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Differences in Osteon Banding Between Human and Nonhuman Bone*

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ABSTRACT: The objective of this paper is to compare patterns of osteon organization in human and nonhuman bone. A linear organization of Haversian systems in nonhuman bone, where osteons line up in rows, has been reported but has not been quantified. The present research provides a quantitative examination of this observation through a comparative analysis of the femoral midshaft from human and nonhuman bone. Femoral midshaft thin sections from 60 humans were compared to femoral midshaft sections from nine sheep and six miniature swine. The presence or absence of osteon banding was recorded and, if present, described. Results indicate that 2 out of 60 human sections and 5 out of 15 nonhuman sections exhibit osteon banding ($\chi^2 = 9.46$; $p < 0.01$). Further, the type of banding present in the human and nonhuman samples is easily distinguished, indicating that human and nonhuman bone can be distinguished where banding is present in this study.

KEYWORDS: forensic science, forensic anthropology, histology, bone, Haversian system

The objectives of this paper are twofold: first, to compare patterns of osteon organization in human and nonhuman bone and, second, to determine whether these patterns are distinctive. In forensic anthropology, it is sometimes necessary to attempt to distinguish nonhuman from human bone based on extremely fragmentary material. In these instances, it is useful to examine the bone microscopically. The existence of pattern differences between human and nonhuman bone has been well established. For example, plexiform bone, which is defined by its horizontal, regular, rectangular organization (Fig. 1) is commonly found in nonhuman mammalian bone but is only rarely observed in human bone, specifically in young humans (1).

Other bone types are more difficult to distinguish between human and nonhuman bone. Secondary osteons, or Haversian systems, are discrete bundles of lamellar bone surrounding a Haversian canal and defined by a cement line. Secondary osteons replace primary bone and can be isolated, scattered or densely packed but tend to be distributed in a haphazard way (Fig. 2). Although most vertebrates do not exhibit dense Haversian bone like humans (2), comparative studies have shown that it may not always be possible to positively identify human bone (2, 3–5).

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In a case reported by Owsley et al. (6), secondary osteons were successfully used to distinguish human from nonhuman bone. Several bone fragments found in association with a forensic case needed to be identified as either deer or human in origin. Histological comparisons with the original autopsy human sample and known deer sample revealed that the fragments were consistent with the human sample. Specifically, secondary osteon density and Haversian canal areas were comparable to the human sample but not the deer sample.

Other types of bone organization may help to distinguish human from nonhuman bone. Enlow (1) describes the arrangement of primary osteons into distinct rows or layers as most common in young individuals in species that have a rapid overall or localized growth rate. This occurs because compact bone is built upon an organized network of cancellous bone. Typically, evidence of these osteons is obliterated over time due to cortical drift.

It was the presence of this type of pattern that was used by Ubelaker (7) to help identify a bone as nonhuman in a forensic case from Alaska. In this case, a fragment of bone with a pseudoarthrosis had been mended surgically with a metal plate well before death, suggesting that the bone might be human. A microscopic section revealed a pattern of layered osteon bands alternating with lamellar bands. Comparisons with a known dog bone revealed a similar pattern, including the involvement of primary and secondary osteons. It was determined that the bone likely belonged to a large dog and that a veterinarian had performed the surgery.

This forensic case provides grounds for the present study. This research examines the question of whether banding patterns provide distinguishing characteristics between human and nonhuman bone. Midshaft femora from a sample of sheep and miniature swine are compared with midshaft femora from a human sample to assess osteon organization and identify osteon bands.

Materials and Methods

Femoral midshaft thin sections from 60 subadult and adult humans ranging from 6 to 99 years of age at death, including 15 aged 5 to 19, 15 aged 20 to 49 and 30 aged 50 and above, were compared to femoral midshaft sections from nine subadult sheep, 1.5 years of age at death and six miniature swine, four months of age at death. The human undecalcified ground thin sections were taken from a collection of 158 skeletons of known sex and age at death recovered from urban cemeteries in the city of Santo Domingo, Dominican Republic. The sheep and miniature swine thin sections were prepared as part of a biomechanical study of nonhuman bone and were provided courtesy of George Washington University.

The entire section was observed for each individual at 40× and 100×, using a standard compound light microscope. The presence or absence of osteon banding was recorded and, if present, de-

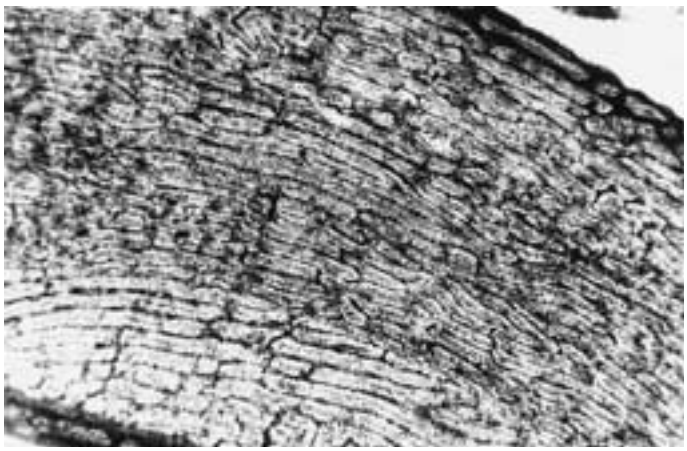

FIG. 1—*Plexiform bone of a sheep femur at 40×.*

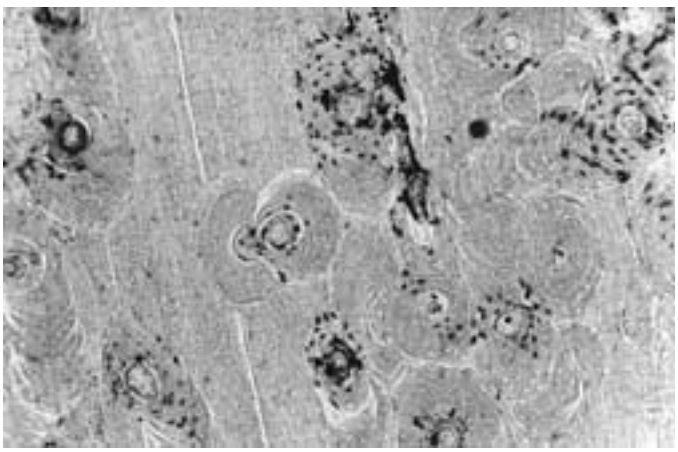

FIG. 2—*Haversian bone of a human femur at 100×.*

scribed. An osteon band was defined as a distinct row of five or more primary and or secondary osteons. The number of osteons in a band was recorded as well as the number of bands.

Results

Results indicate that two out of 60 human sections, four out of six miniature swine sections and one out of nine sheep sections (for a total of five out of 15 nonhuman bone sections) exhibit osteon banding. A chi-square 2 by 2 contingency table indicates that the observed differences between human and nonhuman bone are significant ($\chi^2 = 9.46$; $p < 0.01$). As shown in Table 1, a more detailed analysis of the types of patterns observed reveals further differences. In the two humans with osteon bands, including one adult female, aged 64 years and one subadult male, aged eight years, bands were isolated, consisting of five to six secondary osteons. In both cases, bands occurred within lamellar bone. In general, the human bone exhibited combinations of lamellar bone, primary canals, and primary and secondary osteons. Although there were a number of instances where primary and secondary osteons exhibited a basically linear pattern, osteons did not generally form distinct rows.

In the miniature swine, multiple, consecutive bands of mostly primary osteons ranged from 5 to 20 osteons long (Fig. 3). In three out of four specimens, bands were located in the posterior quadrant of the bone, along the endosteal edge. In one case, bands were located in the anterior quadrant along the endosteal edge. In general, osteon bands alternated with bands of lamellar bone. As shown in Fig. 3, bands were interrupted by resorption spaces in several instances. In one specimen, secondary osteons were occasionally incorporated into the band of primary osteons (Fig. 4). The remainder of each section consisted primarily of plexiform bone.

The one sheep that exhibited osteon banding had a sequence of eight secondary osteons that was surrounded by plexiform bone. In general, the sheep exhibited plexiform bone, with only two sheep exhibiting any osteons.

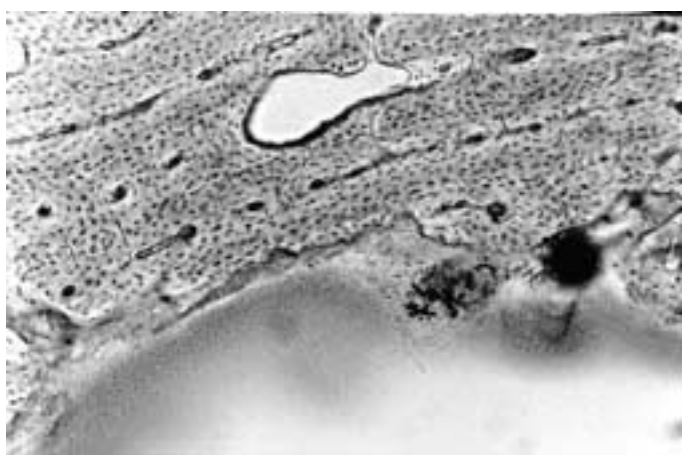

FIG. 3—*Osteon banding in a miniature swine femur at 100×.*

TABLE 1—*Descriptive data for specimens exhibiting banding patterns.*

Specimen Name	Specimen Type	No. of Bands	No. of Osteons in Band(s)	Osteon Type*	Quadrant	Envelope
2Fem	sheep	1	8	2	anterior	endosteal
Envy	swine	2	17, 13	1	posterior	endosteal
Wrath	swine	2	8, 8	1	posterior	endosteal
Gluttony	swine	3	5, 10, 6	1, 2	posterior	endosteal
Sloth	swine	2	21, 20	1	anterior	endosteal
CN-20c. 1	human	1	6	2	medial	middle
CO-32c	human	1	5	2	lateral	periosteal

* 1 represents the presence of primary osteons; 2 represents secondary osteons.

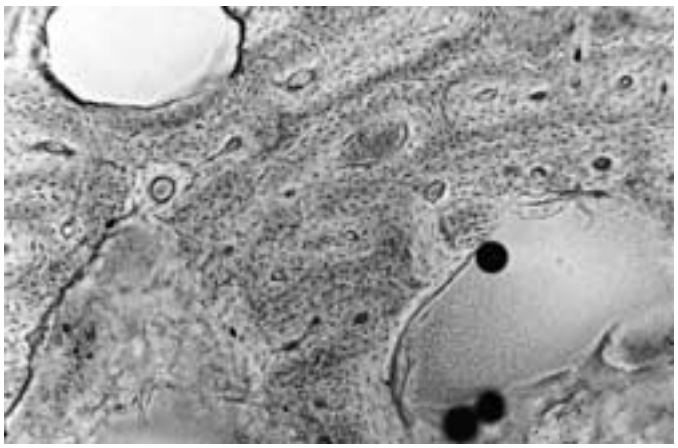

FIG. 4—*Osteon band including secondary osteon in a miniature swine femur at 100×.*

Discussion

In this study, human and nonhuman bone sections exhibited several microscopic differences. Most nonhuman bone was readily distinguished from human bone by the widespread presence of plexiform bone. The lack of osteon formation in the nonhuman samples may be partly attributed to the young age of the specimens, indicating that older specimens should be analyzed for further study of possible banding patterns.

Osteon distributions in the nonhuman bone sections exhibited a different pattern than in the human bone sections. In general, human bone exhibited various types of organization, ranging from a somewhat linear (but not distinct) arrangement of osteons to randomly scattered, sometimes densely packed, secondary osteons. The osteons observed in the miniature swine sections were organized in rows. The two exceptions to this generalization in the human sample were cases of short, isolated osteon bands and were easily distinguished from the multiple bands of varying length observed in the miniature swine as well as the short band of secondary osteons surrounded by plexiform bone observed in the sheep. Comparisons of younger human bone (from individuals younger than six years) are also needed, as osteon patterns may show arrangements more similar to that seen in the young nonhuman bone from this study.

The presence of several secondary osteons and resorption spaces within the primary osteon bands in the miniature swine sections may also indicate that at least initially, secondary bone formation may follow the pattern of the primary osteon bands. The known mature dog bone used as a comparison in the forensic case from Alaska exhibited banding that included numerous instances of secondary osteons. These observations indicate a need for future research to be conducted on the frequency of banding in mature nonhuman bone. Also, since this study of nonhuman bone was confined to two species and the midshaft femur, there is a need for additional studies to be conducted on other species and bones from other parts of the skeleton to better understand the frequency of osteon banding in nonhuman bone. Future studies could address other factors that could have an observable effect on bone organization such as body size and locomotor patterns.

The capability to identify subtle histologic differences between human and nonhuman bone could be of great importance in forensic analyses, particularly in cases where only small bone fragments are available. In some cases, nonhuman bone may be easily distinguished by the presence of plexiform bone. If a fragment lacks this reliable indicator, however, other factors such as banding patterns may be useful for identification.

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