



## LJMU Research Online

**Ghui, M, Eliopoulos, C and Borrini, M**

**A proposed method for differentiating knives from cut marks on bone: A forensic anthropological approach**

<http://researchonline.ljmu.ac.uk/id/eprint/21503/>

### Article

**Citation** (please note it is advisable to refer to the publisher's version if you intend to cite from this work)

**Ghui, M, Eliopoulos, C and Borrini, M (2023) A proposed method for differentiating knives from cut marks on bone: A forensic anthropological approach. Medicine, Science and the Law. ISSN 0025-8024**

LJMU has developed **LJMU Research Online** for users to access the research output of the University more effectively. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in LJMU Research Online to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain.

The version presented here may differ from the published version or from the version of the record. Please see the repository URL above for details on accessing the published version and note that access may require a subscription.

For more information please contact [researchonline@ljmu.ac.uk](mailto:researchonline@ljmu.ac.uk)

<http://researchonline.ljmu.ac.uk/>

# A proposed method for differentiating knives from cut marks on bone: A forensic anthropological approach

Medicine, Science and the Law  
1–5

© The Author(s) 2023



Article reuse guidelines:

sagepub.com/journals-permissions

DOI: 10.1177/00258024231198912

journals.sagepub.com/home/msl



Melodi Ghui, Constantine Eliopoulos and Matteo Borrini

## Abstract

Knife cut marks have been extensively studied in forensic literature, and the results have been beneficial in identifying both the cut mark and implement type on bone. For this study, an assessment in differentiating knife cut marks has been attempted by using sword cut mark characteristics. In addition, a flowchart was created to assist in interpreting such marks. Knives of different serrations (non-serrated, macro- and micro-serrated) were used to inflict cut marks on pig ribs with a forward and backward stab thrust. The analysis revealed that some traits adapted from previous studies applied to knife cut marks and that non-serrated and serrated marks could be distinguished accurately using the flowchart. The distinction between different types of serrated blades was not as successful. However, results show that further research and development of the flowchart can be invaluable in similar analyses.

## Keywords

Forensic science, forensic anthropology, sharp force trauma, knives, cut marks, flowchart, microscopic analysis

Experimental skeletal trauma research has successfully identified characteristics that match a cut mark to an implement.<sup>1–3</sup> In homicides, blunt and sharp force trauma are the most frequent causes of injury and death.<sup>4–5</sup> A survey of the United States medical examiners' offices found sharp force trauma to be the third most common form of trauma.<sup>6</sup> Additionally, in the United Kingdom, sharp force trauma has been suggested to be the leading cause of murder,<sup>7–8</sup> as knife-related assaults have increased by 9% in the last year.<sup>9</sup> Hence, studying sharp force trauma (SFT) in forensic contexts is valuable to understand its impact on the human skeleton further. Several recent studies have advanced our knowledge of the processes involved in sharp force trauma.<sup>10–13</sup> They have also shed more light on the different variables of injury and bone biomechanics and, in some cases, enabling the identification of the causative tool of a cut mark.<sup>1</sup> Per the Daubert standard, a proposed methodology should be subjected to peer review and testing before it is accepted by the scientific community and the legal system.<sup>14</sup>

Several authors have analysed knife cut marks on animal bones and have utilised various traits to identify the implement used. However, a standardised set of characteristics and terminology needs to be improved between studies in this area. Hence, the present study aims to standardise knife cut mark characteristics for identifying and differentiating weapon types. The criteria used in this research were

adapted from studies on sword and saw cut marks due to the similarities between both forms of sharp force trauma.<sup>15–16</sup>

Moreover, this study presents a flowchart (Figure 1) designed to assist in the knife-type determination process for forensic analysis and training practitioners in the field, e.g., forensic anthropologists, physicians and crime scene officers.

## Materials and methods

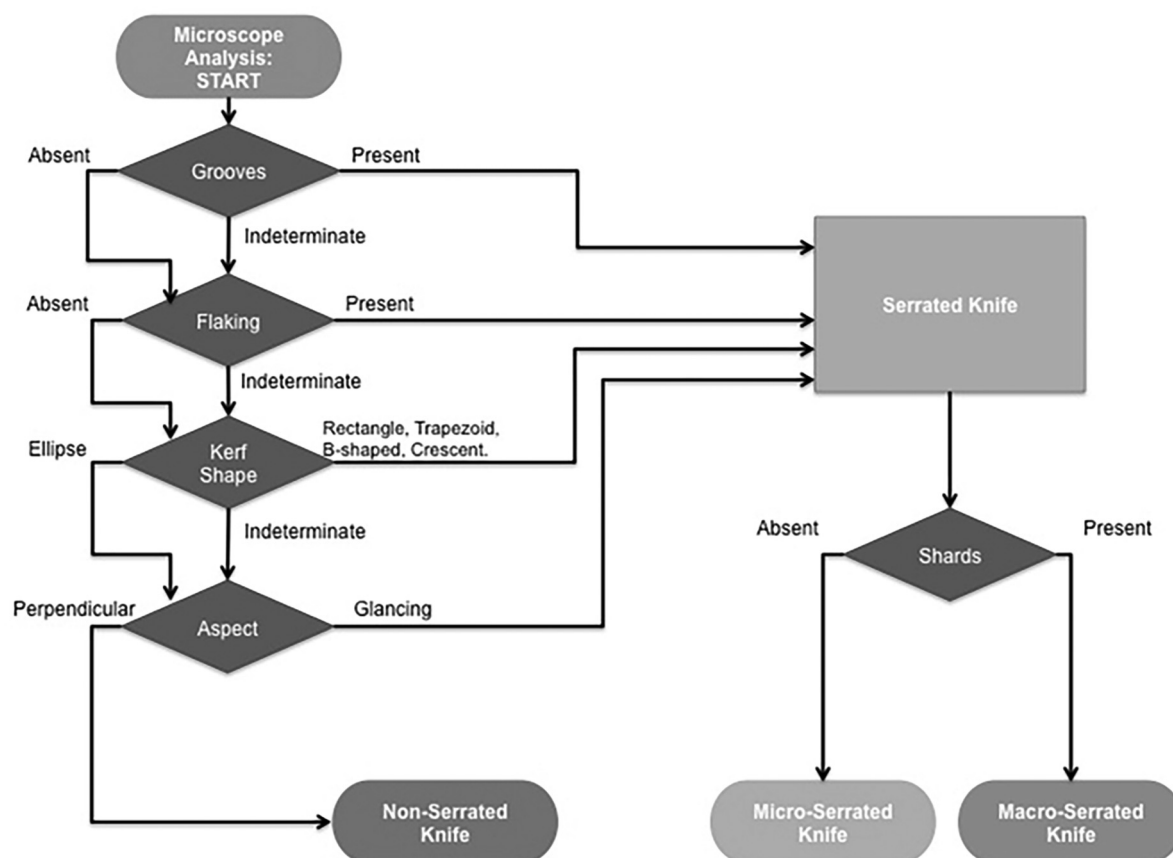
Domestic pig (*Sus scrofa*) rib bones were purchased from local butchers: no animals were killed for the present study. Porcine bones were selected for their suitability as substitutes for human rib bones, mainly due to their similarities in morphology, mineral density and macrostructure.<sup>8,17–18</sup> However, choosing to utilise porcine bones could present an aspect that may affect the results. For example, their denser trabecular matrix leads to difficulty in identifying cut-mark characteristics.<sup>17,18</sup> Likewise, as a

School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool, UK

### Corresponding author:

Matteo Borrini, School of Biological and Environmental Sciences, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, United Kingdom.

Email: m.borrini@ljmu.ac.uk



**Figure 1.** The flowchart for differentiating between knife types.

proxy for human bone, pig bone is similar but not identical in exhibiting cut marks that would be present on the human skeleton. Ribs were specifically chosen, as the thorax is a common site of stabbing incidents and has been used frequently in forensic anthropological research.<sup>8,19–21</sup> Before the experiment, the manually defleshed specimens were macerated in untreated tap water.<sup>22</sup> The bones were then left to dry, numbered and labelled to guarantee precise data recording.

The authors categorised the 15 knives into two broad groups: non-serrated (5 knives) and serrated (10 knives). Serrated knives were differentiated further into macro-serrated and micro-serrated (5 knives each) according to the width between each serration, calculated in teeth per inch (TPI).<sup>23</sup> This measurement was taken using a standard digital calliper; the average width of macro and micro-serrated knives was 5 TPI and 8 TPI, respectively.

All the knives used in the present study had one bevelled edge on the left side of the blade. A metal table clamp was used to ensure that the bone was stabilised before cuts were made swiftly forward and backward, perpendicular to the edge of the bone. The knife was rinsed under untreated tap water between each cut mark to remove any bone fragments. This was performed to ensure that no fragments would be left in the following cut, which could result in misinterpretation during analysis. Each knife was used to make ten cut marks

on the ribs, resulting in 150 cut marks. The first author inflicted these cut marks, using her right hand to strike the bone along the cranial and caudal edges of the bone.

All nine traits used in the present study are described in Table 1. The majority of these have been based on the definitions by Lewis.<sup>15</sup> However, two new characteristics have been identified by the authors of this study: the “B-shape” of the kerf (a subcategory of trait 9) and grooves along the kerf edge (trait 3, Figure 2). Additionally, the crescent shape of the kerf has been added as another subcategory of trait 9. Although the crescent shape incision was identified by Ferllini<sup>27</sup> previously, the assessment of the shape in differentiating between the knife types was not clarified in her study.

Two other traits from Lewis’ study, breaking and cracking, are not included in the present study. These characteristics seemed inapplicable to knives because a sufficient amount of force and blade weight is needed to cause such damage to bones.

According to common procedures for tool mark analysis,<sup>8,28–30</sup> all cut marks inflicted on the ribs were examined and evaluated with a stereo-zoom microscope. In this case, a Microtec ( $10^7 \times 10^{45}$ ) with a Microtec 5 mg CMOS colour camera (TEC Microscopes LTD, Somerset, England) was used.

**Table 1.** The nine traits adapted and used for microscopic analysis.

Trait	Description of Trait	
Trait 1	False starts	Normally used as a trait in saw cut marks, false starts are multiple cuts with an established kerf or cut in the bone. <sup>23</sup>
Trait 2	Shape of the kerf at cross-section	The shape of the cut mark produced when viewed cross-sectionally. The cut can include one of the following four shapes: V, U, W, Y. <sup>15,24–26</sup>
Trait 3	Grooves along the kerf edge	The presence or absence of grooves along one edge of the kerf wall, typically on the bevelled side of the knife.
Trait 4	Flaking	The breakage of bone that is flake-like during the forward and backward motion of the blade. <sup>15</sup>
Trait 5	Feathering	Small, “wispy” damage to the surface, sides or edges of the cut mark. <sup>14</sup> Also known as lateral pushing back, where the edge of the wall of the kerf is “pushed back”.
Trait 6	Location of feathering	Bilaterally or unilaterally (left or right according the anatomical location of the cut).
Trait 7	Shards	Tiny splinters within the kerf of the cut mark. <sup>15</sup>
Trait 8	Aspect of entry	The aspect, or angle of entry can be perpendicular (symmetrical) or glancing (asymmetrical). <sup>15</sup>
Trait 9	Kerf shape at the cut mark	Five unique shapes that can be seen when viewed cross-sectionally: Ellipse, rectangle, trapezoid, B-shaped, crescent-shaped. <sup>15,27</sup>

**Figure 2.** Example of grooves along the kerf wall.

## Results

To ascertain whether the traits identified in this study correlate to the different categories of knives, statistical tests such as  $\chi^2$  tests were conducted. The statistical analysis of the nine traits showed that they are all linked to the various knife types. Four traits were chosen as they best differentiated between non-serrated and serrated knives. These four traits are shown in Table 2. Trait 7, shards, was chosen to differentiate between micro and macro-serrated knives (Table 2).

As an additional tool in the classification of cut marks, a flowchart was developed based on the accuracy of each trait. The flowchart aims to enable the classification of blades used to inflict trauma on the bone from the microscopic morphological characteristics of the cut mark.

As a final test, the accuracy of the flowchart was checked by performing a blind test on 30 additional cut marks made by two external participants (one male and one female, both using their right hand). Using the flowchart, the first author assessed the cut marks without prior knowledge of which blade was used. Additionally, ten observers were selected among Liverpool John Moores University (LJMU) forensic

**Table 2.** Traits chosen for differentiation between knife types.

	Trait	$\chi^2$ and p-value
Non-serrated vs. Serrated knives	Grooves along kerf edge	$\chi^2 = 55.98$ , $p = 5.991$
	Flaking	$\chi^2 = 18.55$ , $p = 5.991$
	Kerf shape	$\chi^2 = 145.54$ , $p = 5.991$
	General aspect	$\chi^2 = 159.42$ , $p = 5.991$
Micro vs. Macro-serrated knives	Shards	$\chi^2 = 25.91$ , $p = 5.991$

anthropology undergraduate and postgraduate students. These participants had different levels of experience in bone analysis but no prior knowledge and training on cut marks.

They were subjected to a similar blind test of 100 cut marks using the original set of cuts. A microscopic assessment of these cut marks was made using the flowchart, and the definitions of the traits were given to assist in identifying the knife type used.

The outcome of the blind test revealed that the accuracy in differentiating between non-serrated and serrated knives ranged from 61–90%. However, the accuracy of discriminating between the two types of serrated knives was lower at 28–56%. Overall, postgraduate students performed better at linking the knife type to its resultant cut mark.

## Discussion

Several studies in the past have successfully identified knife blade characteristics on bone.<sup>8,16,25,29–33</sup> Some of these have compared traits not included in this study, such as the length or width of the cut mark. These were excluded from the present study due to the lack of consistency related to the amount of force, angle, and motion of the implement, as well as the porosity of the bone. The present research has selected traits that performed well

when tested and provide a high accuracy rate of distinguishing between non-serrated and serrated knives.

This study demonstrates not only that there is a correlation between the characteristic of the marks left by a blade on the bones but also that some of them are more diagnostic than others. The most indicative traits for knife-type determination are the shape of the kerf mark at the cross-section, flaking, feathering, the aspect of entry, grooves along the kerf edge and kerf shape. As a characteristic in differentiating between serrated knives, the presence of shards in the kerf can confirm whether a micro-serrated knife was used. However, a small number of macro-serrated inflicted kerfs was found to have shards. This anomaly may account for the low accuracy of the differentiation between micro and macro-serrated blades. To increase the accuracy and reliability of the classification, more traits should be identified, such as shard detail, angle or other traits. Once these have been tested and proved accurate, they should be introduced as additional steps in the flowchart. It is also important to note that the participants involved in the accuracy test had no prior knowledge of cut mark analysis, which reasonably affected the value of the results. For this reason, accuracy is expected to increase if experienced individuals perform the tests. However, considering the observers' limitations, the results seem promising and supportive of the role of the flowchart as a valuable teaching tool.

Before starting the experiments, it was hypothesised that the results from this study would be dissimilar to those in the study by Lewis.<sup>15</sup> This was assumed due to the utilisation of different implements (knife vs sword) and motion (i.e., stabbing vs chopping). However, it was found that some of the traits are transferrable from one category (sword) to the other (knife). Despite the differences in size, weight and ability to inflict a cut mark on bone, the results from the independent and blind tests have shown that the function of the implement is negligible when interpreting cut marks. Using some of the traits described by Lewis<sup>15</sup> and other sources,<sup>8,15,25,34</sup> we could differentiate between non-serrated and serrated knives.

## Conclusions

Despite the differences between swords and knives, the results of this study have shown that the traits from sword cut marks can be modified, adapted and identified in knife cut marks. These traits can also differentiate between non-serrated and serrated knives and supplement other features utilised in the field. Identifying a new characteristic provides an additional distinct marker in differentiating between non-serrated and serrated knives as well, even if improvement on the number and quality of traits is required in this specific field of research. Moreover, this study has explicitly shown that using a flowchart has proven effective and valuable and can be employed as a tool in performing such analyses.

Even though the results in differentiating between micro- and macro-serrated knives are promising, the authors agree that further work should be conducted to increase the degree of accuracy. It is hoped that the flowchart can be used as a teaching tool and by practitioners in examining cut marks on bone.

## Acknowledgements

The authors would like to thank all our colleagues at the 68<sup>th</sup> Meeting of the American Academy of Forensic Sciences in Las Vegas, Nevada, in February 2016, for giving us some constructive feedback on our work.

## Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.



## Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

## Previous distribution and/or publication

This work was presented as a poster at the 68th Meeting of the American Academy of Forensic Sciences in Las Vegas.

## ORCID iDs

Constantine Eliopoulos  <https://orcid.org/0000-0002-5285-6770>  
Matteo Borrini  <https://orcid.org/0000-0003-3863-4992>

## References

1. Kroman AM and Symes SA. Investigation of skeletal trauma. In: DiGangi EA and Moore MK (eds) *Research methods in human skeletal biology*. Oxford: Elsevier, 2013, pp. 219–239.
2. Dirkmaat DC, Cabo LL, Ousley SD, et al. New perspectives in forensic anthropology. *Am J Phys Anthropol* 2008; 137: 33–52.
3. Gibelli D, Mazzarelli D, Porta D, et al. Detection of metal residues on bone using SEM-EDS—part II: sharp force injury. *Forensic Sci Int* 2012; 223: 91–96.
4. Fischer J, Kleemann WJ and Tröger HD. Types of trauma in cases of homicide. *Forensic Sci Int* 1994; 68: 161–167.
5. Orthmann CH and Hess KM. *Criminal Investigation*. 10th ed. Delmar, NY: Delmar Cengage Learning, 2004.
6. Smith OC, Pope EJ and Symes SA. Look until you see: identification of trauma in skeletal material. In: Steadman DW (eds) *Hard evidence: case studies in forensic anthropology*. London: Pearson Education, INC., 2009, pp. 190–204.
7. Knight B. The dynamics of stab wounds. *Forensic Sci* 1975; 6: 249–255.
8. Thompson TJU and Inglis J. Differentiation of serrated and non-serrated blades from stab marks in bone. *Int J Legal Med* 2009; 123: 129–135.
9. ONS. Crime in England and Wales: Year ending December 2015 [Internet]. 2015 [cited 2016 Mar 9]; Available from: <https://www.ons.gov.uk/peoplepopulationandcommunity/crime>

- andjustice/bulletins/crimeinenglandandwales/yearending december2015#summary-by-crime-type.
10. Tucker BK, Hutchinson DL, Gilliland MF, et al. Microscopic characteristics of hacking trauma. *J Forensic Sci* 2001; 46: 234–240.
  11. Symes S, Williams J, Murray E, et al. Taphonomic context of sharp-force trauma in suspected cases of human mutilation and dismemberment. In: Haglund WD and Sorg MH (eds) *Advances in Forensic Taphonomy Method, Theory, and Archaeological Perspectives*. Boca Raton, FL: CRC Press, 2002, pp. 404–433.
  12. Crowder C, Rainwater CW and Fridie JS. Microscopic analysis of sharp force trauma in bone and cartilage: a validation study. *J Forensic Sci* 2013; 58: 1119–1126.
  13. Lynn KS and Fairgrieve SI. Microscopic indicators of axe and hatchet trauma in fleshed and defleshed mammalian long bones. *J Forensic Sci* 2009; 54: 793–797.
  14. *Daubert vs Merrell-Dow Pharmaceuticals Inc.* U.S. Supreme Court. 1993.
  15. Lewis JE. Identifying sword marks on bone: criteria for distinguishing between cut marks made by different classes of bladed weapons. *J Archaeol Sci* 2008; 35: 2001–2008.
  16. Symes SA, Chapman EN, Rainwater CW, et al. *Knife and Saw Toolmark Analysis in Bone: A Manual Designed for the Examination of Criminal Mutilation*. 2010.
  17. Pearce AI, Richards RG, Milz S, et al. Animal models for implant biomaterial research in bone: a review. *Eur Cells Mater* 2007; 13: 1–10.
  18. Aerssens J, Boonen S, Lowet G, et al. Interspecies differences in bone composition, density, and quality: potential implications for in vivo bone research. *Endocrinology* 1998; 139: 663–670.
  19. Capuani C, Telmon N, Moscovici J, et al. Modelling and determination of directionality of the kerf in epifluorescence sharp bone trauma analysis. *Int J Legal Med* 2014; 128: 1059–1066.
  20. Hunt AC and Cowling RJ. Murder by stabbing. *Forensic Sci Int* 1991; 52: 107–112.
  21. Karlsson T. Homicidal and suicidal sharp force fatalities in Stockholm, Sweden. Orientation of entrance wounds in stabs gives information in the classification. *Forensic Sci Int* 1998; 93: 21–32.
  22. Steadman DW, DiAntonio LL, Wilson JJ, et al. The effects of chemical and heat maceration techniques on the recovery of nuclear and mitochondrial DNA from bone\*. *J Forensic Sci* 2006; 51: 11–17.
  23. Symes SA. Morphology of saw marks in human bone: identification of class characteristics. 1992.
  24. Shipman P. Applications of scanning electron microscopy to taphonomic problems. *Ann N Y Acad Sci* 1981; 376: 357–385.
  25. Tennick CJ. *The Identification and Classification of Sharp Force Trauma On Bone Using Low Power Microscopy*. 2012.
  26. Bartelink EJ, Wiersema JM and Demaree RS. Quantitative analysis of sharp-force trauma: an application of scanning electron microscopy in forensic anthropology. *J Forensic Sci* 2001; 46: 1288–1293.
  27. Ferllini R. Macroscopic and microscopic analysis of knife stab wounds on fleshed and clothed ribs. *J Forensic Sci* 2012; 57: 683–690.
  28. Love JC, Derrick SM, Wiersema JM, et al. Validation of tool mark analysis of cut costal cartilage\*,†. *J Forensic Sci* 2012; 57: 306–311.
  29. Kooi RJ and Fairgrieve SI. SEM And stereomicroscopic analysis of cut marks in fresh and burned bone. *J Forensic Sci* 2013; 58: 452–458.
  30. Puentes K and Cardoso HFV. Reliability of cut mark analysis in human costal cartilage: the effects of blade penetration angle and intra- and inter-individual differences. *Forensic Sci Int* 2013; 231: 244–248.
  31. Shaw K-P, Chung J-H, Chung F-C, et al. A method for studying knife tool marks on bone. *J Forensic Sci* 2011; 56: 967–971.
  32. Bailey Ja, Wang Y, van de Goot FRW, et al. Statistical analysis of kerf mark measurements in bone. *Forensic Sci Med Pathol* 2011; 7: 53–62.
  33. Tegtmeier CE. *A Comparative Analysis of Serrated and Non-Serrated Sharp Force Trauma to Bone*. 2012.
  34. Capuani C, Rouquette J, Payré B, et al. Deciphering the elusive nature of sharp bone trauma using epifluorescence macroscopy: a comparison study multiplexing classical imaging approaches. *Int J Legal Med* 2013; 127: 169–176.