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Sharp Force Trauma: the Effects of Blade Damage on Cut Mark Characteristics

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Abstract

A considerable number of homicides in the UK are committed by stabbing. While tool mark analysis is fairly accurate in identifying class characteristics of the knife that caused a certain cut mark, the literature lacks studies about individual characteristics transferred from the knife blade to the cut mark. The aim of this study was to determine whether damage on a knife blade was capable of transferring individual characteristics that are unique enough to identify a specific suspect weapon. The blades of six knives were damaged in different ways and used to stab pig ribs (*Susscrofadomesticus*). The results of this study proved that entrance and exit shape, kerf floor and grooves on the kerf walls closely corresponded to the damage on the knife blade. While it might not yet be possible to identify a specific knife from a cut mark, this study positively recognized on which side of the blade the damage occurred, by assessing the characteristics of the cut marks. These findings can prove to be very useful in investigations where stab marks are caused by a knife with a damaged blade.

Keywords

Forensic Anthropology; Sharp Force Trauma; Knife Type; Cut Mark Analysis

Introduction

In the UK, the most frequently encountered homicide is committed by stabbing. [1-3]. While the UK imposes a very strict gun law that restricts access to guns, knives are easily available. Simple kitchen knives are the most frequently reported weapon in fatal domestic stabbings [1, 2, 4, 5]. Only a small number of stabbings are committed on the street with a pocket knife [5]. Several studies conducted agree that the chest was the most common area to be stabbed [1, 2, 6-8]. As a result of the tightly stretched tissue across the ribs, a knife can easily penetrate the skin in this area and result in sharp force trauma to the ribs, sternum and vertebrae [3]. Sharp force trauma is defined as trauma that is caused by a tool with a point or bevelled edge [9-12]. The slow-loaded, compressive and narrowly focused force of any tool with an edge bevel can cause an incision into soft tissue and bone [10]. When analysed, this incision can provide indications of class characteristics of a suspect weapon used in the crime. A close cooperation between forensic anthropologists and tool mark experts is necessary in order to achieve the best results in sharp force trauma analysis. While the former are responsible for discovering, locating and classifying the trauma type and timing, the latter aretasked with determining the class of tool used as well as comparing characteristics of the impression with a suspect tool [13]. A well-studied example of these class

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characteristics is the absence or presence of striations on the kerf wall of a cut mark, which can class the suspect weapon into non-serrated or serrated knives [8, 14-20]. Burd and Kirk [21] suggested that in cases where it is possible to attain the shape and dimensions of a compression mark, and where these characteristics are individual enough, it might be possible to identify an individual weapon by the mark caused by it. To study how individual traits affect the characteristics of cut marks, knives with damage to the blades were used in this study to stab pig ribs (*Susscrofadomesticus)*. The aim of this study was to determine whether damage on a knife blade was capable of transferring individual characteristics that are unique enough to identify a specific suspect weapon.

Materials and Methods

Bone Sample Preparation

Four racks of fresh pig (*Susscrofadomesticus*) ribs were purchased from a local supermarket. The pigs came from France but any further information such as age and rearing conditions of the animals were not available. Pig ribs have been chosen for this study because of their known close similarity in their structure and general density to that of human bone [4, 8].

Each rack was left to simmer in a pot on a hot plate for about one and a half hours. From time to time, any loose pieces of meat were removed with plastic forceps. No metal instruments were used in an effort not to leave any marks on the bone. Once the main pieces of meat were removed, Terg-A-Zyme biological detergent was added to the water to dissolve the grease on the bones. The bones were then taken out of the water and the rough side of a dish sponge and washing up liquid were used to remove any last pieces of meat and grease.The bones were left to air dry on a trayfor one day.

Knife Preparation

Standard knife terminology and anatomy is used according to Pounder and Reeder [17]. The edge of the blade described the cutting edge of the knife; opposite this edge, on the top of the blade was the spine of the knife. In single-edged knives, this surface is unsharpened. The forward quarter of the blade was termed the tip of the blade and included the point of the knife. The right side of the blade described the side of the blade that was on the right when holding the knife by the handle, tip uppermost and the edge facing away from the person holding the knife. Likewise, the left side was the left side of the blade under the same conditions. Grinding referred to the sloping of one side of the blade edge to the midline, which was manufactured into the knife blade to produce a sharp cutting edge.

In total, nine knives were used in this study, three non-serrated, three micro- and three macro-serrated knives (Table 1). One knife of each type was used as the control. Knives are referred to as non-serrated control (N/C), micro-serrated control (Mi/C) and macro-serrated control (Ma/C); no damage was inflicted to these knives, and they were not used previously to ensure that there was no use damage on the blade. To imitate wear and tear of a knife blade from use, the blade of the second knife of each type was damaged using a hammer and pliers.Knives are referred to as non-serrated damage 1 (N/D1), micro-serrated damage 1 (Mi/D1) and macro- serrated damage 1 (Ma/D1). This treatment resulted in small nicks on the non-serrated blade and bend teeth in the serrated blades. The same was done to a second knife of each type but to a greater extend, resulting in more severe damage (knives are referred to as non-serrated damage 2 (N/D2), micro-serrated damage 2 (Mi/D2) and macro-serrated damage 2 (Ma/D2). The sharpness was also taken from the blades by using them on the flat surface of a hammer.

Inflicting the Cut Marks

Test trials were conducted to find the best method to stab the bones. The stabbing was conducted by the first author using the right hand. A comfortable position was found with the left foot forwards and 30cm away from the foot of the table and the right foot further behind and 62.5 cm away from the foot of the table. These positions were marked with tape on the floor, so the same distance to the target could be maintained throughout the experiment. With the feet in position and slightly bend knees, the bone was then stabbed with the elbow of the arm holding the knife moving from the side of the body at chest height in a forwards and backwards movement. The bone, in a clamp fixed to the table, was struck perpendicular to its long axis. in the same fashion, each knife was used to produce 20 cut marks, three on each cranial and caudal surface of the ribs, resulting in a total of 180 cut marks. Every effort was made to keep the force and the angle of the stab as constant as possible throughout the experiment. With a marker pen, the side of entrance of the knife was marked on each cut as well as the code for the knife that was used to inflict the cut mark.

Table 1: Class characteristics of the three types of knives used.

Knife type	Non-serrated	Micro-serrated	Macro-serrated
Code	N/C	Mi/C	Ma/C
Total length	9.45“; 24cm	7.20“; 18.3cm	12.6“; 32cm
Blade length	5“; 12.7cm	3.66“; 9.3cm	7.9“; 20cm
Blade grinding	left and right	left and right	left
Handle to first serration	0.47“; 1.2cm	0.39“; 1cm	0.6“; 1.5cm
Tip to first serration	n/a	none	0.4“; 1.1cm
Teeth per inch	n/a	21	5

Microscopic Analysis

The cut marks on the ribs were then viewed with a light microscope and the following traits were observed:

*Entrance shap*e: the bone was viewed from the side that was marked as the entrance and the observed shape of the cut was noted down.

Exit shape: was observed from the opposite site as the entrance shape and recorded the shape of the cut left when the tip and part of the knife blade exited the bone.

Kerf floor: the kerf floor was observed by looking from straight above into the cut mark and the characteristics were noted down [4, 22].

Edge mound: described any bone that was pushed out of the cut mark by the knife and was now mounded on the edges around the cut. Here, the side that the edge mound occurred was also recorded [15].

Shards: described any small pieces of bone found in the cut mark and their presence or absence was recorded [23].

Wastage: described the loss of a piece of bone around the cut mark due to breakage caused by the knife [8]. The side on which the wastage occurred was recorded.

False starts: described any small incisions around the cut mark made by the knife before the actual cut mark [24].

Grooves on the kerf wall: described any grooves, striations or irregularities along the kerf walls.

Results

A Spearman's correlation test was conducted to analyse the relationship between the nine different knives and the characteristics observed on the cut marks. This test is used to determine the covariation between two variablesand whether they increase or decrease proportionally [25].

Observed was a strong positive correlation between these pairs: knife type and entrance shape, knife type and false starts and knife type and grooves on the kerf walls. Strong correlation was also found between entrance shape and grooves on the kerf walls, kerf floor and shards and kerf floor and grooves on the kerf walls.

In order to determine differences between the data as a whole, the Kruskal-Wallis test was conducted. The Kruskal-Wallis test is used to determine whether two or more samples originate from the same distribution. While this test indicates that at least one of the samples is significantly different from the other, it does not identify which of the samples it is [26].

The data exhibited significant difference between the nine different knives and the median of each characteristic observed in this study ($p< 0.05$).

A Mann-Whitney test was performed to test for significant difference between the median of two independent samples. In contrast to the Kruskal Wallis test, the Mann-Whitney U test determines the exact sample that significantly differs from the other [27]. The results of this test illustrated that the great majority of tests reported significant difference. It came to attention that in most cases where no significant difference was observed, one of the variables tested was edge mound or false starts.

Discussion

Burd and Green state that the impression made into a surface is the negative reproduction of the tool surface [28]. This principle could be observed in this study, where the shape of the cut marks changed with the different knife types and also with the different damage inflicted to the knife blade. Therefore, to determine which of the nine different knives caused a cut mark, the entrance as well as the exit shape proved to be highly indicative of a certain knife, but also other characteristics showed high significance and were therefore valuable. Figure 1 summarises all the entrance shapes observed and the knife that caused the shape.In accordance with this principle, the overall shapes of the cut marks were characteristic V-shapes (figure 1) [4,13,14, 19, 20, 22, 23], but these changed depending on the side of the edge grind and the damage caused to the blade. The Ma/C knife for example, left wider cut marks in the bone than the N/C and Mi/C because the blade itself was wider [20]. Additionally the

Ma/C blade was ground on the left side and therefore the V-shape changed to a -shape (figures 1, 2) where the grind on the left side caused the curved left arm of the V.

In the cuts made with the Mi/D2 knife for example, where the teeth of the knife were bent to the left and the right side, the cuts were found to be -shaped (figures 1, 3) andtherefore closely resembling the shape of the knife.

In the Ma/D2 knife, where the teeth were not completely bent, but only the scalloped tips of the teeth, the V-shape changed to a -shape (figure 1), where the damaged blade left a jagged kerf floor.

Figure 1:The reproduced entrance and exit shapes and their frequency of occurrence (in percentage).

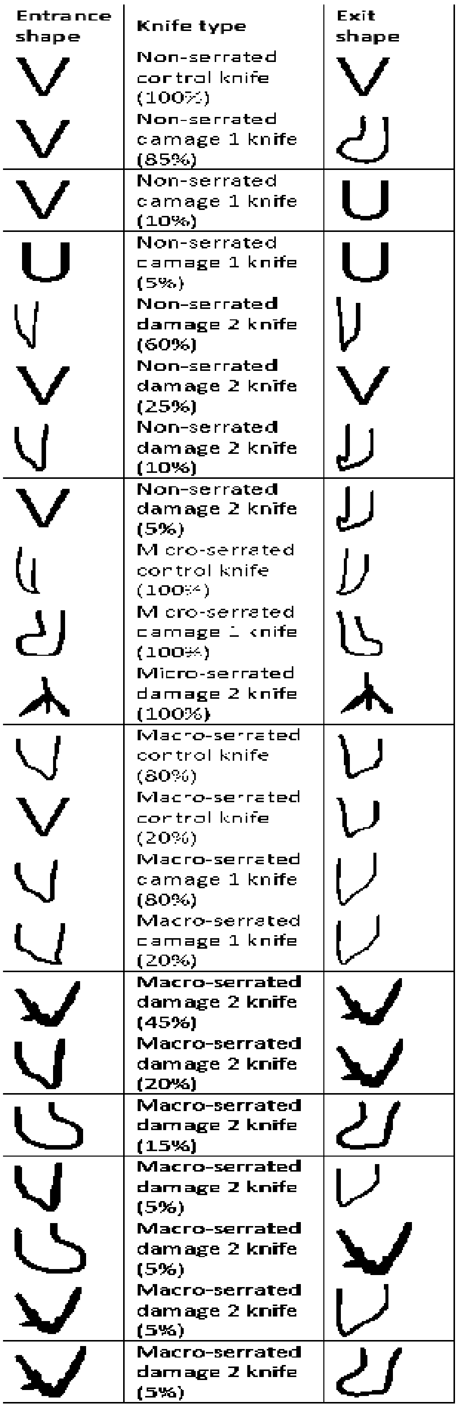


Figure 2: top: Ma/C knife, the hilt is on the right side, bottom: exit shape of a cut mark produced by the Ma/C knife.

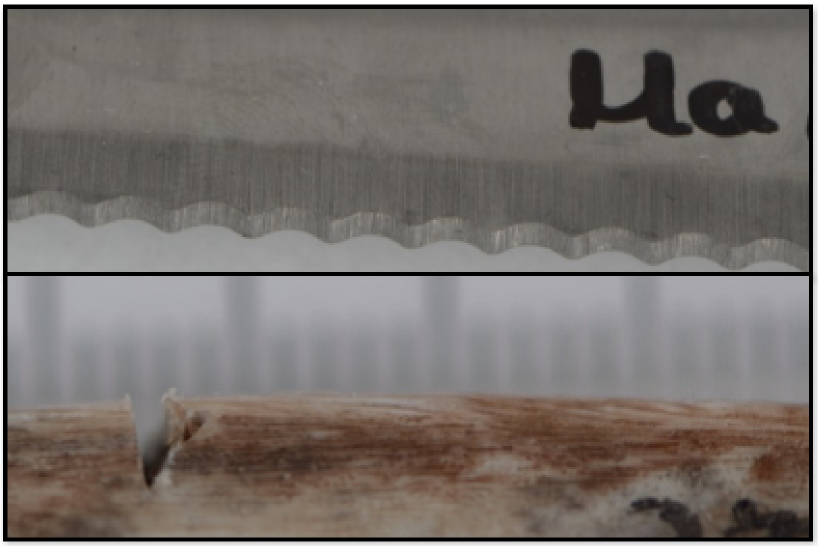
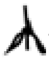
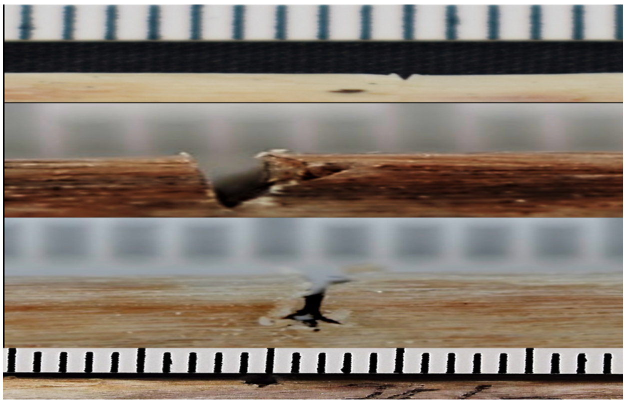


Figure 3: -shaped cut made with the Mi/D2 knife.



The kerf floor was another characteristic that closely resembled the knife type used to inflict the cut marks. While unfortunately the kerf floor was not observable in any of the cut marks made by the micro-serrated knives because the cut marks were too narrow, in the cut marks made by the non-serrated and macro-serrated knives changes were observed corresponding to the degree of damage to the blade. The control knives produced a clean straight line in both knife types. This line became increasingly wider, irregular and less straight in the non-serrated knives with increased damage and even jagged in the macro-serrated knives. In a study comparing cut marks made by un-retouched flint flakes and those made by metal knives, Bello and Soglio [22] reported that a sharp cutting edge left a smaller, more defined kerf floor, while the less sharp flint flakes left a wider and more irregular kerf floor. This principle can be transferred to the study at hand, where the damage to the blade reduced its sharpness and caused the irregularities on the kerf floor. In the same way that Bello and Soligo used the size and regularity of the kerf floor to infer the level of refinement of the flint flake, the degree of damage to the blade could be concluded from the characteristics of the kerf floor.

In a study using 14 different knives (serrated as well as non-serrated knives) Crowder et al. [15] made the observation that edge mound in cut marks made by serrated knives occurred on the side of the kerf that corresponded to the side of edge bevel on the blade. While the same observation was made for the N/C, N/D1,Mi/D1 and Mi/D2 knives (edge bevel occurred on the left and right side since the blades were bevelled on both sides), this could not be confirmed in the Mi/C and macro-serrated knives. The Mi/C knife produced no edge bevel and in the macro-serrated knives, no obvious pattern could be established and edge mound occurred either not at all, on both sides, only on the left or the right side or the margins were jagged but no edge mound occurred. Even though no conclusive pattern in edge mound was found, the frequency of occurrence was 70.5% and thus much higher than reported by Kooi et al. [8], who found a frequency of 35% in their study using a serrated and non-serrated knife to stab racks of pig ribs. Therefore, edge mound was not considered a very reliable characteristic in determining the knife type that caused a particular cut mark, even though further studies would be necessary to investigate how damage to the blades influences edge mound. Wastage occurred in only 10 of the 180 cut marks. Of these ten, only one occurred in a cut mark made by the Mi/D2 knife, the other nine were produced by the macro-serrated knives. Kooi et al. [8] recorded a higher prevalence of 30%. However, the low percentage of wastage observed is consistent with Reichs [24], who states that wastage is normally found at a low frequency in knife stabbings.

Several studies have been conducted with the aim to distinguish between serrated and non-serrated knives by assessing different characteristics in the cut marks [8,13, 15-19]. In all of the studies, the presence or absence of striations on the kerf walls was a highly indicative factor to help with the identification of class characteristics of the knife that caused the cut. Grooves on the kerf walls was another characteristic observed that was highly significant and therefore a good indication as to what type of knife was used. Even though it was impossible to see the kerf walls in the cut marks made by the micro-serrated knives because they were too narrow, fine irregularities could be identified on the kerf walls of the cuts made by the N/D1 knife. In the cases of the N/D2, Ma/D1 and Ma/D2 knives, greater damage was observed on one side. Further analysis of the damage to these knives revealed that the kerf wall with the more extensive and irregular grooves corresponded to the side of the blade that exhibited damage to a greater extent. The grooves on the kerf walls seemed to closely reflect the damage to the knife blades, a fact that was also observed in a study by Pounder and Reeder [17], where they state that the pattern of the striations on the kerf walls reflected the pattern of the serrations on the blade. Here, the damage to the blade seemed to be similar to a saw, where the distal portions of the teeth deviate laterally from side to side in an alternating pattern [10]. As a result of the bending outwards, the teeth reached the kerf walls and caused the grooves observed. Owing their significant difference and close correspondence to the blade damage that caused the mark, the grooves on the kerf walls were highly indicative of the type of knife used to inflict a cut mark; therefore, it might be a useful characteristic to look for in cases where damaged knives have been used.

Attention must be payed to the fact that the grooves on the kerf walls can be affected by the angle [15, 21], as well as motion of the knife while stabbing the victim. In this study, a forwards and backwards motion was used to stab the bone. The backwards motion could destroy grooves on the kerf walls that were created in the forward motion. In their study Pounder and Reeder [17] reported problems when looking for class characteristics in cut marks made with partially serrated knives, since in these cases, the pattern of grooves on the kerf walls depended on the part of the blade that passed through the bone while cutting it. While in this study every effort was made to keep the motion of the knife constant and to pass the complete length of the blade through the bone while stabbing it, little variation could not be avoided and is therefore expected to have affected the outcome of this study.

Conclusion

The aim of this study was to determine whether damage on a knife blade was capable of transferring individual characteristics that are unique enough to identify a specific suspect weapon. Highly significant differences were observed especially in the entrance and exit shape, kerf floor and grooves on the kerf walls produced by the nine different knives. The nicks on the knife blade and bend teeth closely corresponded to the shape of the cut marks as well as the grooves left on the kerf walls. Similar to the laterally deviating teeth of a saw, the bend teeth of the knife widened the kerf floor and caused an irregular appearance.

Based on the findings in this study, it is the opinion of the authors that individual blade characteristics can be transferred to the cut mark. This study is the first of its kind and therefore more elaborate research is necessary, but the results indicate great potential for the possibility to identify individual characteristics of the knife blade in the cut mark. While it might not yet be possible to identify a specific knife from a cut mark, this study positively identified on which side of the blade the damage occurred, by close examination of the characteristics in the cut marks. These findings can prove to be very useful in investigations where stab marks are caused by a knife with a damaged blade.

Improvements to this study could have been made by using scanning electron microscopy (SEM) to record the cut mark characteristics in more detail, especially the grooves on the kerf walls, which were not observable in some cut marks.

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