists) was significantly higher ($P \leq 0.0001$) than the expected number correct by guessing (10). In other words, the chance of these pro-

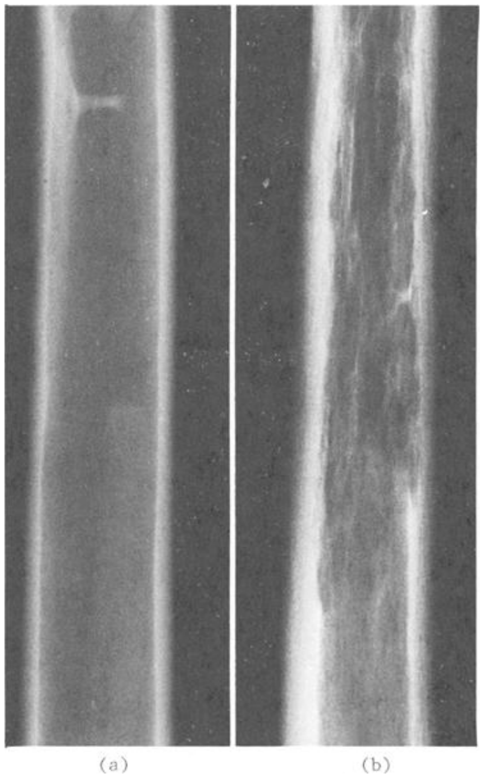

FIG. 4—*Radiograph of midshaft area of human* (a) *and nonhuman animal* (b) *long bone.*

TABLE 1—*Identification of bones used in study.*

Bone No.	Human Bone Type	Bone No.	Animal Group	Animal Bone Type
1	fibula	3	carnivora[a]	humerus
2	humerus	5	juvenile deer	femur
4	humerus	7	jack rabbit	femur
6	femur	9	badger	femur
8	radius	11	juvenile deer	tibia
10	femur	12	bobcat	tibia
15	fibula	13	white-tail deer	femur
17	fibula	14	puma	fibula
19	humerus	16	peccary	tibia
20	femur	18	puma	humerus

[a]Species unknown.

fessionals correctly declaring a bone to be human or animal is estimated to be 79.6% by these data.

The Kappa statistic (K), to investigate agreement of response, was calculated for each category of raters (dentists and archeologists) and each category of bones (human and animal) (Table 3). All four Kappa values were significantly different from zero, with dentists showing more agreement than archeologists. Both dentists and archeologists showed more

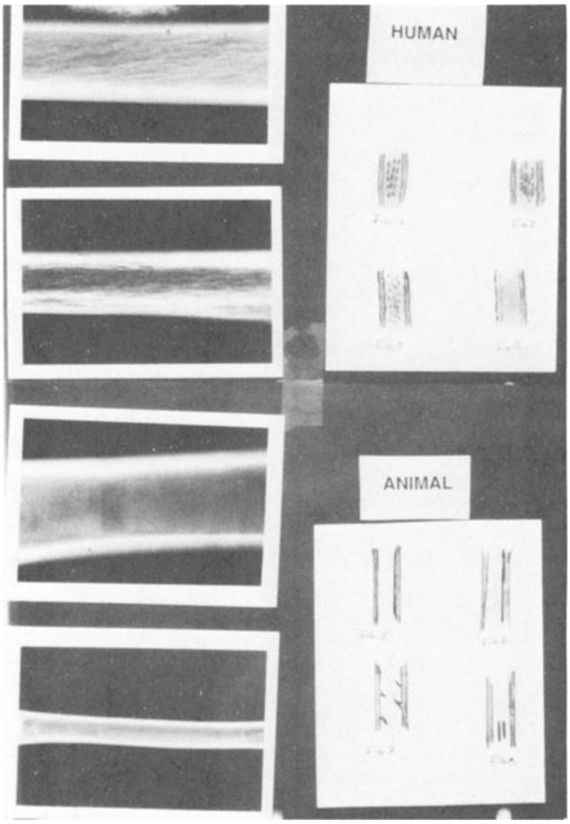

FIG. 5—*Diagrams used in study, which illustrate radiographic differences between human and animal long bone patterns.*

TABLE 2—*Summary of scores for differentiating human from animal midshaft radiographs.*

Bone	Right	Wrong	Difficult	Total
Human bones	197	34	9	240
Human bones, %	82.1	14.2	3.7	100
Animal bones	185	43	12	240
Animal bones, %	77.1	17.9	5	100
Total	382	77	21	480
Total, %	79.6	16	4.4	100

agreement on animal bones than human bones. The Kappa values (not shown) for individual categories (correct, incorrect, and difficult to determine) indicated that in all conditions, there was greater agreement on a correct answer than a "difficult to determine" response. Table 4 presents the descriptive statistics for bones identified correctly, broken down by archeologists and dentists. Radiographs which were guessed at, regardless if response was correct or incorrect, were removed from this analysis. Differences between the two groups of

TABLE 3—*Scores for radiographic analysis: agreement statistics, human bones.*

	Archeologists			Dentists		
Bone No.	Right	Wrong	Difficult	Right	Wrong	Difficult
Human bones:						
1	10	1	0	8	5	0
2	11	0	0	13	0	0
4	11	0	0	13	0	0
6	10	1	0	13	0	0
8	10	1	0	12	0	1
10	4	3	4	0	11	2
15	11	0	0	13	0	0
17	9	1	1	8	4	1
19	10	0	1	11	2	0
20	9	2	0	11	2	0
Kappa (S.E.)		0.13 (0.03)			0.41 (0.03)	
Animal bones:						
3	11	0	0	12	1	0
5	11	0	0	13	0	0
7	11	0	0	13	0	0
9	4	3	4	1	11	1
11	8	0	3	13	0	0
12	8	2	1	13	0	0
13	10	1	0	13	0	0
14	7	2	2	12	0	1
16	3	7	1	1	11	1
18	10	0	1	11	0	2
Kappa (S.E.)		0.21 (0.032)			0.665 (0.038)	

TABLE 4—*Summary of scores for differentiating 20 radiographs as representing human versus animal midshafts by profession.*[a]

		Radiographic Identification					
		Correct		Wrong		Difficult	
Profession	*n*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Archeologists	11	16.27	1.74	2.64	1.50	1.64	1.80
Dentists	13	16.08	0.95	3.62	1.04	0.69	1.18
t		0.35					

[a]Questions guessed are omitted from analysis.

professionals were tested using the Students t statistic. No significant difference between archeologists and dentists was noted. Archeologists correctly identified, without guessing, 80.9% of the sample compared with 78.5% correct for dentists.

Discussion

In reviewing the literature, no research studies were found suggesting the use of radiographs in the identification of human versus animal long bone fragments. The results of this study confirmed that participants were successful in distinguishing human from animal long bones, based on the proposed radiographic differences at a significant rate of probability. The effects of age, growth phase, and activity on bone morphology were not examined relative to the characteristic morphologies identified. The effect of these components need to be systematically studied to identify the degree to which they may impact on the reported reliability of this technique. The human bones used in this study were taken from biological supply house materials and primarily presented individuals morphologically aged from young to middle adult. The nonhuman animal bones represented subjects of both preadult and adult ages.

It was apparent from the study that some bones were difficult to identify because radiographic features resembled both human and animal. Raters had difficulty identifying bones 9, 10, and 16 for this reason. Of those who ventured a guess as to the identification of these bones, the overall percent correct responses (including correct guesses) was only 54.5%, standard deviation (SD) 39.5, suggesting that the radiographic characteristics originally described were not sufficient for the raters to distinguish species (Table 5). This compels us to conclude that when the radiographic appearance was not initially suggestive of human or animal, a guess as to the nature of the bone was not recommended. Statistical summary revealed that, overall, the archeologists guessed more often ($P = 0.153$) than the dentists and were correct more often (61.9%, SD = 34.3) than the dentists (41.7%, SD = 50.0); however, neither statistic was significantly different. It is interesting, however, that when guesses are included in the scores, a statistically significant overall difference in mean number correct between the two professions is indicated by the Wilcoxon test. We suggest that this significant disparity is due to the archeologists' better ability to follow the instructions of the study or to their training in attribute description, which allowed them increased interpretive abilities in this case. Previous experience in interpreting radiographs was not shown to be an important facet in correct classification.

Conclusions

Based on the results of this study, it was concluded that certain radiographic features are useful in identifying human versus animal long bone fragments. Also, in situations where the radiographic characteristics of a bone are difficult to distinguish, venturing a guess will not lead to a high frequency of correct identifications of bone species. Additional studies are planned, with a larger sample size, to further test the efficacy of this technique as a useful adjunct in forensic science identification.

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TABLE 5—*Scores with guesses included.*

	Total (n = 24)		Archeologist (n = 11)		Dentist (n = 13)		
Response	Mean	S.D.	Mean	S.D.	Mean	S.D.	P-value
No. right	16.8	1.3	17.4	1.5	16.4	1.0	0.049[a]
No. guessed	1.1	1.5	1.6	1.8	0.7	1.2	0.153
% right	84.2	6.7	86.8	7.5	81.9	5.2	0.049[a]
% guessed	5.6	7.7	8.2	9.0	3.5	5.9	0.153
% guessed right	54.5	39.5	61.9	34.3	41.7	50.0	0.626

[a]Significant difference between the two groups by the two-sample Wilcoxon test.

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