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A pilot study of a new fingerprint powder application method for the reduction of health risk

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Abstract As a traditional method to apply fingerprint powder, brush method ("dusting") can create a risk to the health of crime scene investigators due to the inhalation toxicity of harmful and fine powders. Therefore, as a new method of applying powders, we tried to evaluate the potential of a chamber method for the development of latent fingerprint using fans in a closed chamber with a fixed capacity that can prevent the powders from being blown outside and exposed to the users, by comparing with the development results of the conventional brush method. Fingerprints on glass and plastic (PET) were extracted with black powder and green fluorescent powder, and the sharpness and minutiae of the developed fingerprints were compared for each method. The results of the black powder showed similar results, but the effect of the chamber method was slightly decreased when the green fluorescent powder was used. In order to improve the development with the green fluorescent powder, the mixture (50 : 50) of the fluorescent powder with the silica gel was tested and the results were similar to those of the brush method. It is expected that the chamber method has a high potential as a new powder application method considering the health of the crime scene investigator after fine tuning of development conditions with additional studies.

Key words: powder application method, hazards of fingerprint powder, chamber method, brush method.

1. Introduction

Fingerprint development is a powerful tool in forensic science, which has also been accepted as an effective method for personal identification.[1] The methods for developing latent fingerprints are determined based on multiple factors, including the properties, texture, condition, and color of the surface, where the latent fingerprint is left behind.[2] Among these methods, the powder method, which has been used since the early days of latent fingerprint development technology, involves the detection and development of fingerprints by applying finely ground powder on residues left behind on surfaces that have been touched. Moreover, the powder method is a relatively easy and economical method

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for developing latent fingerprints on non-porous surfaces, which makes it useful for on-site use.[3,4]

However, the powder used in the powder method could be hazardous to the health of the user and can cause other problems, such as contamination of the surrounding environment. Some powders containing carcinogens, such as lead or mercury based powders, which were initially used, have been discontinued.[5,6] Moreover, metal components in magnetic powders used today and carbon black used in black powder could cause respiratory diseases, such as pneumoconiosis. In other words, most of the powders used for fingerprint development contain substances that pose chronic health risk.[7] Furthermore, the particle size of the powder is 1-10 μm, which is comparable to the size of typical fine dust (≤ 10 μm). Fine dust particles of the size of ≤ 10 μm could enter through the respiratory system and accumulate in the lungs, while particles sized ≤ 2.5 μm could cause serious health problems as they move into the body through the respiratory tract and the blood stream.[8] Accordingly, the use of safety equipment, such as masks and goggles, for the prevention of powder inhalation is recommended and the importance of proper ventilation is emphasized. However, assuring the safety of forensic investigators is uncertain depending on the conditions and circumstances they work in. Also, the mask and goggle's blocking efficiency against fine powder inhalation typically recommended for evidence collection is unclear. According to a questionnaire survey conducted in Korea among forensic investigators, the most common diseases suffered by forensic investigators were found to be respiratory, eye, and skin diseases,[9] while studies outside of Korea have reported that, although it may be difficult to generalize powder as the direct cause of the diseases, occupational exposure to fingerprint powder is associated with higher than expected incidences of skin and visual impairment.[10] Moreover, powder contaminates indoor air and surrounding environment, requiring cumbersome cleaning and washing after the investigation and can cause a decrease in the efficiency of the investigation work performed by forensic investigators.[11]

The brush method, which is the conventional method used to apply the powder, involves coating the brush with adequate amount of powder and applying it on the sample for fingerprint development. It has been established as a method most commonly used on site due to the advantages of using simple tools and the method itself being simple and economical. However, latent fingerprint development techniques could produce different results according to the competency of each individual, and individual errors may occur.[12] In particular, the brush method relies more on experience and skill than other development methods, making it more prone to human errors. Moreover, it is estimated that approximately 10 % of the latent fingerprints developed on site using the brush method are unidentifiable, which is presumed to be due to damages to the ridges caused by the brush contacting the fingerprint.[13] In case of sebum-rich fingerprints, using the brush method could partially or entirely damage the ridges, and the probability of damaging the fingerprint is increased when the fingerprint is fresh and there is more contact with the brush.[14,15] The brush method creates a powder dust cloud in the air,[16] and since the spread of the powder cannot be prevented, the probability of the powder being inhaled by the user is even higher. To overcome the shortcomings of such brush method, a method of using a brush with a magnetic powder has been used, but this method is more expensive than is the method involving a brush with a regular powder and requires greater caution for making a contact between the brush and the sample surface.[17] Moreover, due to the weak auto-adhesion of magnetic powder, repeated brushing could cause the powder to adhere to surfaces where no fingerprints have been left behind, which could degrade the quality of fingerprints. Moreover, magnetic powder can't be used on metallic surfaces.[18]

Studies that were conducted to address such health issues associated with the powder method have been limited to those on reducing the risk of powder material by using natural ingredients and organic substances[11,19] or developing new brushes. While various studies have been published on electrostatic method, glove-type powder application device, and other powder application methods, including the use of an atomizer, sifter, or aerosol spray, these methods showed inferior fingerprint development capabilities than the brush method or were not universally commercialized.[20-22]

Recently, there have been efforts to prevent powder inhalation by forensic investigators with consideration for the use of portable powder suction devices as a countermeasure to address the on-going health risk of powders, but further studies are needed on powder application methods that consider the health risks faced by forensic investigators, as well as protecting the surrounding environment by preventing scattering of powder. Accordingly, the present study designed a novel powder application method that can reduce the health risks faced by forensic investigators from fingerprint powder and reduce errors in fingerprint development between individuals. This chamber method involves installing fans inside a chamber with a set capacity and operating the fan with the sample and powder inside the chamber to adsorb the powder on latent fingerprints by scattering the powder by wind for fingerprint development. This method develops the fingerprints inside the chamber while eliminating contact with the fingerprints by objects other than the powder to minimize the risk of damage to the fingerprints, which also prevents direct inhalation of powder by the user from scattering of powder. To determine whether the chamber method, as a novel powder application method, has valid latent fingerprint development capability, the study compared its level of fingerprints development against conventional brush method to test its usability.

2. Materials and Methods

2.1. Reagents and apparatus

Fingerprints left on slide glass (MARIENFELD, Germany) and hand-coating paper (PET, Hansol, Korea) using a load cell (KERN KB1200-2, Germany) under the same conditions were stored in a file cabinet (SYSMAX, Korea) for a set period. The fingerprints were developed using black powder (SIRCHIE, USA) and green fluorescent powder (IDTECH, Korea) with Patriot marabou feather duster (SIRCHIE, USA). When preparing the mixed powder, silica gel powder (Silica gel 60, Merck, Germany) was used. Inside the acrylic octahedral chamber (11 L) for the chamber method, two propellers (NaRiKa, Japan) and two motors (15000 rpm, China) were installed and a power cable (3V, Taeyoung SMPS, Korea) was connected to set up the experimental apparatus (*Fig.* 1). The latent fingerprints developed by each method were imaged using a digital camera (Nikon D5300, Japan) and micro-lens (Nikon AF Micro Nikkor 60 mmf/2.8D, Japan). The latent fingerprints developed using the green fluorescent powder were imaged at a wavelength of 505 nm under an orange filter by loading Velox (IDS, Korea), a multi-lighting source module, on a digital camera. Each fingerprint image was analyzed using Adobe Photoshop CS6 (Adobe system Incorporated, 64 bit, USA), densitometric image analysis program CP Atlas 2.0 (Lazarsoftware, USA), and Automated Fingerprint Identification System (AFIS). The results were arranged in Excel 2016 (Microsoft, USA) and SigmaPlot 10 (Systat Software Inc., USA) and were displayed as graphs.

2.2 Experimental methods

2.2.1. Latent fingerprint impression and development methods

After using 70 % ethanol to clean the right thumb of a female in her 20s, the residue was evenly loaded by rubbing her thumb around the nose area and rolling with other fingers five times. On each surface, impressions of the split and whole fingerprints were left under the same conditions of 0.5 kg/f and 2 s, which were stored for 3 and 14 days respectively, before being used in the experiment. For the split fingerprints, the impressions were left in the center of two sheets of same surface placed next to each other. With split fingerprints, various factors such as residue composition, deposition time, and deposition pressure could be controlled when leaving the fingerprint samples, which allows direct comparisons according to different treatment methods.[23,24] For more accurate comparison

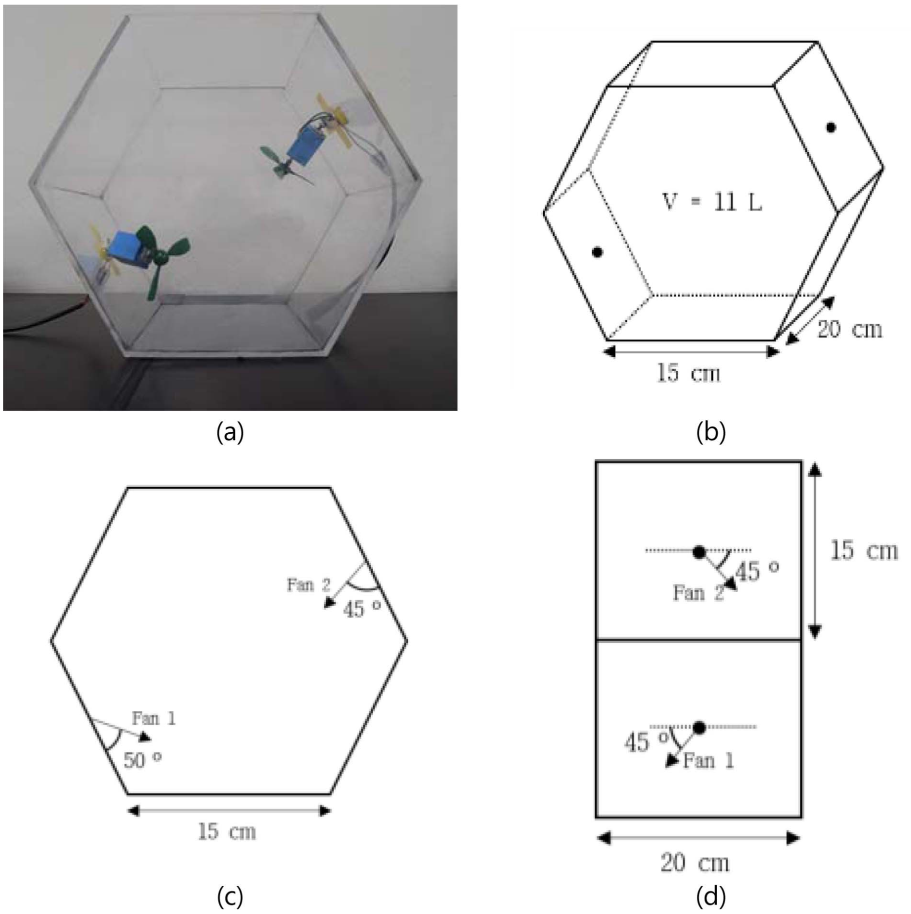


Fig. 1. The actual image of the chamber and diagrams, (a) a chamber with two fans, (b) structure diagram, (c) front view, (d) side view.

of the fingerprint development capabilities between the chamber and brush methods, each part of the split fingerprint samples were developed by different methods and imaged for use in the densitometric image analysis. For the analysis of minutiae in whole fingerprint samples, whole fingerprint impressions were left on each surface for use in the experiment.

For the chamber method proposed in the present study, the latent fingerprint sample and powder were placed in the bottom section of the octahedral chamber and two fans positioned at appropriate angles were turned on to attempt latent fingerprint development by generating a powder cloud. Using a set amount of powder, the fans were turned off after specific development time. The samples were removed and imaged, after which they were placed back in the chamber to repeat the development process. The experiment using black powder was carried out with 1, 2, and 2.5 g of powder and interval of 0.5, 1, 2, 3, and 5 min in between development, while the experiment using green fluorescent powder was carried out with 0.3, 0.5, and 0.7 g of powder and interval of 10 s each up to 1 min., since it is finer than black powder and has greater sensitivity when using fluorescent powder for development by the chamber method, a set amount of fluorescent powder and silica gel powder were mixed together to enhance the development capability for PET surface. The conventional brush method was performed by the typical method of coating the brush with an adequate amount of powder (average per sample - black powder: 0.2 g, fluorescent powder: 0.1 g) and applying the powder on the fingerprint left behind. The powder used for each method was commercial fingerprint powder typically used. All experiments were repeated nine times each.

2.2.2. Latent fingerprint assessment method

To assess the fingerprint development capability of each method, the minutiae and clarity of fingerprint images were analyzed and compared. For densitometric image analysis, densitometric intensity within a set range on the image was expressed as a graph and the quantitative area value of the designated zones (peaks) was calculated. Higher values indicated higher density relative to surrounding background, which was determined to show higher clarity. Accordingly, by measuring the area value representing the densitometric intensity of the ridges relative to the background in fingerprints with repeated appearances of peaks and valleys, it would be possible to determine the clarity of the ridges relative to the background of the surface where the latent fingerprint was left. For this purpose, previous studies have conducted experiments on whether semi-quantitative evaluation of fingerprint quality from the area of the fingerprint ridges relative to the background could be possible.[25,26] Therefore, latent fingerprints left on each surface were developed using black and green fluorescent powders and the area values of the fingerprint ridges were calculated using densitometric image analysis.

With respect to the settings for densitometric image analysis program, the fingerprint images developed using black powder were analyzed under the settings of dark on light background, grayscale channel, and 100 % zoom. The fingerprint images developed using the green fluorescent powder were analyzed

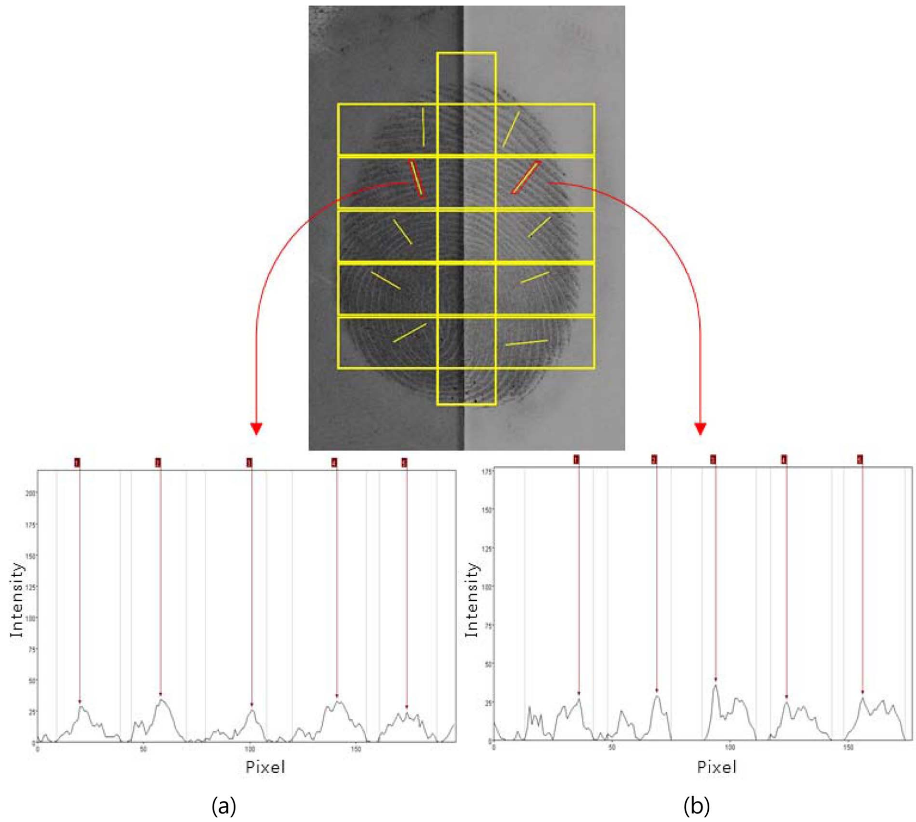


Fig. 2. An example of actual densitometric image analysis using inserted frame, (a) chamber method, (b) brush method.

using green fluorescent light with dark background with settings of light on dark background, green channel, and 100 % zoom. To analyze ridges from the same locations, a frame with five lines on each side, excluding the center where error could have occurred when leaving a split fingerprint, was inserted. For each line of the image aligned with the frame, measurement lanes with same size were set for five ridges for each line, and a base line for the peaks of graph derived was designated to remove the area value of noise and background color. The peaks corresponding to ridges were designated as individual zones and area value for each ridge was calculated (*Fig*. 2). To minimize errors during analysis or partial errors occurring during fingerprint development, five measurement lanes were drawn on each part of a split fingerprint and five ridges were acquired from each lane, whereby the mean area value from a total of 25 ridge peaks was derived. This process was repeated on images obtained from nine repeated experiments, and the mean area value and standard deviation (SD) were derived from repeated experiments for each application method.

It is well known that the comparison of minutiae from developed fingerprints cannot be a measure for an absolute determination of fingerprint quality. However, comparing the number of minutiae could be important for verifying the effectiveness of fingerprint development methods since the purpose of fingerprint development is personal identification. Accordingly, the present study aimed to verify the effectiveness of the chamber method by comparing the number of minutiae between the chamber and brush methods and the minutiae was extracted by using the automatic extraction function in AFIS program. Experiments were carried out using the whole fingerprints that were left for AFIS analysis and images obtained from nine repeated experiments were analyzed to derive the mean number of minutiae and SD.

3. Results and Discussion

The present study first checked whether latent fingerprint development was possible with the chamber method, which is a novel method for powder application designed for the study in consideration, for the safety of forensic investigators. When using the chamber method, latent fingerprint development was possible by adsorption of the powder on the fingerprint ridges from wind generated by the fans inside the chamber. Because the fingerprint development process took place inside the chamber, isolated from the outside, direct contact with the powder by the user was prevented. Since optimization of the amount of powder and development time was required for the development of latent fingerprints using the chamber method, a pilot experiment was conducted on the amount of powder and ages of fingerprints for each surface to establish the optimal conditions, based on which the quality of developed fingerprints with respect to clarity and minutiae was compared against that obtained using the brush method.

3.1. Comparison of development capability of latent fingerprints left on glass surface

3.1.1. Black powder

When using black powder to develop latent fingerprints left on glass surface, the conditions for using the chamber method were established first to compare the development capabilities between the chamber and brush methods. The area values of fingerprints developed under different amounts of black powder and development time were analyzed, the results of which showed that the highest area value for fingerprint developed with 2 g of powder and 2 min of development time (results not given). Accordingly, the area values and number of minutiae of fingerprints developed using the brush method under the optimal conditions for the chamber method were compared against those of the chamber method.

In fingerprints that had been stored for 3 and 14 days, the mean area value was higher with the chamber method, by 14.5 % and 8.2 %, respectively, while the mean number of minutiae in fingerprints that had been stored for 3 and 14 days was similar for both methods, with a difference less than 1 (*Fig.* 3). In

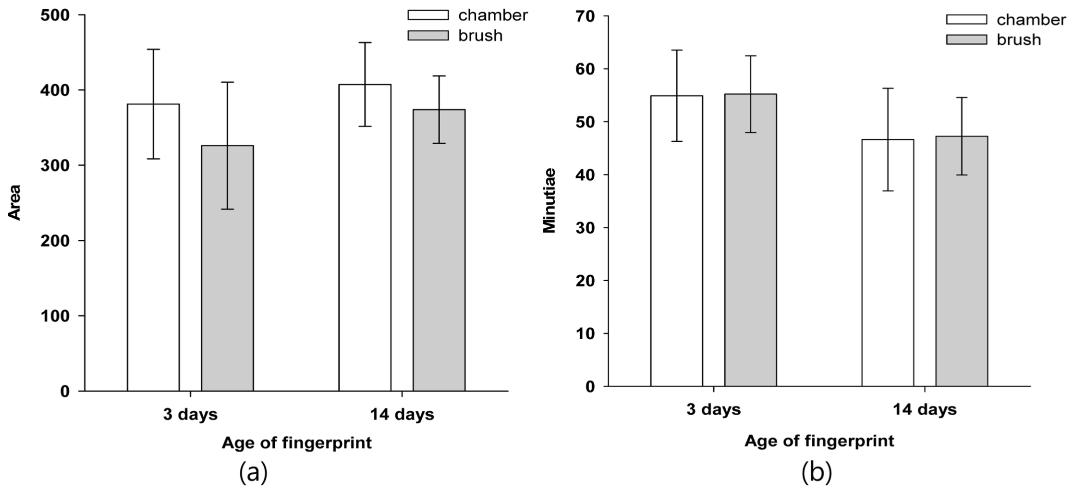


Fig. 3. The results of developed latent fingerprint with black powder on glass surface, (a) area, (b) minutiae.

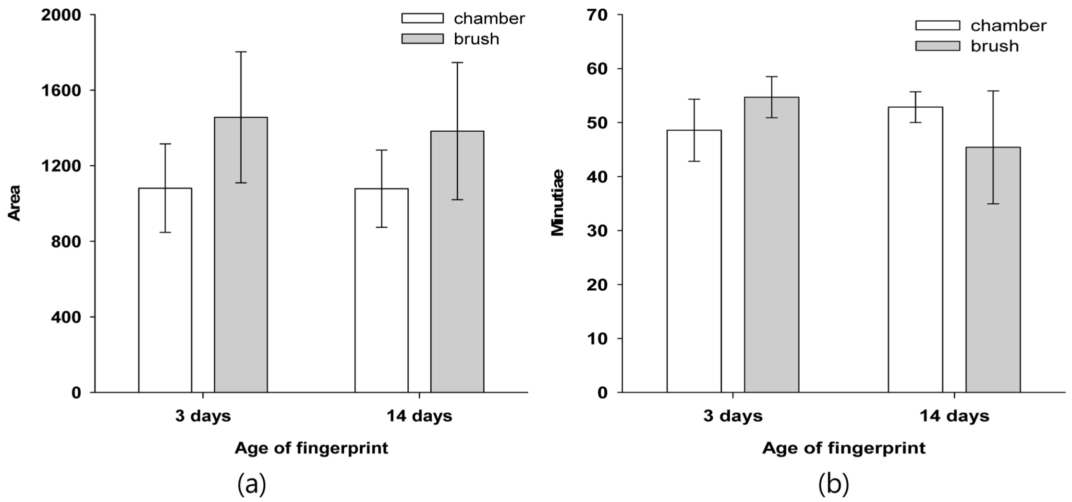


Fig. 4. The results of developed latent fingerprint with green fluorescent powder on glass surface, (a) area, (b) minutiae.

other words, when using black powder for development of latent fingerprints left on glass surface, the chamber method showed similar development capability as the conventional brush method, which confirmed the usability of the chamber method.

3.1.2. Fluorescent powder

To find the optimal conditions for using fluorescent powder to develop latent fingerprints left on glass surface by the chamber method, the area values of fingerprints developed under different conditions were measured. The results showed the highest area value for fingerprint developed with 0.5 g of powder and 20 s of development time (results not given). Accordingly, the area values and number of minutiae of fingerprints developed by the brush method under these conditions were compared against those of the chamber method.

When latent fingerprints left on glass surface and stored for 3 and 14 days were developed using fluorescent powder, the mean area value was higher with the brush method, by approximately 25.7 % and 22.0 %, respectively (*Fig.* 4(a)). With respect to the number of minutiae, approximately 6 more minutiae were found with the brush method in the fingerprints stored for 3 days and 7 more minutiae were found with the chamber method in the fingerprints stored for 14 days (*Fig.* 4(b)). The analysis of clarity of ridges showed superior results for the brush method. It is believed that due to fluorescent powder having the characteristics of being finer and having higher sensitivity,[27] using fluorescent powder would require greater caution due to high likelihood of over-development of latent fingerprints. Moreover, with the brush method, excess powder left on the background could be removed as the brush touches the surface, whereas with the chamber method, removing the fine fluorescent powder left on the surface would be relatively more difficult due to static electricity and other factors, which may have resulted in lower clarity relative to the background. However, the mean number of minutiae showed a similar tendency and superior results over time. Therefore, the chamber method using fluorescent powder for developing latent fingerprints on glass surface did not show clarity in ridges relative to the background, but it could be viewed as having development capability comparable to the brush method with respect to distinction of fingerprint ridges and minutiae.

3.2. Comparison of development capability of latent fingerprints left on PET surface

3.2.1. Black powder

To check the conditions for using the chamber method with black powder for developing latent fingerprints on PET surface, densitometric image analysis was performed on fingerprint images developed with different amount of powder and development time. The results showed that fingerprints developed with 2 g of powder and 1 min of development time had the highest area value (results not given). Accordingly, the area values and number of minutiae of split and whole fingerprints developed using the chamber method under the conditions of 2 g and 1 min were derived by densitometric image and AFIS analyses for comparison against the values obtained using the brush method.

For fingerprints that had been stored for 3 and 14 days, the areas of the ridges obtained using the chamber method was higher by approximately 4.4 % and 37.0 %, respectively, while the clarity was comparable or similar to that obtained using brush method (*Fig.* 5(a)). Moreover, the area values obtained using the chamber method according to the number of days the fingerprints were stored (3 and 14 days) were similar, but the fingerprints developed using the brush method showed a large decrease of

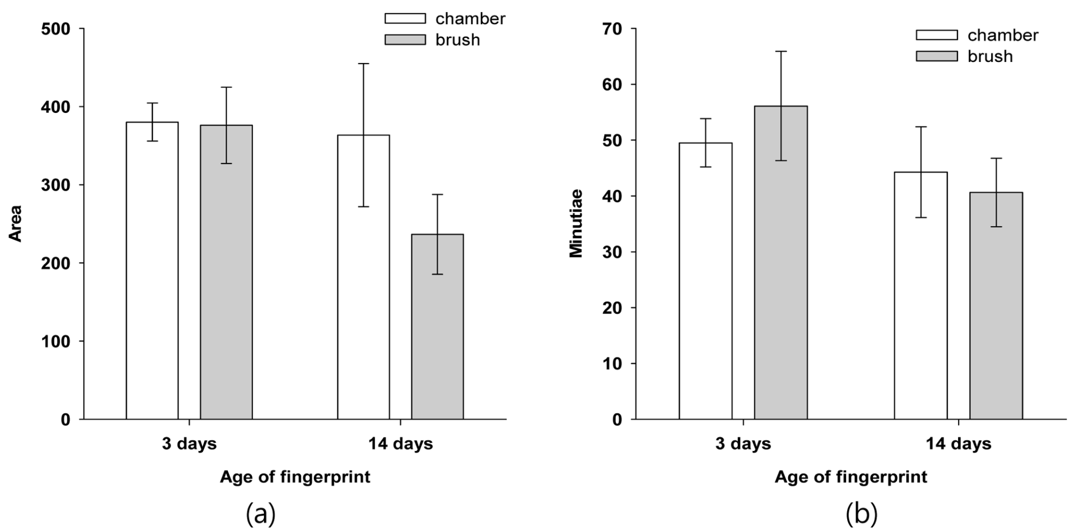


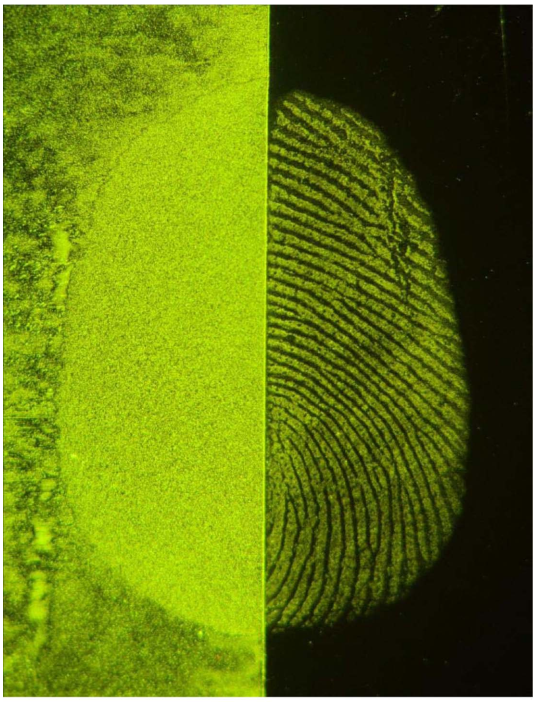
Fig. 5. The results of developed latent fingerprint with black powder on PET surface, (a) area, (b) minutiae.

34.9 % in area value. With respect to the mean number of minutiae, approximately 7 more minutiae were found in fresh fingerprint samples (3 days) when the brush method was used, while approximately 4 more minutiae were found in relatively older fingerprint samples (14 days) when the chamber method was used (*Fig.* 5(b)). Both methods showed a decrease in the mean number of minutiae according to the number of days the fingerprints left on the PET surface, but the chamber method showed a decrease of 5 points (10.5 %), whereas the brush method showed relatively greater decrease of approximately 16 points (27.6 %).

Generally, fingerprints residues are known to be destroyed or lost more quickly in fingerprints left on plastic surface than glass surface.[28] In the case of relatively older fingerprints (14 days), the powder needed to come in contact with small amount of residue left on PET surface. With the brush method, adhesion of small amount of residue and contact with the brush present high probability of damaging the ridges, which may have resulted in large decrease in clarity and number of minutiae. On the other hand, the chamber method does not generate any contact with other objects, besides the powder, and thus adhesion of powder to the residue was easier, resulting in higher clarity and number of minutiae. In other words, when the chamber method is used on aged fingerprints, superior results could be obtained. Therefore, it is predicted that even better results may be obtained by using the chamber method on fingerprints that are older than the ones used in the present study, which should be verified through additional experiments.

3.2.2. Fluorescent powder

For using fluorescent powder to develop latent fingerprints on the PET surface, the fingerprints were developed under the same conditions as those used for a glass surface, as mentioned above, for the optimization of the chamber method. Densitometric image analysis was performed on the developed fingerprint images to establish the optimal conditions and compare the results to the fingerprints developed using the brush method. However, it was impossible to visually distinguish the ridges in the latent fingerprints developed by the chamber method (*Fig.* 6), and changes occurring on the basis of the amount of powder used and development time were relatively unclear. Consequently, optimal conditions were unclear and the area values were significantly lower than those obtained using the brush method (*Fig.* 7). Difficulties in using fluorescent powder to develop fingerprints on PET surface by the chamber method are believed to be caused by the fact that PET is a material on which static electricity could be generated easily on the surface. Thus, the friction between the powder (which is a fine organic substance scattered by wind and has high adhesiveness) and the surface may have caused the powder to adhere to the surface indiscriminately. Accordingly, a problem with using fluorescent powder to develop latent fingerprints on PET surface by the chamber method was identified and an additional



(a) (b)

Fig. 6. An image of developed latent fingerprint using green fluorescent powder on PET surface, (a) chamber method, (b) brush method (age of fingerprints: 3 days, chamber method condition: 0.5 g, 20 s).

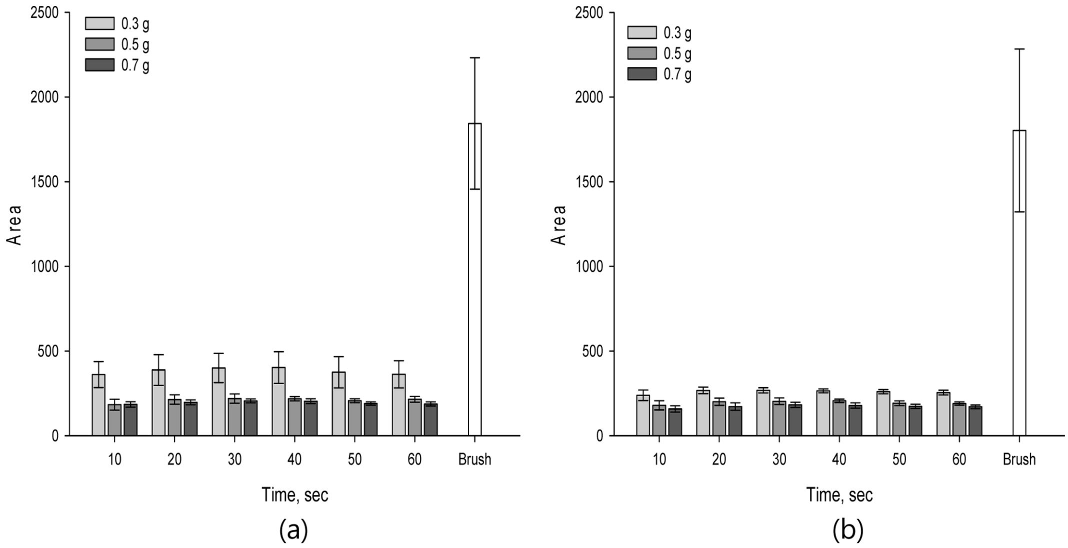


Fig. 7. The results of areas of the ridges of developed latent fingerprints using fluorescent powder on PET surface, (a) 3 days, (b) 14 days.

experiment was conducted to look for measures to address this problem.

3.3. Enhancing development capability of the chamber method when using fluorescent powder on PET surface

In the previous experiment on using fluorescent powder to develop latent fingerprints on PET surface by the chamber method, identification of ridges was impossible due to indiscriminate adhesion. To address this problem, an attempt was made to develop latent fingerprints using fluorescent powder mixed with silica gel. Silica gel is a non-stick, hygroscopic powder, which was expected to reduce adhesion between organic PET surface and fluorescent powder. Moreover, it has been reported that fingerprint development capability was enhanced by preparing powder using silica gel as the carrier and silica gel in mixed form or as a stand-alone powder, was relatively effective in developing latent fingerprints.[29] Accordingly, a powder mixture with fluorescent powder and silica gel was prepared by mixing varying silica gel content (10, 25, 50, and 75 %) over a set amount of time. Subsequently, densitometric image analysis was performed on images developed using 0.3 g of the prepared powder. The experiment was a pilot experiment for determining the usability of mixed powder containing fluorescent powder and silica gel. The experiment was repeated 3 times each on fingerprints left for 3 days and the mean area value and SD were derived as shown in *Fig.* 8.

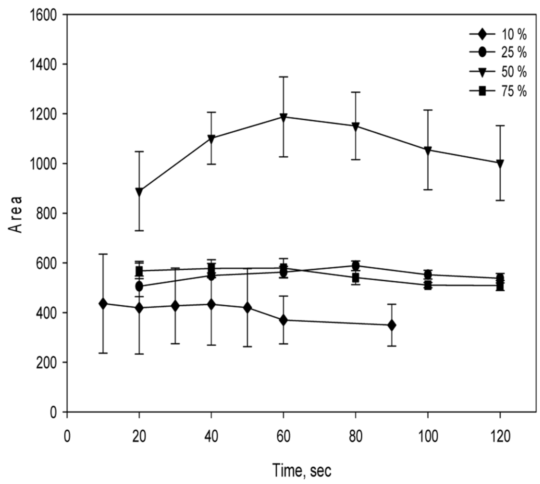


Fig. 8. The changes of the average areas of the fingerprint ridges developed by chamber method based on the amount of silica gel and developing time on PET surface.

As silica gel content increased, the area values also increased, but decreased again at 75 %. It also showed a tendency of increasing over time, but

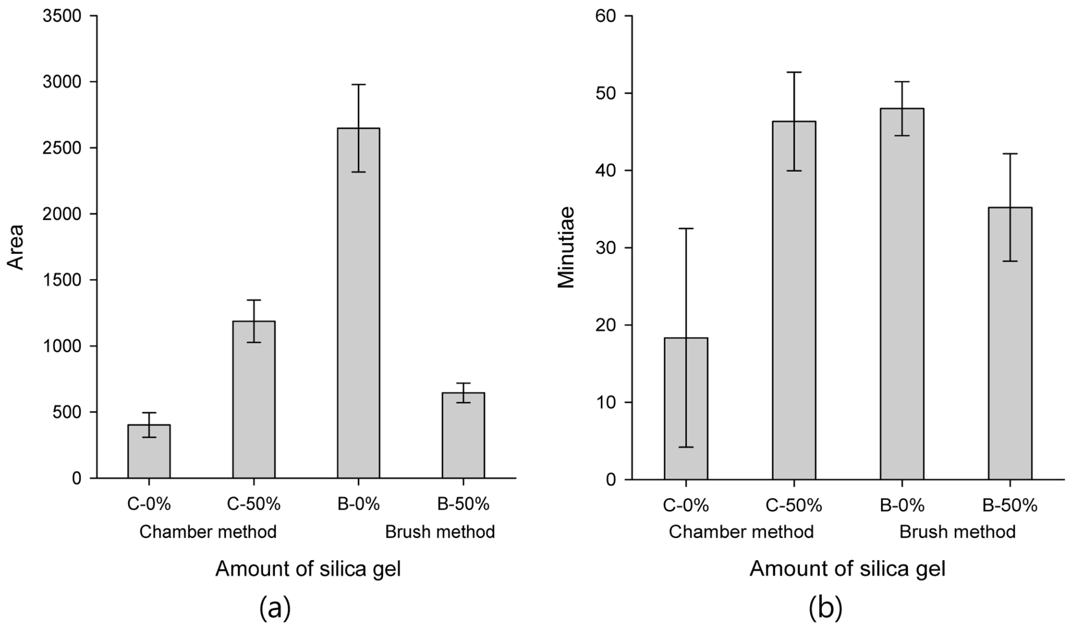


Fig. 9. The comparison of chamber method with brush method using a fluorescent powder-silica gel mixture on PET surface, (a) area, (b) minutiae.

decreasing after reaching a peak point. However, the differences were very weak at 10 %, 25 %, and 75 %, being similar within the range of error. When silica gel content was 50 %, the results showed relatively clear differences according to development time with the highest area value shown at 60 s.

Therefore, when using mixed powder containing fluorescent powder and silica gel to develop fingerprints, the optimal conditions were set as using 0.3 g mixed powder containing 50 % silica gel with development time of 60 s. The area value and number of minutiae of fingerprints developed under these conditions were compared against those of the brush method (*Fig.* 9).

When the value and number of minutiae of fingerprints developed by both chamber and brush methods using the existing condition of fluorescent powder 100 %, mixed powder (50 % fluorescent powder and 50 % silica gel), the results showed that the fingerprints developed by the brush method showed much high area value than those developed by the chamber method, which indicated that much clearer fingerprints could be obtained by using the brush method. However, the area value was

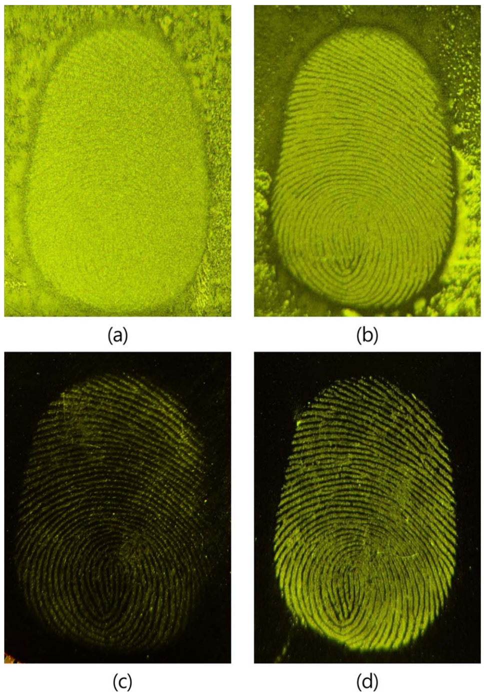


Fig. 10. The images of developed fingerprints on PET surfaces, (a) chamber method with fluorescent powder (100 %), (b) chamber method with a fluorescent powder-silica gel (50:50) mixture, (c) brush method with fluorescent powder-silica gel (50:50), (d) brush method with fluorescent powder (100 %).

approximately 3 times higher when fingerprints were developed by the chamber method using the mixed powder with 50 % silica gel, as compared to using 100 % fluorescent powder 100 %, and the difference was noticeable to the naked eyes (*Fig.* 10).

Moreover, in the analysis of minutiae in whole fingerprint by each experimental condition, the number of minutiae extracted with 100 % fluorescent powder, mixed powder with 50 % silica gel, and the brush method was approximately 18, 46, and 48, respectively. The results showed that the development capability could be enhanced by using mixed powder with 50 % silica gel, instead of fluorescent powder 100 %, to the point of showing similar number of minutiae as the brush method. Therefore, low development capability of the chamber method when using fluorescent powder on PET surface could be enhanced, and if future studies are conducted on reforming of powder and mixing with other powders, then such study may show results comparable to the brush method.

The experimental results discussed above are from a pilot study that used two types of surfaces and two types of powder traditionally used when attempting to develop latent fingerprints. Therefore, additional confirmatory experiments on the development capabilities of the chamber method for other surfaces and powders and other types of fingerprints in different conditions other than the fingerprints used in these experiments are needed for proof of methodological usability. During the experiments, damage due to wind speed or agglomeration of powder was not found, but since there is some concern about the influence of such factors, measures for uniformity of powder application and damage due to wind speed should be considered. Methods for removing excess powder when powder is applied excessively are needed, and as such measures, powder could be removed by generating wind inside an empty chamber using the same method or adding a new excipient to the powder to prevent not only powder agglomeration, but also powder sticking to the surface. When considering the material of the chamber, the risk of static electricity and spontaneous combustion due to fine powder particles is present. Therefore, static electricity being generated could be mitigated by changing the material of the chamber to an antistatic material or applying an antistatic coating, while enhanced development capability and safety could be assured by doing so. Moreover, because of the limited capacity of the chamber, there are difficulties in attempting to develop fingerprints under all situations where fingerprints may be present on different types of surfaces, and thus, additional studies are needed on the portability and flexibility of the chamber. However, since rough estimation of optimization of amount of powder used and development time according to the capacity of the chamber is possible, this could be considered as an objective fingerprint development method with low development error rate between individuals. Therefore, additional experiments on such aspects could increase the usability of this method.

4. Conclusions

To examine in advance the usability of the chamber method, which is a novel method of applying powder that can reduce the health risk faced by forensic investigators when developing latent fingerprints using the powder brush method of application, the present study tested the possibility of developing latent fingerprints by the chamber method and compared the development capability against the conventional brush method. Based on the findings, the following conclusions were derived.

During latent fingerprint development by the chamber method, powder application took place inside the chamber, which blocked direct contact between the powder and user. Fingerprint development was possible from the powder scattered by fans adhering to the ridges of latent fingerprints.

When the development capability of the chamber method was compared against the conventional brush method with respect to clarity and minutiae, the overall results were similar, regardless of the surface, when black powder was used. The chamber method showed relatively inferior development capability when fluorescent powder was used, but the number of minutiae of fingerprints left on glass surface was actually higher by approximately 13 % over time. It is believed that this is due to adsorption and desorption of powder adhering to the surface for not being easy when the chamber method is used, and thus, additional studies are needed on methods for removing excess powder.

When fluorescent powder was used, additional experiment was conducted on PET surface to enhance the development capability of the chamber method. When silica gel (50 % by content) was mixed with fluorescent powder, the results showed clarity that was approximately 3 times higher than using fluorescent powder alone (100 %), while also showing a similar number of minutiae as the brush method. Therefore, it is believed that the development capability could be enhanced even further through additional studies on reforming of fluorescent powder and mixing with additional powder excipients.

In summary, using the chamber method as a method for applying powder could block direct contact with powder that could be harmful to health, and when it was used while being cautious about the surface and powder conditions, the chamber method showed similar development capability as conventional method. Supplementary studies on the chamber method indicate that it is a novel method of powder application that accounts for the safety of forensic investigators.

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