# Part IX
# Forensic studies

# 44

# TEXTILE DAMAGE IN FORENSIC INVESTIGATIONS

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Damage to textiles plays a part in many forensic studies. Civil liability litigation was the motivation for the work described in Chapter 37 on automobile seat belts. The questions to be answered in such cases are: *Did the belt fail due to some fault of the manufacturer? Or was it misuse by the owners of the vehicle? Or was it deliberately cut in order to impute blame to the belt supplier?* There are many similar examples where textiles deteriorate or where their failure leads to other losses and claims are made. For example, if ropes break in towing or mooring, the loss of a vessel or an oil-rig may lead to very large claims. Significant claims, though not as large, may be made when a product, such as a carpet, does not perform in a guaranteed or expected way and its useful life is shorter than it should be. The information spread throughout this book on many types of textile and many applications provides a means of approaching problems of this sort. For example, the evidence in **34G** showed that the breakdown of overalls used in a virology laboratory was due to the autoclaving conditions and not to any fault of the linen-hire company in selecting the fabric.

The use of textile evidence in criminal cases raises more specific questions. Damage to fabrics caused by knives and other more or less sharp objects is significant over and over again in clearing up certain kinds of crimes and forms the principal subject of this chapter and the next. Earlier reports on damage to clothing by cuts and tears include the papers by Monahan and Harding (1990) and by Heuse (1982). In contrast to the effects of stabbing, the damage to textiles caused by bullets in shooting incidents has been much less studied or used, but the results of a recent investigation are given in Chapter 46.

Crimes involving knives or other sharp objects are mostly a bloody matter because they often deal with murder or violence. The leisure jacket shown in **44A(1)**, dressed on a mannequin, is a typical example. It shows three damaged areas, marked by white arrows in order to demonstrate their relation to the injured parts of the body. The one stab only injured the right shoulder but the two others injured the left kidney and the liver respectively. These last stabs were fatal, indicating that the weapon must have been of a certain length. The example also demonstrates that the examination of damage to textiles should generally include information from the medical protocol, if there are injured persons, or the post-mortem protocol, if there are fatalities.

In cases where damage to textiles plays a role the forensic expert has to answer two sets of questions. One set is: What type of damage is present? Why is it angular, **44A(2)**? Was it caused by cutting or by tearing? Or was it caused by other effects, for example by rubbing caused by a fall onto the pavement, as in **44A(3)**? The other set is: What kind of object has caused the damage? Was it a knife or another tool, for example a screwdriver? Was it sharp or blunt? Did it have one edge or two edges? Some possibilities are shown in **44A(4)**.

There is no manual which describes the procedure for the examination of damage to textiles. There is the basic knowledge that two important facts dominate the examination of such damage. The first is that the features of the damage are of a morphological nature; the second is that these morphological features are clearly preserved in different ways in the different parts and the different kinds of textile constructions — the fabric, the threads, the fibres. The morphological characteristics of damaged areas are usually better preserved and more definite in the edges of damaged non-wovens or woven fabrics than in those of knitted fabrics. The characteristics are mostly clearer in fabrics made from non-textured filament yarns than in fabrics made from textured or staple yarns. Concerning the fibres, the characteristics of the fibre ends may show a greater or lesser degree of variance depending on the type of fibre and on the kind of weapon used to cause the damage. This indicates that the development of the morphological features in a damaged area is strongly influenced by the elasticity of the fabric, by the flexibility of the position of the yarns, by the construction of the yarns and by the fibre material itself. This knowledge leads to two simple rules for the general course of action.

The first and the most obvious rule is: *do not alter the damage by stretching the object or by any other kind of moving and manipulation.* The other rule follows the same principle, which dominates crime scene working: *at first you only have to look at the damage in order to get an overview of the potential morphological information.* From the beginning of the examination a stereomicroscope is therefore needed to get a detailed view. Besides this you finally need your eye and your brain to store and to combine the features that you have seen.

Sometimes, as shown by **44A(5)**, which is referred to in more detail later, SEM pictures at higher magnification are useful. However, as discussed in the next chapter, the microscopical features of the fibre ends in textile damage vary over a wide range, so that it is difficult to determine the cause of damage from the observation of single fibre ends. In the present state of the art, this limits the value of SEM observations in forensic examinations.

The next question is: Where are the features located which can be used to characterize damage? There are two areas of interest — the edge lines and the end areas of the damage. Sometimes, the features are not clearly pronounced in the damage to the outer fabric, for example in the case of jackets, overcoats or trousers made from thicker fabric. Then you should try to look at the damage to the lining or to the interlining of the clothing. Further, it must be mentioned that the macroscopic appearance of the edge lines can often be ambiguous. The damage to a knitted cotton T-shirt, **44B(1)**, demonstrates this. The split was caused by a combined cutting and tearing process. This is not indicated by its macroscopic form. It only becomes clear if the yarn ends are examined. A cut yarn with the typical plain end is first seen, **44B(2)**. Then, in contrast to that, a torn yarn with the characteristic formed end like a thin pointed beard or brush is also visible, **44B(3)**.

From this example we can deduce that as a general rule the most important characteristic which is located in the edge lines is the form of the yarn ends. The importance of that knowledge is emphasised by two other pictures. In **44B(4)**, we see a macroscopic view of the damage in a lining made from acetate fibres. It only gives ambiguous information as mentioned above. In **44B(5)**, we see the edge line under the stereomicroscope once more showing the typical plain form of the cut yarn ends.

Now to the other area of interest — the end areas of the damage, which are the most important parts to study. They often have clear contours which indicate whether a cutting tool like a knife was used and if that tool was one-edged or two-edged. **44C(1),(2)** shows the two end areas of the damage to a nylon shirt belonging to a murdered pensioner, which was obviously caused by a one-edged kitchen knife. In **44C(1)**, you see the pointed end caused by the edge, and in **44C(2)**, the other end formed by the back of the blade. That blade must have had a broad angular back in order to form the swallow-tailed end. In this case, the jacket of the murdered pensioner was also pierced by the same stab. **44C(3)** demonstrates the same form of damage to the interlining of the jacket. The damage in these parts of the clothing was more precisely defined than in the outer fabric.

In another murder case the clearest view of the damage was found in the nylon lining of the anorak of the victim. In this case, the macroscopic form, **44C(4)**, already indicates that the tool must have been sharp and one-edged and had a broad but round back. The last can be deduced from the deformed end area at the left (marked by arrows) and is clearly to be seen under higher magnification, **44C(5)**.

From some systematic experiments carried out a few years ago we have noticed that further interesting features may be located in the end areas of damage. Fig. 44.1 demonstrates the finding that the stabbing device can draw the pierced fabric into the body because the fabric and the body are both elastic and can be stretched. So, some part of the drawn-in fabric may come in a certain contact with the edge of the knife. That may cause the smaller area of secondary damage, which is seen in **44D(1)**. The drawing in of the fabric may also result in only a few of the fibres on the surface of the yarns of the fabric being cut, as shown in **44D(2)**.

The same experiments also showed that two edged knives mostly cause more or less bent damage. The reason for this is that in practice the tool does not penetrate the fabric without any twisting movement and in an exact rectangular position. The effects are schematically demonstrated in Fig. 44.2. The first diagram A shows that a twisting movement of the knife has the tendency to cause a double bent damage. B and C demonstrate that stabs tilted at an angle cause damage with only one, more or less sharp bend. **44D(3)** shows a practical example of the double bent type of damage caused by a two edged knife.

A simple, but not everyday, case story, which did not involve a crime, shows the value of forensic examination of clothing. An alcoholic was found bleeding to death on the street. The damage to his shirt, **44D(4)**, and the fatal injury in his chest were congruent in their size and their position. A damaged and bloody plastic bag with some broken bottles in it was collected from near the corpse. The criminal police asked if the injury and the damage in his shirt could have come from a fall on to the plastic bag with the broken bottles in it. Although the damage in the shirt showed an irregular macroscopic form, **44D(5)**, it was seen under the

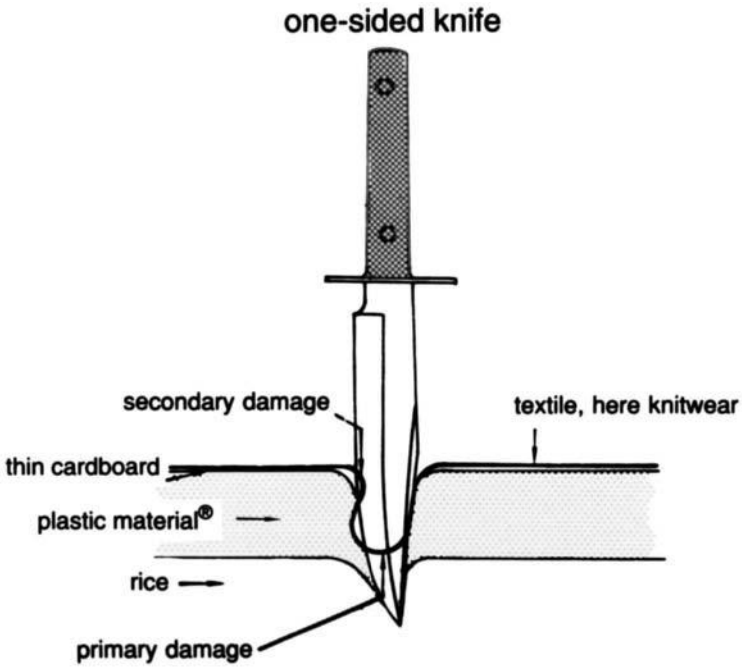


Fig. 44.1 — How secondary damage is caused.

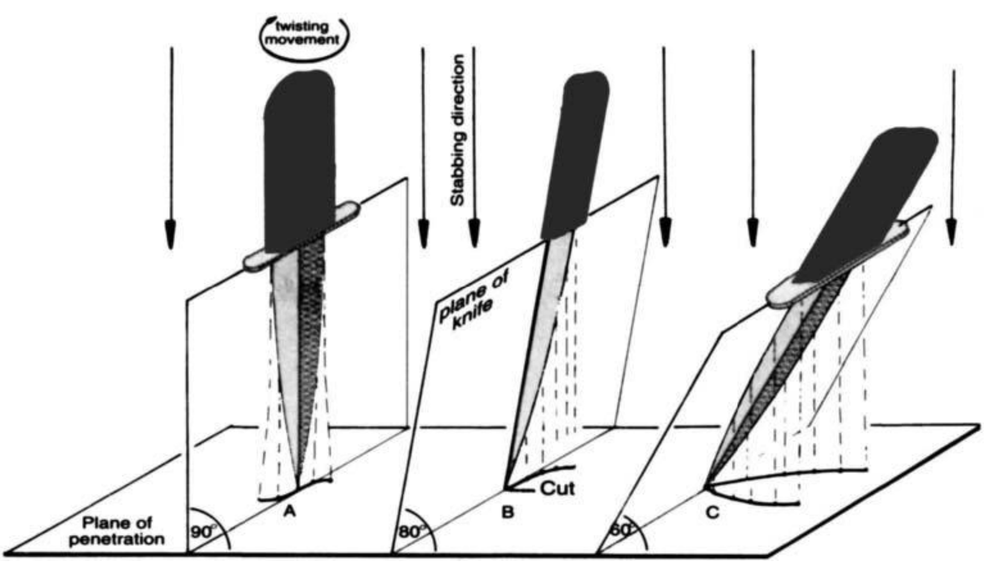


Fig. 44.2 — Principle of the origin of bent damage caused by two-sided knives.

stereomicroscope that all threads in the edge lines were definitely cut by a very sharp object. Even the unusual formed end areas did not show any characteristics of a tearing process. From the examination of the plastic bag it was apparent that there were some smaller cuts and a larger one. The larger cut, **44D(6)**, matched the damage in the shirt of the alcoholic in size and in form. From this and from other information the criminal police concluded that the death of this man must have been an accident.

In addition to the evidence from macroscopic observation, studies of detail in fibre ends can also be of use. The various forms of tensile and fatigue breaks, which may have resulted from normal wear, or, for example in the high-speed breaks in Chapter 6, from violent tearing, are spread through the early chapters of the book. Cutting and burning, which will be more relevant in forensic work, is covered in Chapter 20. In particular, **20F** consists of pictures from Foos (1993) of Bayerischen Landeskriminalamtes, which were taken with forensic applications in mind. **44A(5)** is also from the paper by Foos and shows acrylic fibres welded together in a garment damaged in an offence. The appearance matches fibres from a test made with the suspect blunt knife and shown in **20F(5)**.

Another real application of the examination of fibre ends in the SEM is described in a paper by Stowell and Card (1990). The fibres came from a woman's black nylon nightgown after an alleged sexual assault. The garment was supposed to have been cut into two halves by a knife along the vertical strips of lace on each side of the nightgown and across the shoulder straps. The investigators made experimental studies of the fabric cut by scissors and by a sharp unused scalpel blade and also when torn by hand. Fibre ends were examined in the SEM and characterised according to the type of damage. The scissor cuts were described as *squeezed inward on both sides and flattened* and the illustration is similar to the scissors-cut polyester fibre, **20A(6)**. Fibres from the torn fabric were reported as having *smooth, nonfractured* [sic] *ends with a more or less pronounced 'bulb' formation . . . although, in a few torn fibers, the bulb was seen only in parts of the edges of the fiber end.* This description is slightly misleading. The fibres from the torn fabric are clearly fractured, in the sense of being broken, and are typical of high-speed breaks of nylon fibres. One illustration is similar to **6A(3)**, with a complete mushroom end, and the other is similar to **6A(4)**, with a small V-notch indicating a transition between a high-speed break and a slower ductile break. The ends of fibres from the scalpel *showed a variety of shapes and forms*. Some were *relatively clean cut ends*, including some with *striations across the cut surface*, which were similar to the razor-cut nylon fibre ends in **20A(1),(3)**. Others *varied from elongated and twisted to fractured*, with illustrations reminiscent of the ductile twist breaks of nylon in **17A(2)–(4)**. A few *had indications of a 'bulbous' formation*. The first group will be fibres that were directly cut by the scalpel, while the other two sets of fibres will have failed as a result of secondary tearing and stretching of the fabric in regions away from the blade.

Thirty-six fibres from the nightgown were also examined. The most notable feature of the investigation was the use of a quantitative comparison of the incidence of the forms of break, as shown in Table 44.1. The quantitative evaluation of break types is discussed further by Pelton in the next chapter.

From their analysis, Stowell and Card concluded that, although the visual and macroscopic evidence could not determine the cause of break, the SEM micrographs indicated *that the shoulder straps could have been cut by a knife*. Neither the macroscopic appearance nor the SEM evidence was conclusive for the sides of the gown. The predominance of bulbous ends shows that the fibres had been broken by stretching and not by cutting with a sharp blade. The occurrence of fractured and elongated ends, which were not present in the experimental tears, leads to a suggestion that *an instrument of some kind*, possibly *a knife with a much blunter blade edge than . . . the scalpel . . . but it could also have been an instrument other than a knife* — or it might have been tearing by hand in a different way.

The information in this chapter and elsewhere in the book shows that examination of damage to clothing and other textiles can be valuable in solving crime or providing evidence in litigation. Where civil law-suits are for claims on the textile itself or are the direct result of failure of a product, detailed examination of the textile is clearly essential. As Johnson and Stacey (1991) say:

*if a mountaineer is found seriously injured at the bottom of a cliff and his climbing rope is severed in two, it is necessary to determine why the rope failed. It may simply have been too worn or too light for the task, but if it appears to have failed due to a manufacturing fault, the injured party may attempt to sue the manufacturer. On the other hand, the possibility that someone has deliberately damaged the rope must be considered. There is also the possibility that the injured climber's friend has deliberately severed the rope after the fall so that a claim can be made against the manufacturer. It is the task of the forensic textile scientist to determine just which of these possibilities provides the most likely explanation.*

**Table 44.1** — Incidence of damage

| Specimens | Number of fibres | Types of break and approximate percentage |
|---|---|---|
| EXPERIMENTAL | | |
| scissor cut | 21 | squeezed [100%] |
| tearing | 15 | bulbous and smooth [100%] |
| scalpel cut | 31 | clean cut [45%]/fractured and elongated [22%]/bulbous [33%] |
| FROM NIGHTGOWN | | |
| shoulder straps | 18 | clean cut [25%]/fractured and elongated [50%]/bulbous [25%] |
| sides of gown | 18 | fractured and elongated [25%]/bulbous [75%] |

For greater use in criminal cases, more research is need into characterising damage according to the weapon used and the nature of the attack. Some studies have been made by Johnson and Stacey (1991) at the University of New South Wales (UNSW), who point out that the experimental conditions must be carefully chosen. The backing is important and, since *human volunteers are hard to find*!, a side of pork with the skin on is a good approximation. *Quite different morphologies are created if the knife movement is artificially created at a constant speed, and if the fabric is held tensioned in a mounting frame. An accurate simulation requires the scientist to act out a frenzied stab attack on the fabric draped over a piece of pork.* Nevertheless, at that stage of their research, they stated that *because of the great variety of fabric and weapon types, it is not possible to develop a generalised description of the morphology of stabbed fabrics.* More recent research at UNSW is reported in Chapter 46.

It is perhaps because of these difficulties that fibre/textile damage rated only two paragraphs by Carroll (1992) in a book on *Forensic examination of fibres.* His conclusion was that:

*While the forensic specialist is often asked to 'match' a suspect weapon with damage found in a garment, this is rarely possible. The garment can be examined to characterize the age of damage present, for example, 'recent' or 'fresh' versus 'old' in nature; the proviso to distinguish recent from old being that the garment has not been laundered since the damage occurred. The type of damage may be characterized as cut, rip, or seam separation. The suspect weapon may also be used to produce test damage, simply to indicate whether or not it is capable of producing damage consistent with that in the garment.*

This is a minimalist approach. The co-operation of skilled microscopists with textile scientists is capable of more.

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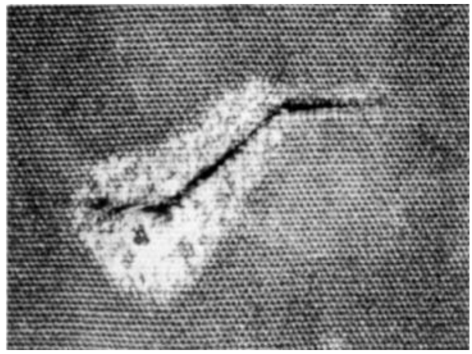

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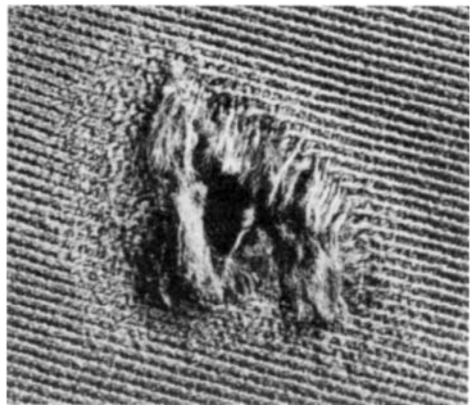

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**Plate 44A — Damage in fabrics.**
(1) A leisure jacket with three stab cuts marked by arrows. (2) An angular cut. (3) A break from rubbing against a pavement. (4) A range of cutting instruments. (5) SEM picture of acrylic fibres welded together after attack with blunt force, from Foos (1993), scale mark = 10μm.

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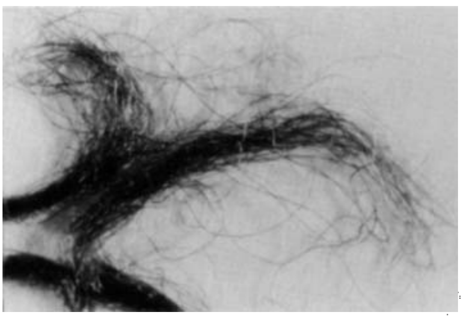

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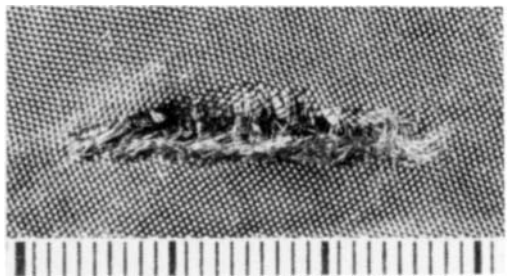

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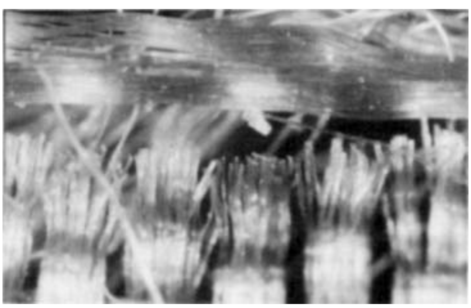

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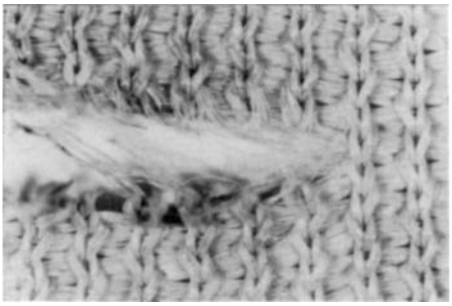
**Plate 44B — Cutting and tearing in a knitted cotton shirt.**
(1) General view. (2) Cut yarn end. (3) Torn yarn end.
**Damage in an acetate lining.**
(4) Macroscopic view. (5) At higher magnification, showing cut ends.



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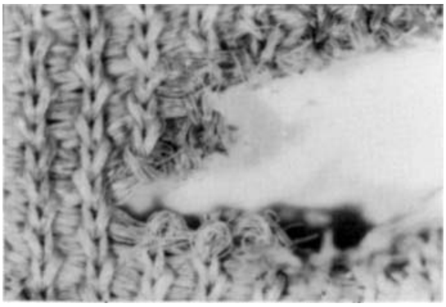

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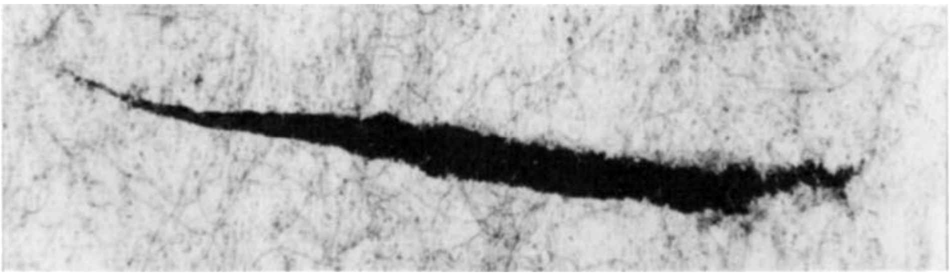

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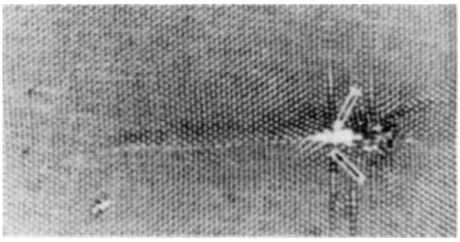

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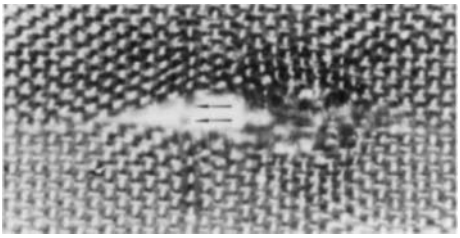

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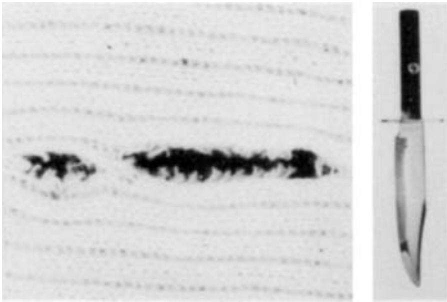
**Plate 44C — Case of a murdered pensioner.**
(1),(2) Opposite ends of cut in the nylon shirt. (3) The interlining of the jacket in the same case.
**Another murder case.**
(4),(5) Cut in nylon lining of anorak.



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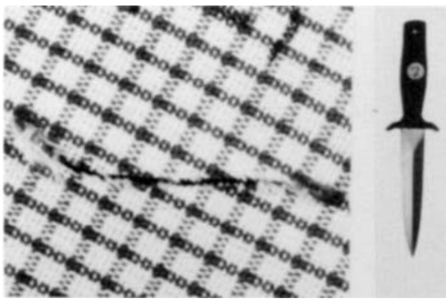

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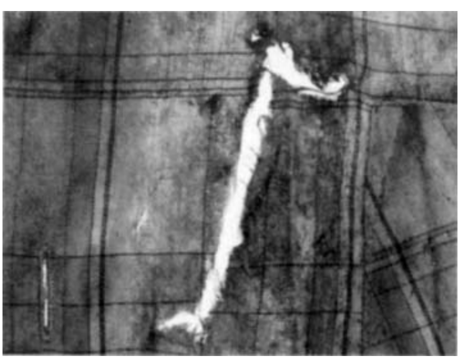

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**Plate 44D — Experimental knife cuts.**
(1),(2) Cut with a one-sided knife. (3) Cut with a two-sided knife.
**Fabric damage, but not a crime.**
(4) Cuts in a shirt. (5),(6) Matching cuts in the shirt and in a plastic bag full of broken glass.

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# USE OF SEM IN TEXTILE FORENSIC WORK

William Pelton

The field of forensic sciences today utilizes sophisticated laboratory instrumentation and incorporates many disciplines of which textile science is one. Both forensic and textile scientists have been using SEM micrographs of fibre and yarn damage in forensic investigations to:

(1) create a record for evidence;
(2) identify fibre or yarn features associated with different sources of damage, Choudhry (1987), Ishizu *et al.* (1974), Paplauskas (1973), Pelton (1995), Stowell and Card (1990), Wong (1984);
(3) report the results of controlled experimentation into known sources of textile damage, Pelton and Ukpabi (1995), Stowell and Card (1990).

Sources such as glass-fragments, knives, scissors, blunt-instruments, tearing, animal bites, animal claws and abraded hoisting cable strands have been identified as causes of textile damage. There is no established forensic protocol to identify the source of textile damage by observing fibre-end morphology. Scientists *have been using* ad hoc *procedures to present SEM fibre and yarn evidence. . . .* [Investigators have] *presented* [evidence] . . . *with very few micrographs to support their opinion*, Pelton (1995). There has been little comment on the diversity of fibre-end features which could appear in a single source of fabric damage. Scientists have raised issues associated with the use of the SEM to identify unknown sources of textile damage and the forensic interpretation of these SEM micrographs, Crispin (1987), Pelton (1995), Young (1989).

Forensic scientists, such as Choudhry, Ishizu, Paplauskas and Wong, and not textile scientists, first suggested that SEM micrographs of fibre- and yarn-end appearances could be used to distinguish knife-cuts from scissor-cuts, sharp instrument cuts from tearing, and sharp instrument damage from animal bites. Currently, the forensic literature does not have a database of SEM fibre or yarn micrographs, illustrating fibre-end appearances, which could be used to compare unknown to known damage sources. The problem is that much of the published textile SEM data has been based on single fibre experimentation. Textile damage observed in a forensic investigation is normally associated with an assembly of twisted fibres in a fabric structure. Therefore, the source of the damage is not the only variable; fibre type, yarn structure, fabric construction, applied finishes and fabric orientation in garment construction are variables which also influence the appearance of the textile damage observed. Forensic investigators tended to overlook the influence of these critical textile variables when the specific mechanism creating the fabric damage was allegedly identified using SEM micrographs of individual fibres, individual yarns or a montage of yarn ends. A montage is created by scanning and photographing several millimetres of fabric damage. Individual micrographs are then positioned in the correct orientation and glued together forming a record of the damage which could be observed by the naked eye as evidence in court.

In Australia, one criminal case, the trial of Linda Chamberlain for the alleged murder of baby Azaria Chamberlain, has been documented in which SEM micrographs of individual fibres, individual yarns and a montage of yarn ends were introduced as evidence at different points from the initial investigation to the final Royal Commission Inquiry by The Honourable Mr Justice T. R. Morling into wrongful conviction, Crispin (1987), Morling (1987), Young (1989). The Chamberlain Defense argued that a dingo had taken the 9-week old child from the campsite tent, while the Crown alleged that the mother had murdered the child in the car, placed the body in a camera bag and subsequently disposed of the body. The child's body was never found but her damaged garments were discovered by a tourist approximately 4 kilometres from the camp site. At the inquests and trial, the Crown's textile expert produced SEM micrographs of fibres and yarns from the damaged portions of the jumpsuit and indicated that:

- some of the damage portions appeared to be straight;
- the severed fibres in individual yarns terminated in a similar plane;
- the appearance of one fibre within one yarn cluster was identical to that of the classic scissor-cut (i.e., a pinched end with lateral compression), R v Chamberlain and Chamberlain (1982).

The Defense did not use a SEM until the Royal Commission commenced.

The Crown conducted one experiment with a zoo dingo and their experts concluded that the gross morphology of the fabric damage was consistent with tearing. Since the experiment was carried out in wet weather, much of the damage was encased by dried mud. The Crown's textile expert was unable to produce any SEM micrographs of dingo severed fibre-ends. No additional dingo experiments were conducted by the Crown until the Royal Commission commenced. The Crown's forensic experts were familiar only with fabric damage caused by an attacking canid, not with the damage caused by a canid picking up an infant and carrying it away.

Meanwhile two scientists, Chapman and Smith, started conducting experiments in which a domestic dog was offered food sewn into a small knitted fabric bag approximately 20 × 15 cm, Crispin (1987). Bags were produced from fabric identical to that of the missing child's jumpsuit. From their first experiment, Chapman and Smith found 'tufts' of yarn (i.e., short lengths of yarn) floating in the dog's water bowl after it had extracted the food from the bag. Earlier, the Crown had established that yarn tufts along a damaged segment of knitted fabric was a clear indication that fabric was cut and not torn. Chapman and Smith continued to experiment with dogs and dingoes. Their information was used by the Defense in the appeal process. By the end of the Royal Commission, Chapman and Smith had produced 75 specimens of canid damaged fabric. Specimens with similar macro features to scissor damaged fabric were scanned by the SEM. Defense experts felt that the SEM micrographs (100×–300×) of consecutive damaged yarns did not add any further information to the macro examination (5×–40×).

Using a low power stereo-microscope during the inquiry, the Defense textile expert found 28 points of similarity between canid-damaged fabric and the child's damaged jumpsuit, Crispin (1987). *Of those twenty eight points, he found that twelve would have been difficult to reproduce with scissors even if one had known what kind of damage to cause. Four points of similarity would be very difficult to reproduce, if not impossible, to reproduce with scissors,* Crispin (1987) page 291. A number of the similarities were observed in the exhibit of the Crown's initial dingo experiment. Over the years, the dried mud had disintegrated revealing damage which, it had been assumed, could be produced only by cutting.

During the inquiry, the textile evidence focused on SEM micrographs of individual fibres, individual yarns and, particularly, montages of yarn ends. The Crown introduced evidence suggesting that canids crushed fibre-ends in the severing process, whereas scissor-cuts produced a 'planar array' of consecutive yarn ends. Planar array was defined as a precise *alignment of severed ends of fibres within a number of consecutive yarns*, Crispin (1987) page 284. This was the first time the phrase *planar array* was associated with textiles. The definition of *precise* varied from one Crown expert to another. Crown experts suggested that planar array was visible in SEM micrographs but not visible under low power optical microscopes. No SEM micrographs of individual fibres severed by canids or cut by scissors were submitted as inquiry evidence, but SEM montages of both dingo- and scissor-damaged fabric were introduced by the Crown. Crown experts claimed that the dingo-severed fabric could not achieve the same degree of planar array that scissor-damaged fabric could. Under cross-examination, Crown experts could not agree on the planar array definition nor on the limit of deviation in the planarity. A law court is no place to establish textile definitions. Only established terminology accepted by the scientific community should be used in court evidence.

Defense experts testified that the use of SEM montages to distinguish the 'planar array' was beyond the limitation of the micrograph interpretation, Crispin (1987). They agreed that the montages produced a clear magnified image of the damage, but the two-dimensional SEM montages did not have a reference scale to detect fibre-end deviation measurement within and between the yarn clusters of a three-dimensional structure. No quantitative data were produced by the Crown. When Crown experts were cross-examined about mounting procedures to attach a fabric specimen to the SEM stud, manipulation of specimens around the stud and method of attachment could alter the degree of planarity observed. Since textile materials are flexible, knitted fabric specimens were observed curling towards or away from the stud, Morling Transcript (1987). Again, this fabric curling could influence the degree of planarity observed as the stud is rotated, and moved back and forth to capture the best image. As with terminology, a law court is no place to argue SEM protocol. Only established protocol accepted by the scientific community should be used to prepare court evidence. If necessary, in particular difficult cases, this may involve going back further into the scientific presentation in order to find an acceptable starting point.

In order to establish the validity of the Crown experts' claims that scissor-cuts could be distinguished from dingo-damaged fibre-ends, Raymond, the Commission's forensic scientist, set up a blind experiment for the Crown and Defense textile experts, Young (1989). He prepared a SEM stud with five different short tufts of nylon yarn. This experiment gave scientists the opportunity to demonstrate the significance of fibre-end appearances as a means of distinguishing scissors-cut from dingo-severed fibres. After viewing the five specimens for more than two hours fibre by fibre, no-one volunteered any comment. The characteristics observed in each tuft had many similar overlapping features. Several fibres had an appearance consistent with the micrograph **37D5**, which was published later in the first edition of this book. This micrograph depicts features of a nylon seat-belt fibre severed by a dog. No unique feature such as the classic scissor-cut appearance was noted in any one specimen. Raymond then revealed that three tufts were taken from dingo-damaged jumpsuits, one was produced by a pair of scissors, and the final tuft was the Crown's inquest exhibit from the missing child's jumpsuit. Raymond's experiment made a significant impact in this case on the reliability of SEM fibre-end micrographs to distinguish the cause of fabric damage, Morling (1987).

The inquiry then turned its attention to the SEM montage evidence and called its own textile expert in an attempt to clarify the impasse created by the Crown and Defense textile experts (Crispin, 1987). He testified that textile scientists used the SEM to study features of severed or ruptured fibre-ends; however, they relied on a low-power optical microscope when asked to determine the planarity of a severance line. He felt that the term 'planar array' had been misused. The concept meant that the alignment of fibres must be within extremely fine tolerances produced by very sharp scissors. After observing several SEM montages of yarn-ends, this expert found similar planarity in damaged specimens produced by sharp instruments (i.e., scissors and knife) and by dingo dentition. In his opinion, the planarity of the damaged fabric in the child's jumpsuit had less planarity than that created by sharp scissors. He stated that one could not expect the fabric structure (i.e., single jersey pile fabric) in the child's jumpsuit to produce 'planar array' as defined by Crown experts.

The reliability of the SEM montage procedure was also challenged in the cross-examination of the Crown's SEM expert. One particular specimen, which the expert had cut with a scalpel, had produced two different SEM montages of the same damage. The only difference was the way the specimen had been mounted to the stud: one montage had the fabric face against the stud, while the second had the fabric back against the stud. The expert testified that the one montage illustrated the concept of planar array while the other montage contained no planar array. Specimen mounting techniques changed the textile interpretation of the SEM montages. This type of SEM observation was unreliable.

By the end of the Royal Commission, the validity and reliability of the SEM micrograph interpretations were both seriously challenged. Although the SEM has been a useful diagnostic instrument of fibre failure morphology, the problem was that no appropriate database of SEM micrographs existed. This was certainly true prior to the publication of the first edition of this book in 1989, and, even now, the database is limited in its relevance to forensic investigations. At the time of the 1987 inquiry, no scientist was able to quote references to any published SEM research distinguishing scissor-cut from tears, or scissor-cut from dingo-severed fabric. Research into features to distinguish one source of damage from another was conducted throughout the course of the criminal proceedings. Initial speculation on the appearance and features of dingo-damaged fabrics was proved incorrect by the conclusion of the inquiry. SEM micrographs, however, contributed to the inquiry by illustrating that canids could produce features similar to those caused by sharp instruments. The micro-analysis, therefore, supported the macro-analysis.

In order to move towards the establishment of a database, Ukpabi and Pelton (1995) first reviewed the use of the SEM to identify the cause of fibre damage in forensic investigations and found only six journal articles reporting some aspect of SEM usage to document evidence, to describe unique features, and to report the results of known forensic textile damage. Scientists have expressed different opinions on the usefulness of the SEM to distinguish the cause of textile damage and, in some cases, have not agreed on the interpretation of SEM micrographs. Included in the review was the quantitative investigation by Stowell and Card (1990), which was referred to in Chapter 44.

Reports of a more extensive quantitative study have been published by Pelton (1995) and Pelton and Ukpabi (1995). A plain woven untextured multifilament nylon fabric was damaged in three ways: cutting with sharp 21 cm dressmaker's shears (scissors cut); cutting with a sharp carving knife with a 20 cm blade (knife cut); and rupture on an Elmendorf tear tester (impact tear). For the cuts, one person held the fabric under minimal tension, with no supporting substrate, while another cut the fabric with scissors or slashed it with the knife. The prior expectation was that the shearing action of the scissors would cause lateral compression, the knife would give a clean cut, and the high-speed tear would give the characteristic mushroom cap. These forms are illustrated in Fig. 45.1.

Pelton examined over 600 damaged fibre ends in the SEM, either in yarn clusters or as individual fibres, and assigned 322, which showed clearly defined features, to the above

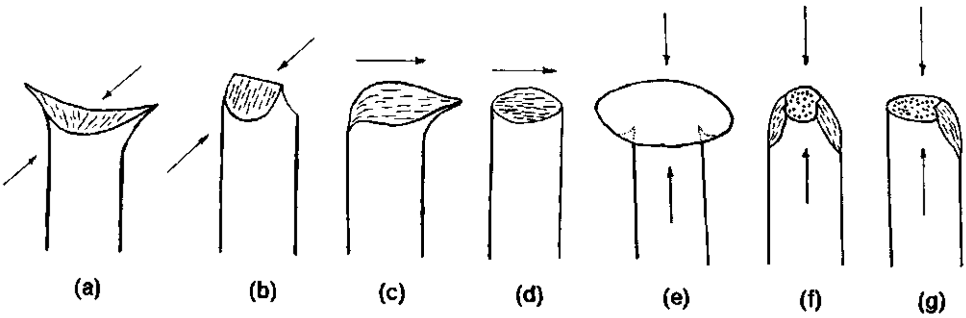


**Fig. 45.1 — Classification of fibre breaks.**

| | |
|---|---|
| SCISSOR (shearing action): | (a) pinched, lateral distortion; (b) pinched |
| KNIFE (slashing action): | (c) flat top with lip; (d) flat top |
| IMPACT TEAR: | (e) mushroom, bulbous |
| LOW STRAIN RATE TEAR: | (f) double ductile fracture; (g) single ductile fracture. |

**Table 45.1** — Assigned causes of fibre damage, Pelton (1995)
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| Actual source | Assigned descriptors | | | | |
|---|---|---|---|---|---|
| | Lateral compression | Clean cut | Mushroom cap | Undefinable | Total for source |
| scissor | 6 | 89 | — | 8 | 103 |
| knife | 14 | 60 | 6 | 25 | 105 |
| tear | — | 5 | 92 | 17 | 114 |

categories, plus an additional 'undefinable' category for those which did not conform to any of the three types. The results are shown in Table 45.1.

Pelton and Ukpabi (1995) then asked a panel consisting of a textile technician, a textile professor, a textile graduate student and 11 undergraduate clothing and textile students to view 117 micrographs. They were given written instructions on how to view the unknown pictures, and how to assess damage based on the theoretical models, shown in Fig. 45.1, and SEM micrographs of known scissor cut, knife cut and impact tear micrographs. In addition to the three options and the undefined category already mentioned, a slow-speed ductile fracture, also shown in Fig. 45.1, was included among the available choices. Appropriate statistical procedures were used to randomise the presentation and determine *recognition probabilities* for assigning correct cause; a value of 0.2 or less would result from a random allocation of cause, and 1 would show perfect assignment. The result of the study was that the recognition probabilities for individual panellists ranged from 0.35 to 0.46. The mean percentages of correctly assigned causes were 15% of the 39 scissor cuts, 37% of the 42 knife cuts and 72% of the 36 impact tears. Table 45.2 shows how the causes were assigned.

Finally, Pelton and Ukpabi attempted to assign 248 fibre end micrographs to descriptors developed from those used by Stowell and Card (1990). Their results are shown in Table 45.3. Comment on the meaning of the descriptors is included in the discussion of the micrographs in **45A,B** below.

The experimentation reported by Stowell and Card (1990), as described in the previous chapter, and by Pelton and Ukpabi (1995) has been significant in starting to establish an SEM database for forensic textile applications. However, in total, the studies were limited to four sources of damage, three fabrics, and one fibre type. The two studies reported results using different quantitative approaches and neither relied solely on qualitative observations. Pelton and Ukpabi replicated the damage created by Stowell and Card but used a different fabric structure. Stowell and Card reported unique features distinguishing cuts from tears and scalpel-cuts from scissor-cuts. Pelton and Ukpabi's experiment found that subjects could identify correctly most of the torn fibre-end specimens but were mostly unable to identify either the knife-cut or the scissor-cut specimens. The two studies reported completely different conclusions using similar sources to create the textile damage. Their conclusions are significant because the results suggest that fabric structure, amount of fabric cover and/or amount of yarn twist could influence what is seen in SEM micrographs. The fabric used by Pelton and Ukpabi was a tightly woven structure with a compact multifilament yarn; whereas, Stowell and Card described one component as lace which is normally an open structure.

When Pelton and Ukpabi's scissor-cut and knife-cut results are compared to those reported in the Chamberlain investigation, the compact woven fabric structure may have

**Table 45.2** — Actual and assigned causes, Pelton and Ukpabi (1995)
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| Actual cause | Total | Average assigned cause | | | | |
|---|---|---|---|---|---|---|
| | | Knife | Scissor | Tear | Ductile | Jndefined |
| scissor | 39 | 17 | 6 | 3 | 7 | 6 |
| knife | 42 | 16 | 8 | 5 | 5 | 8 |
| tear | 36 | 1.4 | 0.6 | 26 | 4 | 4 |

**Table 45.3** — Distribution of fibre end forms, Pelton and Ukpabi (1995)
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| Descriptors | Actual cause | | |
|---|---|---|---|
| | Scissors | Knife | Tear |
| pinched appearance* (with or without lateral distortion) | 0 | 14 | 9 |
| rivet head | 16 | 25 | 0 |
| mushroom cap (bulbous and smooth*) | 0 | 0 | 48 |
| smooth cylindrical end* (flat top) | 16 | 28 | 9 |
| smooth cylindrical end with lip | 15 | 39 | 0 |
| cylindrical concave end | 4 | 0 | 0 |
| ductile fracture | 0 | 0 | 2 |
| undefinable (fractures, elongated*) | 3 | 18 | 2 |
| Total | 54 | 124 | 70 |

* Denotes descriptors similar to those reported by Stowell and Card (1990).

created more variation in the fibre-end appearances than those from an open knitted structure. Pelton (1995) has suggested that SEM research associated with forensic textile investigations is creating more questions than it is currently solving.

When researchers have experimented with thermoplastic fibres, they have expected a clean-cut fibre end from a sharp knife or razor, though more squashing from a blunter knife, lateral compression from scissors, a mushroom cap from an impact (high velocity) tear and a ductile fracture from very low velocity rupture. Pelton (1995) used a series of SEM micrographs to document why the subjects in Pelton and Ukpabi's experiment (1995) had difficulty in distinguishing between scissor-cut and knife-cut fabric damage. Examples of the appearance of fibre ends, similar to those published by Pelton (1995), are shown in the following SEM micrographs. They are all from a tightly woven, multifilament nylon fabric and show overlapping features. The pictures are arranged with scissor cuts on the left, **45A,B 1(a)–1(f)**, knife-cuts in the centre, **45A,B 2(a)–2(f)**, and impact tears on the right, **45(A),(B) 3(a)–3(f)**.

Both the knife cut, **1(a)**, and the scissors cut, **2(a)**, have similar pinched ends with lateral distortion, which might have been anticipated only with the shearing action of scissors. Lateral distortion is also visible in **1(b)** for scissor-cut and in **2(b)** and **2(c)** for knife-cut. Striations are apparent on the surfaces cut by both scissor, **1(b)(d)(e)**, and knife, **2(b)(d)(e)**. In **1(c)**, which shows a double-cut fibre end, both blades of the scissors have sheared the fibre; this feature was unique to fibres cut by sharp scissors and could possibly distinguish scissor-cut from knife-cut yarns, Pelton and Ukpabi (1995). A clean-cut with lip is evident in **1(e)** for scissor-cut and in **2(e)** for knife-cut; the lip and striations indicate the direction of severance. Shown in **3(a)–(f)** are a variety of fibre-end features for impact tears. Descriptors such as mushroom, **3(a)**, rivet-head, **3(b)**, inverted mushroom, **3(c)**, globular **3(d)**, double-ductile with catastrophic fracture, **3(e)**, and globular with initial crack, **3(f)**, appearance could describe the different shapes of the impact tear specimens. According to theories of fibre rupture, ductile fractures should not be associated with impact tearing. Fabric and yarn variables may be causing ductile fractures to occur. The scissor-cut, knife-cut and torn fabric fibre-ends in **1(f)**,**2(f)**, and **3(f)**, respectively, all have similar features which are associated with tensile fractures. The appearances of **1(f)** and **2(f)** suggest that some fibres are fractured in fabrics before the blade can make contact with the fibre, as a result of pressure on the part of the fabric that is in contact. The high magnification allows detailed surface features to be observed in several of the micrographs, in addition to the general forms described above.

Scissors are essentially two pivoting knives contacting and cutting a material in opposite directions. In theory, the effect of the two blades coming together could be visible on a single fibre-end (i.e., a pinch-end with lateral compression). This observation should not be anticipated in damaged fabric since the fabric is made from yarns which are usually twisted bundles of fibres. Fibre cross-sectional shapes could also influence fibre-end appearances of thermoplastic fibres. Yarns from the same set of experiments are shown in **45C(1)–(4)**. The scissor-cut in **45(C)(1)(2)** suggests that the fibres could remain 'tightly clustered' with 'all fibre ends terminating in a similar plane'. The sharp scissors causing the damage have created different fibre-end appearances (i.e., clean cut, cut clean with lips, double-cut). No pinched-end with lateral compression examples are visible in this yarn. The compact fabric and yarn structure may account for this feature not being detected. Many individual fibre-ends within the yarn cluster of **45(C)(1)** have features similar to those within the yarn cluster of **45(C)(3)**, a knife-cut specimen. All yarn micrographs were produced at 250× magnification.

Fibres within the knife-cut yarn, **45(C)(3)** are 'loosely clustered' with 'all fibre ends terminating in a similar plane'. The majority of fibre-end appearances in this micrograph could be described as clean-cut. A closer examination of the fibre ends in the yarn cluster reveals a series of parallel striations suggesting a direction of severance. The grooves in the knife-cut striations are more prominent than those of scissor-cut striations. The depth of grooves could be associated with the method of sharpening and could possibly distinguish one sharp instrument from another.

Impact tearing, **45(C)(4)**, exhibited 'no clustering' of the fibres. Fibre ends 'terminated in different planes' with a 'random orientation'. Descriptors such as bulbous or mushroom shaped would characterize most fibre ends. The range and distribution of impact tear features was quite different from those observed for either knife- or scissor-cut fibres. Neither the knife-cut nor impact tear fabric samples exhibited the tightly clustering features of **45C(1)** or the fibre-end feature indicated in **45A(1c)**.

As illustrated in these micrographs, fibres ruptured within a fabric instead of fractured individually have increased the range of fibre-end appearances observed in a given source of damage. The difficulties of making valid interpretations of fibre breaks are emphasised by the scissor-cut, knife-cut and torn fabric fibre-end appearances in **45(B)(4a,b,c)**, respectively. These illustrate some of the unexpected features which Pelton and Ukpabi (1995) catalogued as undefinable. The enlarged diameter and inverted-cone shaped end in the scissor-cut **45B(4a)** could be associated with an impact tear force; the elongated fracture in **45B(4b)** resembles an insect damaged fibre-end appearance; and the enlarged twisted fibre end in **45B(4c)** may show the influence of twist on yarn rupture. Fibres, therefore, can be fractured by tensile or shearing forces before a severing instrument makes contact. The effect of fabric structure, yarn type, and different generic fibres on fibre-end appearances must be studied further.

Forensic protocols exist for fundamental textile analyses such as fibre identification. In situations such as identifying the cause of fabric damage, however, there is no established protocol or substantial body of published research to draw upon. Interpretation of the damage depends on the scientist's knowledge of textile garment, fabric, yarn, and fibre properties, and the possible interactions of these properties. In identifying the cause of fabric damage, the investigation should be systematic — moving from the macro to the micro (i.e. from garment to fabric to yarn to fibre). SEM micrographs, as illustrated above, could be associated with the latter two components. A system similar to the concept used in fingerprint comparison in which 'points of similarities and differences' are established could give more useful information about the cause of textile damage than assessing the damage against a set of known criteria. This approach has been illustrated in discussing features observed in **45A,B(1,2,3a–f)**.

SEM yarn or yarn montages should not be used to measure the planarity of the three-dimensional image. **45C(1)** and **45C(2)** are micrographs of the same scissor-cut yarn, but viewed from different perspectives. Another typical scissor cut yarn from the test fabric is shown in side view in **45C(5)** and in end view in **45C(6)** at different magnifications. These micrographs illustrate some advantages of the SEM to record and document fibre-end features. **45C(2)** gives a clearer indication of the fibre-end appearances — fibres at the bottom of the micrograph having the clean-cut lips pointing up to the yarn centre, while fibres at the top have their lips pointing down. In another yarn example, the perspective presented in **45C(5)** shows that the severed fibres within the yarn all terminated in a similar plane. If the stud were rotated and tilted to give a perspective similar to Fig. 4(b) from Pelton (1995), reproduced as **45C(6)**, fibres in the yarn centre may be seen to have been severed by both blades (i.e., double-cut) with a similar appearance to **45A(1c)**. As the stud is rotated and the angle changed from one position to another along the damage, better images of the features can be recorded. The degree of planarity among the fibres or the deviations from a common cutting plane, however, could not be viewed in either **45C(1)** or **45C(2)**.

The SEM can be a useful diagnostic instrument for fibre morphology in forensic textile investigations. SEM micrographs document evidence which the scientist sees under the microscope and present a clear image of what the scientist is attempting to explain. Judges, lawyers and jury members are not experts and visual documentation assists in technical explanations of textile evidence. Because of the many variables involved when damage is created, scientists need to document the range of features which were observed under the SEM. To date, scientists have viewed damaged fibre features on the SEM but have not presented courts with sufficient documentation about the range of features that one could expect.

With the current limited SEM information published on damaged fibre end appearances associated with yarns and fabric, assessing the cause of damaged fabrics using a set of criteria could be problematic because another source may produce similar criteria, as demonstrated in the case against the Chamberlains. The concept of 'similar and different' observed features provides the scientist with more concrete evidence. As well as looking for differences in the SEM micrograph features, the scientist should also be asking the question 'what other sources could cause similar features to these observed in the SEM micrographs?'. Often forensic laboratories are not associated with the primary investigation. The investigator presents the scientist with the damaged textiles and asks the question 'Could a given source (e.g., glass fragment, knife, screw driver, etc.) cause this damage?' Scientists have been responding that the damage *is consistent* with the identified source without stating in their written documentation that the damage *could also* be produced by other sources based on macroscopic examination. Written statements can be misinterpreted in the jury room to mean that the identified source is the only possible source. SEM micrograph features could confirm a particular source (e.g. screw driver) or could suggest a number of possible sources (i.e. glass fragment, knife and scissors).

A final question which should be asked is 'what are the limits on the interpretation of SEM micrographs in forensic textile investigations?' At present, scientists do not have enough knowledge and understanding to give a full answer to such a question. However, several points do come to mind. The first limitation on forensic textile interpretation is our inadequate knowledge of SEM features caused by different rupturing sources. The second is associated with comparing the damaged fibre features taken from fabrics to those established for single fibre fractures. The third is related to the limited number of SEM observations, which are currently being used in court to support an informed opinion. The fourth is the use of SEM montages to establish the degree of planarity observed along the severance. The fifth is the fact that some fabric structures give similar overlapping features for sharp instruments.

In conclusion, no SEM protocol exists to distinguish the cause of textile damage in forensic investigations. A SEM protocol should require scientists to examine a number of adjacent damaged yarns, the clustering of fibres within yarns and individual fibre-end features in a systematic manner. The systematic analysis should be documented by a series of SEM micrographs.

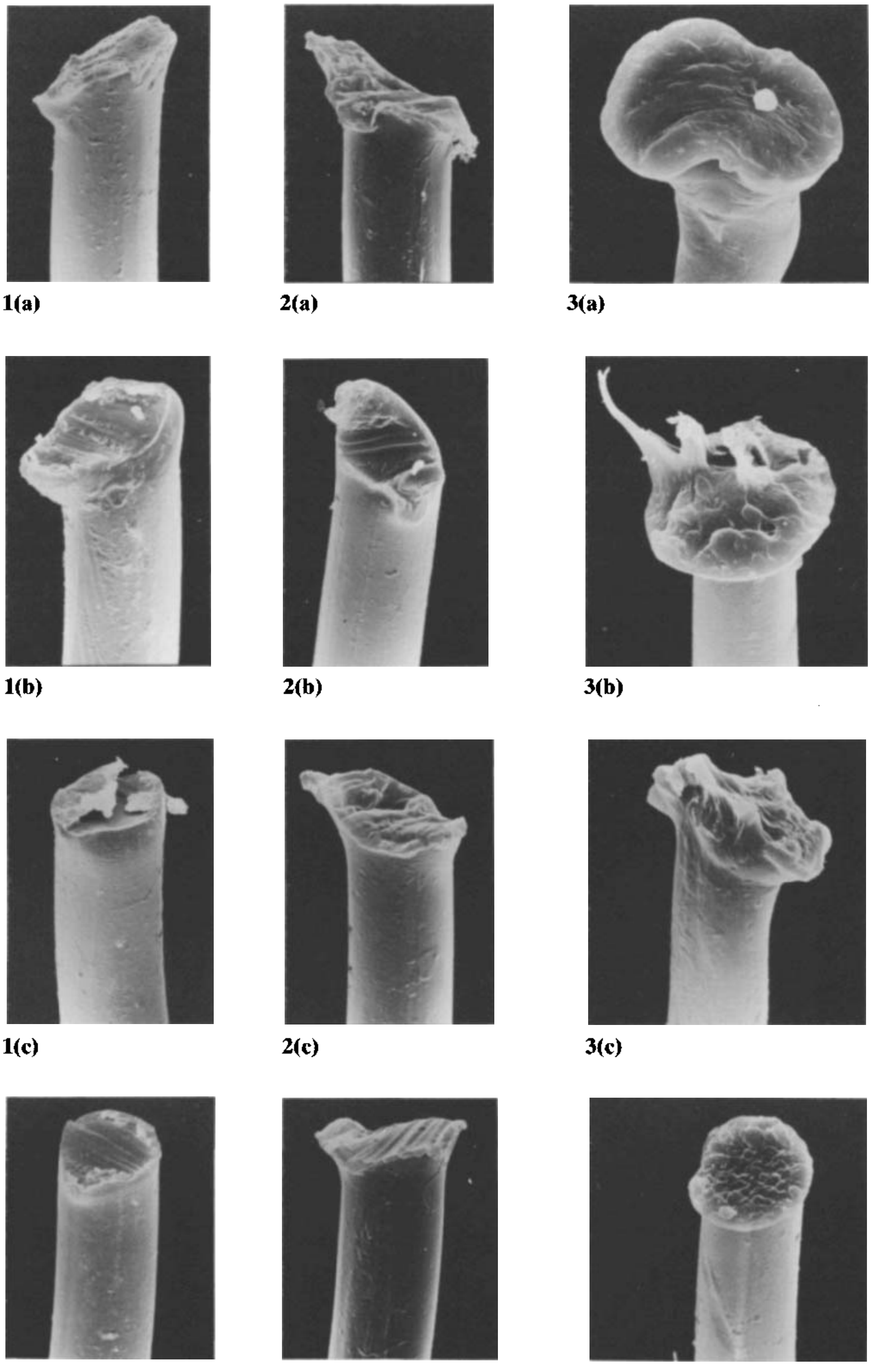


**Plate 45A — Severed fibres from woven nylon multifilament fabric.**
1 (a–d) Scissors cut. 2 (a–d) Knife cut. 3 (a–d) Impact tear.

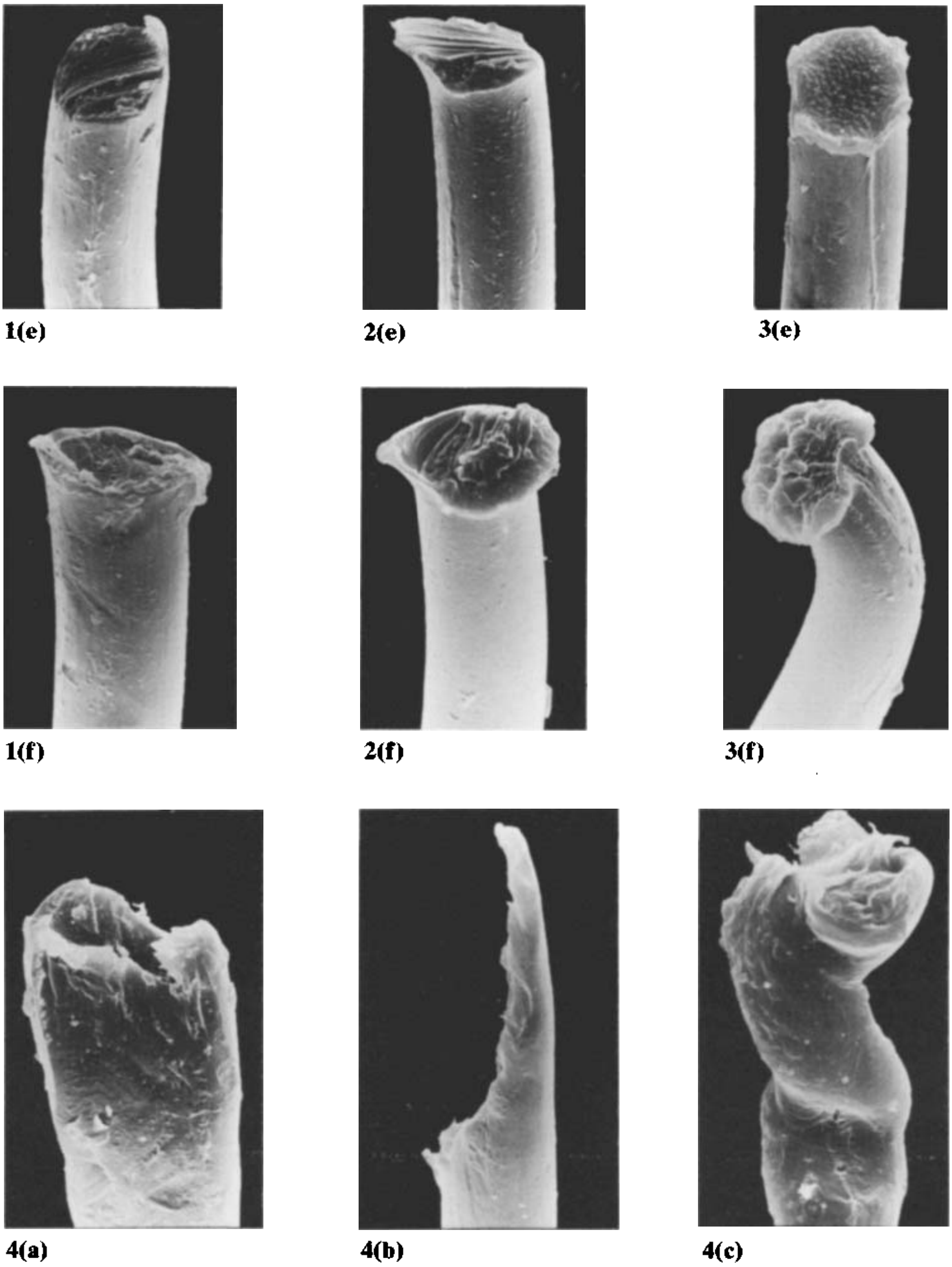


**Plate 45B — Severed fibres from woven nylon multifilament fabric (continued).**
1 (e–f) Scissors cut. 2 (e–f) Knife cut. 3 (e–f) Impact tear.
**Severed fibres showing unusual features.**
4 (a) Scissors cut. 4 (b) Knife cut. 4 (c) Impact tear.
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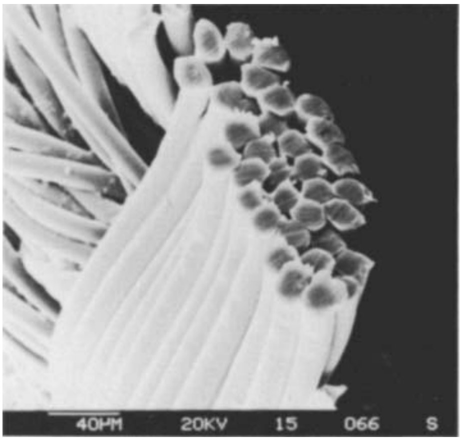


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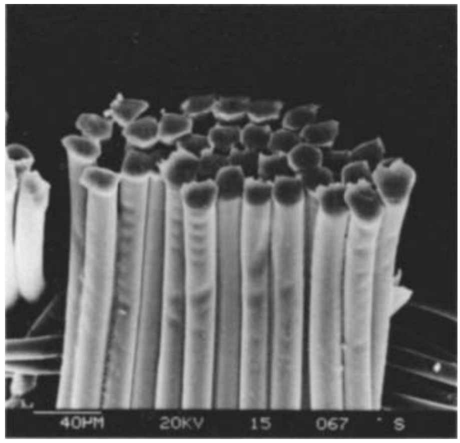


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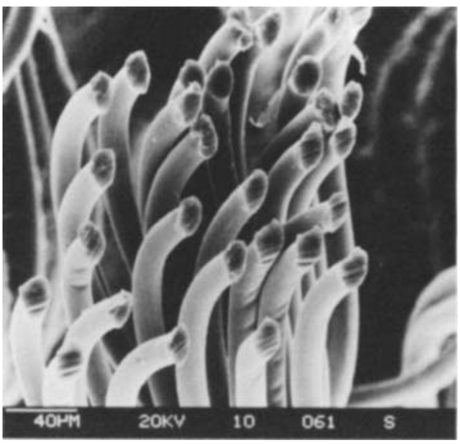


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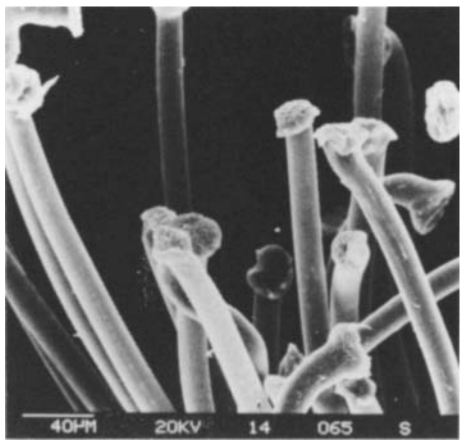


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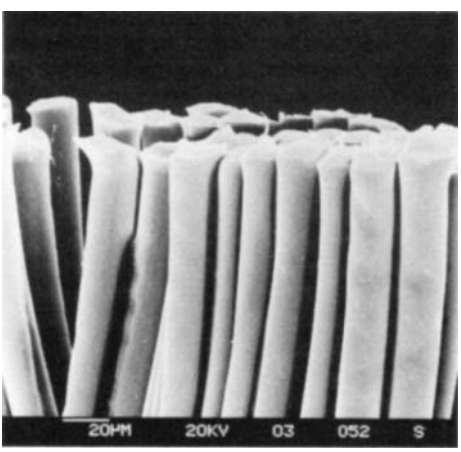


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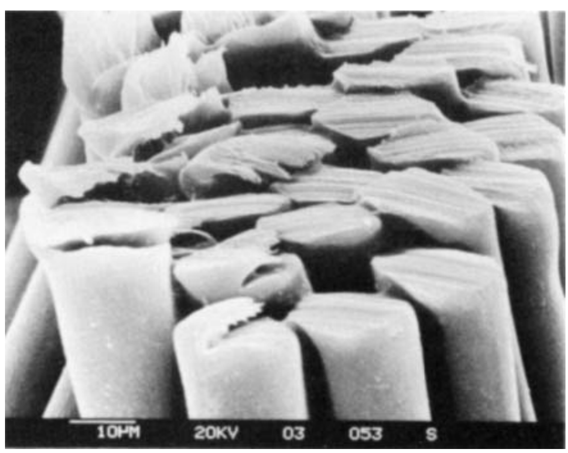



6

**Plate 45C — Severed yarns from the fabric of 45A,B.**

(1) Scissors cut. (2) Scissors cut viewed from another angle. (3) Knife cut. (4) Impact tear.



**Another scissors cut yarn.**

(5),(6) Viewed from different angles at different magnifications.

# 46

# COMPARISON OF BULLET AND KNIFE DAMAGE

Fran Poole and Michael Pailthorpe

*NOTE: This chapter consists of edited extracts from the report by Fran Poole (1996).*

The examination of clothing in murder cases, where the body has decomposed, often calls for expert interpretation concerning the cause of death. A key aspect often relied upon is the type of damage to the clothing, and an opinion as to what caused it. Chapters 44 and 45 discuss damage due to knife cuts and related causes. However, apart from laboratory testing of aramid and nylon fabrics for 'bullet-proof' garments, as shown in **40H(5)(6)** and **40L**, and the few early observations by Paplauskas (1973), there has been extremely little research to examine the relationship between the mode of damage and the appearance of damaged ends associated with ballistic impact. Consequently, limited information is available on the differences in the appearance of fibre ends damaged by bullets versus severance by knives. As mentioned in the last chapter, the lack of information on the causes of damage to textiles has, in cases like the death of Azaria Chamberlain, left textile expert witnesses wide open to criticisms concerning the validity of their judgments.

In July 1996, Ivan Millat was convicted of the murders of seven backpackers. Five of the bodies were skeletonised, which made it impossible for the pathologist to establish the cause of death, but partial remains of clothing had the potential for assisting forensic examiners with their determinations. Textile experts were consulted and were able to comment on the severance damage in the fabric, but they were unable to offer any opinion on the ballistic damage to the clothing because of the lack of research available to support opinions concerning ballistic impact.

The aim of the present study was to examine the differences in failure morphology caused by ballistic impact versus severance, as seen at three levels of resolution, namely macroscopic, microscopic and SEM. A simulated human torso was created by securing a large thick piece of pork belly to a canite backboard mounted on a metal frame. The test garment was fitted over the pseudo-torso. Five attacks were made on different parts of the torso. A common murder weapon, a .22 calibre rifle, was used to fire two types of bullet through the fabric at two distances, contact and 20cm; and a knife was used to attack each garment with a downward stabbing motion. Details of the five test garments, differing in fibre and fabric type, and of the weapons, which are shown in **46A(1)–(3)**, are given in Table 46.1. The test rig, with and without a garment on the torso, is shown in **46A(4),(5)**.

After the five attacks, the damage was assessed. First, for the macroscopic examination, the shape of the damaged areas and the separated edges were examined visually and photographed. Then a stereo-microscope with a magnification range of 6×–32× was used for the microscopic examination. At low magnification the whole damaged area could be seen and photographed. Finally, the penetration areas were cut out and mounted for SEM examination. A selection of the observations is presented here.

Except for the wool knit, which is discussed below, the fabrics exhibited irregularly shaped, but roughly circular, holes for the bullet damage, and linear severance lines in 'planar array' for the knife damage. The five macroscopic views of the woven polyester/cotton fabric, shown in **46B(1)–(5)**, are a typical set. The knife cut was also sharply defined for the tight nylon warp knit, but was less sharp for the knit cotton, **46B(6)**, and the fluffy knit polyester. The difference between bullet and knife was clear from the macroscopic examination of all four fabrics, excluding the loose wool knit. There are indications that the hollow-point bullets

**Table 46.1** — Garments, fabrics and weapons

| Garment | Fibre type | Fabric construction |
|---|---|---|
| T-shirt | cotton | single jersey weft-knit |
| vest | polyester | single jersey weft-knit |
| business shirt | polyester/cotton | plain weave |
| slip | nylon monofilament | warp-knit |
| jumper | wool | single jersey weft-knit |

Weapons

| .22 calibre *Lithgow* single shot rifle: | | serrated edged steak knife: | |
|---|---|---|---|
| overall length | 1000 mm | overall length | 215 mm |
| barrel length | 610 mm | blade length | 120 mm |
| diameter of bore | 5.61 mm | blade width | 15 mm |

ammunition:
[A] Winchester Superspeed .22 long rifle high velocity **solid-point** bullets at 350 m/s
[B] Winchester Superspeed .22 long rifle high velocity **hollow-point** bullets at 400 m/s

produce sharper edges to the holes than the solid-point. Both contact and non-contact ballistic damaged areas on all five fabrics displayed a darkened ring of gunshot residue around the perimeter of each bullet hole. This was most easily visible on the lighter coloured garments and was more difficult to see on the maroon woollen jumper.

The microscopic appearance of the first four fabrics, shown in **46C(1)–(6)** and **46D(1),(2)** support the macroscopic observations in showing a clear difference between the bullet and knife damage. Gunshot residues were clearly seen around the bullet holes on all five fabrics. In addition, yellow fragments of canite from the backboard were also visible in the ballistic damaged areas and obscured the view of the fibres. Improvements are needed in the mounting of the simulated torso, in order to avoid contamination by the backing.

Microscopic and macroscopic views of the wool knit are shown in **46D(3)–(6)**. There seems to be no significant difference in the appearance of the holes caused by bullets and by the knife, making it virtually impossible to determine visually what caused the damage. The lack of differentiation is due to the resilience of wool and the coarse, loose knit structure of the jumper. Since the transverse dimensions of both the bullet and the knife are comparable to the stitch size of the fabric, their difference in shape is poorly resolved. This is further obscured by the lack of clear stitch definition in the material and by the spring back of the wool due to its good elastic recovery. The structural differences are clearly seen by comparing the holes in the tight, fine nylon warp-knit, **46D(1),(2)**, with those in the wool knit, **46D(3),(4)**.

A number of fibres from each of fifteen samples (omitting the hollow-point damage) were viewed with the SEM. As expected, there were many differences between the fibre end appearances in the different fabrics. However, a more remarkable observation was that a large range of different fibre end appearances were recorded within the same area of fabric damage. Examples of the fibre appearances are shown in **46E–G**.

The cotton fibre ends, illustrated in **46E(1)–(4)**, displayed no clear pattern for either ballistic or severance, and were a mixture of what would be expected from tensile breaks and from flexing and transverse pressure. The ballistic fibre ends all exhibited signs of distortion or rupture giving a generally ragged appearance. Some knife severed ends showed elongated projections of the tips, while others showed fibrillation and spitting of the ends or jagged edges cut away from the sides of the tips similar to the result of a sawing action. There were no unique features that enabled bullet damage to be distinguished from knife damage.

Some of the fibre ends in the polyester fabric, which show a mushroom cap, may result from the brushing and napping of the fabric, but they may also result from high-speed rupture. Although the polyester fibre ends, **46E(5)–(10)**, exhibit clearer appearances than was seen in cotton, there was little to distinguish bullet damage accurately from knife damage. The polyester and cotton fibre ends in the woven blend fabric, **46F(1),(2)**, gave the same problems as the 100% cotton and polyester fabrics. The individual fibre ends could be distinguished from each other, but the cause of damage could not be determined.

For the nylon monofilament warp-knit, the difference between ballistic and severance damage at the fibre level was clear. The fibre ends from ballistic impact, **46F(3)–(5)**, showed the classic features of mushroom caps caused by fibres broken at high speed or due to other forms of heating. A similar form is shown in **40H(5)**. Fibre ends from stabbing damage, **46F(6),(7)**, show the characteristic squashed or more sharply cut forms noted in Chapter 20. At a larger scale, the knife damaged ends remained in pockets of yarn clusters clearly showing the line of severance of fibres on a similar plane, whereas the bullet damaged ends were separate from each other.

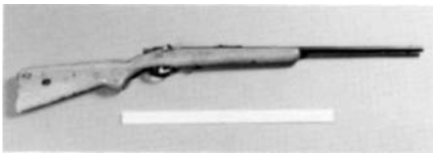
The wool fibre end appearances of the contact damage, **46G(1),(2)**, were not distinguish-able from those of the non-contact damage, **46G(3),(4)**. However, there was a subtle difference between bullet and knife damaged fibres. On several of the fibres from ballistic impact, portions of the cuticle (scales) of the wool had split off the tips of the fibres and had lodged further down the shaft of the fibre. This was not seen in any of the fibres following stabbing, **46G(5),(6)**. Other ballistic damaged fibres showed total rupture of the fibre, displaying the internal structure of the fibre end, or gouged out areas along the fibre path. The severance damaged fibre ends were clean and the edges were rounded.

In summary, the macroscopic and microscopic examinations of damaged clothing made it possible to distinguish between bullet penetration and knife severance in four of the five fabrics: weft-knit cotton, weft-knit polyester, woven polyester/cotton, and warp-knit nylon. SEM studies of fibre ends were successful in distinguishing between bullet and knife damage in only two of the fabrics: warp-knit nylon and weft-knit wool.

Observations at all three levels of resolution are thus of potential value in forensic studies. However, the nature of the damage and the possibility of identifying the cause is highly dependent on the type of fibre and possibly even more on the form of the fabric. It is doubtless also dependent on the details of the gun and the bullet or of the knife and on the particular form of attack. There is also the question of when and where the clothing is recovered. The examination of clothing may be particularly important where the remains are not found until some time after the attack, so that the pathological examination of the body is less revealing. However, changes may then have occurred due to environmental damage, which must be taken into account.

For the full potential of the examination of damage to fibres and fabrics to be realised in forensic studies, an extensive database needs to be established covering the enormous variety of fabrics and causes of damage due to criminal acts or other causes. Until such information is available, the only satisfactory option for forensic scientists is to compare observed damage with appropriate test specimens, which are realistically prepared on similar fabrics subject to relevant forms of simulated attack.

If opinions are going to be sought and given as to the cause of damage to clothing in cases similar to the Lindy Chamberlain or Ivan Millat trials, the textile expert must have knowledge of the range of variables pertinent to the case, which may influence or change the appearances of the fabric damage and the fibre end morphologies. Experts have got it wrong in the past. Further research may prevent this from happening again.



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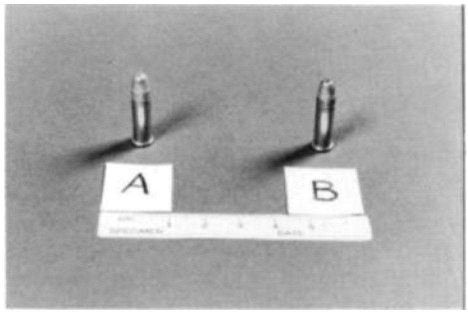


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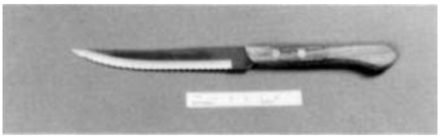

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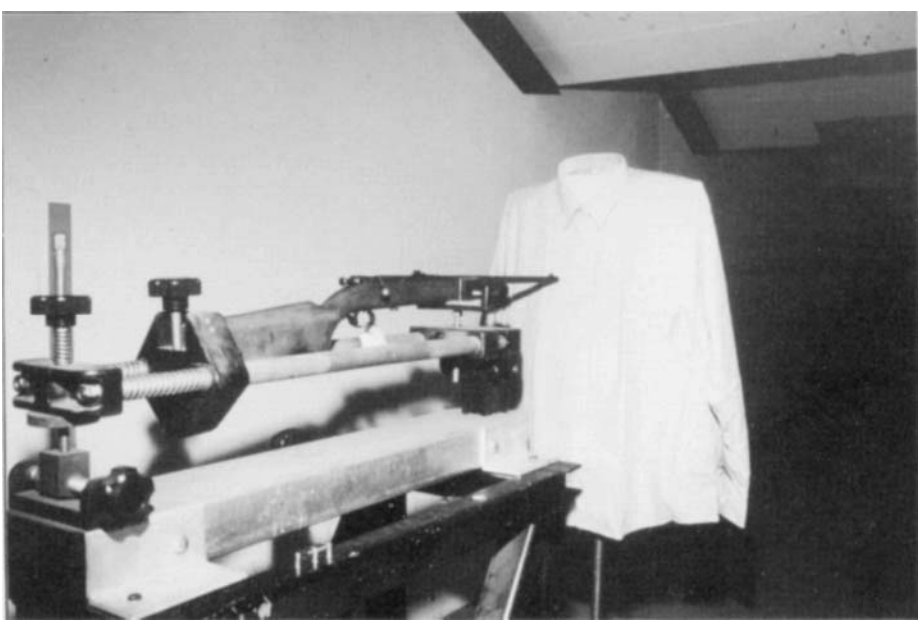

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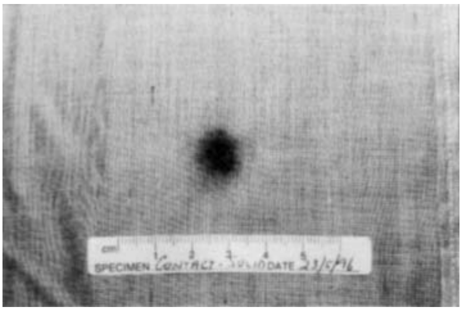
**46A — Experimental facilities.**
(1) *Lithgow* single shot .22 rifle. (2) Winchester superspeed bullets: A — solid point; B — hollow point. (3) Serrated edged steak knife. (4) Rifle secured in the test rig with the simulated torso in front of the muzzle. (5) One garment fitted over the simulated human torso.

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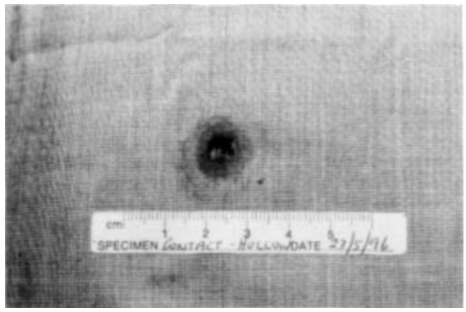


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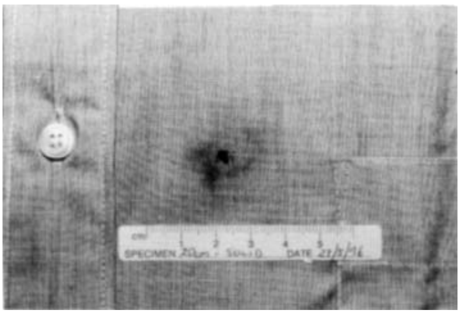


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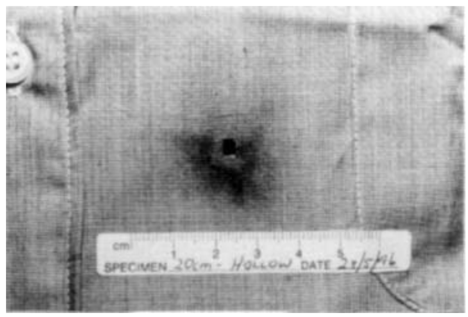


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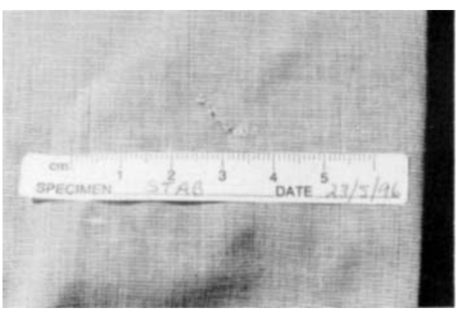


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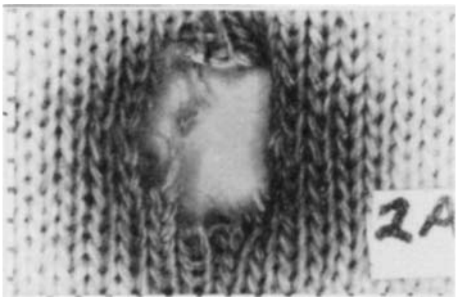
**46B — Macroscopic observation of damage to woven cotton/polyester.**
(1) Contact, solid-point bullet. (2) Contact, hollow-point bullet. (3) 20cm, solid-point bullet. (4) 20cm, hollow-point bullet. (5) Knife stab.
**Macroscopic observation of damage to cotton weft-knit.**
(6) Knife stab. [Scale numbers are in cm.]

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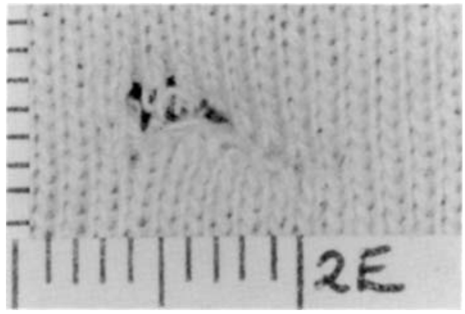


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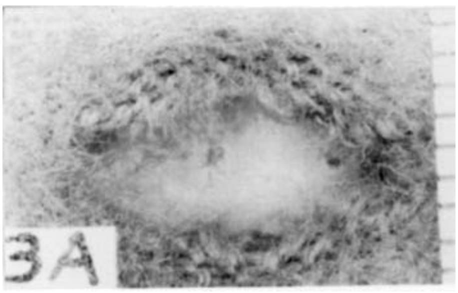


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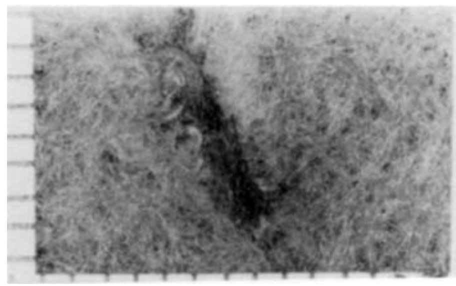

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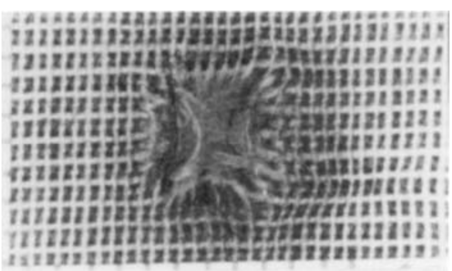

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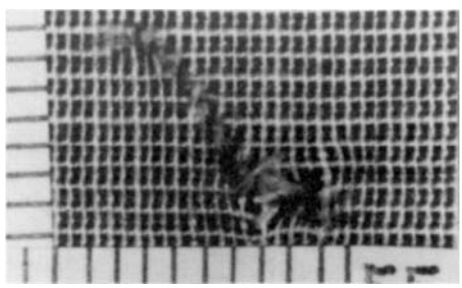

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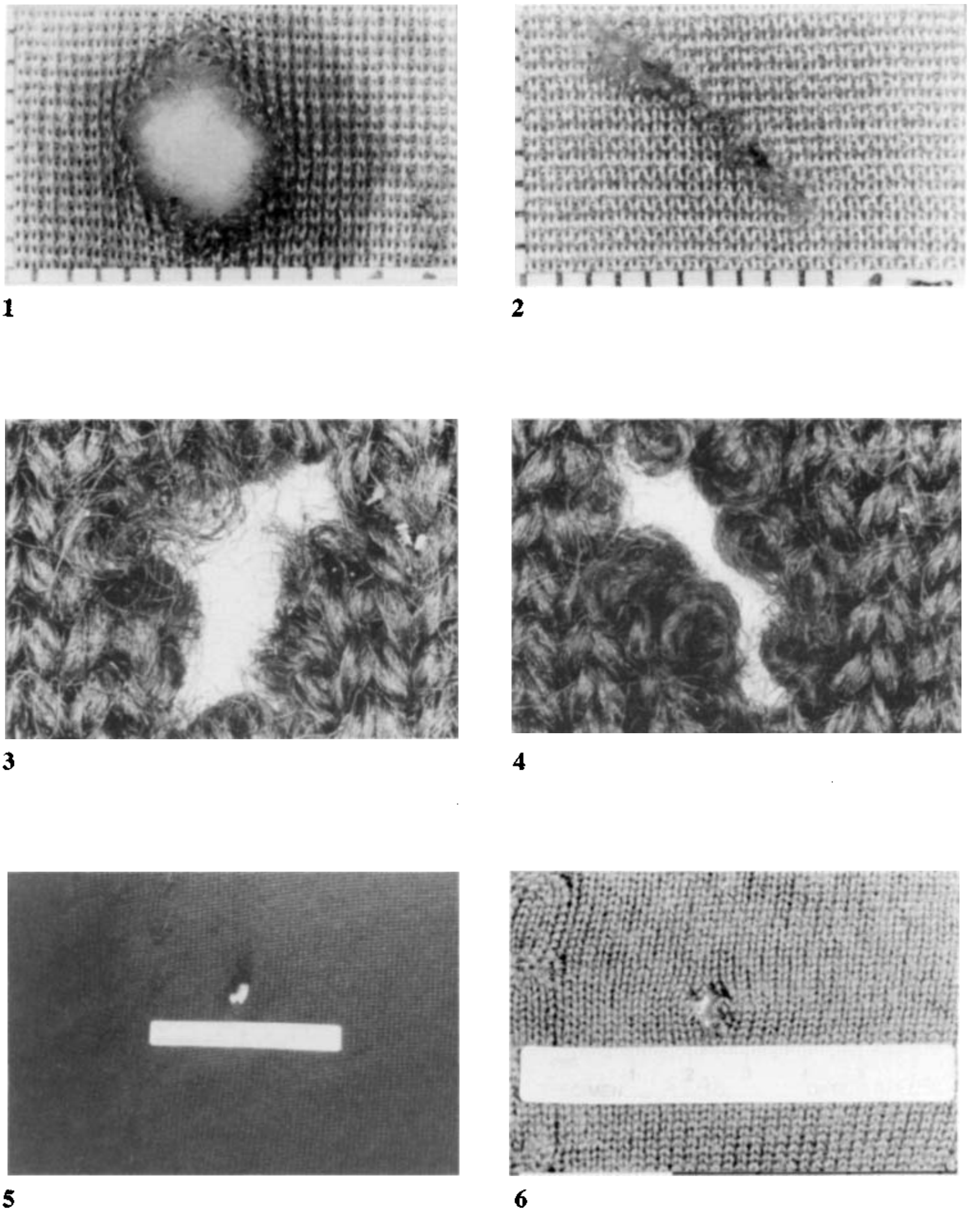
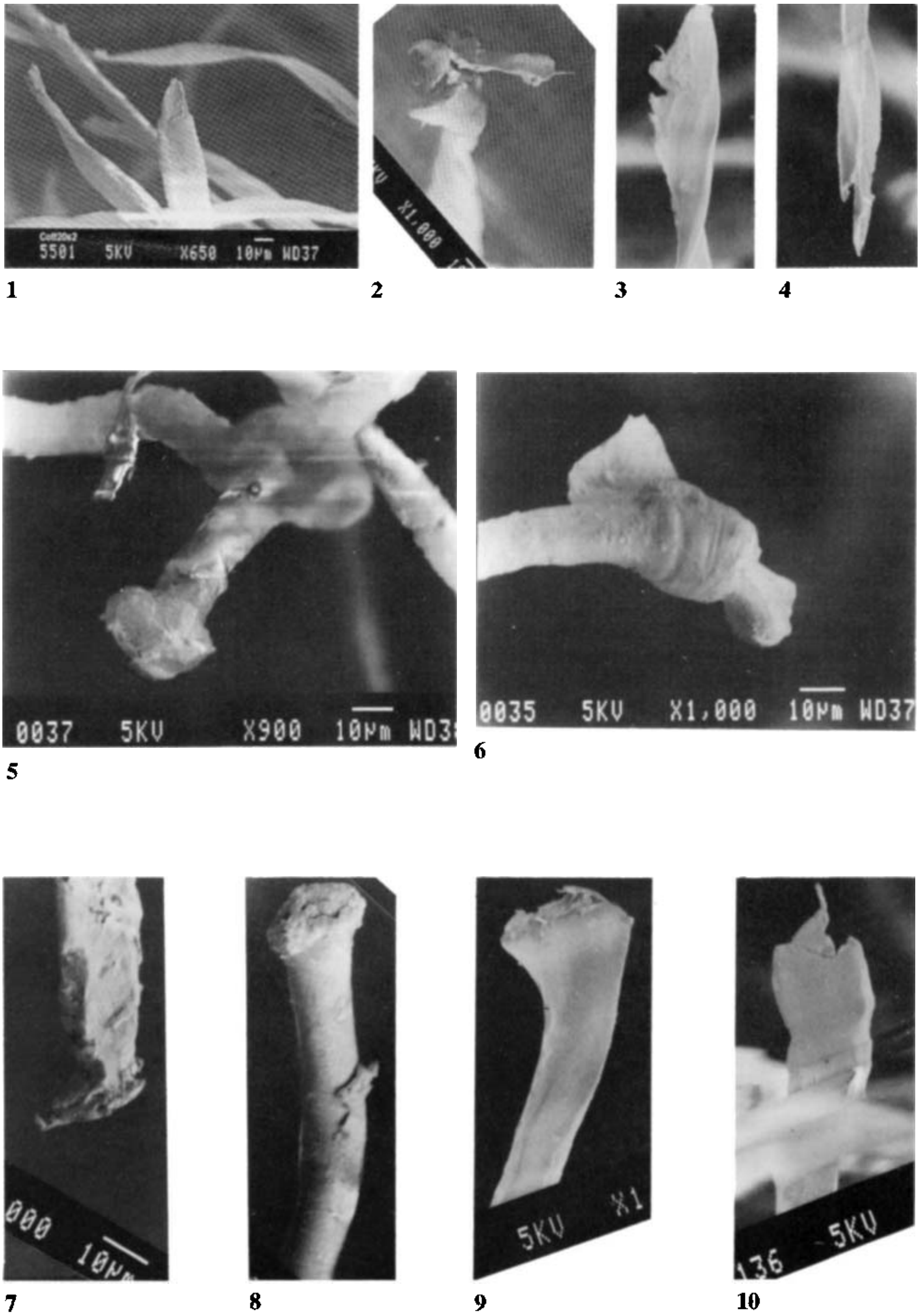
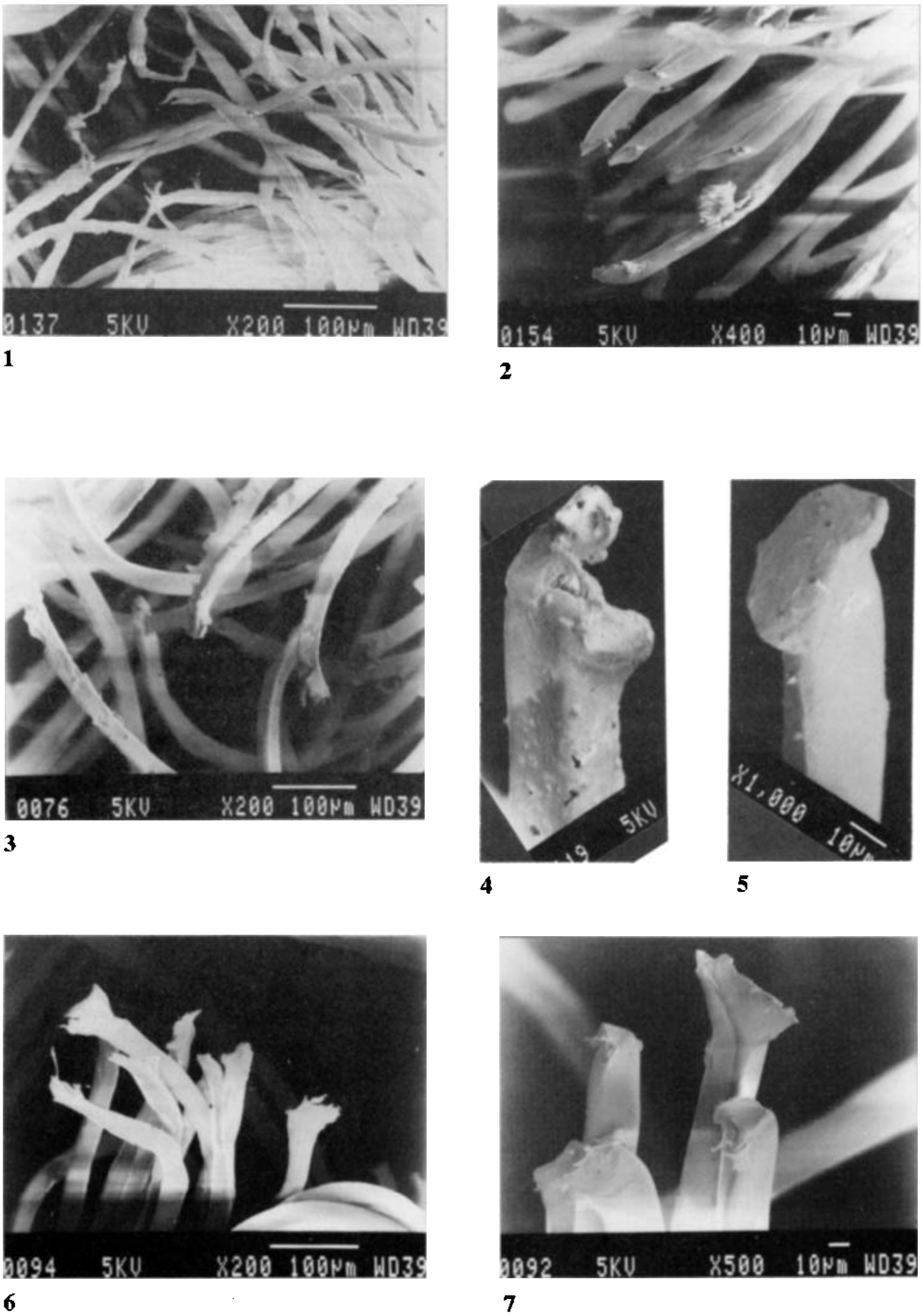
**46C — Microscopic observation of damage.**
(1) Cotton weft-knit: contact, solid-point bullet. (2) Cotton weft-knit: knife stab. (3) Polyester weft-knit: contact, solid-point bullet. (4) Polyester weft-knit: knife stab. (5) Polyester/cotton woven: contact, solid point bullet. (6) Polyester/cotton woven: knife stab. [Scale marks in mm.]




**46D — Microscopic observation of damage (continued).**
(1) Nylon warp-knit: contact, solid-point bullet. (2) Nylon warp-knit: knife stab. (3) Wool weft-knit: contact, solid-point bullet. (4) Wool weft-knit: knife stab.
**Macroscopic observation of damage to wool weft-knit.**
(5) Contact, solid-point bullet. (6) Knife stab. [Scale marks in mm.]

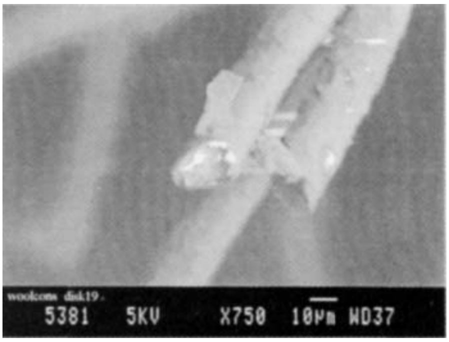



**46E — SEM observations.**
(1),(2) Cotton weft-knit, 20cm, solid-point bullet. (3),(4) Cotton weft-knit, knife stab. (5),(6) Polyester weft-knit, 20cm, solid-point bullet. (7),(8) Polyester weft-knit, contact, solid-point bullet. (9),(10) Polyester weft-knit, knife stab.




**46F — SEM observations (continued).**

(1) Polyester/cotton woven, contact, solid-point bullet. (2) Polyester/cotton woven, knife stab. (3) Nylon warp-knit, contact, solid-point bullet. (4),(5) Nylon warp-knit, 20cm, solid-point bullet. (6),(7) Nylon warp-knit, knife stab.

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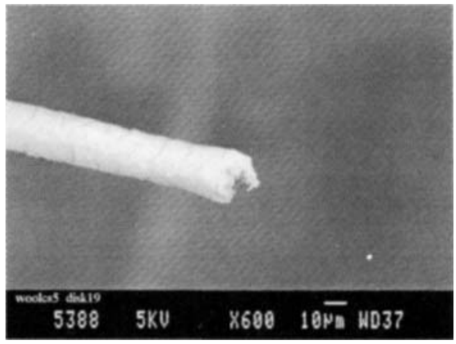


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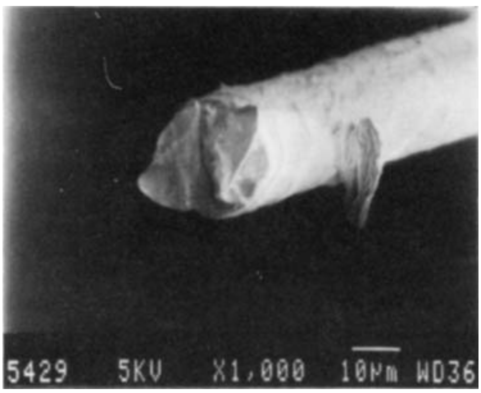


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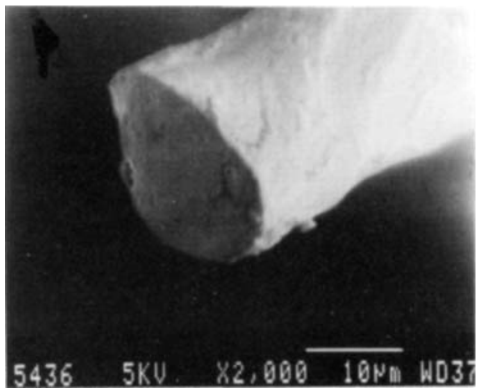


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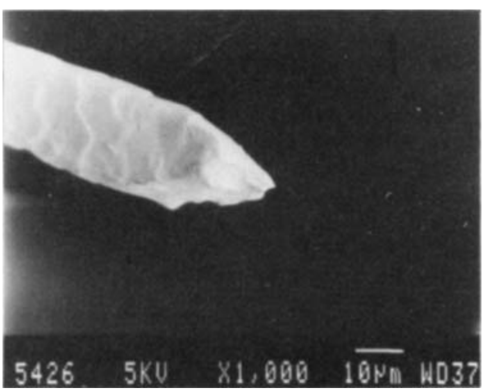


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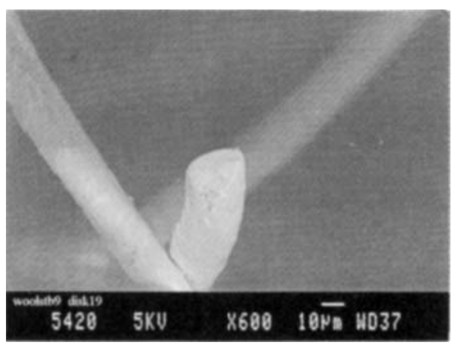


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**46G — SEM observations (continued).**
(1),(2) Wool weft-knit, contact, solid-point bullet. (3),(4) Wool weft-knit, 20cm, solid-point bullet. (5),(6) Wool weft-knit, knife stab.