Weapon-Wound Matching of Sharp Force Trauma to Bone using Micro-CT – A Methodology and Pilot Study

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INTRODUCTION

UK Home Office Statistics 2012 reported 636 homicides between April 2010 – March 2011; 37% of these involved the use of a sharp instrument such as a knife with 14% of investigations not resulting in prosecution[1]. Sharp force trauma in forensic anthropology concerns the analysis of the marks (kerfs) caused by 'sharp' weapons like knifes, ice-picks etc[2]. Tool mark analysis and weapon-wound matching is a developing area and allows anthropologist to establish, either weapon class, or exact weapon used to commit the homicide[3]. This is traditionally done macroscopically but is rarely sufficient to determine weapon class[4] and hence current research trends investigating the use of imaging techniques for post-mortem examination[5]. Newer techniques such as micro-CT, could allow much more detailed investigations into bone trauma indicating great potential for research into weapon-wound matching[6]. Our study aims to use micro-CT and 3D/CAD programs to analyse sharp force trauma which, to our knowledge, will be the first attempt at investigating 3D weapon-wound matching. The applications of this study can potentially lead to new techniques in forensic anthropology for weapon-wound matching and hence aid in criminal investigations.

SUMMARY

Nearly 40% of murders in the UK result from sharp force trauma caused by knives (Home Office 2012). Weapon-wound matching in Forensic anthropology attempts to estimate weapon class from the wound characteristics but few studies have investigated quantitative methods for performing this analysis on the microscopic scale. In this study five cadaveric pig torsos, prepared to mimic human anatomy, will be stabbed in the upright position with 12 different knives by two volunteers. Knife dynamics will be recorded using a Casio high-speed camera (1000fps), with wound tracts being recorded using photogrammetry. Samples will be defleshed exposing the regions on the ribs where the knives have made contact, thus marking the bone, so micro-CT can be performed. All samples will undergo a pre and post-stab CT. The analysis will be performed using various quantitative and qualitative methods to establish the feasibility of weapon-wound matching. Results are pending, however it's hypothesized that, on the macroscopic scale, and individual bladed weapons have their own unique edge profiles which should leave unique striations on the bone for weapon-wound matching. If this is the case, and we can quantify this, then applications in forensic investigation for weapon-wound matching is a natural progression.

METHODOLOGY

To be undertaken on 14th November 2012

Sample Preparation

5 whole pig thoraxes prepared to mimic human anatomy will be sourced from a medical meat supplier and delivered to the surgical training facilities UHCW

Pig samples will have excess subcutaneous fat and skin replaced with sheep's skin to more closely replicated the skin resistance of human skin (right)

Medium-density polyethylene will be inserted into the pig's chest cavity to replicate human organs and a T-shirt material will then be stitched around the samples acting as clothing.

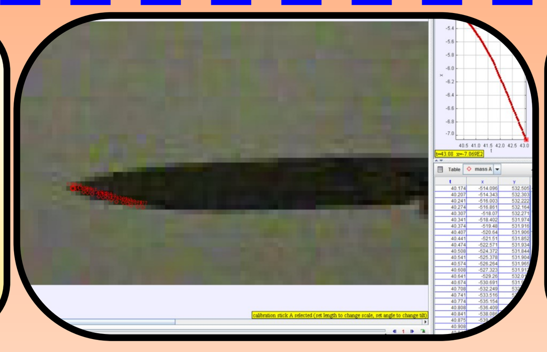
The samples will then undergo the 'pre-stab' medical grade CT at UHCW

Experiment

The pig thoraxes will be fixed in the upright position at the anatomical height of an average male for stabbing.

A selection of 12 knives, some new, some serrated and some from prisoners property will be used to stab the pig samples

During stabbing, the knife dynamics will be captured using a high-speed camera and analysed later



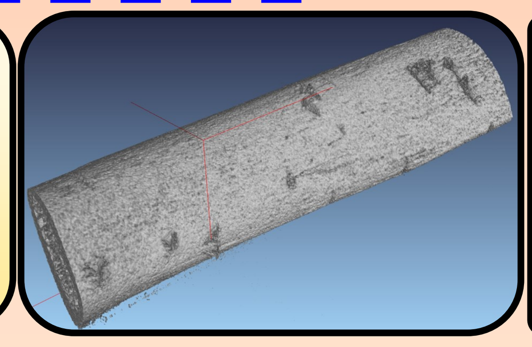
Following stabbing, wounds tracts will be labelled and photographed (making use of photogrammetry). Finally, the post-stab CT will be conducted

Sample Defleshing

Samples will be surgically defleshed and then chemically defleshed to remove the final soft tissue using an anti-formalin solution. Ribs will then be stored in a tissue preserving solution

Finally the bones will be brought to WMG so that they can be scanned using micro-CT

Scans will then be reconstructed and calibrated ready for the analysis of knife marks



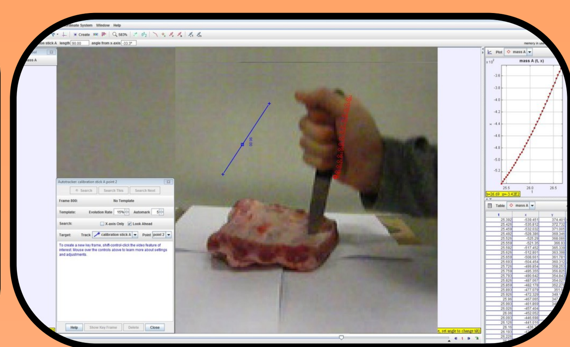
Analysis

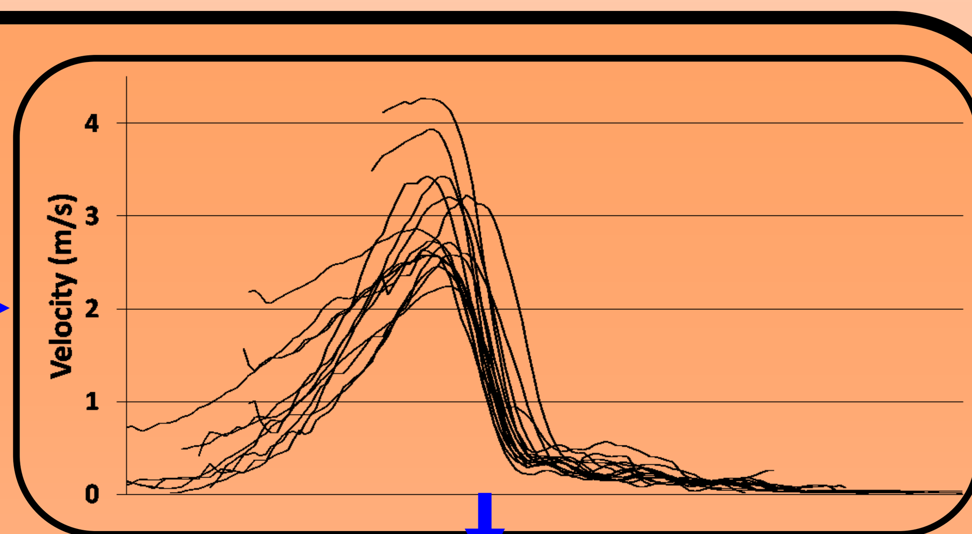
PILOT STUDY

Pilot study conducted to investigate the scale of the marks being studied, the velocities of the stabs and the effectiveness of the antiformalin solution

Pork ribs were purchased for a butcher and then stabbed using 3 different kitchen blades. 1 serrated blade and 2 non-serrated blades, one small and one large.

Stab motion was recorded using high-speed camera and using Tracker, blade velocities were plotted

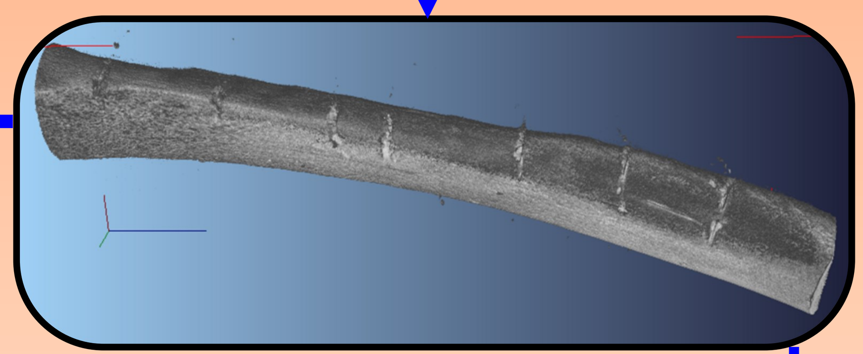




Notice that the max knife speed here is approximately 4m/s at impact with the sample. More analysis comparing velocity and force on wound characteristics and blade type will follow.

The ribs were then defleshed by placing them in an anitformalin solution for ≈ an hour ($NaCO_3$, $Ca(OCl)_2$, $NaOH$ and H_2O)

Individual ribs were then micro-CT scanned at ≈60µm before being reconstructed in VGStudio Max for analysis. Here measurements of the kerf width and depth were recorded to an accuracy of 0.06mm



Both a graph and Student's T-test was used to display and analyse the significant of the data recorded for both kerf depth and width for each knife

Student's T-Test

KERF WIDTH:

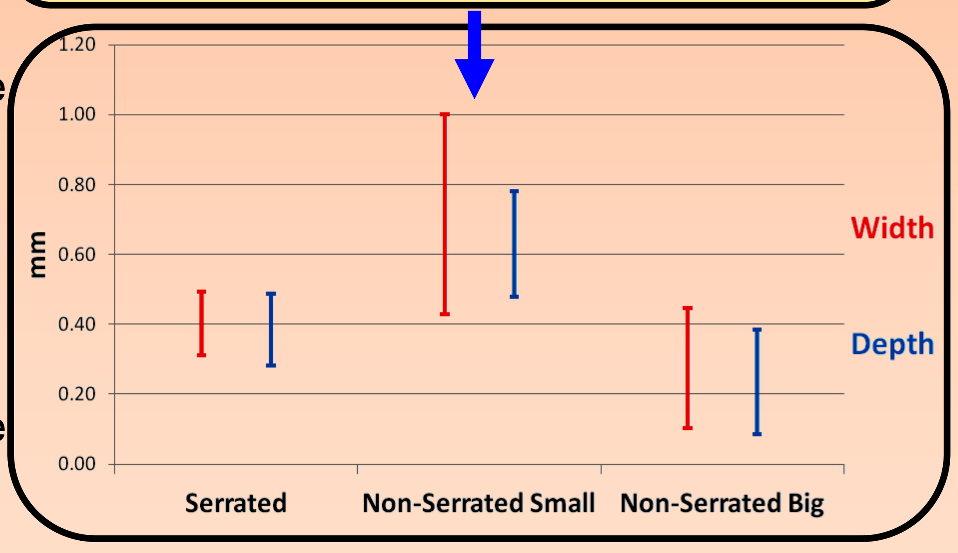
Serrated vs Non-Serrated Blade
$t(12) = 2.751$, $p = 0.018$

Small vs large Non-Serrated Blade
$t(12) = 3.500$, $p = 0.004$

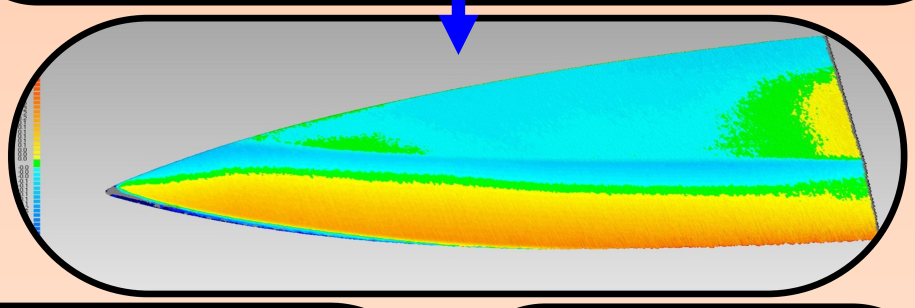
KERF DEPTH:

Serrated vs Non-Serrated Blade
$t(12) = 3.552$, $p = 0.004$

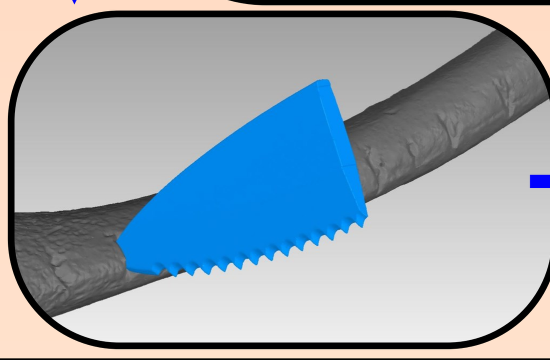
Small vs large Non-Serrated Blade
$t(12) = 4.902$, $p = 0.000$

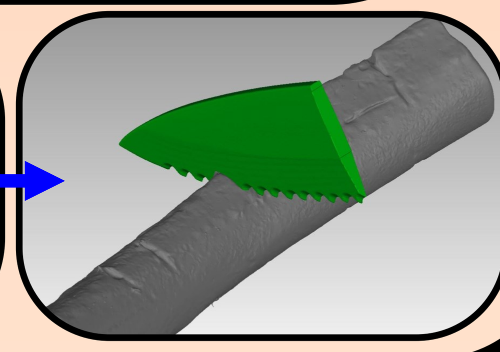


To determine whether it is possible to distinguish marks left by 'identical' knives two of the same kitchen knives were scanned and compared using a surface deviation analysis. The results show that these knives do differ on scales of ≈1/10th mm. Whether these microscopic difference leave unique striations in kerf walls has yet to be investigated



Data was extracted from VGStudio to create a mesh surface where the scanned knife blades could be digitally matched up to the wounds. Further work on this will follow to investigate the accuracy of this approach





Both the Student's T-Test and graph show that there exists a statistically significant difference in the basic dimensions of marks left on bone from different types of knives. It appears that both serrated knives and large kitchen knives leave a narrower and shallower mark than small non-serrated knives indicating that determining probable knife type is possible

FURTHER WORK AND APPLICATIONS

The pilot study hints at the potential of micro-CT in providing detailed information on the dimensions of the cuts left behind on bone by various knives. Whether striations are visible on the kerf wall has yet to be considered but will follow. The impact of velocity on bone damage will also be investigated. Also the use of mesh and CAD software for weapon-wound matching will be explored along with possible 3D printing of marks left. Furthermore, having compared two 'same knives' it appears that their are microscopic differences between them that may results in unique cut mark features that could be used to determine the individual knife used. Following the results of this experiment (commencing November 14th) further work potentially using human cadavers will be conducted to control for the differences between pig tissue and bone and human. If the research indicated that micro-CT is a powerful tool in aiding in weapon-wound matching for sharp force trauma then methods for application in forensic cases will be investigated.

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The Forensic Science Society

METROPOLITAN POLICE

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