Re-Engineering Forensic Anthropology:
New Technologies in Sharp Force Trauma Analysis

THE UNIVERSITY OF WARWICK

URSS

Project conducted between Oct 12—Oct 13

D.G. Norman[1*] B. Burnett[2], G.J. Gibbons[4], J. Barnes-Warden[3] & M.A. Williams[4]

*Corresponding Author: D.Norman.3@warwick.ac.uk

[1]School of Engineering, University of Warwick [2]University Hospital Coventry and Warwickshire [3]Operational Technology, Metropolitan Police Service, [4]WMG, University of Warwick

INTRODUCTION

Given the number of knife fatalities in the UK (≈300 a year), and the unfortunate reality that many cases are never solved[1], any advancements in forensic analysis through scientific research is crucial to ensuring perpetrators are brought to justice. However, current literature regarding the analysis of toolmarks left by knife attacks appears to lack standardisation, ecological validity and quantitative analysis[2-4]. New imaging technologies such as micro-CT have been proposed as a potential tool for micro-morphological analysis of knife marks, but very little research on this has actually been conducted[2-5]. Given the forensically useful information that can be extracted from the micro-CT analysis of knife marks (including weapon type, impact trajectory and possibly impact velocity), scientific analysis of this area is mandatory[6-8]. Even with many established reverse engineering methods for quantitative analyses of microscopic features, the application of this discipline to knife mark analysis is, surprisingly, unheard of. Finally, despite the advancements in 3D visualisation and 3D printing as a common output of the reverse engineering process, very few studies have considered the application of these outputs for use in forensic expert testimony in court[9-10]. As a result of the issues noted above, this study will aim to explore, consider and test various possible solutions using current engineering technology.

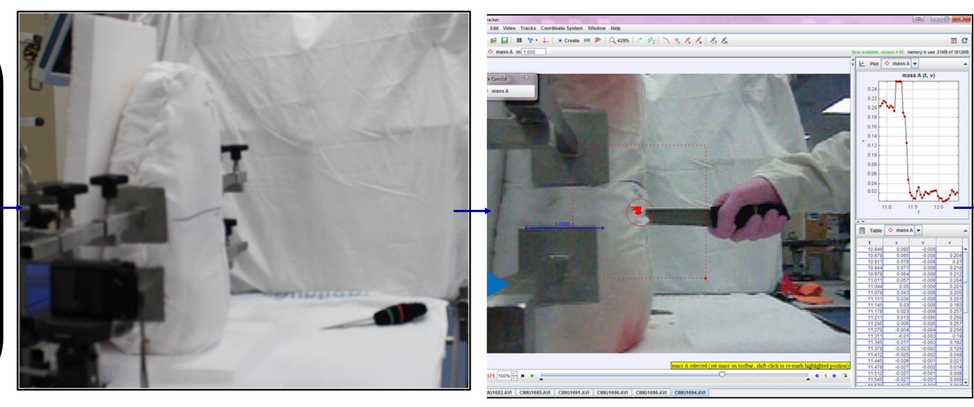
SUMMARY

In forensic anthropology the analysis of microscopic tool marks found in skeletal sharp force trauma is a challenging area. Many different imaging methods have been employed to measure cut mark characteristics in aid of developing diagnostic tools for estimating knife type used for these marks. Furthermore numerous experimental methods for creating tool marks for analysis have been used. A novel method for creating, analysing and presenting tool marks using reverse engineering and metrology was investigated. 5 Pig torsos prepared to mimic human anatomy were stabbed using seven different knives. Following chemical defleshing the ribs were micro-CT scanned for the analysis of tool marks left from the knives. Other methods including SEM, Digital microscopy and Laser scanning were also considered. Various geometrical measurements of the cut mark micro-morphology were taken. These measurements were statistically analysed using SPSS. Knife types gave statistically significant different cut mark width, length, wall angle, floor radius and shape (p<0.001). Knife sub-types and individual knives also gave statistically significant differencing in width and shape (p<0.001). Statistical classification of cut marks as either serrated or non-serrated made marks was shown to be 90% if width, length, wall angle and floor radius were accounted for. This indicated that determining knife type quantitatively is possible and could aid criminal investigators with their enquires. 3D models of these cut marks could also be developed for potential use in court for forensic expert testimony.

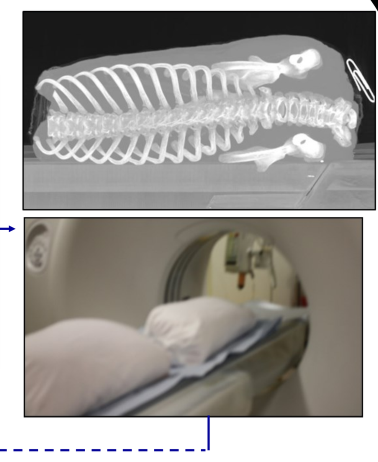
METHODOLOGY

Seven different 'used' knives confiscated by the Met Police were used for this study

Five cadaveric pig torsos were ethically acquired and prepared to mimic human anatomy. They were then stabbed by 2 volunteers in an upright anatomical position. Over 650 stabs were performed with each stab recorded using high-speed camera 1

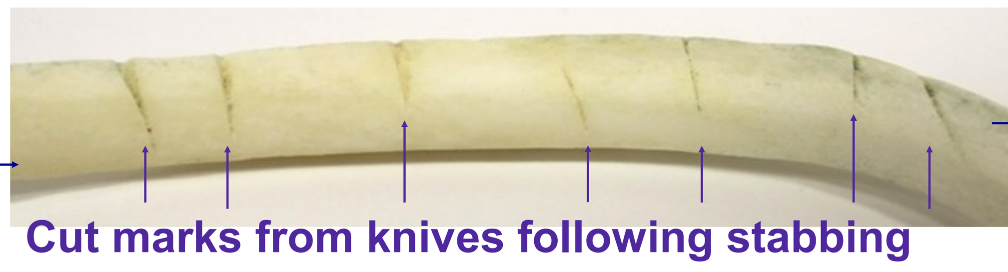


The samples were imaged using medical grade CT as to capture the anatomical positions of the individual ribs



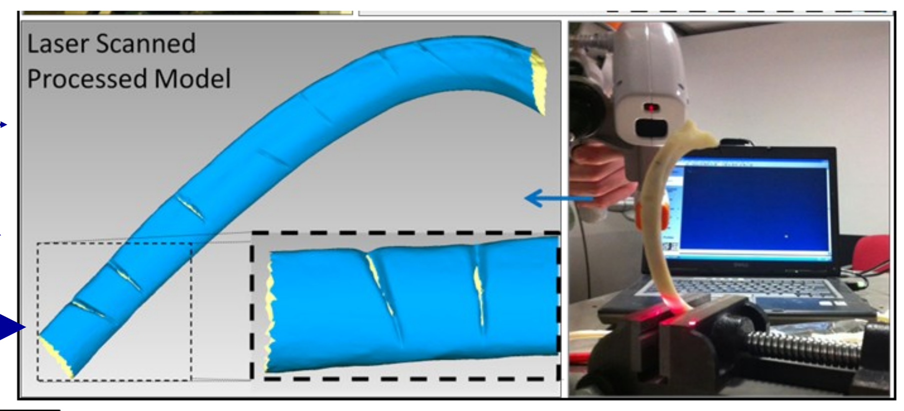
Samples were defleshed with a chemical solution

This resulted in 60+ defleshed ribs and 150+ marks ready for scanning and analysis

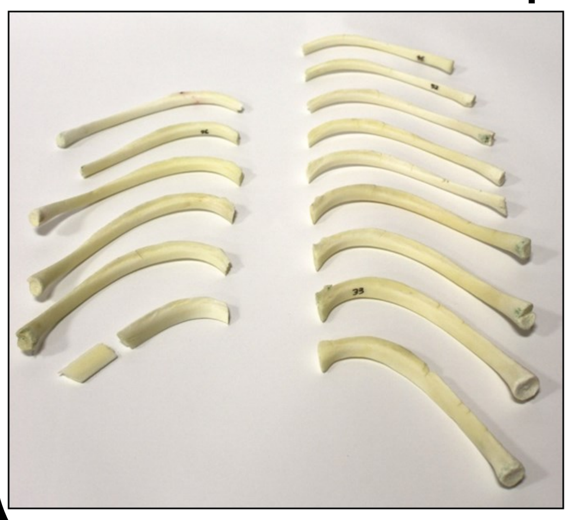


Cut marks from knives following stabbing

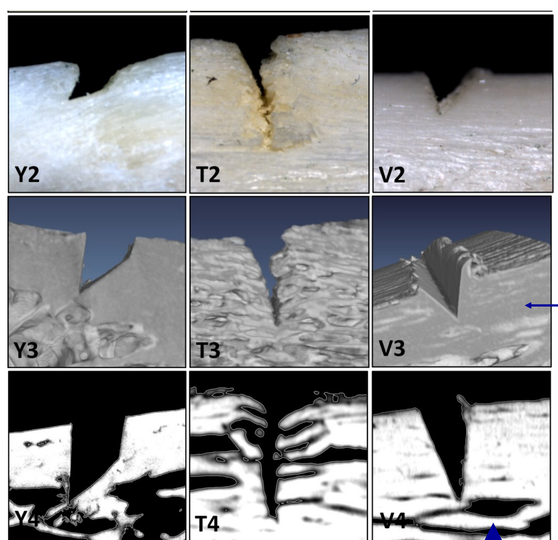
Ribs were scanned using various methods:



Laser Scan

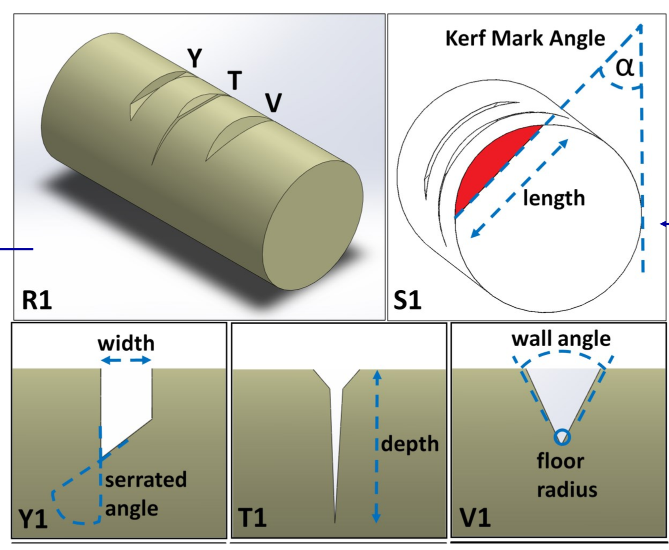


Set of ribs from one sample



Different cut mark shape types from literature

Measurements Taken



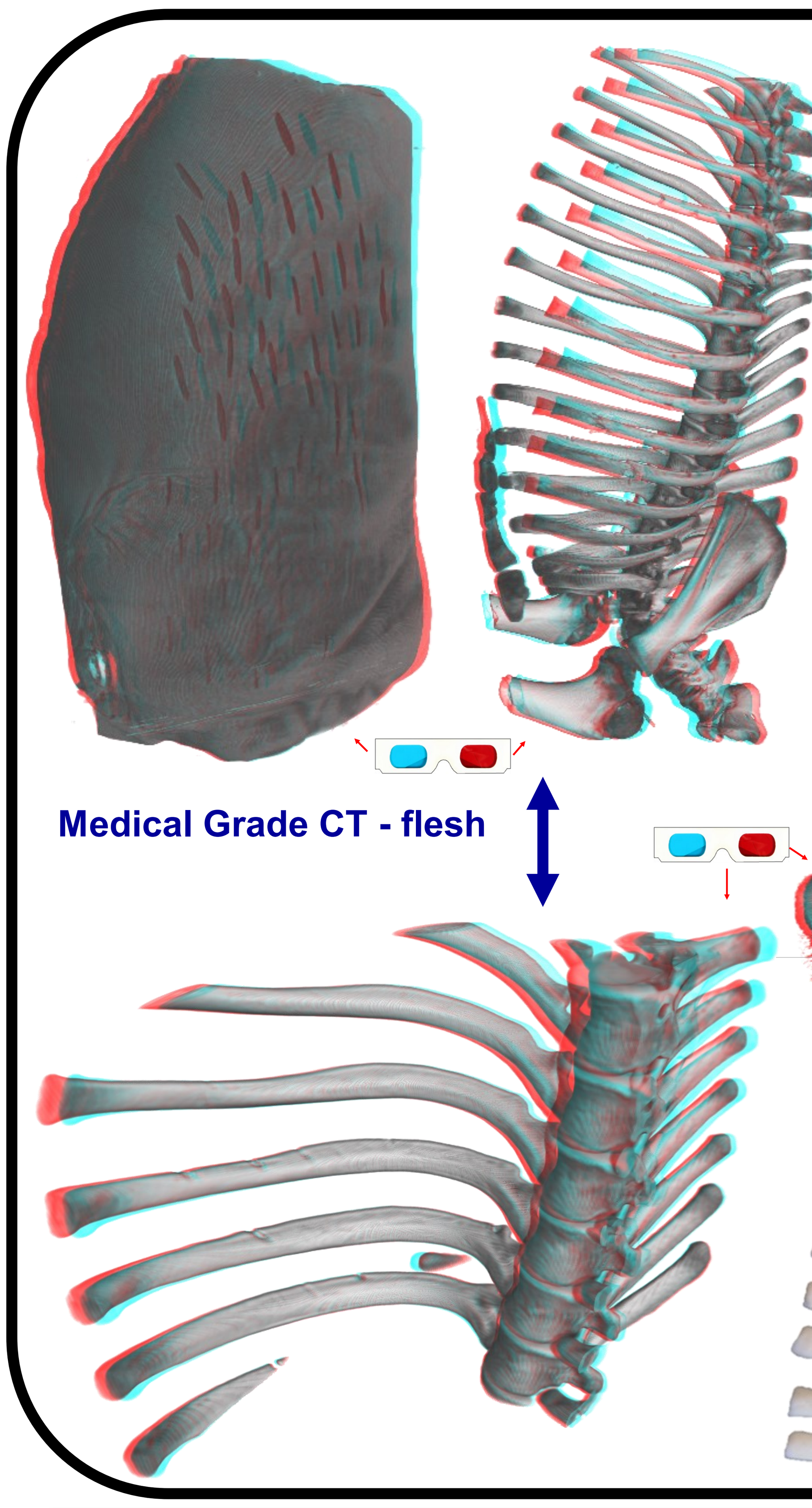
Following micro-CT scanning of the cut marks, various quantitative measurements of each mark were taken (e.g. Width, wall angle etc) and the shape categorised as either Y, T or V

Micro-CT

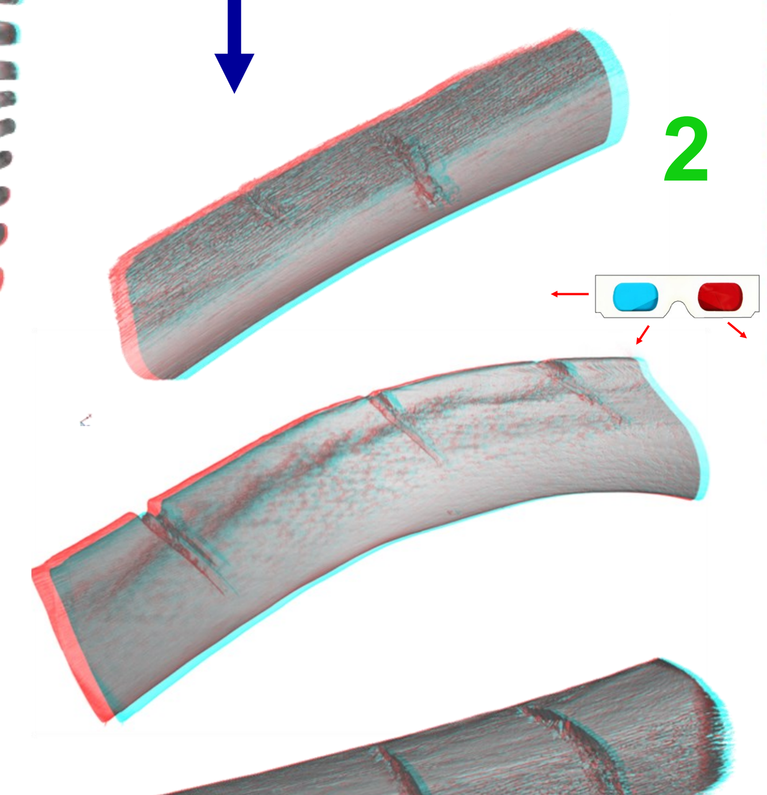
SEM

Microscope

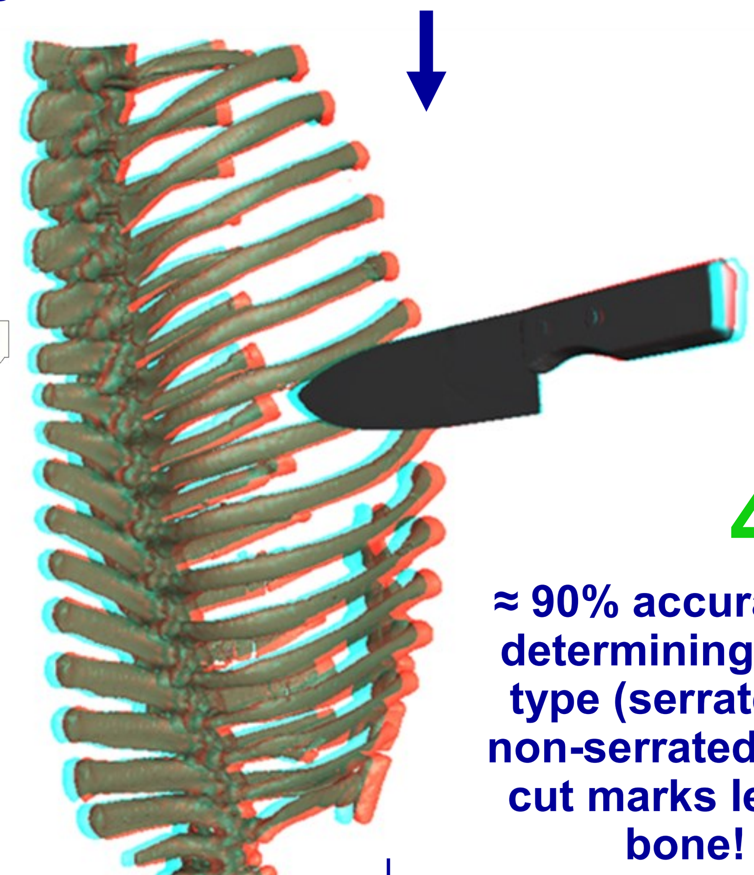
RESULTS



Medical Grade CT - flesh



Micro-CT of Cut Marks



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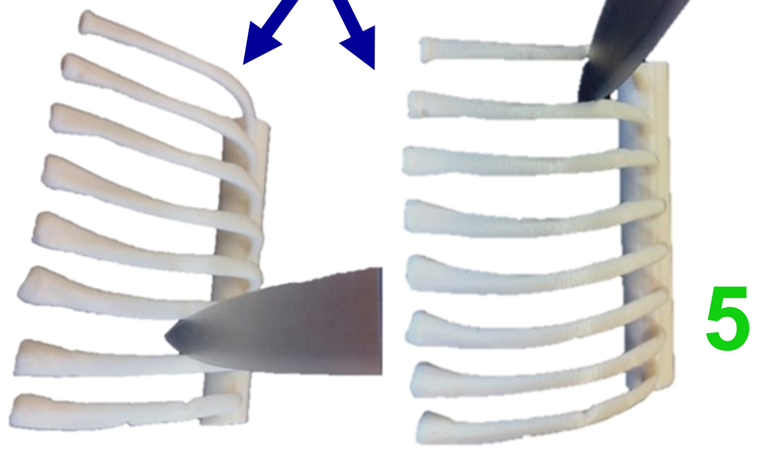
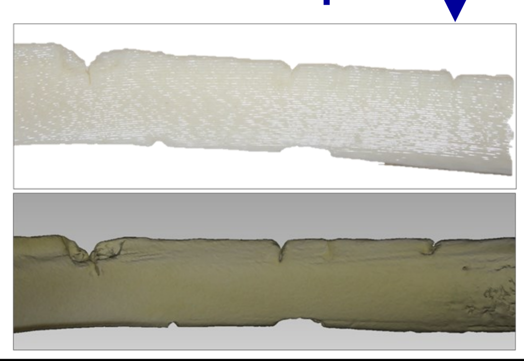
High Resolution 3D Models Generated



3D Printed Models

5

Zoomed in



Comparison between 3D models and print

Statistical Analysis of Cut Mark Measurements

Independent	Dependent	Test	Result
Knife Type	Mark Length	T-test	t(76)=-4.257 p<0.001
	Mark Width	T-test	t(73)=-8.721 p<0.001
	Mark Wall Angle	T-test	t(73)=-3.311 p<0.001
	Mark Floor Radius	T-test	t(73)=-4.630 p<0.001
	Mark Shape	Chi-Square	X^2 = 34.347, df=2, p<0.001
Individual Knife	Mark Width	T-test	t(37)=5.431 p<0.001
Knife Teeth Angle	Mark Serrated Angle	Correlation	r=0.8, n=40, p<0.001
Knife Edge Thickness	Mark Width	Correlation	r=0.732, n=68, p<0.001
Stab Trajectory	Mark Face Angle	Correlation	r=0.707, n=30, p<0.001

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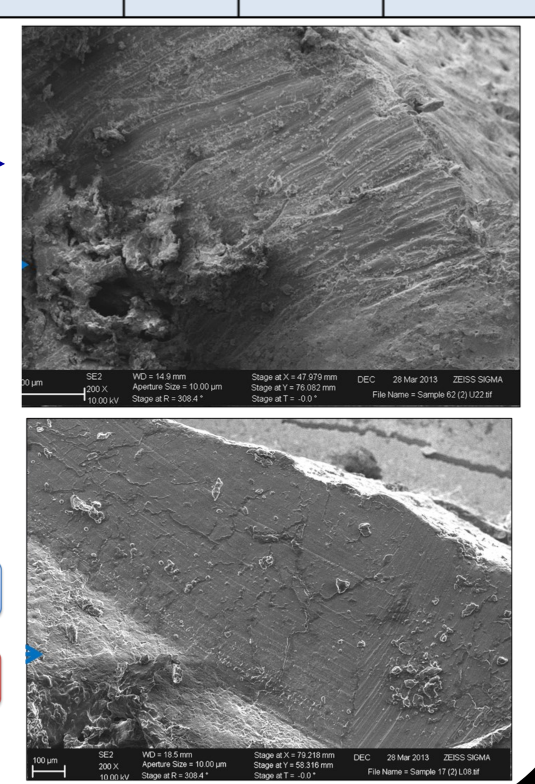
≈ 90% accuracy in determining knife type (serrated or non-serrated) from cut marks left on bone!

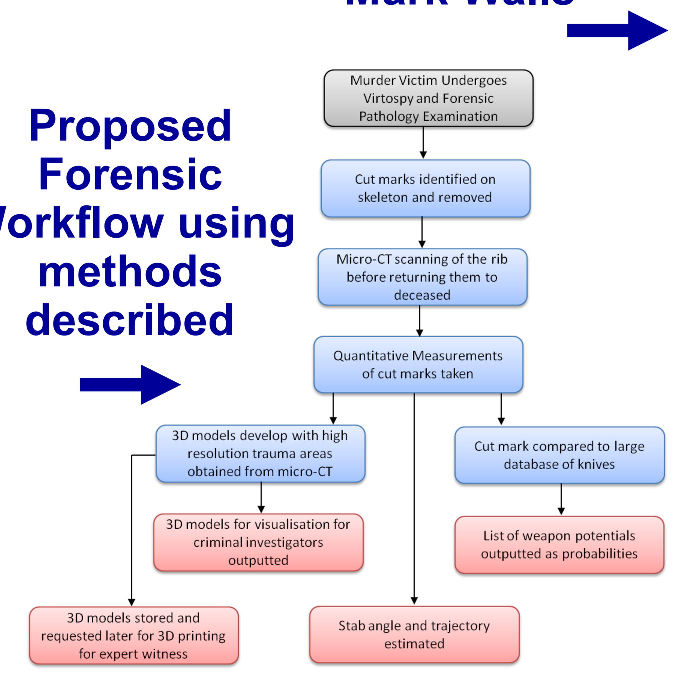
3

% Match between Blade Type and Cut Mark Geometry following Canonical Discriminent Analysis					
Non-Serrated			Serrated		
Matches	Mismatches	% Correct	Matches	Mismatches	% Correct
32	4	88%	34	3	91%

SEM Images of Cut Mark Walls



Proposed Forensic Workflow using methods described



CONCLUSIONS

1. An ecologically valid process was developed for creating realistic knife marks
2. Micro-CT was found to be a superior technology for tool mark analysis
3. Knife Type can be determined from cut mark micro-morphology with a 90% accuracy
4. Knife impact trajectory is strongly correlated with cut mark trajectory
5. High Resolution 3D models for visualisation and 3D printing can be developed

FURTHER WORK

- Whether analysis of marks left in a controlled stabbing of a 'standard' material could be used to statistically determine knife type used on an unknown stab wound
- The procedure and effects of using 3D printed models in court could be investigated
- The analysis of over 600 more high-speed videos considering impact velocity prediction.
- 174 cut marks were collected but only around 80 were analysed in this study.
- SEM images of more samples to answer questions raised in the literature

ACKNOWLEDGEMENTS

- Metropolitan Police Physical Protection Group for supply of both knife data and the confiscated knives used
- UHCW Surgical Training Facilities, - Brian Burnett and Jennie Hoyle, for their extraordinary help during the experiment
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- Derrick Watson for his very useful advice on the statistical aspects of the work

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*Note that 3D anaglyph glasses (hanging next to poster) are needed to view some the 3D images. These images are labelled with this symbol: