TECHNICAL NOTE

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Use of Scanning Electron Microscopy (SEM) to Identify Cuts and Tears in a Nylon Fabric

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ABSTRACT: Scanning electron microscopy (SEM) micrographs were obtained for fiber ends of a nylon fabric which had been experimentally cut with a scalpel or scissors, or torn by force. In the nylon fabric used, these three types of damage were identifiable on the basis of features of the fiber ends.

KEYWORDS: criminalistics, fabrics, clothing damage, scanning electron microscopy (SEM), cuts and tears, fiber end surfaces, nylon, textiles

When forensic scientists are required to give an opinion on the nature of a particular type of damage to clothing, the conventional method of examination is to study the separated edges of the fabric visually and under a low-power stereo microscope. In many instances this examination allows a scientist to form an opinion as to whether the fabric could have been cut or torn. However, sometimes the success of this type of examination is lessened by the condition of the separated edges, the nature of the fibers used in the fabric, and the construction of the fabric (woven or knitted). On these occasions, more information on the nature of the damage may be obtained by studying details of the fiber ends by scanning electron microscopy (SEM). Although SEM is widely used in forensic science examinations, only a few studies on its use in examining clothing damage have been published [*1,2*], and to the author's knowledge, no studies have been published in forensic science journals.

The need for the present study arose during a crime investigation, in which unusually bulbous fiber ends in broken edges of a nylon fabric were seen under a low-power microscope. In the visual examination, signs of tearing were observed in the separated edges, but the use of a single-bladed instrument could not be excluded. To assist the examination, the present experiment using SEM was designed to study characteristics of

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the nylon fiber ends experimentally cut by a scalpel or scissors, or torn by force. This paper describes these characteristics, which are shown in SEM micrographs.

Materials and Methods

The source of the nylon fabric was a woman's black nightgown from a sexual assault case. The nightgown had allegedly been cut into two halves by a knife along the vertical strips of lace on both sides and across the shoulder straps. No knife was available for investigation. The manufacturer's label indicated that the garment was nylon. The fabric of the lace and shoulder straps, which was used in the experiments, was confirmed as being nylon by the microscopic appearance of the fibers, and by birefringence and solubility tests.

The experimental cuts were made by a previously unused scalpel blade and a pair of scissors. During the scalpel cutting of the sides, the fabric was supported by hand above the cut. Some stretching of the fabric occurred during cutting. During the scalpel cutting of the shoulder strap, the strap was supported from above and below the cut by hand. The experimental tears were made by pulling the fabric apart by hand. Fiber samples for SEM were taken at random from the broken edges. For each type of experimental damage, between 15 and 31 fibers were viewed.

The fibers were mounted onto an SEM stub with double-sided adhesive tape. The end to be examined was raised above the stub so it could be examined from any angle. The stub was coated with a thin layer of carbon and gold/palladium to minimize charging effects during examination. The fibers were then examined in a Cambridge Stereoscan 250 Mark II scanning electron microscope at 20 kV, and micrographs of the fiber ends were recorded.

Results and Discussion

The SEM micrographs showed that the nylon fiber ends resulting from scalpel cuts, scissors cuts, and tearing were clearly different (Table 1 and Fig. 1). The ends of the fibers cut by scissors were squeezed inward on both sides and flattened, as expected, by the action of a two-bladed instrument (Fig. 1*a*). The extent of squeezing inward varied, but it was observed in all scissor-cut fiber ends ($n = 21$).

Smooth, nonfractured ends with a more or less pronounced "bulb" formation were

TABLE 1—*Description of broken fiber ends shown in SEM micrographs of a nylon fabric.*

Type of Damage	Description of Fiber Ends
Experimental damage	
Scissor cut	all squeezed ($n = 21$)[a]
Tearing	all bulbous and smooth ($n = 15$)
Scalpel cut	clean cut, fractured and elongated, bulbous ($n = 31$; approximate ratio of the fiber end types, 2:1:1.5)
Unknown damage	
Shoulder straps	clean cut, fractured and elongated, bulbous ($n = 18$; approximate ratio of the fiber and types, 1:2:1)
Sides of nightgown	fractured and elongated, bulbous ($n = 18$; approximate ratio of the fiber end types, 1:3)

[a]The letter *n* refers to the number of fiber ends viewed by SEM.

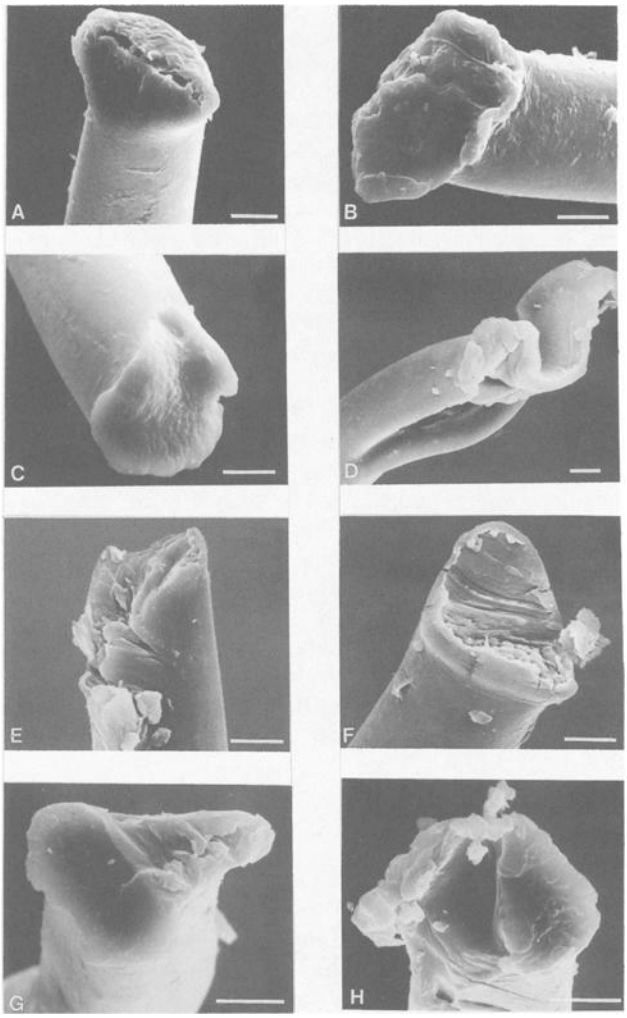

FIG. 1—*SEM micrographs of broken fiber ends from a nylon fabric cut with scissors* (a), *torn by force* (b,c), *or cut with a scalpel* (d–h). *The bar illustrates the length of 1* μ*m.*

characteristic of torn nylon fibers (n = 15) (Fig. 1*b*), although, in a few torn fibers, the bulb was seen only in parts of the edges of the fiber end (Fig. 1*c*). This feature was therefore markedly different from the torn ends of cotton and polyester fibers described by Choudhry [*1*], who found that torn cotton fiber ends were elongated and not uniform, showing broken filaments and stress fractures and that torn polyester fibers were also fractured and either blunt or elongated.

Choudhry [*1*] described cut ends of cotton fibers as being uneven, whereas cut polyester fibers had smooth ends showing signs of striations across the surface. The other previous study by SEM on clothing damage [*2*], in which a knife, a razor blade, and bullets were used to produce cuts in various fabrics, does not describe differences between different types of damage on different fabrics.

In the present study, the fiber ends of a nylon fabric cut by a scalpel showed a variety of shapes and forms. The ends varied from elongated and twisted (Fig. 1*d*) to fractured (Fig. 1*e*) or relatively clean cut ends (Fig. 1*f*). Some of the ends showed striations across

the cut surface (Fig. 1*f*), and a few ends cut by a scalpel had indications of a "bulbous" formation (Fig. 1*g* and *h*) similar to that of the torn sample. These bulbous ends may have resulted from breakage by stretching associated with the cutting action of a single-bladed instrument. Features of tearing and stretching can be seen in macroscopic examination of the cut edges [*3*]. These may be due to the degree of sharpness of the cutting edge of the knife, the stretching of the fabric during cutting, the nature of the fibers used in the fabric, and the age, degree of wear, and construction of the fabric.

Features of the SEM micrographs of the unknown damage to the nightgown shoulder straps and sides are described in Table 1. From the visual and macroscopic examination, it could not be determined whether the shoulder straps had been broken by tearing or cut by a single-bladed instrument. However, SEM micrographs of these fiber ends showed features similar to those of the experimental scalpel cut ($n = 18$), indicating that the shoulder straps could have been cut by a knife. Use of SEM, therefore, yielded information in addition to that gained from macroscopic examination.

In contrast, the SEM experiment did not add more information to the results of visual and macroscopic examination of the separated sides of the nightgown. Although the use of scissors could be excluded, it could not be determined, either by visual and macroscopic or by SEM examination, whether a knife had been used to cut the sides. The presence of predominantly bulbous ends indicated that the fibers had been mainly broken by stretching (Table 1). Experimental tearing alone, however, did not result in any elongated fractured ends being observed in the nightgown sides (Table 1). This may indicate that an instrument of some kind may have been used to facilitate the tearing of the sides. Because no clean-cut fiber ends were seen, this instrument may have been a knife with a much blunter blade edge than that of the scalpel used for the experimental cutting, but it could also have been an instrument other than a knife. Further studies by SEM are needed to illustrate the extent of tearing in different fabrics by a variety of cutting instruments.

Conclusions

Scanning electron microscopy can be used in the examination of clothing damage to assist or confirm the results of macroscopic examination of the separated edges. The present study on nylon fibers extends the study by Choudhry [*1*], who used SEM to identify tears and cuts to cotton and polyester fabrics. Taken together, these two studies demonstrate that the morphology of the broken fiber ends is dependent on the fiber type used in the fabric. Tearing, especially, can produce markedly different features in the broken ends, depending on the fiber structure.

References

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