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Damage to Clothing—Cuts and Tears

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ABSTRACT: Examination of clothing in forensic science cases often involves forming an opinion as to the age and cause of any damage present. This study, involving a range of possible weapons, clothing types, and types of damage, showed that it is possible to distinguish a cut from a tear and a slash from a stab. The effect of blood on the appearance of the damaged areas was also investigated. In some cases it is also possible to determine the type of weapon used from the appearance of the damage. The study also demonstrated what features to look for in determining whether the damage to the yarns is recent.

KEYWORDS: forensic science, clothing damage, weapons, cuts, tears

In forensic science examinations, the scientist is frequently asked to form an opinion concerning the nature of damage to clothing. Questions often asked include whether the damage is from cutting or tearing, whether the cut is a stab or slash cut, which type of weapon may have been used, and whether the damage is "recent."

This study examined some of the problems involved in answering these questions. A range of weapons, of clothing and of types of damage was tested to determine if any information concerning the weapon used could be elucidated from an examination of the damage. The effect of human blood soaking into the damaged fabric and yarns was studied, as well as the effects of wear and of washing of the clothing, to ascertain if it is possible to determine whether damage is "recent."

Materials and Methods

A variety of knives and other assorted implements were selected which would give a general range of the weapons frequently seen by forensic scientists in homicide and assault cases. The weapons used are described in Table 1.

The clothing selected for this study consisted of types of garments commonly encountered in forensic science casework and, as shown in Table 2, these represent different types of fabric construction. Two sets of clothing, incorporating each type of item, were used.

The clothing was placed over a flank of pork covered with greaseproof paper, with

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TABLE 1—*Weapons used in this study.*

Type	Blade	Tip	Blade Flex, deg	Cutting Edge[a]
Cook's knife	single/smooth	very pointed	< 5	sharp
Bread knife	single/serrated	semicircular	<5	sharp
Utility knife	single/scalloped	very pointed	10 to 15	sharp
Bowie knife	double/both smooth	slightly rounded	<5	reasonably sharp
Pocket knife	single/smooth	slightly rounded	<5	sharp
Table knife	single/scalloped	rounded	< 5	blunt
Household scissors	...	squared	<5	reasonably sharp
Razor blade	...	...	...	sharp
Piece of broken glass (neck of bottle)	...	pointed	...	sharp but thick
Screwdriver	...	squared, flat	<5	blunt
Diver's knife	double/1 serrated, 1 smooth	pointed	<5	quite blunt

[a]Subjective evaluation only—not measured.

TABLE 2—*Clothing used in this study.*

Garment	Fiber Type	Construction
Tee shirt	polyester/cotton	double knit
Sweatshirt	polyester/cotton	double knit
Business shirt	polyester/cotton	plain weave
Jeans	cotton	uneven twill weave

the pork resting on a piece of board. Pork was used because its skin best fulfills the requirements of a model of human skin [*1,2*]. The greaseproof paper was used simply to keep the clothing clean, as it was to be worn in a subsequent phase of the experiment. The flanks of pork averaged about 5 cm in thickness.

Damage was made with each weapon using both a "stab" action (except for the razor blade) and a "slash" action. For one set of clothing this damage was made along the direction of the weft yarn, and for the second set is was made along the warp yarn. In addition, a cut/tear was made, along both the warp and the weft. A scalpel was used to make a straight cut approximately 1 cm long, and then the fabric was pulled apart to produce a tear extending from each end of the cut.

To test the effect of blood on the appearance of the damage, freshly drawn human blood was applied to the inner surface of the clothing and allowed to soak through, simulating the conditions of bleeding after an assault.

The effect of wear was studied after the damaged clothing had been worn for a full working day, mostly being worn as the outer item of clothing but sometimes worn covered by a laboratory coat.

The clothing was washed in an automatic washing machine and dried in a tumble dryer.

Detailed examination of the damage to the clothing, both before and after the various wearing and washing procedures, was performed using a Wild Makroskop M420, with the Wild Photoautomat MPS45, at magnifications up to approximately $\times 50$. Photographs were taken using Kodak Technical Pan black and white film.

Results and Discussion

General Observations

The difference in effort required to make the various weapons penetrate the fabric and the pork was readily apparent. No actual instrument was used to measure the force required, but the cook's knife, utility knife, bowie knife, pocket knife, broken glass, and diver's knife all penetrated easily. All of these weapons had pointed tips, which ranged from sharp and slightly rounded to very sharp and pointed. This observation is consistent with the results of Knight [*3*] and Green [*4*], who found that the sharpness of the first few millimetres of a blade is the paramount factor in the ease of stabbing and gaining penetration. It was possible to get these sharp weapons to penetrate using only one hand, but two hands were required to force the screwdriver, bread knife, and scissors to penetrate. The table knife bent and did not penetrate.

Another observation which agreed with those of Knight and of Green [*3,4*] was the fact that, once a weapon penetrated the skin, it continued, with very little force, right through to the board below. It was also interesting to note in this study that a routine examination of the piece of pork after a "stab" showed that is was possible for the blunter weapons, such as the closed scissors and the screwdriver, to break the skin without actually penetrating the fabric. In these instances, the fabric was dragged down into the wound made, causing the fabric to pucker and dent, without forming an actual hole in the fabric.

Washing the items flattened out the dent and, in the case of the screwdriver, two holes appeared where the corners of the dent had been.

There was some difficulty in producing a tear down the warp in the knitted garments. Every time the tear was attempted, instead of the damage continuing down the warp, it would start tearing along the weft. This was probably because the garments were weft knit and so the tear went off in the direction of the worked yarn. This resulted in right-angled tears.

Microscopic Observations

Initial Examination—Although each item of clothing was constructed from a different fabric, there were many similarities and features of certain types of damage which were common to them all. While the type of fabric obviously made a difference to the final overall appearance, the main factors in determining the appearance of the damage was found to be the type of damage (that is, whether it was a stab, slash, or tear) and the type of weapon (whether it was an especially blunt or sharp point and blade).

Some stab and slash cuts made in knitted garments by sharp weapons produced small segments of yarn which had been cut twice and were positioned slightly above the edge of the cut (Fig. 1). These were formed from knitted loops of yarn which had been cut and they were held in place by a few fibers that were still intact or by fibers from lower yarns.

(a) Stab cut—sharp point weapons (cook's knife, utility knife, bowie knife, pocket knife, broken glass, diver's knife)—Penetration of all garments with this type of weapon was easy. Since the blade edges and tips were sharp, the yarns were generally cut cleanly, resulting in very little fraying of the fibers at the ends of the cut yarns. Thus, the overall cuts appeared neat along the edges, with the length of the fibers uniform both within and between the cut yarns (for an example see Fig. 2).

The appearance of the yarns at the ends of the cuts was examined to determine what type of knife might have caused the damage. While not all cuts possessed characteristics to indicate the type of knife, many of them did and the following general observations could be made:

- If one end of the cut had frayed fibers and distorted yarns, while the other end was cleanly cut with the fibers still "in line" (Figs. 2 and 3), then it indicated that a knife with a single, smooth blade or a double-bladed knife with one serrated and one smooth edge had caused the damage.
- If both ends of the cut had damaged yards with the fibers frayed and distorted, then it indicated that a knife with a single blade with a serrated edge had caused the damage.
- If both ends of the damage were cleanly cut with the fibers at the ends of the cut yarns still "in line," then there was no indication as to whether the weapon was a double-bladed knife or the damage merely did not possess any characteristics to connect it with a particular type of knife.

Not only could the ends of a cut often indicate what type of weapon might have made it, but they could also sometimes indicate how it was made—that is, whether it was a stab or slash. On many of the stab cuts on the tee shirt, sweatshirt, and shirt, there was a short nick to the side at either one or both ends (Fig. 2). While this was not present on all of the stab cuts, it was not visible at all on any of the slash cuts and is indicative of a weapon having been forced into the body rather than cut along it.

A cut in a plain-weave fabric (the shirt) produced an effect not observed in the other fabrics tested (Fig. 4). If the line of the cut was essentially along the weft, but not exactly, then some of the weft yarns, in addition to the warp yarns, were cut. In this case the ends of the cut weft yarns were more frayed than were the warp yarns. In the opposite

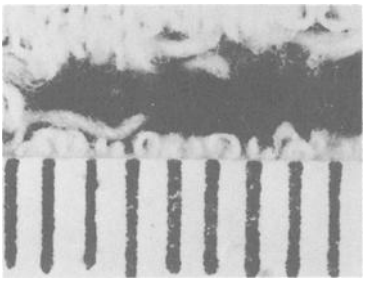

FIG. 1—*A portion of a stab cut, in a sweatshirt, made by the utility knife. This illustrates that, in knitted fabric cut with a reasonably sharp weapon, a short, isolated section of yarn may be present on the edge of the cut. One division = 1 mm.*

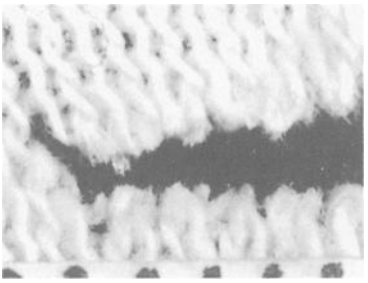

FIG. 2—*The end of a stab cut, in a tee shirt, made by the lower, smooth edge of the blade of the diver's knife. The cut ends of the yarns were clean, with the fibers remaining "in line." The short nick to the side, characteristic of stab cuts, is also illustrated. One division = 1 mm.*

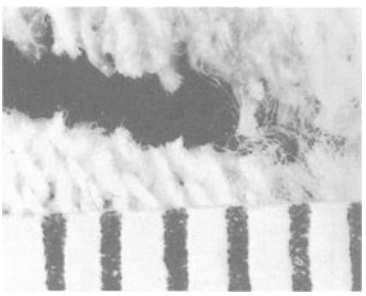

FIG. 3—*The same stab cut shown in Fig. 2, but showing the end made by the upper, serrated edge of the blade. The cut yarns are much rougher than those in Fig. 2; the fibers at the ends of the yarns are frayed and many longer fibers are present. One division = 1 mm.*

situation, that is, when the cut was essentially along the warp, the cut warp years were more frayed than the weft yarns.

(b) Stab cut—blunt weapons (break knife, scissors, screwdriver—The closed scissors, bread knife, and screwdriver were all classified as blunt because they do not have a sharp pointed tip. Their tips, being squared or rounded, tended to break the surface of the fabric rather than cut it, and therefore the damaged yards appeared stretched and broken (Fig. 5). The bread knife differed slightly because, although the tip was blunt, the blade

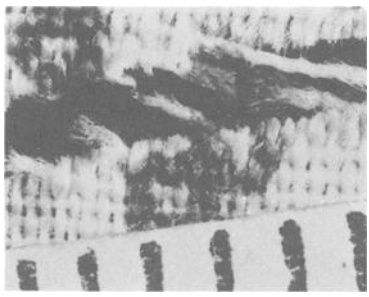

FIG. 4—*The edges of a stab cut, in a plain-weave shirt, made by the cook's knife. Some weft yarns are cut as well as the warp yarns. When the cut is not exactly along the line of the weft, the cut weft yarns are more frayed than the cut warp yarns. If the cut is essentially along the line of the warp the reverse is true. One division = 1 mm.*

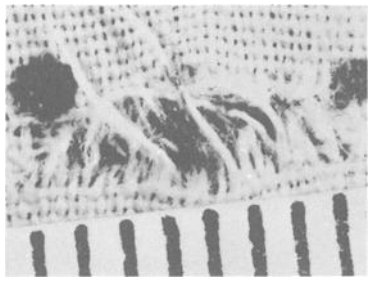

FIG. 5—*A hole, in a plain-weave shirt, caused by a stab with the screwdriver. The yarns are long and stretched, with variation in fiber length both within and between yarns. One division = 1 mm.*

was sharp. This tended to produce damage in which one area had unevenly broken and stretched yarns and another area had an edge similar to that made by the other knives tested.

The stab cuts from the scissors varied in appearance from item to item. These cuts were generally T-shaped, which was probably an effect of the shape of the closed blades. In one of the tee shirts tested there was an area in the middle of the cut where the yarns were still intact, presumably because they had passed up into the space between the two blades.

The screwdriver generally stretched the yarns, which then broke unevenly, leaving a square or oval hole. When garments are damaged in this way the length of the fibers differs both within and between yarns. The damaged area appeared rough and it was difficult to see where the broken yarns had joined (Fig. 5).

(c) Slash cut—Unlike most stab cuts, which had a short nick at the end of the damage, a slash cut started and finished in a V shape (Fig. 6). In some cases, especially with slightly blunt weapons, the ends of the cut were not very well defined since some yarns were intact in between others which were cut—that is, the cuts were not continuous. This also sometimes occurred in the middle of the cut (Fig. 7), whereas for a stab cut the yarns were usually cut through. Often, when yarns were left intact between others that were cut, it was found that some fibers within the yarns were broken but not enough to sever the whole yarn.

In those cases where a slash or cut was made along the warp or weft, yarns that were parallel to the direction of the cut were affected as well as those that ran perpendicular

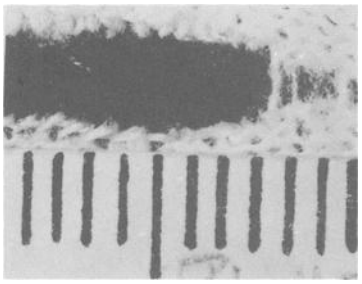

FIG. 6—*A slash, in a sweatshirt, made by the utility knife. The appearance of the end is characteristic of slashes. One division = 1 mm.*

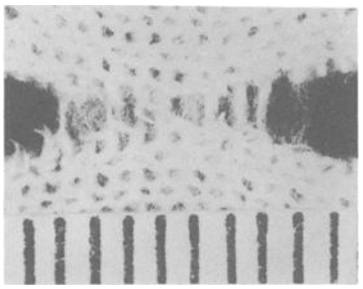

FIG. 7—*The middle of a slash cut, made by the razor blade, in a sweatshirt. The presence of a noncontinuous portion in the middle of the damage is generally indicative of a slash cut. One division = 1 mm.*

to it. If a sharp-bladed tool was used, then few, if any, yarns parallel to the cut would be dislodged (Fig. 8), but if the blade was blunt, then more yarns would be affected (Fig. 9). These dislodged yarns might or might not be cut.

The condition of the ends of the cut yarns along the edges of the damage depended on the sharpness of the blade. With a sharp blade, the lengths of the fibers were fairly uniform both within and between the cut yarns. As the sharpness decreased there was a greater difference in the lengths of fibers both within and between the yarns.

Two ways of cutting the clothing with the scissors were used: one in which the fabric was doubled over before the cut was made (Fig. 10), and another in which the fabric was pierced with the lower blade and then cut (Fig. 11). In the latter case the edges of the cut were similar to those of the sharp knives; however, the wider hold for the pierced area, and the jagged edges, distinguished it from other cuts. For the "double over" cut a distinct "half point" was often visible.

(d) Cut and tear—In all cases, except for the denim, distinguishing a cut from a tear was very simple. Figure 12 illustrates a cut and a tear in the plain-weave shirt. The fibers at the end of cut yarns were "in line" and of similar length both between and within the yarns. In the torn portions the fibers were frayed, with large variations in fiber length both between and within yarns. In addition, there were a lot of yarns out of weave or knit. Also, unlike some cuts caused by blunt weapons, there were no areas in the middle of a tear where yarns were still intact. Finally, yarns at the end of a tear appeared stretched beyond their elastic limit.

The cut/tear distinction in denim was more difficult to detect. As in the cut/tears on

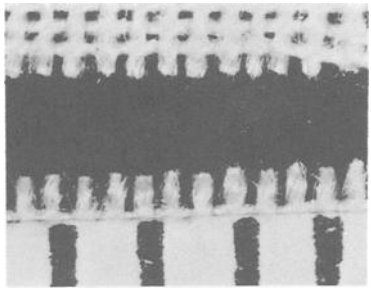

FIG. 8—*A slash cut, made with the cook's knife, on a business shirt. The top ends of the cut yarns are not far from the nearest cross yarn. One division = 1 mm.*

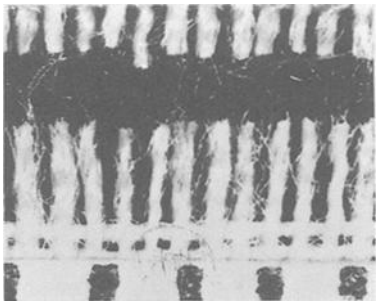

FIG. 9—*A slash cut, in a business shirt, made by the broken glass. The distance from the top ends of the cut yarns to the first cross yarn is larger than that in Fig. 8. There is also more variation in fiber length and more extraneous fibers present. One division = 1 mm.*

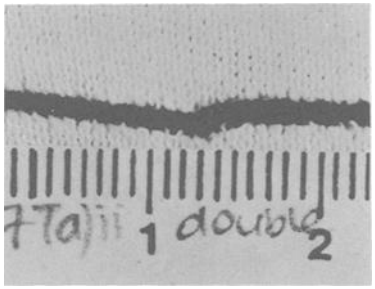

FIG. 10—*Damage where the fabric of a tee shirt was doubled over and then cut with scissors. It is possible to see where the fabric was folded, as the fold was not quite straight, and this has resulted in a slight difference in angle between the two ends of the cut. One division = 1 mm.*

other items, there was a difference in the length of the severed yarns between the cut and torn areas, but in denim this was sometimes not very pronounced. The yarns in denim are thick and closely woven. When they are broken and start to fray there is insufficient space for all the yarns to remain on the same plane, and so some yarns go above and others below the plane of the cut, making the edges of the damage appear raised. This raised "ridge" at the end of the cut was slightly wider and higher for torn

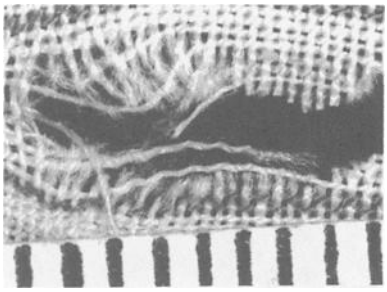

FIG. 11—*A cut in which the lower blade of the scissors pierced and then cut the fabric. Where the blade pierced, the damage is rough and the fibers at the ends of the damaged yarns are frayed. The yarns to the right are located where both blades of the scissors cut, and, in comparison with the left side, these yarns are neat, and the fibers at the end are "in line." One division = 1 mm.*

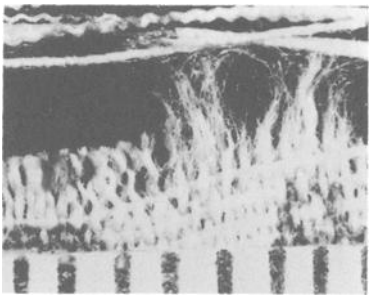

FIG. 12—*The edges of a cut, followed by a tear, in a plain-weave shirt. The cut yarns (at the left) are neat and "in line," while the torn yarns are rough, frayed, and varying in length. All the fibers, even if frayed, are still individual. The tearing action dislodged yarns running parallel to the direction of the tear, in both the torn and cut portions of the damage. One division = 1 mm.*

yarns than for cut yarns. It was not a very clear difference, and without a cut made at the same time to use as a comparison it could be difficult to identify a tear in denim solely on the appearance of the edges.

Effect of Blood on Damaged Edges

The effect of the addition of blood on the appearance of cuts and tears differed depending on the amount of blood added. The general effect of blood was to bind the fibers at the ends of broken yarns together, making them, and therefore the whole cut, appear neater (compare Figs. 13 and 14). This made many of the rougher cuts appear similar to the neater cuts.

If the blood staining was only light, most of the characteristics present originally were still visible. Thus, it was still possible to distinguish between sharp and slightly blunt weapons by the variation in fiber length.

If the blood staining was heavy, the blood could "hide" some of the detail required to identify some characteristics of a cut. In these cases it was not always possible to see detail of individual fibers, and excess blood at the edges of the damage sometimes made the fibers of the broken yarns appear to be the same length as those of cut yarns.

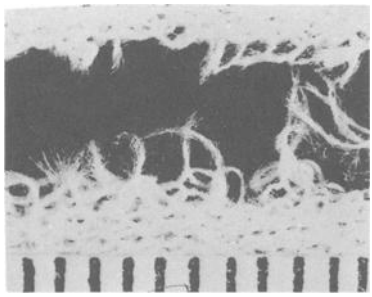

FIG. 13—*The edges of a cut, in a tee shirt, made by the table knife. The edges are rough and the yarns are generally more stretched and broken than cut. There is also variation in fiber length both within and between yarns. One division = 1 mm.*

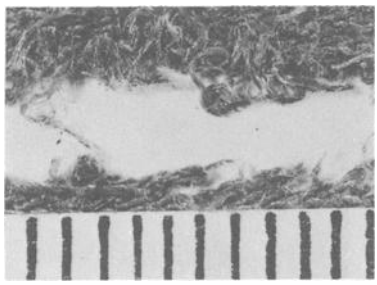

FIG. 14—*The same cut as in Fig. 12, after the addition of blood. The whole cut now appears much neater. One division = 1 mm.*

Wearing Effects on Damage

Examination of the items of clothing after they had been worn for a day showed that there were some changes to the areas of damage in comparison with their initial appearance. Most of the cuts were slightly wider than previously, though each retained the same general shape. The length of the cut yarns did not change, but the appearance of the fibers at the ends of the yarns did. Fibers at the ends of what had previously been neatly cut yarns with all the fibers "in line" started to fray and appeared quite different. Compare the appearance of the yarns in Fig. 15 with those on the left side of Fig. 3. The fibers that had been slightly frayed initially showed no real change.

In addition to the fraying fibers there were also more short, extraneous fibers present, especially from yarns that had been out of knit or weave. These changes in the appearance of the cuts were more pronounced in the areas around the chest and arms of the tee shirt, sweatshirt, and business shirt, probably because there is more body movement in these areas.

The cuts that were most affected by wearing were the ones that had previously been neat and which had ended up slightly frayed. However, after the clothing had been worn for only one day, all the cut yarns were slightly frayed; thus, it is possible to say that a garment with neat "in line" fibers at the ends of cut yarns must not have been worn much since the damage was made.

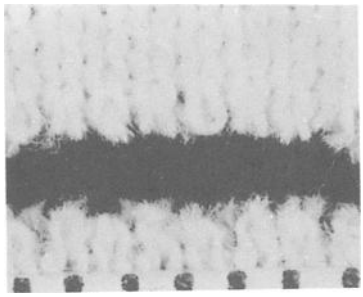

FIG. 15—*The edges of a stab cut, made with the cook's knife, in a tee shirt. This is the result after the tee shirt has been worn for a day. All the cut yarns now have frayed edges, but although the fibers are frayed, they are still individual. Compare the yarns in this figure with those on the left side of Fig. 3. One division = 1 mm.*

Washing Effects on Damage

The fibers at the ends of cut yarns after the garment had been worn but before it was washed were frayed but they were still "individual." After the garment had been washed these fibers matted together and it was no longer possible to see the entire lengths of individual fibers (compare Figs. 12 and 16). This occurred on all items of clothing examined, although the degree to which the fibers matted varied, depending on the length of the "free" fibers available to tangle. The longer the fibers, the more pronounced the matting.

Since none of the fibers were tangled originally, it is possible to say that, if the fibers at the ends of cut yarns are matted, then the garment has been washed since the damage was made. Cuts on all the types of clothing widened slightly after washing, particularly cuts on the jeans, where the cuts were very wide with several intact weft yarns across them. Before being washed these cuts had been narrow, with only one or two yarns across them.

There was no real change in results after a second wash. The matted fibers were slightly more tangled, but no distinction could be made between yarns that had been washed twice and those that had only been washed once.

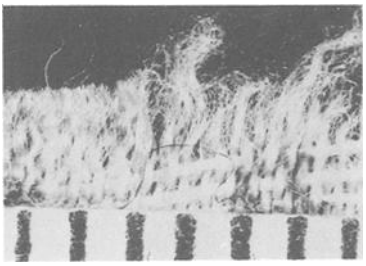

FIG. 16—*The same cut/tear portion as in Fig. 12, after the shirt was washed. The fibers at the end are now tangled together instead of being individual. The matting is more obvious in the longer torn yarns. One division = 1 mm.*

Conclusions

The generally held view that blunt weapons leave rough, uneven cuts in comparison with those made by sharper weapons was confirmed, as was the fact that blood can "tidy up" the cut yarns, thus making the distinction between cuts made by different weapons sometimes difficult to see.

Damage can be classified as recent based on one of the two following criteria:

1. It was found that the appearance of matted and tangled fibers at the ends of cut yarns indicated that the garment had been washed. Thus, under these conditions, "recent" damage means that the garment has not been washed since being damaged, and so any cut with matted fibers is not recent damage.
2. If the fibers at the ends of cut yarns are still completely "in line," perhaps slightly frayed, then "recent" could mean that the garment has not been worn to any great extent since being damaged.

While certain characteristics of damage are often of assistance in determining the type of weapon that caused the damage, there are some occasions in which the conditions of the cut can make this difficult. To enable an accurate interpretation of the damage to be made, it is important that test cuts be made in the garment (if possible) with the weapon in question.

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References

[1] Monteiro-Riviere, N. A., "Ultrastructural Evaluation of the Porcine Integument," *Swine in Biomedical Research*, Vol. 1, Plenum Press, New York, 1986.
[2] Meyer, W., Schwarz, R., and Neurand, K., "The Skin Of Domestic Mammals as a Model for the Human Skin, with Special Reference to the Domestic Pig," *Current Problems in Dermatology*, Vol. 7, 1978, pp. 39–52.
[3] Knight, B., "The Dynamics of Stab Wounds," *Forensic Science*, Vol. 6, 1975, pp. 249–255.
[4] Green, M. A., "Stab Wound Dynamics—A Recording Technique for Use in Medico-Legal Investigations," *Journal of the Forensic Science Society*, Vol. 18, 1978, pp. 161–163.

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