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Use of Squid as an Alternative to Human Skin for Studying the Development of Hit Marks on Clothes

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Abstract

The development of latent skin impressions on a variety of fabrics (cotton, rayon, polyester, nylon, and acrylic fabrics in five colors; white, black, yellow, blue and red) has been studied. Squid soaked in artificial sweat solution or de-ionized water was used as an alternative to human skin to make skin impressions on the fabric. A piece of squid was subjected to a constant force, to transfer the skin components onto the fabric. The fabrics bearing the skin impressions were treated with various reagents such as ninhydrin, 1,8-diazafluoren-9-one (DFO), 1,2-indanedione/Zn (1,2-IND/Zn), Amido black and Hungarian red, to know the most effective method for developing the skin impressions on the fabrics. Comparing the sensitivity of the reagents, stronger development was observed from the impressions made with the artificial sweat soaked squid than the de-ionized water soaked squid. These results show that the development quality of the latent hit mark is influenced by the sweat, as well as other skin components. Also, the development efficiency of the reagents varied depending on the chemistry, color and texture of the fabric. Therefore, before the development of skin impressions on the evidence fabrics, it is suggested to perform a preliminary experiment with different methods on a similar fabric to decide the most sensitive method.

Keywords: Clothes; Fabrics; Hit marks; DFO; Ninhydrin; 1, 2-IND/Zn

Introduction

In a crime scene investigation, impressions such as hit marks, footwear marks or the bite marks become important in linking the criminal, victim and the scene. Therefore, impressions on the human body are an important evidence for the law enforcement agencies. If the contact between the object and the body is not strong enough, the impression would be faint and is not easily visible to the naked eyes. So many scientists have studied the development of such impressions by using chemical, physical and optical methods [1-5].

When a hit or a strong physical contact happens on the body parts covered with clothes, the components of the skin, especially the proteins and the sweat will be transferred on to the clothes contacting the skin, which will create an impression on the inner side of the clothes [6,7]. Such impressions are an important evidence in the criminal investigation [6,7]. Hence, it is important to study the development of latent skin impressions (hit marks) formed on the clothes.

In order to study the development of hit marks on the cloth, the human body parts covered with the clothes should be subjected to a strong force (hit) to make the impressions. But applying strong force on a living person is practically impossible. An alternative is to use corpses covered with clothes, but the ethical issues may not allow using the corpses for research purposes. Moreover, the skin texture of the corpse is not similar to that of a living person, because of the accelerated putrefaction after the death [8]. Instead, animals such as dogs and pigs can be used for the studies. But, the skin textures of animals are not usually similar to humans. In the case of dogs, the skin is densely covered with hair and in the case of pigs; the body secretes a lot of fat [5], which are not the cases with human skin. Therefore, there is a need for the skin which can be used as an alternative to human skin, for conducting experiments to study the development of hit marks on the clothes. So far, due to the lack of an alternative to human skin, there are very few studies reported on the development of hit marks on the clothes [6,7].

Squid (*Todarodes pacificus*) is an aquatic animal, which is widely available, and a favorite food in most of the eastern countries. The surface of the squid is not covered with hair, fat, or scales. Therefore, in this study, squid has been implemented as an alternative to human skin to study the development of hit marks on various kinds of fabrics.

Materials and Methods

Materials

The cotton, rayon, polyester, nylon, and acrylic fabrics were purchased in five colors; white, black, yellow, blue, and red, from the local cloth markets in South Korea. Power III (Human Science, Korea) system was used for the de-ionized water preparation. The Leica M80 stereomicroscope was used to observe the texture of fabrics. Polilight PL500SC (Rofin, Australia) and 610 nm band pass filter (Rofin, Australia) were used to observe the fluorescence of the developed hit marks. The Nikon D5300 camera equipped with 105 mm macro lens was used to take the photographs of the developed hit marks. All the photographs were taken under aperture priority mode.

Artificial sweat

The stock solution of artificial sweat was prepared as proposed by Hong et al. [9]. Table 1 shows the formulation of artificial sweat. L-Serine, Glycine, DL-Alanine, L-Leucine, L-Threonine, L-Histidine, L-Valine, L-(+)-Asparagin acid, L-Lysine, sodium chloride, calcium chloride, magnesium chloride, zinc chloride, iodine crystal, and

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sliver nitrate were purchased from Sigma–Aldrich (UK). The working solution of artificial sweat was prepared by diluting the stock solution 50 times in de-ionized water (Table 1).

Latent hit mark developing reagents

Ninhydrin solution was prepared by dissolving 5 g of ninhydrin powder (NRP02B, Sirchie, USA) in 20 ml methanol, followed by the addition of 10 ml of acetic acid, and mixed with 1 L of petroleum ether [10]. DFO solution was prepared by dissolving 0.5 g of DFO powder (LV500, Sirchie, USA) in 100 ml of methanol, followed by the addition of 100 ml ethyl acetate, 20 ml of acetic acid, and 780 ml of petroleum ether, making the final volume to 1 L [11]. Solution of 1,2-IND/Zn was prepared as two separate reagents and mixed together into a single formulation. Half gram of 1,2-IND (LV508, Sirchie, USA) was dissolved in 15 ml of dichloromethane, followed by the addition of 30 ml ethyl acetate, 5 ml of acetic acid, 2 ml of Zn solution (0.2 g of zinc chloride dissolved in 5 ml of ethyl alcohol) and 448 ml of petroleum ether making the final volume to 500 ml [12].

Water based Amido black solution (B-89600, BVDA, Netherlands) was used as purchased. Two de-staining procedures were performed after the completion of staining with Amido black. The first de-staining solution is solution A, which is a mixture of acetic acid and methanol in a 1:9 (v/v) ratio. The second de-staining solution, solution B is a mixture of acetic acid and de-ionized water in a 0.5:9.5 (v/v) ratio [1]. Hungarian red (B-88001, BVDA, Netherlands) staining solution was used as purchased. The de-staining solution for Hungarian red was prepared as a mixture of acetic acid and de-ionized water in a 0.5:9.5 (v/v) ratio [12].

Preparation of an alternate skin sample

The dried squids were purchased from a local market and thoroughly washed with running tap water for 1 min to 2 min and rinsed with de-ionized water. The squids were cut into approximately 1 × 4 cm^2 pieces and air dried. For the preparation of skin with sweat, the dried squid pieces were soaked in the artificial sweat solution for 20 h and further air dried for 2 h at room temperature. For the preparation of skin without sweat, de-ionized water was used instead of artificial sweat. After drying, the texture of the squid feels almost as moist as the human skin. The total number of squid pieces used in this experiment was approximately 750.

Constituents	Amount (mg)	Concentrations (mM)
Serine	490	9.3
Glycine	294	7.8
Alanine	147	3.3
Lysine	195	27
Threonine	73	1.2
Asparagin acid	73	1.1
Histidine	73	0.9
Valine	49	0.8
Leucine	49	0.7
Sodium chloride	3300	113
Magnesium chloride	4	0.4
Calcium chloride	16	1.4
Zinc chloride	2	0.14

Table 1: Formulation of artificial sweat.

Preparation of shoe molds

An iron mold (15 cm × 10 cm × 0.3 cm) with two grids of about 1.5 cm and 1 cm width over it was fabricated to make a uniform hit mark (Figure 1).

Preparation of latent hit marks on fabrics

A squid piece prepared was placed on the clean concrete floor and a cloth is placed over it. And then, the metal mold, shown in Figure 1 was placed on the cloth, such that the grids can stay in contact with the cloth. Additionally, a metal plate (30 cm × 20 cm × 0.5 cm) was placed on the mold (having two grids) to maintain the hitting stability. A dumbbell weighing 2 kg was dropped from a height of 150 cm on the 'squid – cloth – metal mold – metal plate' setup in a way that the impressions of the squid are formed on the cloth in the shape of the mold. The calculated impact force was 10.38 N.s. The impressions were acquired in two forms (Trial A and Trial B) to evaluate the effect of sweat on the development of impressions/marks. All the experiments were repeated three times.

Trial A – Placing cloth on the squid soaked in artificial sweat

Trial B – Placing cloth on the squid soaked in de-ionized water

Development of latent hit marks

After the hitting process, the cloth pieces were stored at ambient temperature (10°C~28°C) for 48 h, and treated with the reagents prepared.

Amino acid sensitive reagents: The fabrics bearing the latent skin impressions were immersed in ninhydrin, DFO, 1,2-IND/Zn working solutions respectively for 4 s and allowed to dry on a clean paper at room temperature. After complete drying, the clothes were treated with amino acid sensitive reagents. For ninhydrin treatment, the cloth was steam pressed at 180°C for 10 s. For DFO treatment, the cloth was dry pressed at 180°C for 10 s. For 1,2IND/Zn treatment, the cloth was steam pressed at 160°C for 10 s [9]. For DFO and 1,2-IND/Zn treatment, the development result was viewed under 505 nm excitation, using a 610 nm band pass filter.

Protein sensitive reagents: The fabrics bearing latent skin impressions were dipped in Amido black and Hungarian red solution respectively for 3 min and further placed on a filter paper for 30 s to

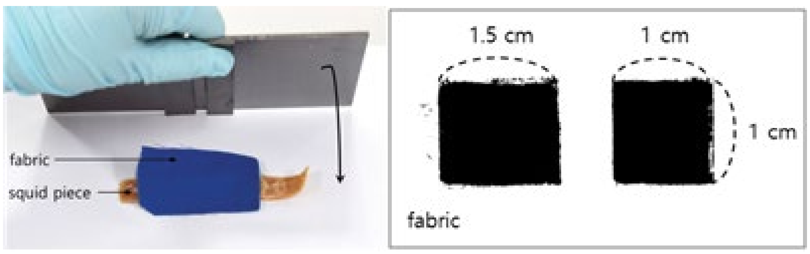


Figure 1: Setting of mold-fabric-squid (left) and an inked impression made with the mold (right).

remove the excess staining solution. The Amido black treated fabrics were further de-stained by dipping in de-staining solutions A and B for 3 min in serial. After de-staining, the fabrics were rinsed with de-ionized water and air dried [1]. The Hungarian red treated fabrics were also de-stained with the de-staining solution, and further rinsed with the de-ionized water and air dried [12].

Evaluation of the developed hit marks

After the treatment with respective reagents, the developed hit marks on the clothes were graded according to the grading system mentioned in Table 2 [13,14]. The grade of each development was derived as an average of opinions taken from 3 individuals. The final grade results were obtained as the average of each treatment (on every cloth) performed in triplicate.

Results

Texture of fabrics

All the fabrics used in the study were observed under the microscope with × 32 magnifications to know the texture and alignment of the fibers. The images are shown in Table 3.

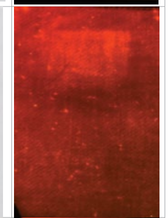
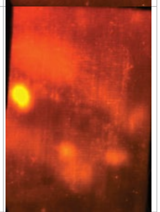
Grade	Details	Examples	
		Ninhydrin treatment	DFO treatment
4	Full development – whole mark clear		
3	>2/3 of mark was developed		
2	1/3 to 2/3 of mark was developed		
1	Signs of contact but <1/3 of mark		
0	No sign of the mark		

Table 2: Grading scheme for the developed hit marks.

Preliminary experiment with protein sensitive reagents

The hit marks were made on all the fabrics. The fabrics bearing hit marks were treated with the protein sensitive reagents (Amido black and Hungarian red). However, hit marks development was hardly obtained from all the fabrics. The developed hit marks were graded according to the grading system shown in Table 2. Among all the grades obtained from the protein-dye processed fabrics, the highest grade was 2.0, which was obtained from the white polyester fabric in Trial B. Therefore, the protein and lipid sensitive reagents were not considered for further experiments. Table 4 shows the representative development results obtained by the protein sensitive reagents.

Development of latent hit marks on cotton fabrics

The hit marks were made on the cotton fabrics. The fabrics bearing the hit marks were treated with different methods. The developed hit marks were graded according to the grading system shown in Table 2. The grades (evaluation results) of the developed hit marks on the cotton fabrics were shown in Table 5. The results in Table 5 show that none of the reagents tested have shown a prominent enhancement effect on the hit marks deposited on blue, red and black cotton fabrics. Also, it is evident that the amino acid sensitive reagents showed higher grades for the hit marks created by Trial A than the ones created by Trial B. The DFO has shown the prominent development of hit marks, irrespective of the trials, on white and yellow colored fabrics. The development efficiency of 1,2-IND/Zn was almost similar to that of DFO in Trial A but decreased in Trial B. Table 6 shows a representative development of hit marks deposited on the cotton fabrics.

Development of latent hit marks on rayon fabrics

Table 7 is a depiction of grades obtained from the hit marks developed on rayon fabrics of different colors using various development methods. The results in Table 7 show that none of the reagents tested have shown a prominent enhancement of the hit marks deposited on blue, red and black rayon fabrics. In Trial A, DFO was most effective on white and yellow rayon. However, in Trial B, DFO was only effective on yellow rayon. Overall, even though there is no prominent difference, the enhancement achieved was inferior on rayon fabrics compared to cotton. Table 8 shows a representative development of hit marks deposited on rayon fabrics of different colors.

Development of latent hit marks on polyester fabrics

Table 9 is a depiction of grades obtained from the hit marks developed on polyester fabrics of different colors using various development methods. The results in Table 9 show that none of the reagents tested have shown a prominent enhancement effect on the hit marks deposited on blue, red and black polyester fabrics. The development with DFO was very prominent on the white fabric, whereas the quality of development was poor on the colored fabrics. In the case of yellow fabric, ninhydrin showed better development compared to DFO. Table 10 shows a representative development of hit marks deposited on polyester fabrics of different colors.

Development of latent hit marks on nylon fabric

Table 11 is a depiction of grades obtained from the hit marks developed on nylon fabrics of different colors using various development methods. The results in Table 11 show that noticeable development was obtained from the colored nylon fabrics by DFO treatment. In the case of white fabric, the best grade was obtained by ninhydrin treatment in

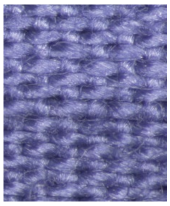
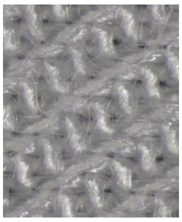
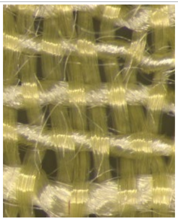
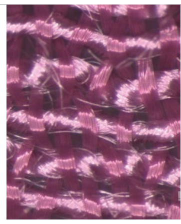
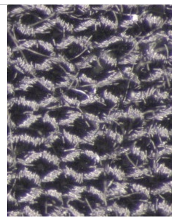
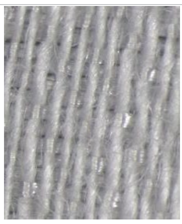
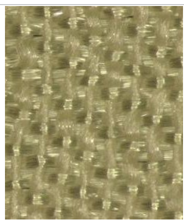
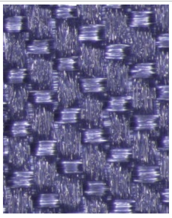
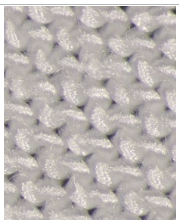
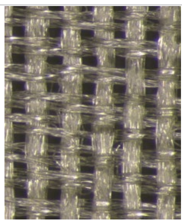
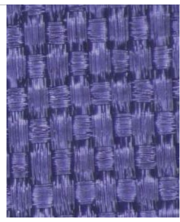
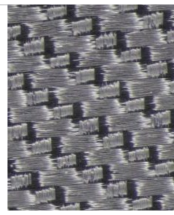
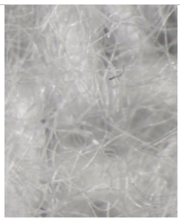
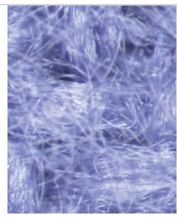
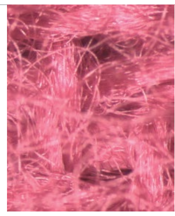
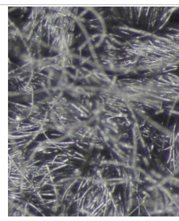
	White	Yellow	Blue	Red	Black
Cotton					
Rayon					
Polyester					
Nylon					
Acrylic					

Table 3: Microscopic images (× 32) of the fabrics used in the experiments.

Trials	A	B	A	A	B
Development results					
Type of fabric	Cotton	Polyester	Nylon	Cotton	Nylon
Developing reagents	Amido black	Amido black	Amido black	Hungarian red	Hungarian red

Table 4: The most effective development results obtained by the protein sensitive reagents from white fabrics.

Trial A, and DFO treatment in Trial B. On the black colored fabrics, DFO has shown a good development on both Trial A and Trial B. However, the results are more promising in the case of trial A, i.e. 2.7 grade, compared to Trial B, i.e. 1.7 grade (Table 11). Table 12 shows a representative development of hit marks deposited on polyester fabrics of different colors.

Trials	Fabric color	Developing reagents		
		ninhydrin	DFO	1,2-IND/Zn
A	white	1.7	3.7	3.3
	yellow	2	3.7	3
	blue	0.7	0.3	0
	red	0.3	1	0
	black	0	0.3	0
B	white	1.3	3	0.3
	yellow	1.3	2	0
	blue	1	0	0.3
	red	0.3	0	0
	black	0	0.3	0.3

Table 5: The average grades of hit marks developed on cotton fabrics.

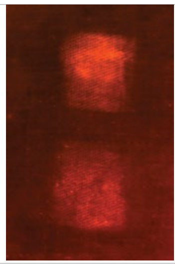
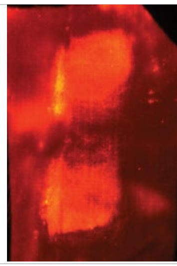
	A	A	A	A
Development results				
Surface color	White	White	White	Yellow
Developing reagents	ninhydrin	DFO	1,2-IND/Zn	DFO

Table 6: Representative results of hit marks developed on cotton fabrics.

Trials	Fabric color	Developing reagents		
		ninhydrin	DFO	1,2-IND/Zn
A	white	1	2.7	1.3
	yellow	0.7	2.7	1
	blue	0.3	0.7	1
	red	0.3	0	0
	black	0	0.7	0
B	white	1.3	0.3	1
	yellow	0.3	3	1
	blue	0	1.3	1
	red	0	0	0
	black	0	1	0

Table 7: The average grades of hit marks developed on rayon fabrics.

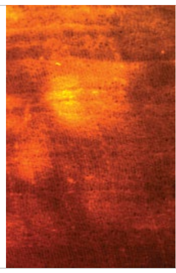
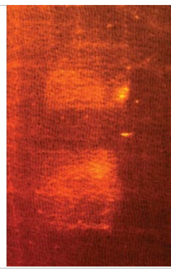
Trials	A	A	A	B
Development results				
Surface color	White	White	Yellow	Yellow
Developing reagents	DFO	1,2-IND/Zn	DFO	DFO

Table 8: Representative results of hit marks developed on rayon fabrics.

Development of hit marks on acrylic fabrics

Table 13 is a depiction of grades obtained from the hit marks developed on acrylic fabrics of different colors using various development methods. The development of hit marks on all the acrylic fabrics was very poor compared to other fabrics. Of all the amino acid, sensitive reagents, only ninhydrin had shown a brief development of impressions on some of the fabrics in both Trial A and Trial B. Table 14

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Trials	Fabric color	Developing reagents		
		ninhydrin	DFO	1,2-IND/Zn
A	white	1.3	4	2.3
	yellow	1.7	0	0
	blue	0.7	0.7	0
	red	1	1	0
	black	0	0	0
B	white	1	3.7	0.3
	yellow	1	0	0
	blue	0.7	0.7	0.3
	red	1	0.7	0
	black	0	0	0

Table 9: The average grades of hit marks developed on polyester fabrics.

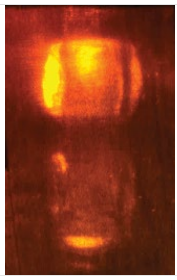
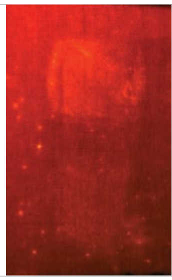
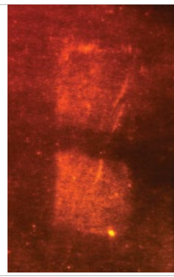
Trials	A	A	A	B
Development results				
Surface color	White	White	Yellow	White
Developing reagents	DFO	1,2-IND/Zn	Ninhydrin	DFO

Table 10: Representative results of hit marks developed on polyester fabrics.

Trials	Fabric color	Developing reagents		
		ninhydrin	DFO	1,2-IND/Zn
A	white	2.3	1.7	0
	yellow	0.7	1	0
	blue	0.3	0.7	0.7
	red	0.7	1.7	0.3
	black	0	2.7	0.7
B	white	1	2	0
	yellow	0.3	0	0.7
	blue	0	1.3	0
	red	0.3	1.7	0.7
	black	0	1.7	0.3

Table 11: The average grades of hit marks developed on nylon fabrics.

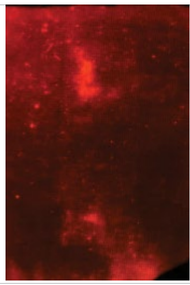
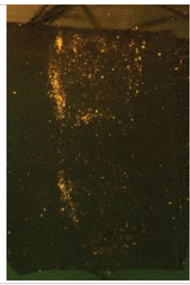
Trials	A	A	B	B
Development results				
Surface color	White	Black	White	Black
Developing reagents	ninhydrin	DFO	DFO	DFO

Table 12: Representative results of hit marks developed on nylon fabrics.

Trials	Fabric color	Developing reagents		
		ninhydrin	DFO	1,2-IND/Zn
A	white	0	0	0
	yellow	0.3	0	0
	blue	0	0	0
	red	0.3	0	0
	black	0	0	0
B	white	0.3	0	0
	yellow	0.7	0	0
	blue	0	0	0
	red	0.3	0	0
	black	0	0	0

Table 13: The average grades of hit marks developed on acrylic fabrics.

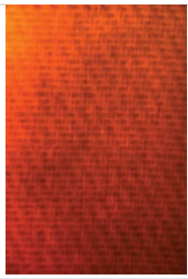
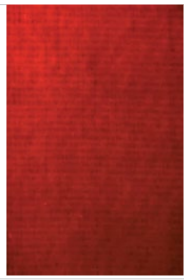
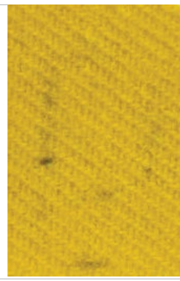
Trials	A	A	B	B
Development result`s				
Surface color	White	White	White	Yellow
Developing reagents	DFO	1,2-IND/Zn	Ninhydrin	Ninhydrin

Table 14: Representative results of skin impressions developed on acrylic fabrics.

shows a representative development of hit marks deposited on polyester fabrics of different colors.

Discussion

The inner side of the clothes contacting a person's skin may carry impressions of the body parts. The impressions of skin on the fabrics are more intense when the body is subjected to a strong force by an external source (fighting, injury etc.). Hence, the clothes are the major pieces of evidence available at the crime scenes. The development of latent skin impressions (hit marks) on the inner side of the clothes has been studied using various chemical methods [6,7]. However, the number of researches concerning the hit marks on the clothes is limited, because it is not possible to impose strong forces on the living individuals to recreate the real crime scene and collect the cloth samples. To overcome this problem, the authors of this study are suggesting an alternative to human skin, i.e. squid.

The human skin secretes sweat. Thus, when a person is subjected to an external force, it is believed that the sweat components, as well as other skin components, are transferred onto the inner surface of clothes making impressions of the contacted body parts. However, the squid does not secrete sweat, whereas the human skin does. To make the squid as similar to the human skin, the authors have soaked the pieces of squid in artificial sweat and water in two trials; Trial A (soaked in artificial sweat) and Trial B (soaked in de-ionized water), and the results were compared.

The clothes worn by the people are made of different kinds of fabrics. The most widely used fabrics; cotton, rayon, polyester, nylon, and acrylic were used to deposit the artificial hit marks. Each kind of fabric was also collected in five colors (white, yellow, blue, red and black) to know the effect of color in the development process. The amino acid sensitive reagents (ninhydrin, DFO, 1,2-IND/Zn) and protein sensitive reagents (Amido black and Hungarian red) were used to develop the hit marks on various kinds of fabrics. Amino acid sensitive reagents (especially DFO) have shown an overall better quality development of artificial skin impressions, compared to the protein sensitive reagents tested. The protein sensitive reagents haven't shown a distinguishable development of hit marks on fabrics studied. These results coincided with the results of Hamer and Price [6].

The clothes treated with Trial B have shown positive responses to the amino acid sensitive reagents. However, a comparison of Trial A and Trial B processes has shown that the Trial A received higher grades compared to the Trial B, in general. This is due to the presence of artificial sweat in Trial A, which can react with the amino acid sensitive reagents. This result means that the development efficiency of latent hit mark is influenced by the sweat, as well as other skin components.

The efficiency of amino acid sensitive reagents (ninhydrin, DFO, 1,2-IND/Zn) varied depending on the kinds of fabrics. For example, on the Trial A processed white polyester fabric, DFO (4.0 grade) was most effective, followed by 1,2-IND/Zn (2.3 grade) and ninhydrin (1.3 grade). On the other hand, on the Trial A processed white nylon fabric, ninhydrin (2.3 grade) was most effective, followed by DFO (grade 1.7), and 1,2-IND/Zn (grade 0.0). These results mean that the efficiency of development depends on the type of fabric. That is, one method cannot be suitable for all the fabrics. Therefore, the development method has to be chosen according to the type of fabric, where the hit marks are deposited.

The efficiency of amino acid sensitive reagents also varied depending on the color of fabrics. The better development efficiency was observed from the white fabrics than the colored fabrics, in general. The inferior development efficiency from the colored fabrics can be attributed to the decreased contrast from the colored fabrics. However, it was not always true. For example, on the Trial A and DFO processed nylon fabrics, the best development was achieved from the black fabric. This result means that the development efficiency does not fully depend on the contrast between the developed mark and the background. Therefore, an unknown chemical interaction between the dye and the developing reagent can be predicted. Further study is needed to explain this phenomenon.

It has been stated that the reaction between amino acids and 1,2-IND/Zn is catalyzed by cellulose [15]. Cellulose is the major component of cotton, and a starting material for making rayon [16,17]. The other fabrics used in the study do not contain any traces of cellulose. Therefore, it was the authors' expectation that 1,2-IND/Zn, a well-known amino acid sensitive reagent, is effective on the cotton and rayon fabrics (especially in the Trial A), and ineffective on the polyester, nylon, and acrylic fabrics. This expectation was proved on the cotton fabrics. The latent hit marks deposited on the white cotton (Trial A) were developed with 1,2-IND/Zn. However, the development of hit marks with 1,2-IND/Zn on rayon was much inferior compared to that on cotton. Also, against the authors' expectation, the 1,2-IND/Zn has also shown the development of hit marks on white polyester fabric, despite the absence of cellulose. This phenomenon of 1,2-IND/Zn on polyester fabric needs a further study.

The acrylic fabric has not shown any development of hit marks by any of the development methods employed. As shown in Figure 1, the texture of acrylic fabrics is less coarse than the others. The fibers in the acrylic fabric are arranged in a very disordered fashion compared to other fabrics, which could have been a hindrance for the absorption or transfer of components from the surface of the skin. In order to prove this phenomenon, additional experiments using another acrylic fabric having different texture is required. But it was practically impossible because woven acrylic fabric is not available in the market.

The present study has shown that the effectiveness of latent skin impression development reagents depends on the chemical (generic class and dye/pigment of fiber composing the fabric) and physical features of the fabrics. However, the reason was not investigated precisely because it is beyond the scope of this study. The main aim of the present study is to suggest and prove squid as an alternative of human skin, for performing hit mark developing experiments on clothes, since the living beings cannot be hit stronger to make hit marks on the clothes.

Conclusion

The development of skin impressions on a variety of fabrics; cotton, rayon, polyester, nylon, and acrylic has been studied. Each kind of fabric was collected in 5 different colors (white, yellow, blue, red and black), thus making 25 unique fabrics altogether. Squid soaked in artificial sweat or de-ionized water has been used as an alternative to human skin to deposit skin impression on the fabrics. The amino acid sensitive reagents (ninhydrin, 1,8-diazafluoren-9-one, 1,2-indanedione/zinc chloride) and protein sensitive reagents (Amido black, Hungarian red) were used to develop the skin impressions on fabrics. Protein sensitive reagents are less effective than the amino acid sensitive reagents in developing skin impressions on various kinds of fabrics. The development efficiency was compared with two kinds of skin impressions; one made with artificial sweat soaked squid, and another made with de-ionized water soaked squid. The experimental results indicate that the sweat components, as well as the protein content of the skin influence the development efficiency of the same reagent. The efficiency of development also varied depending on the chemistry, texture, and color of the fabrics. Therefore, it is suggested to perform preliminary experiments with different methods on a fabric similar to the fabric encountered at the crime scene. This gives a clear idea on the most suitable method to develop hit marks on that particular fabric. The current study was undertaken with a squid and artificial sweat. However, the squid and artificial sweat combination cannot be an alternative to all kinds of human skin, which can have varying degrees of perspiration. Therefore, the authors of this paper are expecting the accumulation of real case studies to prove the feasibility of this paper.

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