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Transfer of Fibres onto Knife Blades in Stabbing Events: Distribution and Determination of the Stabbing Sequence

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Abstract

Knives are among the weapons most frequently involved in criminal cases. They represent the most encountered category of weapons in Swiss homicide cases (completed and attempted homicides considered) and are also frequently employed in assault cases, notably bodily injuries. Whenever a knife is involved in a stabbing event, DNA and fingerprints may be sought. When garments are damaged, fibres can also be investigated. Fibres from the victim's garments might transfer onto the blade of the knife used in the assault and can thus provide useful information to determine whether a particular weapon could have be used to stab the victim. This study simulates vertical stabbings into garments with the use of a special holding device. Different types of knives and blades straight or serrated were used as weapons. Two garments presenting different shedding capacities and garment structures were also considered for the simulations. The distribution of fibres transferred onto the blade (number and position) was recorded for each simulation performed. Sequences of stabbings into the two garments were also carried out to assess whether the order of the stabs could be determined. Several parameters were considered, notably the distribution of fibres transferred onto the blade. The transfer of fibres inside the stab damage ballistic soap was used in this study and on the area near the second damage was also investigated. This study provides new insight into the interpretation of fibres transferred onto knives after a single stab or a sequence of stabbings and into determining the stabbing sequence. Finally, the study brings some guidelines for the search and recovery of fibres on the crime scene and on the blades of knives.

Key words: Damage to textiles, fibre localization, secondary transfer, stabbing simulations, transfer sequence

Introduction

Sharp weapons are one of the most commonly used items during severe assault cases worldwide.[1,2] In Switzerland, this type of weapon is regularly encountered in different criminal situations, notably robberies, or serious bodily injuries.[3] Knives represent the second most encountered weapons in completed homicides, just after firearms.[4] Considering completed and attempted homicides, sharp weapons are more frequently encountered in Swiss domestic homicides than firearms.[5,6]

When a knife or another sharp item is found in a stabbing event, it is common to recover blood on the weapon. DNA sampling on the blade and on the handle of the weapon can thus be performed. Fingerprints can also be searched. Although DNA and fingerprints can provide important information about the victim (e.g., blood on the blade) and/or about the offender (e.g., DNA and/or fingerprints on the handle), they usually cannot help the Court to reconstruct the action itself. Indeed, if several individuals were stabbed with the same knife, it is often not possible to provide information about the order (i.e., the sequence) of stabbings.

In stabbing events, the victim's chest and abdomen are the most frequently injured body parts[7] followed by superior and inferior limbs.[8] As these areas are generally covered with garments, a high proportion of events with sharp weapons involve damage to textiles. Textile damage represents a particular category of evidence that can potentially provide information about the object that caused the damage. The analysis of the damage might thus corroborate or not a crime

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scenario and/or testimony.[9] Besides the characteristics of the damage, transfer of fibres from the garment onto the blade can also occur.[10] It is thus important to be aware of their presence in order to protect and recover them. It might be possible to assess whether a particular knife was used for an event if fibres not differentiated from the garments of the victim (s) are found on the blade. Moreover, fibres could help determining in certain situations whether the suspected knife could have inflicted particular stab damage depending on the nature of the recovered fibres. For example, consider a case where damage is observed at several locations on the victim's clothes (e.g., shirt and trousers). The victim presents a lethal wound in the chest and several minor injuries on legs. The suspect claims only to injure the legs of the victim. In that situation, DNA on the blade would not be useful to determine whether the knife was used to inflict the wound in the chest. Alternatively, if fibres not differentiated from the victim's shirt are found on the blade, these can help assessing whether the knife inflicted the lethal wound or not. The study of the damage and the transferred fibres are thus important to investigate.

The transfer of fibres onto garments,[11-15] skin[16,17] or even car seats[18,19] is well-documented in the literature. Many studies have also been published on damage to textiles.[9,20-24] Although fibres transferred onto knives could often be searched in casework, only one case example has been published.[10] In this example, the victim was injured in a pub by a single stabbing in the chest. The knife was later recovered outside the crime scene. Despite the rainy conditions, 47 fibres of the victim's clothes were found on the blade of the knife.

To the best of the knowledge of the authors, no other study has investigated the transfer of fibres in stabbing events. However, data about the distribution of fibres transferred onto the blade in a stabbing event is crucial not only for the interpretation of the evidence but also for the search and recovery of fibres. To fill the gap in this field, this study focusses on the number of fibres transferred onto the blade straight or serrated of different knives during simulated stabs. Their position and density were also considered.

This study also investigates whether fibres recovered from the blade number, density, and position could help to determine the order of the stabs when multiple stabs are involved (e.g. which stab was executed first and/or which individual was first injured). Sequences of stabbings were carried out on two different garments (e.g. representation of an event with two victims) with a chef's knife. Foreign fibres in the area close to the damage to the second garment were also searched and counted, as well as fibres inside the stab damage (ballistic soap in this study). The data acquisition was conducted during the Master's thesis of Jessica Rodriguez and results are issued from her thesis.

Materials and Methods

Garments

Two garments were selected for this study:

- A burgundy pyjama from the Ellen Amber collection brand[1]. The garment presents a cut pile woven structure with free cut loops that are easily removable. The clothing is composed of 80% cotton and 20% polyester (cotton/polyester blend). The garment was judged to have a high shedding capacity

ii. A black women's shirt (singlet) from the Swiss manufacturer Charles Vögele[2]. The shirt is knitted and composed of polyester filaments (100%). A low shedding capacity was determined.

The composition of the two garments was verified using optical microscopy and Fourier transform infrared spectroscopy. The structure of the garments was selected on the basis of a Swiss case that involved two victims. They were also chosen in order to present fibres with strong colors and a good contrast between the two garments in order to facilitate the recovery, counting, and positioning of the fibres. The garments were new, had never been washed and were never put into contact with each other during the entire simulation process. As newly bought garments may have loose fibres on their surface, taping was performed on each garment before the first simulation to remove potential fibres from the background. Taping was then carried out before each simulation (section 2.5).

Knives

Stabbings were performed using three different knives [Figure 1]:

a. A kitchen knife from the Swiss brand Victorinox with a total length of 182 mm. This is considered as a standard paring knife but does not possess a particular model name. The blade is straight and symmetrical and measures 80 mm × 15 mm (thicker part)

b. A kitchen knife from the brand Victorinox (Switzerland) with a total length of 182 mm. This is the same type of knife as the straight one described above. The difference lies in the shape of the blade as the knife presents a serrated and asymmetrical blade of 80 mm × 15 mm (thicker part).

These knives will be referred to as straight kitchen knife (a) and serrated kitchen knife (b) in the rest of the paper.

1 Migros, Lausanne, Switzerland.

2 Charles Vögele, Lausanne, Switzerland.

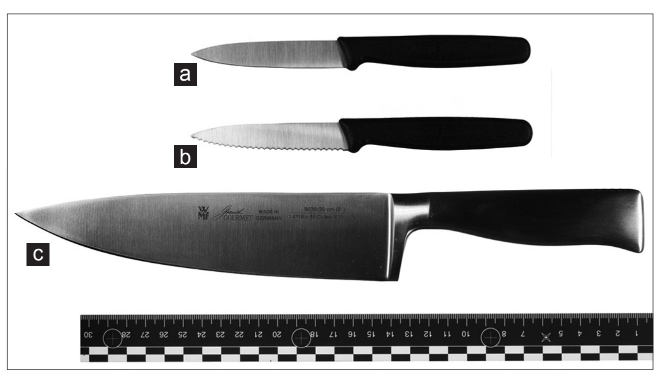

Figure 1: Knives used in the study: Straight kitchen knife (a), Serrated kitchen knife (b) and chef's knife (c)

c. A chef's knife from the German brand WMF, model Grand GOURMET. This knife is considerably longer than the two first knives with a total length of 330 mm. The chef's knife possesses a straight and symmetrical blade of 200 mm × 45 mm (thicker part).

The three knives were bought in Swiss supermarkets. The two kitchen knives straight and serrated were bought at Migros (Crissier, Switzerland) while the chef's knife was purchased at Globus (Lausanne, Switzerland). Kitchen knives were selected because this category of sharp weapons is one of the most commonly encountered in stabbing events.[7,25] Both straight and serrated blades were considered as the geometry of the blade has an influence on the characteristics of the damage[26] and might influence the number and the location of the recovered fibres.

Body part simulants

Garments were fixed on two different simulants. The first simulant was a block of ballistic soap[3] (dimensions 257 mm × 125 mm × 115 mm). The soap was composed of glycerine, alcohol and fatty acids. A similar type of support was already used by Gilchrist *et al*.[27] They claim that ballistic soap has stiffness characteristics comparable to bone cartilage. As stabs possess a poor velocity compared to gun shots (normal use of ballistic soap), the elasticity of the soap might be different. Thus, the number of transferred fibres could be overestimated due to the sticky proprieties of the soap. Thus, a block of soft polyurethane foam (dimensions 450 mm × 320 mm × 130 mm) was also used. This simulant was selected to investigate the transfer of fibres in dry conditions.

Due to practical limitations and the duration of the study, no animal carcasses were used. They could well have simulated the influence of blood on the transfer, but they would have also presented a lot of disadvantages, notably putrefaction, variability in and between the carcasses (various amount of bones, fat or tissues) and complex investigation of fibres that could be transferred inside the stab cut.

Apparatus for stabbings

A special device was created to simulate vertical stab cuts [Figure 2]. The apparatus was constructed like a guillotine with a movable part on the top where the knife can be fixed. The garment was put on a simulant block (ballistic soap or polyurethane foam) that was placed underneath the knife and fixed to the floor. The distance between the attachment points of the knives (at the end of the handle, on the blade side) and the garment was 55 cm and was the same for all the simulations. The stabbing was then performed by letting the knife fall down on the garment, using gravity.

Impacts on the garments were recorded using Canon EOS 60D in order to investigate the interaction between the garment and the blade during the stabbing.

3 Permatin AG, Stein am Rhein, Switzerland.

Simulations

The first set of simulations was called "simple transfer set." A unique stab cut was performed with the three different knives into each garment. These were fixed on polyurethane foam and ballistic soap alternatively [Table 1]. To avoid contamination, the blade was cleaned with ethanol and the garments were taped before each simulation. After each stabbing, the knife was removed from the simulant and the two sides of the blade were taped with adhesives. Each kind of simulation was repeated 5 times in order to assess the variability of the transfer (i.e, the intravariability). Thereby, 60 stabbings were performed for the simple transfer set.

A second set of simulations called "transfer sequence set" was also performed in order to investigate the potential transfer of fibres from the first garment near and inside the stab damage of the second stabbing [Table 2]. The distribution

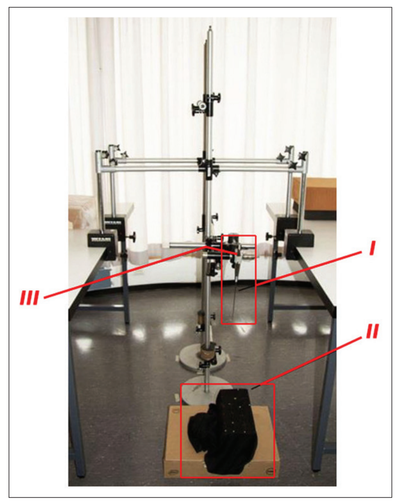

Figure 2: Apparatus used for the stabbing simulations with the designation of the knife (I), The garment (II) and the movable part (III)

Table 1: Simulations of the simple transfer set

Simple transfer set (n=60)		
Kind of simulation	**Garment**	**Simulant**
Number 1	Burgundy pyjama	Ballistic soap
Number 2	Burgundy pyjama	Polyurethane foam
Number 3	Black shirt	Ballistic soap
Number 4	Black shirt	Polyurethane foam

Table 2: Simulations of the transfer sequence set

Transfer sequence set (n=13)				
Kind of simulation	**Garment n°1**	**Simulant n°1**	**Garment n°2**	**Simulant n°2**
Number 5	Burgundy pyjama	Ballistic soap	Black shirt	Ballistic soap
Number 6	Burgundy pyjama	Polyurethane foam	Black shirt	Ballistic soap
Number 7	Black shirt	Ballistic soap	Burgundy pyjama	Ballistic soap

(number and position) of fibres found on the blade of the knife after the second stab was also assessed. Only the chef's knife was used for this set of simulations. A first stab cut was performed in a first garment fixed on ballistic soap or polyurethane foam [Table 2]. The knife was then removed from the simulant block and put back in its initial position without any sampling of fibres. The first garment was replaced by the second garment and fixed on the ballistic soap block. Only this simulant was used for the second garment to allow the use and the recovery of fibres inside the cut. The knife was released again to perform a second stabbing and then removed from the cut. Fibres on the blade, near and inside the second stab damage were investigated (section 2.6). As for the simple transfer set, each kind of simulation was repeated 5 times for repeatability investigations, except for simulation number 6 which was repeated 3 times only.

Search, recovery and analysis

Fibres on the blade of the kitchen knives straight and serrated ones were recovered with a "special police" adhesive (25 mm width), which is currently employed by Swiss investigators. Both sides were taped directly after the stabbing. The sampling on the blade of the chef's knife and on the area around the second damage (transfer sequence set only) was performed using precut adhesive tapes (249 mm × 59 mm) with a high tack power[4].[28] These precut tapes are similar to those used for the one-to-one taping process in Switzerland. Again, the sampling was performed directly after the knife had been removed from the simulant block. Tapes were fixed on acetate sheets after the sampling process.

The edges of the blades and the penetration limit into the simulant were annotated on the adhesive tapes to allow the determination of the position of fibres. The distribution of the fibres was investigated by dividing the blade surface into several zones. The first segmentation was composed of the tip, the center and the limit of penetration [Figure 3]. The limit of penetration was first annotated on the tape and the three zones were then arbitrarily defined. As the limit of penetration was not strictly the same from one test to another, the surface of these areas might slightly vary. The second segmentation comprised the cutting edge, the center, and the back of the blade [Figure 4].

The tapes were observed under a Leica M80 stereomicroscope in reflected light and fibres were searched, counted, and localized manually directly on tapes.

For the stabbing sequences (i.e., simulations number 5, number 6 and number 7), the soap was cut after the second stabbing to investigate the transfer of fibres inside the stab damage (representing the wound). The soap was cut in half in order to observe both sides of the damage. The fibres inside the stab damage were counted and localized manually with a Leica M80 stereomicroscope in reflected light.

4 Étilux, Liège, Belgium.

Results and Discussion

Simple transfer set

Number of fibres recovered from the blade

Pyjama

The number of fibres not differentiated from the pyjama and found on the blade of the different knives is presented in Figure 5. Each simulation was illustrated for comparison purposes. As the number of fibres recovered was not substantially different from one side of the blade to the other, the results presented are the sum of fibres counted on both sides of the blade.

The first statement that can be highlighted is that the number of fibres found on each knife was considerably high for every type of blade. The highest number of fibres was observed on the blade of the serrated kitchen knife after a stab in the pyjama fixed on the ballistic soap. More than 1500 fibres were found on the fifth repetition. On the opposite, the smallest number of fibres (ca. 350 fibres) was observed on the first repetition

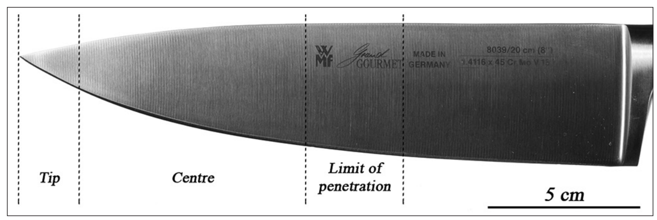

Figure 3: First segmentations of the blade (chef's knife): The tip, the centre and the limit of penetration

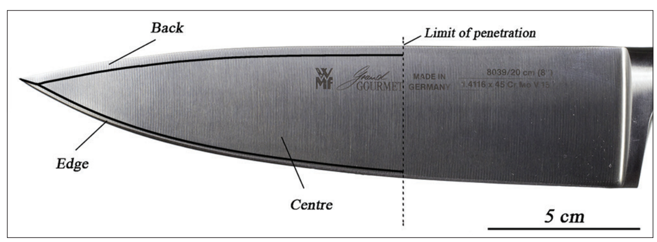

Figure 4: Second segmentation of the blade (chef's knife): The cutting edge, the centre and the back of the blade

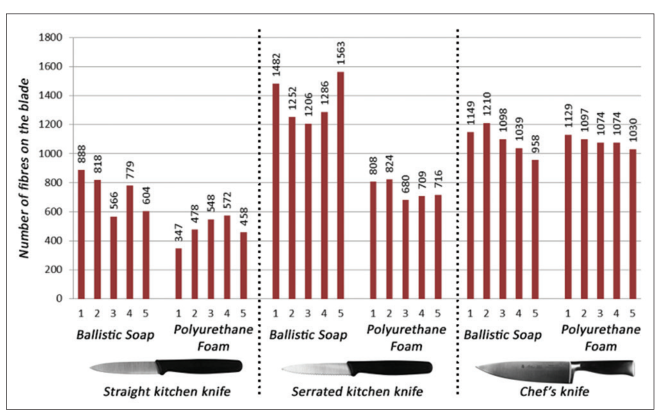

Figure 5: Number of fibres from the pyjama recovered in each simulation (simple transfer set)

of the simulation carried out with the straight kitchen knife and polyurethane foam.

The high shedding capacity and the structure of the pyjama may explain the significant number of fibres recovered from the different blades. Tufts were observed on several adhesive tapes. These tufts could originate from the structure of the garment, notably from the free loops of the cut weft. Fibres composing the tufts were counted and considered in the total number of fibres recovered.

The number of fibres found on each blade was also relatively repeatable. Despite the disadvantages of the stabbings apparatus (e.g., frictions or the inclination of the knife), the same order of magnitude in terms of fibres recovered was observed.

More fibres were counted on the serrated kitchen knife than on the straight kitchen knife. As the only difference between these two knives is the shape of the blade, the results support the proposition that the serrated blade had an influence on the transfer. According to Johnson, the presence of serrations or imperfections on a blade could increase fraying and distortion by pushing fibres and yarns out of the matrix of the textile.[29] Such fraying damage could thus have increased the number of fibres transferred onto the serrated kitchen knife.

More fibres were recovered from the blade of the kitchen knives when the pyjama was fixed on the ballistic soap simulant. This tendency was more pronounced in simulations carried out with the serrated blade. This phenomenon could be explained by the sticky nature of the soap. However, this trend was not observed for the chef's knife. Hence, the authors do not draw a conclusion about the influence of the simulants.

It was also observed that the interaction of the garment with the blade was different given the simulant. With polyurethane foam, the garment came out of the stab damage when the knife was removed, following the movement of the blade [Figure 6]. Conversely, the pyjama remained inside the stab damage with the ballistic soap simulant [Figure 7]. More studies should be carried out to determine which situation best represents the interactions observed in real stabbing events.

More fibres were usually found on the blade of the chef's knife, than on the blades of the smaller kitchen knives. Due to the width of the blade, the chef's knife produced larger stab damage in the garment. Therefore, the number of yarns cut was greater in simulations performed with the chef's knife than in those performed with the two kitchen knives. More fibres were then available for the transfer onto the blade of the chef's knife. The width of the blade is thus an important variable that has to be considered. Besides, as seen before, the shape of the blade serrations and/or imperfections is another critical parameter that should not be neglected.

Shirt

The number of fibres not differentiated from the black shirt and found on the different blades after each simulation is illustrated in Figure 8. The number of fibres recovered did

Figure 6: Interaction between the pyjama and the blade in simulations carried out with polyurethane foam

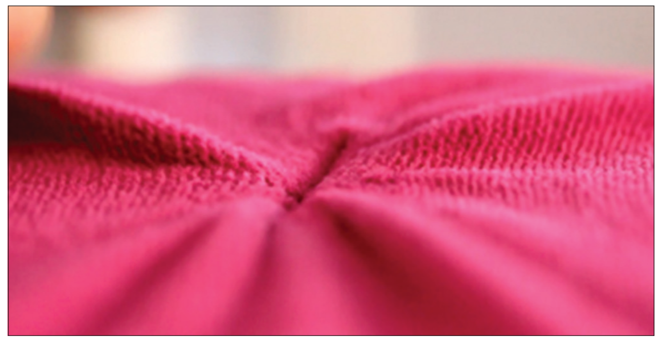

Figure 7: Interaction between the pyjama and the ballistic soap simulant after the removal of the blade

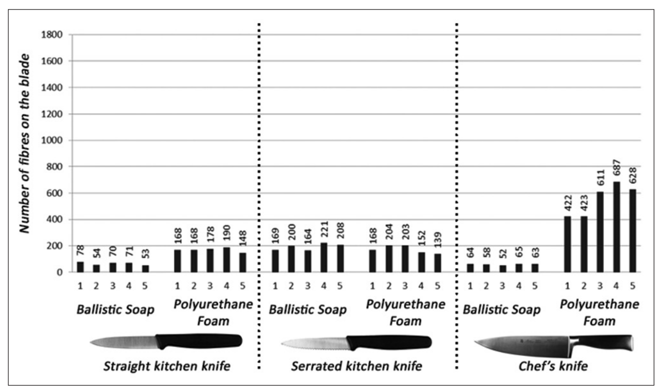

Figure 8: Number of fibres from the black shirt recovered in each simulation (simple transfer set)

not considerably differ from one side of the blades to another, thus the results presented are the sum of the fibres counted on the both sides.

Approximately, 50 fibres were found on several repetitions of simulations carried out with the ballistic soap and with the chef's or straight kitchen knife. These were the simulations with the smallest number of fibres recovered. The highest number of fibres was observed on the fourth simulation performed with the chef's knife and polyurethane foam. More than 650 fibres were recovered. Compared to the pyjama, the number of fibres recovered was substantially smaller but remains high. This difference concerning the number of fibres transferred could be attributed to the low shedding capacity of the shirt compared to the pyjama. The repetitions of the same kind of simulation showed that the number of fibres varied from one test to another. This variation is however estimated as being small. Indeed, the number of fibres among the repetitions was in the same order of magnitude, supporting good repeatability.

Compared to the ballistic soap, the number of fibres recovered from the straight kitchen knife and from the chef's knife was greater when the polyurethane foam was used. This difference was not observed for the serrated kitchen knife. As for the pyjama, these results do not allow us to formulate any conclusion about the influence of the simulants.

Position of fibres on the blade

Pyjama

Except for the serrated kitchen knife in the ballistic soap, all the tests performed (simulations number 1 and number 2, $n = 25$) showed a greater density of fibres (number of fibres/cm^2) at the limit of penetration of the blade, followed by the tip and the center.

The density of fibres observed on the chef's knife is illustrated in Figure 9. As density does not mean number of fibres, it should be noticed that the tip was the zone where the smallest number of fibres was recovered (from 10 to more than 200 fibres). This was observed for all three different types of blades.

The distribution of fibres might be influenced by the movement of the knife through the damage (during the back and forth movement of the blade), but seems not to be dependent on the type of simulant (i.e., ballistic soap or polyurethane foam). When the foam simulant was used, the serrated knife showed the same distribution of fibres as the two other knives, whereas differences were observed with the soap. In three of the five simulations performed with the serrated knife into the ballistic soap, more fibres were found on the tip of the blade, followed by the limit of penetration and the center. The two other simulations were similar to the previous tests (i.e. limit of penetration → tip → center of the blade).

The second segmentation of the blade showed that a greater amount of fibres in terms of density was found on the cutting edge of the blade, followed by the center and the back. This distribution is illustrated on Figure 10 for the chef's knife. The results were comparable for all three knives and the two simulants. The highest density of fibres observed on the cutting edge could be explained by the fact that this part induces the cut. It is also important to examine the morphology of the fibres found on this part of the blade using a microscope or a scanning electron microscope. The fibres on the cutting edge can present characteristic marks on their extremities due to the cut [Figure 11]. These characteristics could increase the probative value given that fibres showing a sharp extremity could not simply be deposited on the blade but will probably result from a cut.

Shirt

In simulations where the polyurethane foam simulant was used, the highest density of fibres was observed at the limit

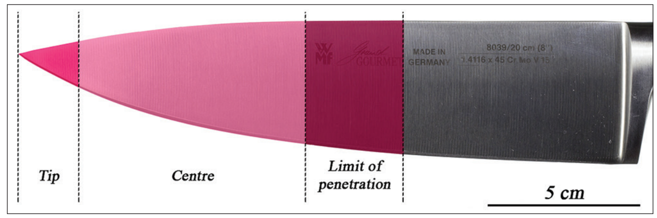

Figure 9: Distribution of fibres (number of fibres/cm^2) from the pyjama found on the chef's knife blade (first segmentation). The highest density was observed at the limit of penetration, followed by the tip and the center

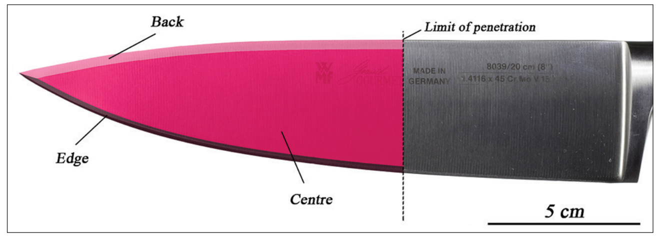

Figure 10: Distribution of fibres (number of fibres/cm^2) from the pyjama recovered from the chef's knife blade (second segmentation). The highest density was observed on the edge (i.e., cutting edge), followed by the center and the back of the blade

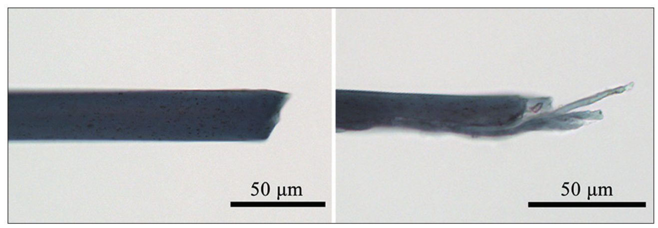

Figure 11: Extremities of a cut (left) and a torn (right) polyester fibre from the black shirt. The cut fibre presents a sharp extremity, while the torn one is frayed

of penetration of the blade, followed by the tip and the center (simulation number 4, $n = 15$). This observation is similar to the results obtained for the pyjama. Conversely, with the ballistic soap (simulation number 3, $n = 15$) a different distribution was observed: Tip of the blade, center and finally limit of penetration.

Concerning the second segmentation of the blade, the greater density of fibres was noticed on the cutting edge of the blade, followed by the center and the back. This finding was observed independently of the knife and the simulant used. The results are similar to those observed with the pyjama.

These data for the pyjama and the shirt provide information about the different zones on knives that are important in stabbing events. In case of conflict between DNA, fingerprint and fibres, a prioritization of the blade areas can thus be defined. The limit of penetration represents an important area for fibre investigation as most fibres were recovered in this zone, both in terms of number and density. However, this zone is difficult or even impossible to define in casework. Conversely, cutting edge is easily identifiable and constitutes another area for fibre investigation. It is however strongly advised to preserve the whole blade for fibre recovery.

Transfer sequence set

Sequence: Pyjama followed by shirt

Using ballistic soap simulant for the two garments (simulation number 5), the number of fibres not differentiated from the pyjama found on the blade of the chef's knife was considerably higher than the number of fibres from the shirt [Figure 12]: On average 350 and 10, respectively. To a lesser extent, this high ratio of the pyjama fibres compared to the shirt is also observed when the pyjama was fixed on polyurethane foam instead of ballistic soap [Figure 13]. On average, 370 fibres from the pyjama and 90 fibres from the shirt were recovered. This phenomenon could be attributed to the high shedding capacity of the pyjama compared to the black shirt. Tufts originating from the pyjama also impacted on the number of fibres recovered.

It is of interest to highlight that many fibres from the first garment (i.e., the pyjama) were still present on the blade, even after a second stabbing. Therefore, despite an intense activity (represented by the second stab cut), fibres from a previously stabbed garment can still be recovered from the blade for comparison. Concerning the distribution on the blade, the limit of penetration presented the highest density of fibres nondifferentiable from the pyjama (similar to the simple transfer set).

Many fibres were also recovered from the surface of the black shirt the second garment near the damage [Figures 14 and 15]. Depending on the type of simulants, the number of fibres from the pyjama varied from 63 to 450. Although variations were observed within the repetitions, the number of fibres was judged high, even for the simulation with the smallest number of fibres recovered.

The number of fibres recovered from the blade in the simple transfer set simulations was greater than in the transfer sequence set, even if fibres recovered from the blade and near the cut were summed. A loss of fibres might thus have occurred between the two stabbings and/or after the last one.

Finally, many fibres of the black shirt were found inside the stab damage [Figure 16]. Only a few pyjama fibres were found (on average 7 fibres). Some very short fibres from the pyjama (<1 mm) were possibly missed due to the search difficulties (notably the low contrast with the soap). However, despite their number, fibres from the pyjama recovered in the stab cut brought crucial information concerning a possible sequence of stabbings. While it is normal to find fibres from the victim's clothing inside the cut, the presence of fibres from a different garment such as the pyjama is not. Foreign fibres

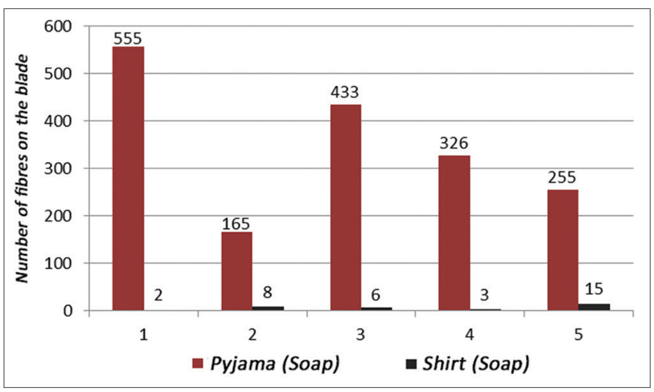

Figure 12: Number of fibres recovered from the blade after each simulation ($n = 5$). The stabbing sequence was pyjama (soap) → shirt (soap); simulation number 5

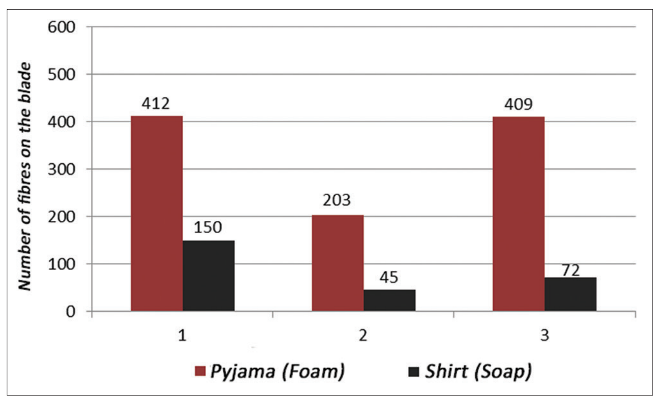

Figure 13: Number of fibres found on the blade after each simulations ($n = 3$). The stabbing sequence was pyjama (foam) → shirt (soap); simulation number 6

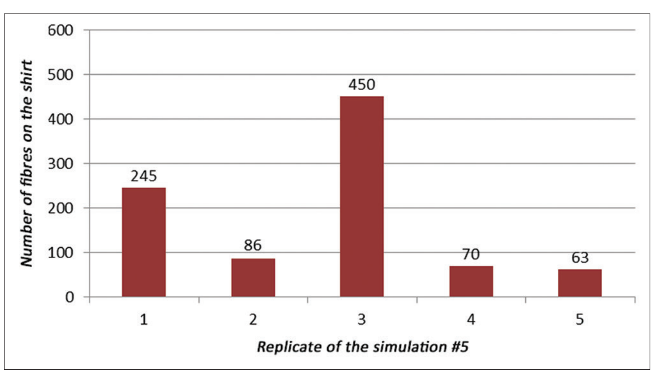

Figure 14: Number of fibres from the pyjama found on the black shirt (second garment) near the cut; simulation number 5

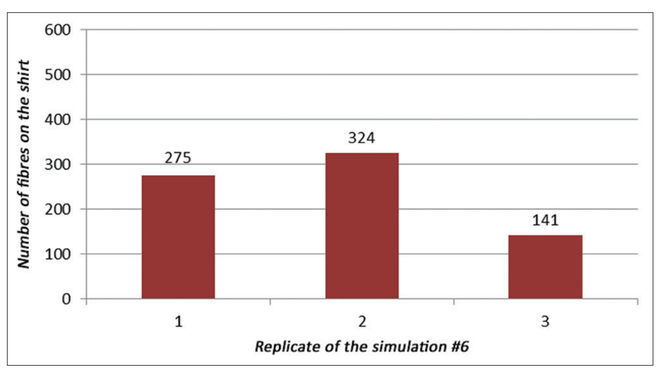

Figure 15: Number of fibres from the pyjama found on the black shirt (second garment) near the stab damage; simulation number 6

found inside the stab wound could thus be decisive information in cases with two or more stabbings and/or victims. Fibres from the pyjama were homogeneously spread inside the stab damage while fibres from the black shirt were aggregated in tufts [Figure 16] on the side of the stab damage caused by the cutting edge of the blade. Some groups of fibres not differentiated from the black shirt were also found on the rest of the surface.

Sequence: Shirt followed by pyjama

The results of the counts performed on the blade of the chef's knife for each repetition of the simulation number 7 are presented in Figure 17.

As before, the number of fibres not differentiated from the pyjama was significantly greater than the number of fibres from the black shirt. This ratio could be explained as discussed previously by the high shedding capacity of the pyjama and its textile structure. However, it is important to highlight that despite of the small number of fibres transferred from the black shirt during the simple transfer set, fibres from this garment were still recovered from the blade after the second stabbing. This emphasizes that even for a garment with a low shedding capacity, fibres could still be recovered and investigated for comparison purposes.

As to the position of the black shirt fibres on the blade, it was not possible to determine a trend concerning the areas with the highest density of fibres due to their low number.

Fibres from the shirt were also observed on the pyjama near the cut [Figure 18]. There were even more fibres near the damage than on the blade (on average 50 fibres, compared to 15 on the blade). These fibres should also be collected for potential analysis.

Fibres from the two garments were found inside the stab damage caused by the second stab cut. For the black shirt, 13 to 17 fibres were recovered inside the stab damage. These fibres were homogeneously distributed on all the area of the cut. A significant number of fibres from the pyjama (i.e., the second garment in these simulations) were observed on the edge of the cut produced by the sharp part of the blade (cutting edge). Fibres were not counted but more than a hundred were present. Fibres from the pyjama were generally observed in tufts.

As many fibres from the first garment were found on the second garment in all simulations of the transfer sequence set, it is crucial to preserve the area near the wound (i.e., stab damage) in stabbing events. Crime scene investigators should systematically search for fibres in this specific area in cases involving several stabbings and/or victims.

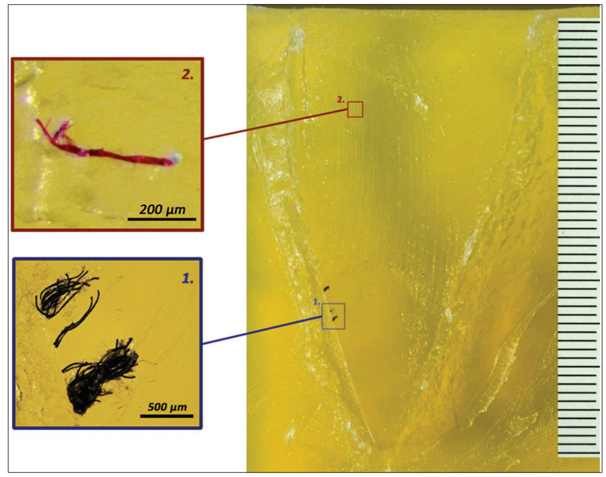

Figure 16: Stab damage (inside the ballistic soap) created by the chef's knife during the stabbing sequence pyjama → shirt (simulations number 5 and number 6). Tufts originating from the black shirt (1) And fibres from the pyjama (2) were recovered

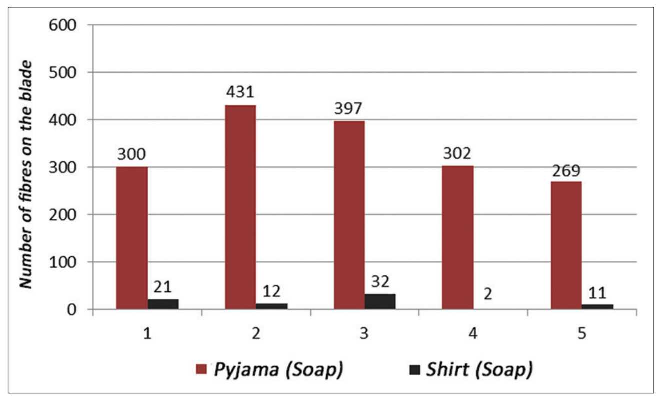

Figure 17: Number of fibres recovered from the blade after each simulation. The stabbing sequence was shirt (soap) → pyjama (soap); simulation number 7

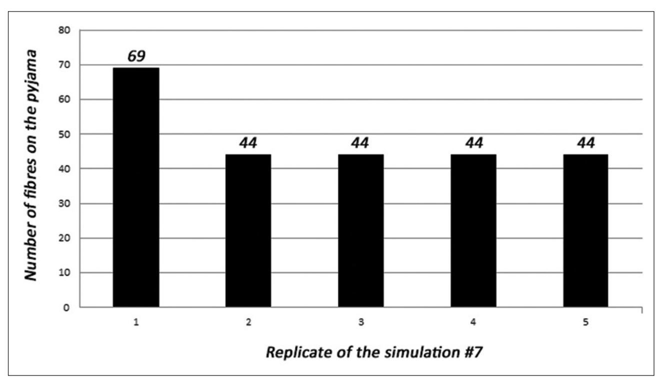

Figure 18: Number of fibres from the black shirt recovered from the pyjama, around the stab cut (simulation number 7)

Conclusion

This research provides new knowledge about the transfer of fibres onto blades after single or sequential stabs through garments. These new insights are useful for investigations of stabbing events involving damages to textiles, both for interpretation and recovery processes.

A significant number of fibres from 50 to more than 1500 were transferred onto the blades of the different knives after a single stabbing. The number of fibres recovered was influenced by the shedding capacity of the garment, the structure of the garment and by the shape of the blade. The highest density of fibres was generally found at the limit of penetration and the cutting edge areas.

This number of fibres may suggest that a certain amount of fibres would persist after a given period of time and/or postactivities. This hypothesis is supported by the results obtained with the transfer sequence set. Indeed, even after a strong activity (represented by a second stabbing) fibres originating from the first damaged garment were still recovered from the blade.

In simulations where two garments were stabbed in sequence, fibres of both garments were recovered from the blade. The quantity of fibres depends more on the garment itself (i.e., shedding and textile structure) than on the order of the stabbings. Thus, the number of fibres recovered from the blade cannot be used to determine the sequence in a two stabs case. Conversely, the presence of fibres originating from the first garment on the second one near and around the damage could be an important indicator of the sequence. It is also of interest to search for potential fibres from the first garment inside the second stab damage, as they could be used to help reconstructing the sequence of stabbings.

This study also highlights that many zones have to be preserved for the search and the recovery of fibres. Fibres could be present on the blade of the knife used in a stabbing event. Therefore, the blade should be carefully preserved for fibre investigation. The area around the stab damage is also a zone to protect. In certain circumstances, it could also be worthwhile to establish collaboration with legal medicine institutes to search for potential fibres inside the wound (s) of the victim (s).

Hence, this work indicates that fibres might be an important element for the determination of stabbings sequences. Further studies should be carried out with more realistic simulations, horizontal stabbings, and other garments. It is also crucial to investigate the persistence of fibres (e.g., on the blade or near the stab damage) as the victim rarely collapses immediately after receiving a stab and frequently recovers from her wounds.[2,7]

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Conflicts of interest

There are no conflicts of interest.

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