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A novel method for the analysis of slash cuts to clothing

ABSTRACT

Slash attacks form a major element of physical assaults involving a sharp implement such as a knife. If the slash attack is inflicted onto a surface covered with fabric, such as clothing, then that fabric may receive a slash cut.

Investigation of the slash cut can provide further information as to the nature of the implement and the action of the attack.

This study aims to identify a quantifiable correlation between the nature of the slash cut and the implement causing said slash cut. The study also aims to develop a method of categorising the damage as well as a way of measuring the sharpness of a knife without blunting the blade.

The two new simple techniques were developed and applied to a range of household implements. A quantifiable correlation could be seen between the damage categorisation and the relative sharpness of the implement. The degree of this correlation varied depending on the fabric type.

Introduction

Knife crimes include possession of an offensive weapon, physical assaults such as grievous bodily harm and homicides. Both Ciallella *et al* [1] and Daeid *et al* [2] agree that sharp force violence is one of the most common ways of committing a homicide or physical assault.

Body injuries normally carry more information and are more suitable for comparative analysis and identification of the implement than clothing damage characteristics. Though in separate cases, the investigation of clothing damage can provide such information about the implement that cannot be received from the investigation of wounds [3]. Such cases include those where wound examination may not be available, such as when the deceased is in an

advanced state of decomposition or where the recipient of the injury has survived following medical intervention.

Two studies by Bleetman *et al* [4,5] indicates that slash wounds are more common than stab type wounds on the scalp, face, neck, limbs and buttocks and therefore many injuries caused by edged weapons seen in clinical practice are from slashing attacks rather than from stabbings. Bleetman adds that approximately one third of assault victims attending hospital are injured by an assailant using a knife. Most of the patients presented superficial slash type wounds [5].

A slash cut is generally produced by a sharp edged tool (knife, razor blade, scalpel etc) travelling in an arc via a swinging motion. The slash may not penetrate the material completely or may penetrate intermittently i.e. the cuts are not continuous. Unlike most stab cuts which had a short nick at the end of the damage, a slash cut started and finished with a smooth V shape [6,7].

Horsefall *et al*, [8] states that there are four different actions that can occur as a knife penetrates the fabric:

Table 1: Definitions of different actions as per Horsefall et al [8]

In general the blunter the point of the knife the more difficult it is to make the initial penetration of the fabric therefore there would be more distortion around the penetration point. The sharpness of the blade will affect the shape of the severance. A sharper blade will neatly cut the yarns as it travels through the fabric with little or no fabric distortion [8]; whereas a blunter knife will not cut through the yarn as neatly.

Taupin *et al* [9] states that by examining the characteristics of the fabric damage it may be possible to indicate the type of implement used.

However, the current technique involves placing the damaged garment over a polystyrene block prior to a test cut being applied using the suspected implement. A visual comparison is then carried out on the suspect cut and the test cut in order to determine whether the suspected implement could have caused said damage. This methodology lacks transparency and it is very difficult to challenge as it is based upon the scientist's highly subjective opinion.

Given the current requirements, especially in the United Kingdom, of increasing transparency and quality assurance of evidence, it has been recognised that this niche discipline needs to be more robust; therefore, alternative or complimentary methodologies need to be explored.

The aim of this study was to investigate the effect of the sharpness of the slashing implement; for which a new technique was developed to measure the blade sharpness. This is referred to as the 'relative sharpness index' or RSI. A method of quantifying the extent of the damage was also devised, which is referred to as Damage Categorization.

Methods and materials

Measuring blade sharpness

The implement was placed in a clamp with the blade facing up. A 20 cm loop of thread was then placed on the blade, 1 cm away from the tip of the implement. Weights were then added to the other end of the thread in increments. The weight required to cut the thread was then recorded. This method utilises the principle that the sharper the blade, the less force is required to cut the fabric. The use of the thread means that only a very small section of the blade is used, therefore the sharpness of the blade is only slightly compromised by repeated testing. For this study, the blade sharpness was measured using a range of different threads, these consisted of 100% cotton sewing thread and a 100% polyester thread, both of these had a tight organised yarn. Also used was 100% cotton sheeting threads and 100% silk thread in

which both of these had a loose and unorganised yarn. The overall performances of each separate thread were compared.

This method of measuring blade sharpness was developed so that it does not cause the blade to become more blunt over time, thus allowing for effective quality control and review by other forensic practitioners as well as reducing drift in the data collected as the blade gets blunter.

Sharpness can be subjective, for example one implement can be sharper than another, but still be considered by some as being blunt if there is nothing to compare it to. Therefore, for the purpose of this study a relative sharpness index (RSI) was developed which allows for variables in measurements between groups. This was done by determining the ratio of sharpness of nineteen blades (see *Table 2*) to an implement considered to be ‘ultimately’ blunt. For the implement of ultimate bluntness a round smooth wooden dowel was used. The weight required to break a thread around a dowel was determined (which also corresponded to the maximum tensile strength of the thread) and the mean was used as the denominator of the ratio. This ratio was applied for each individual measurement and it is this ratio that forms the basis of the statistical analyses. This test was applied to each thread type separately.

Categorising clothing damage

A difficulty associated with assessing damage to clothing is how to quantify the extent of the damage. It was decided that the effective way of doing this was by categorisation, which helped to minimise the subjective nature of the fabric damage analysis. Categorisation of forensic evidence is already in use, for example categorising the quantity of spermatozoa on a slide [10], which is frequently used in a court of law.

Johnson [11] states that most textile items are compound structures composed of up to four levels, these consist of fibres which are formed into yarns (or threads), the yarns are then

interlaced into fabrics either by weaving, knitting etc and the fourth level is the final article i.e. clothing etc. In order to categorise the clothing damage three levels of observation were employed; fabric level, yarn level and fibre level.

At each level a score was given. Table 2 gives an indication of the categorisation and associated scoring. The observations and categorisation were then reviewed and agreed by a second person. The scores at each level are then added together to give a range of 0-8, with 0 representing the smoothest damage and 8 representing the roughest or most ragged damage. This combined score was then used as the raw data for the statistical analyses.

Table 2: The basis for categorising damage to clothing is shown in this table.

Both fabric level and yarn level were taken at x16 magnification whilst fibre level was taken using x40 magnification.

Fig 1: Fabric level, this would be categorised as 0 due to the neatness of the cut.

Fig 2: Fabric level, this would be categorised as 1 due to the slight unevenness of the cut.

Fig 3: Yarn level, this would be categorised as 0 due to the cut having no loose yarns.

Fig 4: Yarn level, this would be categorised as 3 due to the cut having two or more loose yarns.

Fig 5: Fibre level, this would be categorised as 0 due to the cut having no loose fibres.

Fig 6: Fibre level, this would be categorised as 2 due to the cut having a majority of loose fibres. However if the bottom yarns also had a majority of loose fibres then this would have become a 3.

In order to generate reproducible results a pendulum based ‘slashing machine’ was

constructed at the University of Huddersfield. This consisted of a weighted arm with a clamp to hold the implement. A frame is fixed in place at the bottom of the arc; which held a piece of 100% cotton sheeting fabric (this frame has an adjustable height). The cotton was made from single weave (one under and over) and per 1cm³ the material consists of a weave density of 30. The weighted arm was then lifted to a predetermined height and released. The arm would swing down and ‘slash’ through the fabric before being caught on the other side. The resulting damage would then be categorised as above. The variables explored were five different implements and increased force of slashing (adjusted by raising the height of the swinging arm prior to release to raise the momentum).

Length of damage

Following each cut, the length of the slash cuts were measured between two edges of the cut that are the furthest apart. These measurements (in mm) were used for the basis of all statistical analyses.

Extent of fraying

Another parameter explored in this study was the fraying of the damage. The term ‘fraying’ is used to refer to the extent of the displacement of the yarn out of the weave. If an implement is sufficiently sharp it should cut through the fabric with minimal removal of the yarn out of the weave (see *fig 1*), where as if the implement is sufficiently blunt it should ‘pull’ some of the yarn out of the weave rather than cut through it (see *fig 4*).

The fray was measured at yarn level and measured using Motic software using x7 magnification and recorded in mm. The extent of fraying was recorded by measuring the distance from the edge of the cut yarns to the nearest intact warp/weft.

Scalpel Blunting

The RSI was recorded on a new scalpel which was then run gently over a whetstone to help the blade blunt quickly. The RSI was again recorded and the blade was then used to slash 100% cotton fabric. The blunting experiment was continued until the scalpel reached its bluntest point. This was carried out to compare the differences between the sharp and blunt blades as ideally the blunter a blade the shorter the damage length and more threads pulled from the yarn leaving many loose fibres.

Statistical Analysis

Paired sample T-tests were carried out with the null-hypothesis being that the means of measurements from the slashed fabrics caused by implements of different blade sharpness are equal, thus indicating that varying sharpness of the implements has no effect on any features of the slashed fabric. The alternative hypothesis is that at least one of the means of the measurements from the slashed fabric caused by implements of differing blade sharpness, thus indicating that varying the blade sharpness has an effect on the parameters of the slash cut. A paired sample T-test was carried out as opposed to an ANOVA is due to the assumptions that the samples are independent and that the variances of the populations are equal being unreasonable.

Results:

Table 3: Knife Descriptions and codes with statistics from the blade sharpness test

Table 4: Relative sharpness of all knives using individual threads from the sharpest to the bluntest - It was observed that K14a had a similar RSI to the dowel due to the maximum tensile strength of the thread being reached. The knives in bold are the implements used in this study

Figure 7: Relative Sharpness in knife order using 100% Cotton Sewing Thread.

Figure 8: Relative Sharpness in knife order using 100% Cotton Sheeting Thread

Figure 9: Relative Sharpness in knife order using 100% Silk Thread

Figure 10: Relative Sharpness in knife order using 100% Polyester Thread

Figure 11: The categorisation of a slash cut caused by four different implements.

Paired sample T-tests were carried out on the overall data (n=8) and the values were significantly different ($p > 0.05$) between the scalpel and each of the knives. However, there was no significant difference between the sharp (K6) and the blunt (K4) knives ($p = 0.875$); sharp and the utility knives ($p = 0.785$) and between the utility and the blunt knives ($p = 1$). The numbers on the x-axis represented the angle away from a loose hang from which the knife was released, in other words it corresponds to the height of the knife as it is released. This result shows no significant differences between changing the angle of release.

Figure 12: The correlation between the relative sharpness index and the categorisation damage caused by being slashed by said implement (steak knife, scalpel, (SK1) utility knife, (K6) sharp knife, and the (K4) blunt knife). Refer to table 4 for order of implements.

R² values: cotton sheeting = 0.88, Silk = 0.89, cotton sewing = 0.81, and polyester = 0.80.

Figure 13: The correlation between the relative sharpness index and the extent of the fraying damage caused by being slashed by said implement (steak knife, scalpel, (SK1) utility knife, (K6) sharp knife, and the (K4) blunt knife). Refer to table 4 for order of implements.

R² value: cotton sewing = 0.71, cotton sheeting = 0.36, Silk = 0.65 and polyester = 0.46.

Figure 14: The correlation between the categorisation level and the extent of the fraying damage caused by being slashed by said implement (steak knife, scalpel, (K6) sharp knife, (SK1) utility knife and the (K4) blunt knife).

The graph indicated an R² value of 0.56.

However if the scalpel and steak knife was removed from the experiment the R² value increases to 0.99.

Figure 15: The correlation between the relative sharpness index of the blunting scalpel experiment and the length of damage caused by being continually slashed by said implement. This gives a R^2 value of 0.93.

Discussion:

The aim of this study was to determine whether there is a correlation between a slash cut and the implement that caused said slash damage. The feature of the implement that was being investigated in this study was the sharpness of the blade. Preliminary work and case work experience demonstrated that the sharpness of the implement had a direct affect on the appearance of the slash cut, which is common sense; but was it possible to use the information from the slash cut to form a reliable opinion as to the sharpness of the implement?

The knives used in all these experiments consisted of a steak knife, 10 blade scalpel, utility knife (SK1), a sharp vegetable knife (K6) and a blunt vegetable knife (K4).

Blade Sharpness Testing

All available knives were given a sharpness test and it was noted that different forces were required for the individual threads to break due to the uniformity of the manufacturer and because of this all the results relating to the threads have been individually calculated (see *fig 7 to 10*).

When using the dowel to measure the ultimate bluntness the threads broke due to the maximum tensile strength of the threads being reached. This was also the case for K14a when the cotton sheeting thread was used i.e. the blade was very blunt and was unable to cut the thread before it snapped. This may also apply to cases where implements had a high RSI value of 0.9 and above.

In comparing the sharpness test with a subjective assessment of the sharpness, it is clear that this method is accurate and effective.

Categorising Clothing Damage

When combining the results of categorisation alongside the results of the relative sharpness index, it was shown that cotton sheeting has the highest R^2 value (0.92) and the polyester has the lowest R^2 value (0.78).

These results show that the lower the categorisation measurement the sharper the knife is, this also shows that there is a correlation when combining categorisation and the relative sharpness index measurements, therefore demonstrating that the categorisation can be linked to sharpness.

Length of Damage

The principle behind this experiment was to show that the sharper the blade the less force was required to cut the fabric. The experiment showed that the sharp scalpel blade was able to glide through the material whilst cutting therefore creating a longer smoother damage path than the blunt vegetable knife as this struggled to cut the material therefore creating a shorter uneven damage path. This was carried out in an attempt to identify an RSI value at which the blade may fail to cut entirely through the fabric. Such a value was not identified.

It was found that there was a poor correlation between length of damage and the RSI, categorisation and fray damage. Therefore, it can be seen that the length of the damage does not assist in providing information as to the nature of the slashing implement.

Extent of Fraying

A correlation between the fray results and the RSI could be observed to a lesser or greater extent depending on the fabric type.

The highest R^2 value was 0.97 and came from the cotton sewing thread; however the cotton sheeting thread closely followed with an R^2 of 0.95. The lowest came from polyester thread (0.78). This element is also considered within the damage categorisation and when the categorisation was compared alongside the fray damage the R^2 value was 0.93 indicating that the less the fray damage present, the lower the categorisation measurement and therefore there is a correlation when using both fray and categorisation measurements.

However data relating to the scalpel is removed from this experiment a higher correlation could be observed ($R^2 = 0.99$).

Scalpel Bluntness

The scalpel was able to cut the fabric with no difficulties until it reached 0.23 RSI (see *fig 15*). At 0.23 RSI it was observed that the cuts were smaller than previous cuts made and there was also pushing of the material (the yarn was moved out of the plane of the fabric). The damage length consists of both the length of the cutting and scoring i.e. started with a cut and ended in scoring.

At 0.32 RSI (the bluntest measurement) the scalpel blade was no longer able to cut the fabric and could only push the material out of the way. The damage length that has been recorded is the scoring that the blade left behind.

When combining the blunting experiment with the RSI results a correlation is seen and the R^2 value is 0.93.

It offers no surprises in that the sharper the implement the smoother the damage. This study demonstrates, using a simple variable, the proof of principle in that it is possible to correlate a

quantifiable feature of the cut with a quantifiable feature of the implement. Considerable further work is required to translate this proof of principle into a valid operational forensic tool.

Further studies will expand this to include a wider range of implement (as shown in Table 3) upon the same materials as well as other materials commonly used in garment manufacture. The data will be used to create a database which can be used to relate damage categorisation to blade sharpness or even to a particular type of implement.

In time, this data will also be applied to a number of case work samples, both mock cases and real cases in conjunction with our own in-house forensic practitioners.

Conclusions

Two new techniques have been identified which allow for a quantifiable assessment of damage to fabric and of blade sharpness. A correlation between these two parameters has been demonstrated statistically which supports the empirical observations. This also demonstrates the principle that observations of the damage can provide information relating to the relative sharpness of the implement and therefore allow for the presentation of far more reliable and robust forensic evidence.

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