J Forensic Sci, Sept. 2002, Vol. 47, No. 5
Paper ID JFS2001317_475
Available online at: www.astm.org

TECHNICAL NOTE

Spencer de Gruchy,[1] B.A.; and Tracy L. Rogers,[2] Ph.D.

Identifying Chop Marks on Cremated Bone: A Preliminary Study

ABSTRACT: The purpose of this analysis is to evaluate the effects of burning on hacking trauma inflicted with a cleaver and to assess the diagnostic potential of cleaver marks exposed to fire. Thirty pig forelimbs (radius and ulna) and 30 beef ribs were each subjected to five blows with a cleaver and five cuts with a knife prior to burning in an outdoor fire. Bones were deliberately agitated to ensure maximum cremation and induce fragmentation. Results indicate that hacking weakens bone, making fire-induced fragmentation more likely at the sites of trauma. Chop marks were easily identified on burned bone, their characteristics largely unaffected by cremation.

KEYWORDS: forensic science, animal bone, cleaver, cremation, hacking trauma, heat fractures

Cremation refers to the disposition of a body by fire (1). It is a custom observed in many cultures throughout time. In some countries, cremation has a history of being the prevailing method of body disposal; in others, it has only recently gained popularity due to land restrictions and the high cost of burial. In England, legal cremation accounted for 72% of the funerary practices conducted in 1998 (2). Similar rates have been observed in British Columbia, Canada (3), and the frequency of cremation continues to rise in the United States (2).

Illegal cremation is also a common method of body disposal (4,5). The popular view assumes fire will destroy all evidence of the manner and cause of death and make identification of a body virtually impossible. In fact, destruction of hard tissue is dependant upon several factors, including: temperature, duration of burning, agitation during burning, presence of accelerants, type of wood used, addition of water, presence of soft tissues, fresh versus dry bone, and cortical versus cancellous bone (6,7). Although it is difficult to analyze burned remains, the primary obstacle is the fragmentary and fragile nature of the material, not the absence of useable features, since complete eradication of a body by fire is rare (1,6,8,9). It is often possible to determine sex, estimate age, assess ancestry, and evaluate the pathological and traumatic conditions of burned human remains (4,6,10).

Some of the changes bone undergoes when exposed to fire can create difficulties for trauma analysis. When bone is heated, water evaporates, causing the hydroxy bonds of the apatite mineral to break down and fissures to occur. This causes the bone to crack, resulting in at least five different types of heat-induced fractures, including: longitudinal, curved transverse, straight transverse, delamination, and patina (8,10). Longitudinal fractures extend down the long axis of the bone and may twist slightly. Curved transverse, or thumbnail, fractures are arched and are said to indicate the presence of flesh during burning, although this is open to debate (8). The straight transverse fracture may intercept a longitudinal fracture at one end, forming a step, or may proceed short distances around the circumference of the bone. Delamination refers to the separation of cortical bone from cancellous bone, while patina occurs primarily at the epiphyses and has the appearance of old paint (8). Familiarity with the appearance of heat-induced fractures will aid in the interpretation of trauma on bone, particularly in distinguishing these taphonomic features from perimortem sharp force trauma.

Cut mark analysis is well represented in the literature (5,11–14). Knife wounds that affect bone result in relatively shallow V-shaped incisions with smooth sides and, occasionally, a slight ridge oriented parallel to the cut. Knife marks retain their characteristic appearance when exposed to fire (8,10). The literature concerning chop marks resulting from hacking trauma is less comprehensive. Perimortem chop marks have been observed, but not described, by a number of authors (10,15,16). Wenham provides the most complete analysis of hacking trauma, identifying a number of diagnostic characteristics that are independent of blade type (17). His criteria may be summarized as follows:

1. As the blade enters the bone it produces a smooth, flat, cut surface. If the angle of entry is greater than 90°, the obtuse surface will be smooth, the acute surface rough, ending in fractured bone.
2. At the margin of the acute surface, the outer bone layer detaches to form thin flakes. These flakes are usually missing in older remains, but are retained by the periosteum in recent cases.
3. Large fragments may fracture away from beneath the bone as the blade passes through it.

[1] Department of Anthropology, University of Alberta, Edmonton, Alberta, Canada.
[2] Department of Anthropology, University of Toronto, Mississauga, Ontario, Canada.
Received 14 Sept 2001; and in revised form 18 Feb. 2002; accepted 18 Feb. 2002; published 17 July 2002.

Humphrey and Hutchinson (18) tested the applicability of Wenham's descriptions to post-cranial pig bones hacked with cleavers, machetes, and axes, and assessed the replicability of the wound characteristics produced. They observed the following:

1. Chops made with a cleaver, perpendicular to the long axis of the bone, are incapable of penetrating the entire bone. Instead, kerf floors are produced (a kerf is the groove made by a cutting tool and the kerf floor refers to the point at which the cut terminates).
2. With few exceptions, cleaver trauma is characterized by a clean entry, approximately 1.5 mm wide at the midpoint, with a smooth obtuse-angled surface and a fractured acute-angled side.
3. Cleaver wounds do not produce radiating fractures at the entry site, but sometimes generate fractures from the kerf floor.
4. Striations are oriented perpendicular to the kerf floor.

Humphrey and Hutchinson conclude that cleaver damage to bone is recognizable and may be assessed with low interobserver error (18). Whether these diagnostic characteristics are retained when bone is subsequently exposed to fire and the probability of identifying cleaver damage on burned bone are unknown. The purpose of this analysis is twofold: it evaluates the effects of burning on hacking trauma inflicted with a cleaver and assesses the diagnostic quality of cleaver marks exposed to fire.

Materials and Methods

Thirty pig forelimbs (radius and ulna) and 30 beef ribs were selected for experimental cremation. Animal bones were used due to ethical considerations. Evidence suggests that there is little difference between the components of human and animal bone (19). Ribs were selected for this analysis because the chest is frequently targeted during an attack on a human being (20). Forelimbs were selected to represent defensive or parry wounds (12,13,20).

Approximately 1 cm of muscle remained on the pig forelimbs at the time of experimentation. The depth of tissue was intended to represent the estimated amount of flesh covering the posterior border of the human ulna. The forelimbs were frozen during the three-week collection period. Prior to burning, they were defrosted for approximately 1 h by means of a water bath. The ribs were purchased fresh and were never frozen. The meat was not removed from the ribs.

Five marks were made with both a cleaver (length of blade 16 cm, width of blade 0.2 mm) and a knife (length of blade 21.5 cm, width of blade 0.2 mm) on each bone prior to burning. The blows were randomly inflicted with variable strength to produce different depths and directions of trauma. The knife marks were made for comparative purposes to determine whether it is possible to distinguish them from chop marks, once bone is burnt.

Studies involving experimental cremations often employ blower furnaces, crematorium retorts, or electric ovens to allow investigators to control the temperature of the heat source and recover most of the bone (1,8,21). A small number of researchers have chosen to use outdoor fires to replicate the conditions associated with cremations of the past (7,22,23). In this analysis, an outdoor fire was used to mimic the circumstances of a forensic cremation. The fire was created at an orchard in Summerland, British Columbia, Canada. It was contained within a ring of steel measuring 107 cm in diameter by 42 cm high. Wood used included cherry, cedar, and small cedar shrubs. No accelerants were employed. Hardwood produces a hotter fire and causes greater bone destruction than softwood. The use of both hard and soft woods was intended to generate variable temperatures and resulted in fragmentary, yet identifiable fragments. The fire was tended and agitated periodically for 3 h to ensure the bones experienced the maximum amount of modification possible through cremation. The remains were cooled overnight. Fifteen hours after the fire had completely died, some of the bones were hot to the touch. They were placed in the wet grass to facilitate cooling and prevent further fragmentation.

The largest fragments were collected and packaged first. The pieces were evenly spaced in a box, layered between 2.5 cm of paper towel. The smallest fragments were collected by shovel shaving the fire debris and passing the material through a ¼ in. mesh screen. The fragments were packaged in paper towel and zip lock bags for transportation to the lab, 350 km away. Minimal bone dust was present when the bags were reopened at the lab.

Bones were sorted on the basis of visible trauma. A stereoscopic zoom microscope at 1.6× magnification was used to visualize the lesions clearly. The marks were identified on the basis of criteria established by Wenham (17) and Humphrey and Hutchinson (18), and examples were available for comparative purposes during the sorting process. Two measurements were taken for each lesion: maximum length and width.

An inexperienced individual was given the descriptions of cut marks and chop marks used in this analysis and asked to differentiate between cleaver and knife impressions in order to test the effectiveness of the descriptions as a means of classifying sharp trauma on burned bone.

Results

Chop marks made with the edge of a cleaver are characterized by their depth, appearance of their angled surfaces, and lack of entry fractures. The force of a chopping blow produces a V-shaped mark, notably deeper than the average cut mark. The point at which the cleaver enters the bone, the area of penetration, is smooth. The exit point is rough, due to the wrenching action of the blade as it is removed from the bone. Glancing blows produce oblong lesions with shallow angles of entry. Direct blows produce semicircular marks with steeper angles of entry (Fig. 1). Chop marks made with the tip of a cleaver are characterized by their triangular shape, smooth area of penetration, and depth (Fig. 2).

Marks made by using a knife to chop, in the manner of a cleaver, produced a recognizable V-shaped knife mark, with no area of penetration or roughened exit point. It did, however, produce a slight depression fracture on either side of the lesion.

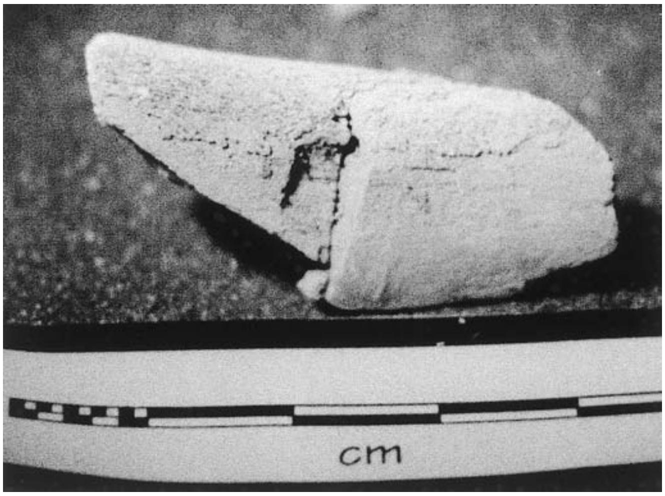

FIG. 1*a*—*Chop mark made by cleaver edge.*

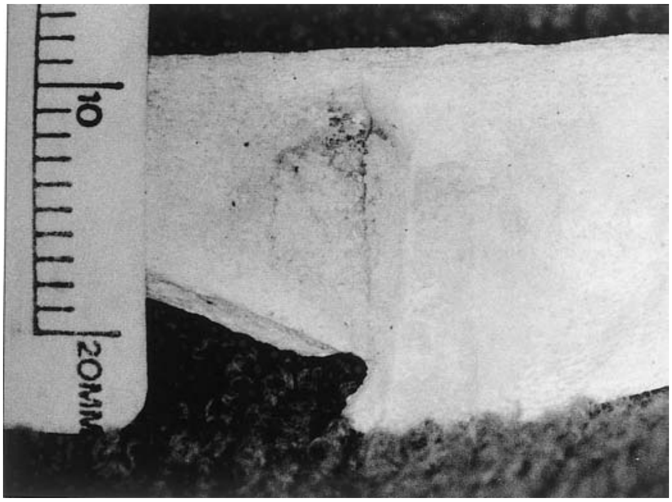

FIG. 1*b—Closeup of chop mark made by cleaver edge.*

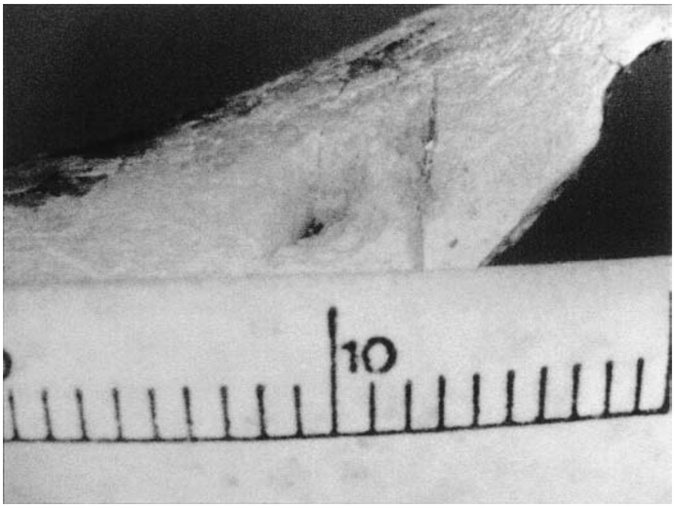

FIG. 2—*Triangular mark made by cleaver tip.*

The cremated bone exhibited high fragmentation, cracking, and white and light gray coloration. Chop mark characteristics were largely unaffected by burning, although bone shrinkage due to burning may slightly reduce the size of the mark. The only notable difference between chop marks observed on fresh and burnt bone was the size of the roughened point of exit, which increased when exposed to fire. Extracting the blade from the bone creates bone fragments that get burned off during cremation, producing a larger point of exit. Of the 150 chops inflicted on the forelimbs, 99 fragmentary and complete marks were identified on 83 cremated fragments. No conclusive chop marks were observed on the ribs due to the almost complete destruction of these elements by fire.

The trauma created by cleavers makes the bone susceptible to cracking and fragmentation near, or extending from, the chop mark. It is, therefore, essential to observe the fractured surfaces of cremated bone for evidence of trauma that may not be immediately apparent. Straight transverse fractures are the most common form of heat fracture associated with chop marks on cremated bone.

When faced with 83 cremated bone fragments and a description of cut and chop marks, the inexperienced observer identified 107 lesions as chop marks. Only 99 were true chop marks.

Discussion and Conclusions

Successful analysis of trauma on cremated bones is contingent upon the size and condition of fragments, which are significantly influenced by: temperature, duration of burning, agitation during burning, presence of accelerants, type of wood used, addition of water, presence of soft tissues, fresh versus dry bone, cortical versus cancellous bone, proper recovery of elements, and appropriate packaging and transportation of the material. The likelihood of recovering cremated bone is increased when those involved in the process are familiar with the human skeleton and have experience processing fire scenes.

The debris associated with a fire is extensive, even at a restricted scene involving the cremation of a human body in a single outdoor fire pit. In one case in British Columbia, Canada, experienced police investigators recovered 147 fragments of material, most of which was subsequently determined to be non-bone. In this example, crime scene personnel collected a sample of the material found in the pit. It was later discovered that the perpetrator attempted to expedite the destruction of the body through prodding and striking the remains, and stirring the contents of the fire. Under such circumstances, bone fragmentation increases, human remains become mixed with the debris in the pit, and smaller fragments shift to the bottom of the pile. Since antemortem trauma increases the susceptibility of the bone to fractures, smaller fragments that shift to the bottom are apt to exhibit evidence of trauma. It is imperative to screen all the material in a fire pit, including the soil forming the bottom and walls of the depression, to facilitate sorting and ensure complete recovery of the remains.

Cremated bone becomes increasingly difficult to analyze when it turns to dust due to poor handling. Separating fragments of burnt bone and packaging it in layers of paper towel secured in zip lock bags and protected by boxes was an effective means of transporting material in this analysis. To maintain the integrity of the bone, the fragments should be handled as little as possible and not repackaged until the analysis is complete. A designated workspace places the materials at the disposal of the investigator and decreases the need for movement of materials. Select samples may be embedded in epoxy to preserve their form and/or facilitate thin sectioning for histological age estimation.

Although this work is preliminary, it appears that chop marks inflicted with cleavers can be identified on cremated bone fragments as small as a few millimetres. When investigating an illegal cremation, the ability to identify a small portion of a chop mark on a piece of burned bone can point investigators in the direction of a potential weapon and result in a conclusive determination of the manner and mode of death.

Acknowledgments

The authors would like to thank Diana Rossi for her assistance, support, and participation in the interobserver error study; Dr. Mark Skinner for the use of his camera; and friends and colleagues for their suggestions.

References

1. Shipman P, Foster G, Schoeninger M. Burnt bone and teeth: an experimental study of colour, morphology, crystal structure and shrinkage. J Archaeol Sci 1984;11:307–25.
2. Mitford J. The American way of death revisited. New York: Alfred A. Knopf, 1998.

3. Morrison A, manager, Vancouver Memorial Services and Crematorium, personal communication.
4. Dirkmaat D, Adovasio J. The role of archaeology in the recovery and interpretation of human remains from an outdoor forensic setting. In: Haglund W, Sorg M, editors. Forensic taphonomy: the postmortem fate of human remains. Boca Raton: CRC Press 1997;39–64.
5. Stewart TD. Essentials of forensic anthropology. Springfield: Charles C Thomas, 1979.
6. Reinhard K, Fink M. Cremation in south-western North America: aspects of taphonomy that affect pathological analysis. J Archaeol Sci 1994;21:597–605.
7. Stiner MC, Kuhn SL, Weiner S, Bar-Yosef O. Differential burning, recrystallization and fragmentation of archaeological bone. J Archaeol Sci 1995;22:223–37.
8. Mayne P. The identification of precremation trauma in cremated remains [unpublished master's thesis]. Edmonton: University of Alberta, 1990.
9. Mayne Correia P. Fire modification of bone: a review of the literature. In: Haglund W, Sorg M, editors. Forensic taphonomy: the postmortem fate of human remains. Boca Raton: CRC Press 1997;275–93.
10. McKinley J. Cremated bone. In Sancton I Anglo-Saxon cemetery excavations carried out between 1976 and 1980. Archaeological J 1993;150: 243–365.
11. Frayer DW, Bridgens JG. Stab wounds and personal identity determined from skeletal remains: a case from Kansas. J Forensic Sci 1985;30:232–8.
12. Maples W. Trauma analysis by the forensic anthropologist. In: Reichs KA, editor. Forensic osteology: advances in the identification of human remains. Springfield: Charles C. Thomas 1986;218–28.
13. Merbs C. Trauma. In: Iscan MY, Kennedy KAR, editors. Reconstruction of life from the human skeleton. New York: Wiley-Liss 1989;161–189.
14. Sauer NJ. Manner of death: skeletal evidence of blunt and sharp instrument wounds. In: Rathbun TA, Buikstra JE, editors. Human identification: case studies in forensic anthropology. Springfield: Charles C. Thomas 1984;176–184.
15. Bond JM. Burnt offerings: animal bone in Anglo-Saxon cremations. World Archaeology 1996;28:76–88.
16. Gifford-Gonzalez D. Ethnographic analogues for interpreting modified bones: some cases from East Africa. In: Bonnichsen R, Sorg MH, editors. Bone modification. Peopling of the Americas Publication 1989; 179–246.
17. Wenham SJ. Anatomical interpretations of Anglo-Saxon weapon injuries. In: Chadwick Hawkes S, editor. Weapons and warfare in Anglo-Saxon England. Oxford: Oxford Committee for Archaeology Monograph No. 21, 1989;123–39.
18. Humphrey JH, Hutchinson DL. Macroscopic characteristics of hacking trauma. J Forensic Sci 2001;46:228–33.
19. Dunlop JM. Traffic light discoloration in cremated remains. Medicine, Science Law 1978;18:163–73.
20. Ormstad K, Karlsson L, Enkler L, Rajs J. Patterns in sharp force fatalities—a comprehensive forensic medical study. J Forensic Sci 1986;31: 529–42.
21. Bradtmiller B, Buikstra JE. Effects of burning on human bone microstructure: a preliminary study. J Forensic Sci 1984;29:535–40.
22. Buikstra JE, Swegle M. Bone modification due to burning: experimental evidence. In: Bonnichsen R, Sorg MH, editors. Bone modification. Peopling of the Americas Publication 1989;247–58.
23. Thurman MD, Willmore LJ. A replicative cremation experiment. North Am Archaeologist 1981;2:275–83.

Additional information and reprint requests:
Dr. Tracy Rogers
Department of Anthropology
University of Toronto at Mississauga
3359 Mississauga Rd North
Mississauga, Ontario
Canada
L5L 1C6
E-mail: trogers@utm.utoronto.ca