An Innovated Fingerprinting Procedure for Human Identification

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An Innovated Fingerprinting Procedure for Human Identification

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Dedicated to

My Family, Kyung Ran and my parents, whose sacrifice and love has made it possible to complete this dissertation.

And to

My mentor, Jong-Bae Kim,

who was an invaluable source of strength and inspiration during the most difficult hours, who instilled in me a love for Biomedical Laboratory Science.

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And to

all the support, from colleagues, friends.

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ABBREVIATIONS

ANOVA : Analysis of variance

BC : Before Christ

iAFIS : Integrated automated fingerprint identification systems

ID-card : Identification card

MS : Mean of square

PCR : Polymerase chain reaction

PET : Polyethylene terephtalate

RSS : Residual sum of square

SD: Standard deviation

SPSS : Statistical package for the social sciences

TTVI : Thai tsunami victim identification

USA : United States of America

ABSTRACT

An Innovated Fingerprinting Procedure for Human Identification

Fingerprinting is a frontier technique that is the most frequently applied for human identification throughout the world. All citizen over 17 years old living in the Republic of Korea must be fingerprinted to obtain a certificate of resident registration. In Korea, for this reason, human identification through fingerprints has been far better developed and used efficiently both in crime scene investigation and in confirmation of an unidentified body. Scientific approaches have been made to accurately extract a metamorphosed fingerprints in various environments. Because most of the studies on fingerprinting have been accomplished with biometric techniques, researches on restoration of human dermal tissue and taking custody data after collecting fingerprints have been comparatively undermined. In this study, a newly innovated method for fingerprint extraction was developed using the high temperature-moisturizing method and polyester film with print powders. Compared to the conventional fingerprinting method of paper with ink, minutiae numbers of fingerprints were greatly increased in polyester film with print powders after restoration of fingertips by high temperature-moisturization. This newly developed procedure would be an efficient fingerprinting technique which could be utilized in scientific investigation and in personal identification in the future. Futhermore, the new method for restoration and extraction of fingerprints are easy and

inexpensive to practice for a number of human identification.

Key words : fingerprinting, minutiae, polyester film.

I. INTRODUCTION

Fingerprints have been more extensively used in many applications than any other traditional personal identification systems compared. In particular, the fingerprints that have conventionally served for easy identification in crime scenes are no longer effective even with the diverse use of equipments. Besides, the identification of criminals using partial fingerprints have become a great burden due to insufficient amount of information, even for police officers who have been specialized in interpreting the fingerprints with a long experience.

In recent years, genes have been used to confirm the identity of individuals by PCR (Kwon *et al.*, 2003). However, the genetic identification of individuals, also bears some problems regarding the differentiation of identification between monozygotic twins. Thus, the growing importance of fingerprints in every day investigation can be hardly overemphasized, especially when biometric recognition techniques augment the more traditional forensic applications. Thus comes the focus on the fingerprints, which is unquestionably the part of our every lives. With the pattern of the epidermal ridges on our fingers, palms and soles, it is characterized by almost parallel ridges that form distinguishable configuration (Hirsch *et al.,* 1973).

The crucial period of fingerprint development in humans starts by the 10th week of pregnancy. At that time the epidermis consists of three layers (the outside periderm, the intermediate layer and the basal layer at the interface to the dermis) located on top of the dermis which consists of amorphous tissue of fibroblast and fibers (Kucken *et al.*, 2004). Epidermal ridges first appear as localized cell proliferation in the basal layer of the epidermis around 10-11 weeks post-fertilization. This cell proliferation actually forms shallow

corrugations, termed primary ridges, that project into the superficial layer of the dermis (Okajima *et al.,* 1988).

The number of ridges continues to increase as new ridges are formed either adjacent to or between existing ridges. During the period of primary ridge formation, the characteristic ridge pattern is formed at the interface of epidermis and dermis (Babler *et al.*, 1978). Around 14 weeks, sweat glands begin to develop at uniform intervals along the apices of the primary ridges. Almost immediately after the initiation of sweat gland development, secondary ridges, lacking of sweat glands, begin to form between the existing primary ridges. Contingent with the secondary ridge formation, primary ridge formation ceases and epidermal ridges first appear on the volar surface (Mulvihill *et al.,* 1969).

The dermal papillae develop in the concavities between the epidermal ridges on the deep surface of the epidermis around 24 weeks. Until this time the morphology of primary and secondary ridges is a smooth ridge of tissue. As the depth of secondary ridges approximates that of the primary ridges, peg-like structures of the dermal papillae, a characteristic of the definitive dermal ridge, are progressively formed (Hale *et al.*, 1952).

Most of the fingerprint classifications currently used worldwide are variants of Henry's classification scheme (Davide *et al.*, 2002). The four most common classes are arch, loop, whorl and injured pattern as shown in Figure 1.

A fingerprint is comprised of ridges and valleys. The ridges are the dark area of the fingerprint and the valleys are the white area that exists between the ridges. Many classifications are given to patterns that can arise in the ridges as shown in Figure 2. In current fingerprint recognition technologies, these points are also known as the minutiae which are ridge endings and bifurcations because they can be easily detected by only looking at the points surrounding them.

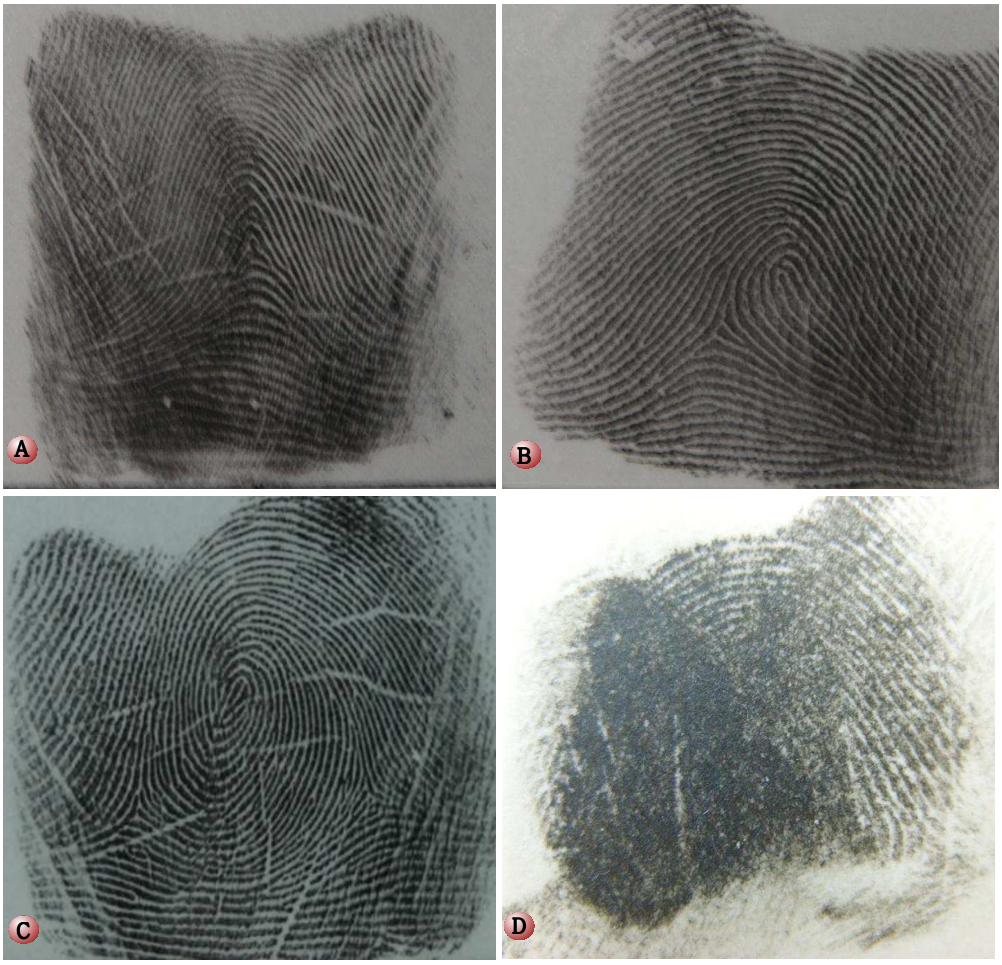

Figure 1. Typical fingerprint patterns.

A, a arch pattern; B, a loop pattern; C, a whorl pattern; D, an injured pattern.

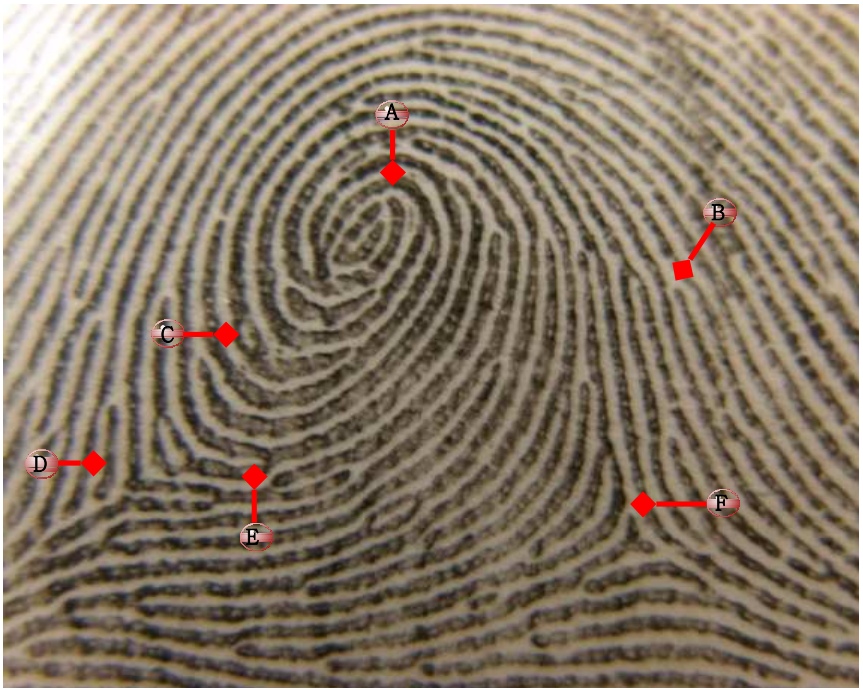

Figure 2. Examples of minutiae.

A, a core; B, a bifurcation; C, a island; D, an inclosure E, a ridge ending F, a delta.

The uniqueness of a fingerprint is determined by the characteristics and the relationships of local ridges, which are also called minutiae (Luo *et al.*, 2000). Minutiae of a fingerprint include ridge bifurcations, ridge endings, short ridges and enclosures. Among various minutiae, ridge bifurcations and ridge endings are commonly used in fingerprint recognition (Lin *et al.*, 1998; Ratha *et al.*, 1995). The extraction of the minutiae is derived from the thin image obtained from fingerprint preprocessing (Jain *et al.*, 1997).

Extraction of fingerprint features and matching their algorithm depends critically upon the quality of inputted fingerprint image. While the quality of a fingerprint image cannot be objectively measured, it roughly corresponds to the clarity of the ridge structure in the fingerprint image. Whereas a good quality of fingerprint image has high contrast and well-defined ridges and valleys, a poor quality fingerprint is marked by low contrast and ill-defined boundaries between the ridges (Sharat *et al.*, 2005). However, there are many fingerprint images that are noisy or lacking in quality by definition, caused by dust, oil, moisture, scars or excessively wet or dry fingers. As such, clear patterns of orientation patterns could not be always obtained (Yau *et al.*, 2004).

The history of fingerprint utilization as a means of identification has even outnumbered 2000 years. The identification skills have, along the way, been extensively studied and scientifically recorded by a number of anthropologists and biologists (Michael *et al.*, 2005). The history of fingerprinting usage can be archaeologically traced back as early as 7000 to 6000 B.C. by the ancient Assyrians and Chinese. Clay pottery from these periods sometimes contain fingerprint impressions placed to mark the potter. Some chinese documents bore clay seal marked by the thumbprint of the originator. Furthermore, bricks used in houses in the ancient city of Jericho were sometimes imprinted by pairs of thumb prints of the bricklayer. However, even though the fingerprint individuality has been indeed recognized, there is no detailed evidence

regarding that it was used on a universal basis in any of those societies (Berry *et al.*, 1994).

The country where the fingerprints were first used to identify the individuals was ancient Chinese Tang dynasty. Thereafter, a British anthropologist Francis Galton acquired the Chinese classification system based on which the fingerprints were divided into a circular form and a gyrate form. This has been established as the current classification system for fingerprints (G.P.P.A., 1996). In the mid-1800's a number of scientific studies have established two critical characteristics of fingerprints, that are agreed to be still true to these days: (1) no two fingerprints from different individuals have been found to have the same ridge pattern and (2) fingerprint ridge patterns remain unchanged throughout life. Those studies have led to the initial utilization of fingerprints for criminal identification, first in Argentina in 1896, then in Scotland in 1901, and in other countries in the early 1900's (Gorman *et al.*, 1998).

The first person to use fingerprinting for identification of individuals was British Sir William Herscel (Henry *et al.*, 2001). Working as a manager of colony affairs in the Bengal district of India from 1858, he required his Indian customers to seal their fingerprints on official documents for the purpose of preventing the forgery of certificates of Indian people (James *et al.*, 2003). Henry Faulds, a British doctor who served at Tsukiji Hospital in Tokyo, Japan, had a genuine interest in the fingerprints identified in the pottery art of ancient Japan and then published a research literature under his name (Faulds, 1880). In addition, a British Sir Edward Henry first developed a printing skill named as a Henry-type fingerprinting. Since July 1st of 1901, it has been established as the official classification method for fingerprinting in Britain and has ultimately become commercially available in other countries including U.S.A. Afterwards, another method called the Hamburg was developed by

Gustav Roscher, a prime minister of police agency in Hamburg, Germany, 1903. It has been used in Germany, Japan, and Korea.

In recent years, the fingerprinting identification has been effectively applied in massive casualties throughout the world. A tsunami, which occurred in South Western Asia on December 26, 2004, produced more than 300,000 casualties in the countries adjacent to the Indian Ocean. That incidence had encouragingly led to establish Thai Tsunami Victim Identification (TTVI) process, composed of more diverse nations than ever marked by human history. Korea had placed a remarkable major role in confirming the identification of casualties (Chung *et al*,. 2007).

Nowaday, fingerprints have been extracted on the spot from unidentified dead bodies. Accurate identification of unknown subjects using fingerprinting is an critical step to resolve the accidents afterwards. The fingerprinting has been most effectively applied to solve the cases of forgery, including theft and use of personal ID. In addition, the fingerprinting has been frequently used in a wider sense, more than for criminal investigation. It now plays a crucial role in demonstrating the public identification and concurrently in protecting the rights of people. The fingerprinting technologies developed for identification of criminals are now able to ensure the public security.

Classification of reference print collections was considerably straightforward, and have allowed identification of suspects previously fingerprinted. Moreover, from the 1970s the algorithmic research on fingerprints has brought to the field of efficient search algorithms that have been implemented in most nations, in the form of automated fingerprint identification systems (AFIS) (Nicole *et al.*, 2007). In the 1980s, innovations in the technology areas of personal computers and optical scanners have enabled the tools to capture fingerprints, yielding also practical utilization in non-criminal applications such as for ID-card programs. Thus, nowadays, the introduction of inexpensive fingerprint-

capturing devices and the development of fast, reliable matching algorithms have set the stage for the expansion of fingerprint matching widely to personal utilization (Sen Wang *et al.*, 2004).

The majority of the automatic systems for fingerprint comparison are based on minutiae matching. However, since structures of ridges in fingerprint images are not always well-defined, it is crucial to prepare an enhancement algorithm which can improve the clarity of ridge structures. Therefore, clarity enhancement is one of the most important steps in the automatic fingerprint identification system (Hong *et al.*, 1998).

In order to understand the process of fingerprinting, it is only logical to have a deep apprehension on the print formation process. Fingerprints are left behind due to various chemical substances secreted from the sweat glands. One of the major chemical constituents are fatty acids including palmitic acid, palmitoleic acid, oleic acid, stearic acid, tetradecanoic acid, lauric acid, pentadecanoic acid, linoleic acid, linolelaidic acid, arachidic acid, lignoceric acid, myristoleic acid, pentadecenoic acid, heneicosanoic acid and erucic acid. Another major constituent are amino acids including serine, glycine and threonine (Choi *et al.*, 2007). Various heavy metals are also important components of fingerprints.

The fingerprinting is one of the four primary identification criteria to identify a deceased individual. A number of techniques are available to recover fingerprints from cadavers (Teige *et al.*, 1982, Guo *et al.*, 1992, Kahana *et al.*, 2001, Knobe *et al.*, 2005). These techniques are originally derived from the procedures using powder dusting (James *et al.*, 1991), ninhydrin spraying (Oden *et al.*, 1954), and iodine fuming (Feldman *et al.*, 1982). That are the most commonly used techniques in the recovery of fingerprints unde ordinary circumstances. However, human fingers can be easily injured and contaminated. Under these conditions, the conventional methods of fingerprinting development

are often no longer effective.

Demands for appropriate and effective fingerprinting have led the researchers to spend their effort to develop innovative technologies. Zugibe *et al.* (1986) reported a new method of fingerprint restoration, which is a simple technique based on an entirely new concept utilizing disodium ethylenediamine tetraacetic acid in a detergent solution adjusted to a pH of 7.5 has been successfully used to obtain satisfactory to good fingerprint. Haglund *et al.* (1988) also proposed a new method that made injured tissue flexible based on two chemical compounds using metaflow and restorative liquid material. However, this method asked a longer time for skin regeneration from several hours to a few days. Ineichen *et al.* (1995) provided a very unique technique of fingertip restoration. They first made a silicone rubber cast of the fingertip and then the positive fingertip using artificial skin made of white glue and talcum powder. More recently, Davide *et al.* (2007) proposed a new method, based on using a latex film. Trapecar *et al.* (2007) also brought a new method which is based on using magnetic jet black, magnetic silver, silver special, swedish black and ruthenium tetroxied substances. Shin *et al.* (2008) suggested a new method of regenerating the fingerprints in corrupted and dried fingers which were on water using and elastic cord and gauze.

These studies have mainly focused on the regeneration of fingerprints by extension of skin tissues. There are numerous problems in the preexisting methods which are not easily acceptable by the Korean police. Because of their relatively long processing time, the Korean police still uses the conventional method of paper with ink to transfer fingerprints for human identification. But this method can not bring well-obtained, clear minutiae in various environments. When fingers are excessively stained with red stamp ink, the ridge lines are easily smudged on the fingerprint paper, which may yield unwanted fingerprinting method, adoptable by the Korean police.

In this research, a new innovative method is contrived using print powder and polyester film (thickness: 0.1mm) instead of preexisting method of ink and paper. In order to suppress capillary waves and ink jammed, fingerprint powder is used. Fingerprint powder is composed of many different ingredients which can vary greatly depending on the formula used. The powder adheres to the humid, sticky, or greasy substance and is relatively simple and inexpensive not to mention the minimum experience required in order to obtain satisfactory results. Polyester film is composed of polyester group of PET (polyethylene terephtalate) constituents, and it absorbs well the water content, mineral oil, and glycerol (Dhouha *et al.*, 2002). Owing to this, the substance secreted from human body is well transcribed on the film. Polyester film which is currently commercially available has noticeably served for the detailed absorption of various mineral on the surface. Therefore, it is unquestionable for its more advantageous in developing the fingerprint.

The palms and soles are much more comprised to dead keratin cell than other region in body. The dead keratin cell is very dry so that it can be easily reconditioned in water condition. Moreover, the dead keratin cell has more and more water activity on tissue in accordance with high temperature, so it puts ahead a swelling rapidly (Jocobi *et al.*, 1958).

In this study, new method of fingertip regeneration was also developed and named a high temperature-moisturizing method. This technique used hot water to elicit greater thermodynamics and osmotic responses. The hot water gave rapid and effective rehydration of the dried skins, raising friction ridge details and eliminating body fluids associated with decomposition. The restored fingertips were brought to fingerprinting on polyester film with print powders. These two innovative procedures for fingertip regeneration and fingerprinting provided clearer fingerprints even from submerged, putrefactive or mummified dead bodies

Ⅱ. MATERIALS AND METHODS

1. Study Population

The study population consisted of 350 subjects (236 men and 114 women; a range of age, 24-71 years; mean age, 43 years) who were young, elderly, laborer, putrefactive, submerged or mummified dead bodies in nation-wide Korea Provincial Police Agencies from May 2007 to July 2008. Fingerprints were extracted from volunteers and cadavers before autopsy.

2. The General Method of Fingerprint Extraction

Prior to extraction of fingerprints, fingertips of volunteers were cleanly rinsed with soap water. Fingertips of cadavers were cleaned with a toothbrush or a gauze which was immersed in alcohol to remove the foreign substances coated on the ridge line. When a cotton immersed in alcohol was used, the remnants of cotton micro-particles which might alter the ridge lines was cautioned.

The general method of fingerprint extraction on polyester film (thickness: 0.1mm, polyester fingerprint kit, Altlight Inc., Seoul, Korea) with print powders (Sirchie Finger Print Laboratories, Inc., Medford, NJ, U.S.A.) is shown in Figure 4. The dry black print powders and a dusting brush should be prepared (Figure 4A). The black powders were applied to the brush and then evenly smeared to the direction as which the ridge line was progressed. The powders were lightly brushed down not to smear excessively (Figure 4B). Constituents of the powders included ninhydrin, magnetic particles, and sticky chemicals. A lifter (attachment tapes) was lightly attached to the center of a fingertip and

then firmly attached from the left to the right area at a rotation of 180° (Figure 4D).

Prior to the attachment of a lifter to the anterior surface of polyester film, the presumptive name, age, and sex, the cause of investigation, and the name of extractor (a responsible person) had to be specified using a marker (Figure 4E).

A great care had to be taken not to alter the order of fingerprints recorded on the detached lifting tapes. The lifting tapes were then attached to the posterior surface of polyester film for identification of individuals (Figure 4F). The anterior surface of polyester film should be confirmed for proper extraction of fingerprints (Figure 4G).

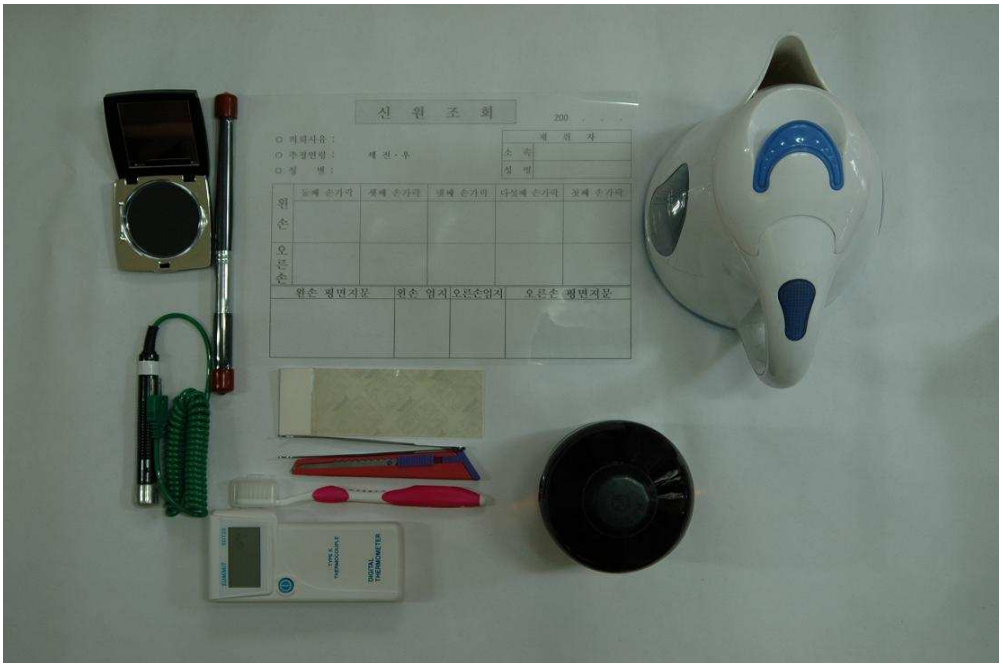

Figure 3. Equipments for fingerprint extraction. Materials used in fingerprint extraction include a black print powders, a toothbrush, alcohol, an electric kettle, an attachment tape, and a customized polyester film of police certificate.

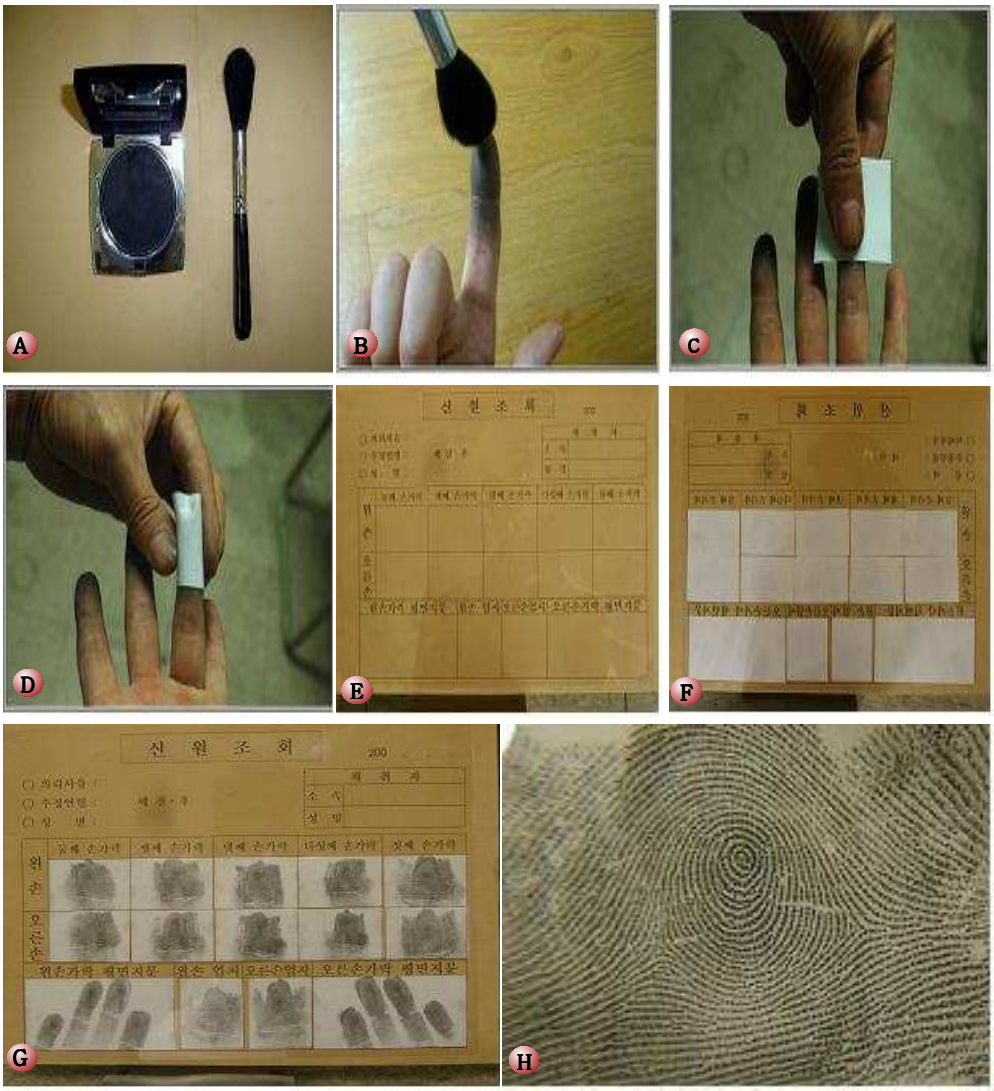

Figure 4. A procedure to obtain fingerprints on polyester film with print powders. A, powders and a brush for fingerprinting; B, powder spreading to fingertips; C-D, extraction of fingerprints rotating lifters throughly; E, polyester film for fingerprints; F-G, attachment of lifters to polyester film; H, a fingerprint image on polyester film.

3. Restoration and Extraction of Fingerprints

The procedure of fingerprint extraction on polyester film with print powders after restoration of fingertips of submerged, putrefactive or mummified dead body using the high temperature-moisturizing method is shown in Figure 5. Foreign substances were removed using a toothbrush, forcep and a gauze. Ensured that this process did not further damage the skin, keeping it intact as much as possible. When a sore oozes, it should be washed with alcohol, and then dried up by a piece of cloth (Figure 5B). The epidermal layer might be separated or soaked in water on occasion. Decayed hands without the epidermal layer often showed no visible friction ridges in detail. In these cases, fingerprint extraction should be done after restoration of fingertips using the high temperature-moisturizing method.

In submerged dead bodies, impurities should be removed away in order to display the ridges well (Figure 5B). After pictures of the fingertips were taken, those were restored using the high temperature-moisturizing method. The fingers were placed into the hot water at 30~100℃ for 3 to 10 seconds (Figure 4D). This process was not repeated more than 3 times. If the friction ridge on the fingers contains abrasion or cuts, instead of placing the fingers into hot water, a sponge soaked in hot water was used over the friction ridge. In case of mummified dead bodies, hot water was injected into the dried fingertips (Figure 5E). The friction ridges were dried using a blow dryer or by pouring alcohol on the fingers and blotting with towels.

Fingerprinting was then performed as described earlier (Figure 4F-4H). The fingerprints recorded on polyester film were sealed in a hygienic transparent plastic bag for safe delivery. The fingerprints were sent to the iAFIS searching system (National Police Agency, Seoul, Korea) using a scanner (OMAX Inc., Bucheon, Korea). The identified information and the name of fingerprint extractor should be written on polyester film, and then the data should be stored in an appropriate folder of unnatural death.

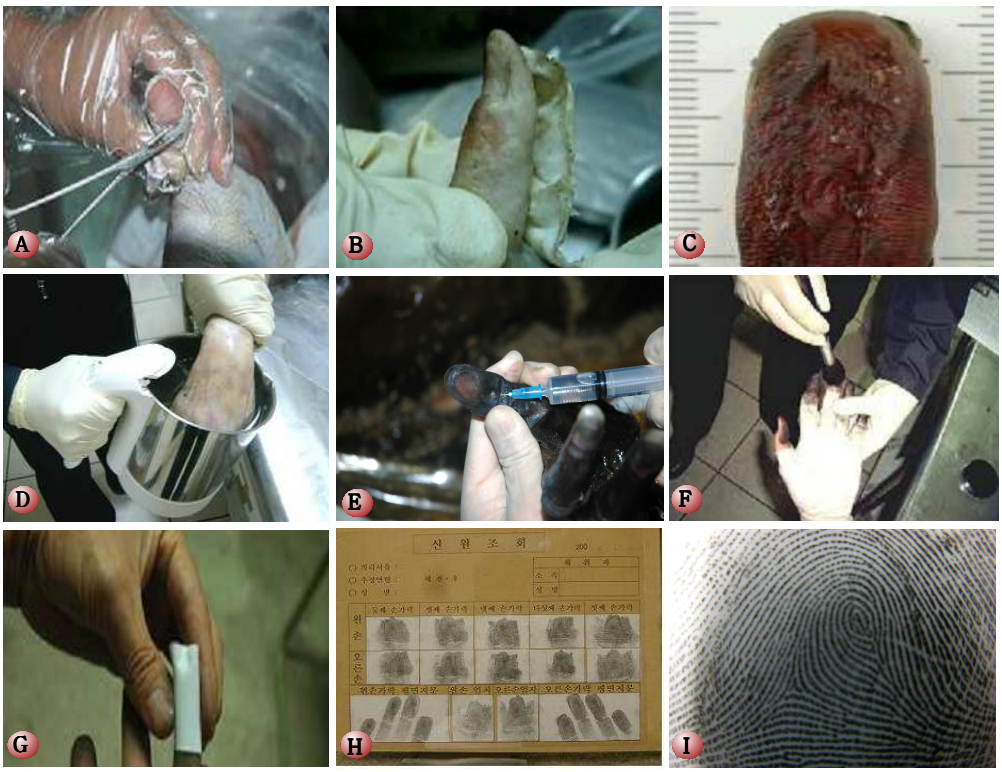

Figure 5. A procedure to obtain fingerprints from a dead body on the polyester film with print powders after fingertip restoration by high temperature-moisturization. A, B, C, removal of foreign substances in submerged, putrefactive or mummified dead bodies; D, E, restoration of fingertips in hot water or by injection of hot water; F, fingerprint powder spreading; G, lifting of fingerprints; H, lifter attachment to polyester film; I, a fingerprint image.

4. Statistical Methods

S.P.S.S. version 15.0 (S.P.S.S. Inc., Chicago, IL, U.S.A.) was used for database management and statistical analysis. All experimental data were compared by calculation of means, variance, F-ratio and p-value based on the ANOVA (analysis of variance).

Ⅲ. RESULTS

1. General Fingerprints on Paper and Polyester Film

Sometimes conventional fingerprinting with stamp ink appears unreadable ridge lines by excessive stamp ink. Fingerprinting on newly-developed polyester film was compared with conventional fingerprints with stamp ink on paper(Figure 6).

Fingerprinting on polyester film with print powders exhibited more clear fingerprints (B, D) than conventional fingerprinting on paper which smeared ridge by excessive ink remnants. In A and C major minutiae which were bifurcation, ending point and delta could not be seen by unbalanced ink spreading. On the other in B and D major minutiae could be seen by polyester film with print powers method.

Figure 6. The comparison of fingerprints obtained on paper with ink (A, C) and on polyester film with print powders (B, D).

2. Fingerprints of Elderly and Laborer on Paper and Polyester Film

When fingerprint extraction with conventional method of paper with ink was carried out from disabled men, laborer or charity patients, there might be some difficulties of fingerprint extraction with smeared and partial fingerprints. A newly-developed fingerprint extraction on polyester film with print powders was proved effective especially in extracting fingerprints from those people having eroded and damaged fingerprints.

In comparison of the two methods (Figure 7), polyester film with print powders produced better results (B, D) which have many minutiae with more clearer ridge line on fingerprints than preexisting paper with ink method (A, C) with few minutiae due to excessive and unbalanced ink application.

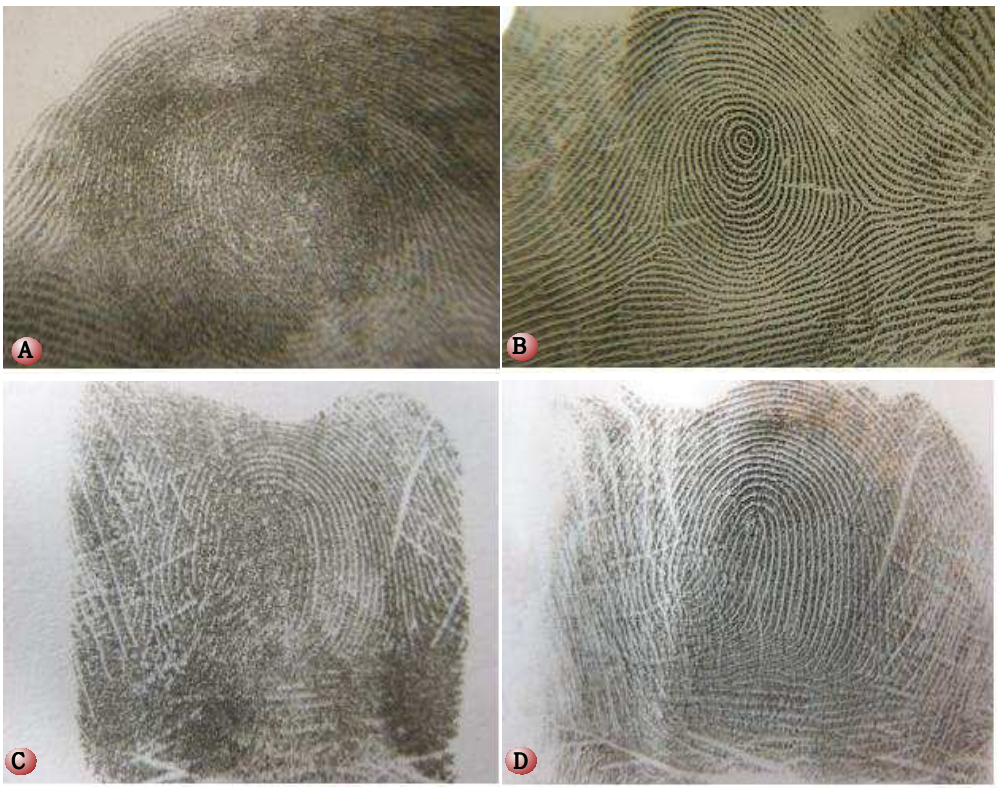

Figure 7. The comparison of elderly and laborer fingerprints on paper with ink (A, C) and on polyester film with powders (B, D).

3. The Number of Minutiae Using Paper with Ink and Polyester Film with Print Powders

Most classical fingerprint recognition algorithms take the minutiae including their coordinates and direction as distinctive features to represent the fingerprint in the matching process. Minutiae extraction mainly includes orientation field estimation, ridge extraction or enhancement, ridge thinning and minutiae extraction.

Minutiae number of fingerprints is important for the identification of individuals. To estimate changes of the number of minutiae, fingerprints extracted from 10 fingers were compared between conventional method on paper with ink and on polyester film with print powders.

For the proper evaluation of data, statistical analysis were performed using S.P.S.S. program. All of the minutiae numbers of fingerprints on polyester film with print powders was increased highly significantly ($p < 0.01$) compared with those of paper with ink in general people (Table 1, Figure 8). These data imply the great enhancement in extracting fingerprints on polyester film with print powders.

And the minutiae numbers of thumb finger and middle finger among ten fingers were remarkably higher than that of other fingers in both paper with ink method and also in polyester film with print powders method.

Table 1. The Number of Minutiae in Fingerprints on Paper with Ink and Polyester Film with Print Powders in General People

Method (Sub.)	Finger (Mean ± S.D.)									
	Index (L)	Middle (L)	Ring (L)	Little (L)	Thumb (L)	Index (R)	Middle (R)	Ring (R)	Little (R)	Thumb (R)
Paper (230)	38.1±14.9	44.8±16.7	29.3±11.5	27.7±12.1	70.7±19.7	40.3±14.0	44.7±14.3	31.7±13.3	26.9±11.6	72.7±19.1
Polyester (230)	85.0±10.0	89.5±10.3	60.2±16.9	50.4±15.5	95.0±8.6	84.3±10.7	89.9±11.0	65.9±17.0	50.2±17.3	95.8±7.9

Abbreviation. Sub, Subject; S.D., Standard Deviation; L, Left; R, Right.

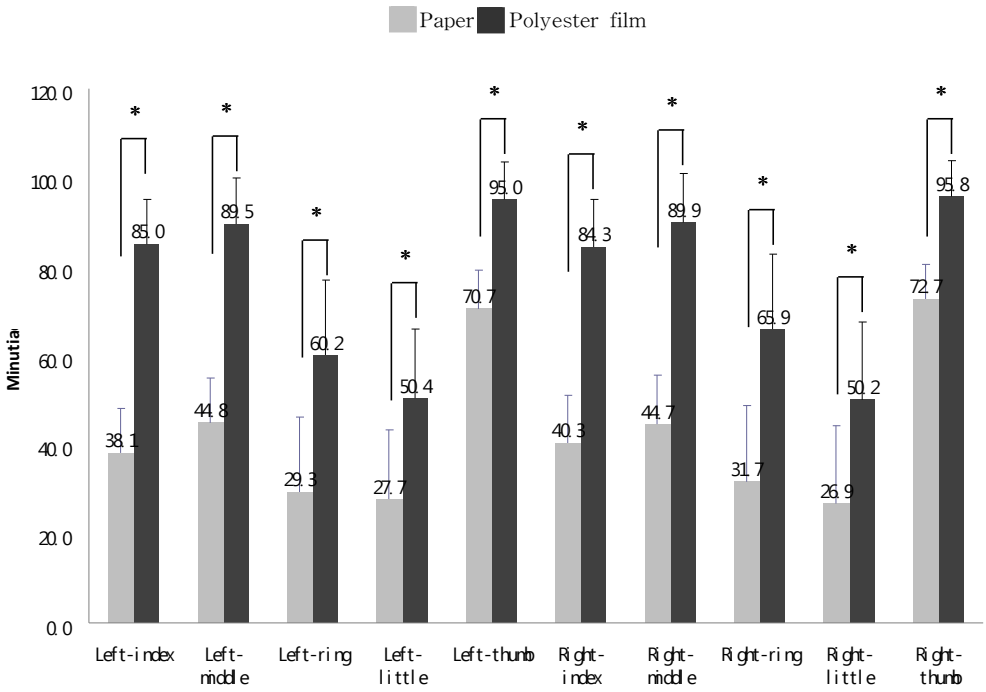

Figure 8. Minutiae comparison between in fingerprints on paper with ink and polyester film with print powders in general people.

The results are expressed as the means ± S.D. *, p <0.01.

4. Effects of Heating Time and Water Temperature on Fingerprint Restoration of Cadavers

Restoration of fingerprints may be difficult or impossible in cases of severly putrefactive, submerged or mummified dead bodies. A newly developed high temperature-moisturizing method was designed to restore the friction ridge on the skin of fingers with rehydration.

The degree of restoration of finger tissues of cadavers was evaluated according to the treatment time and temperature. Excellent degree of restoration was obtained around 90℃ for 3 to 5 seconds, while the poor restoration was observed in the treatment below 90℃ and beyond 95℃ (Table 2).

Table 2. Effects of Heating Time and Water Temperature on Fingerprint Restoration of Cadavers

Time (sec)† / Temp. (℃)‡	3 seconds	5 seconds	More than 10 seconds
100℃	Harm the skin	Harm the skin	Harm the skin
90℃	Excellent§	Excellent	Harm the Skin
60℃	Unsatisfactory*	Unsatisfactory	Unsatisfactory
30℃	Not usable	Not usable	Not usable

† Incubation time in water; ‡ water temperature; §identifiable friction ridge impression; * unsatisfactory friction ridge impression.

5. Comparison of Fingerprints Extracted on Paper and Polyester Film after Fingertip Restoration

The fingerprints cannot be extracted well using the conventional type of an ink for fingerprinting. After the restoration of fingertips through high temperature-moisturizing method, fingerprints extraction were compared between on paper with ink and on polyester film with print powders. The restoration of finger tissue was performed in submerged, putrefactive or mummified dead bodies.

In comparison of the two methods, polyester film with print powders produced better results (B, D, F) with more clearer ridge line on fingerprints than paper with ink (A, C, E) (Figure 9). In A, C and E, a few minutiae were seen but chief delta region for human identification was not confirmed. But all delta region in B, D and F were confirmed. This made the extraction of fingerprints possible even in cadavers whose dermal tissue only was left because they were submerged, putrefactive or mummified dead bodies.

These results might indicate the applicability of restoration of fingerprints with high temperature-moisturizing even in severely damaged cadavers.

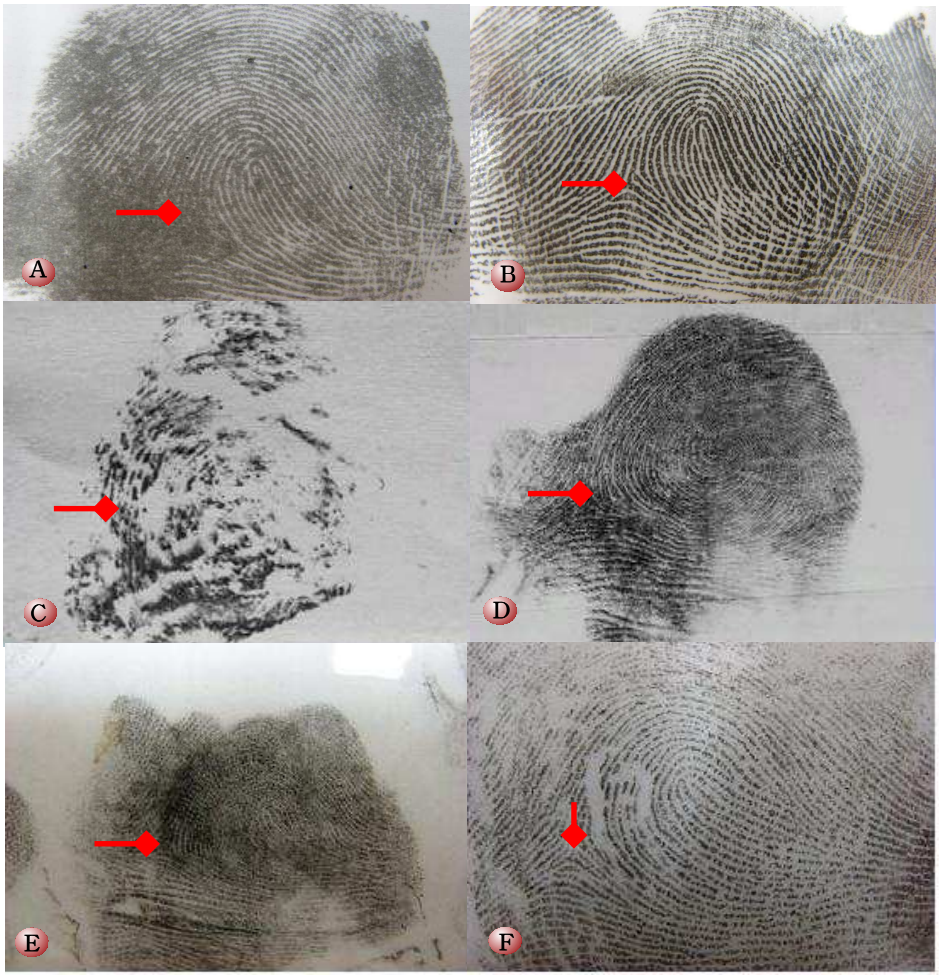

Figure 9. Comparisons of fingerprints of submerged, putrefactive or mummified dead bodies on paper with ink and polyester film with print powders. Fingerprints submerged (A, B), putrefactive (C, D) and mummified (E, F) dead bodies were extracted on paper with ink (A, C, E) and polyester film with print powders (B, D, F) after tissue restoration by high temperature-moisturization. Delta minutiae were not seen in the picture A, C, E while they were clearly seen the picture B, D, F. Arrows indicate the delta region.

6. The Number of Recognizable Minutiae in Fingerprints on Polyester Film after Restoration at Varied Temperatures

After the restoration at different temperature-moisturizing of finger tissue of cadavers recovered several months after death, changes of fingerprint minutiae were compared. From 90 to 95℃, successful restoration of finger tissue were obtained. The optimal temperature for restoration of fingertips was revealed at 95℃ with more minutiae numbers than any other temperatures.

The restoration at 95℃ reproduced the discernable friction ridges impression that were easily seen. Obtained minutiae were processed by iAFIS for the purpose of making an identification of the individual.

Table 3. The Number of Recognizable Minutiae in Fingerprints Restored at Varied Temperatures

Finger	Temperature		
	91℃	93℃	95℃
Index (L)	30.6 ± 23.6	35.6 ± 21.5	45.5 ± 17.9
Middle (L)	40.8 ± 26.1	44.4 ± 21.2	53.2 ± 18.3
Ring (L)	25.6 ± 11.6	37.1 ± 16.3	33.8 ± 12.6
Little (L)	25.9 ± 15.4	33.0 ± 16.9	32.7 ± 17.2
Thumb (L)	73.5 ± 18.9	68.0 ± 22.2	82.3 ± 20.4
Index (R)	29.2 ± 19.2	32.0 ± 14.4	41.1 ± 14.8
Middle (R)	40.6 ± 23.5	56.3 ± 24.2	56.8 ± 27.2
Ring (R)	23.3 ± 20.6	31.7 ± 15.8	37.9 ± 20.6
Little (R)	23.6 ± 12.5	29.0 ± 16.4	36.8 ± 18.2
Thumb (R)	79.3 ± 15.2	79.9 ± 18.5	85.7 ± 10.9

Abbreviation. L, Left; R, Right.

7. Comparisons of Restored Fingerprint Minutiae from Varied States of Dead Bodies on Polyester Film

When extracting fingerprints from corpses in a bad state of preservation especially in submerged, putrefactive, or mummified dead bodies, many problems may be encountered.

Minutiae numbers of different state of dead bodies were compared after restoration of fingertips at 95℃ for 3~5 seconds. Minutiae were obtained from 10 fingers on polyester film with print powders and further processed with iAFIS. There were no statistical differences in minutiae numbers between in the kinds of dead bodies of mummified, submerged or putrefactive cadavers.

Table 4. Comparisons of Restored Fingerprint Minutiae from Varied States of Dead Bodies on Polyester Film

Finger	State of Dead Bodies (Mean ± S.D.)		
	Mummified	Submerged	Putrefactive
Index (L)	48.0 ± N.A.	38.6 ± 20.1	31.6 ± 16.6
Middle (L)	63.0 ± 7.1	48.4 ± 23.1	50.7 ± 24.8
Ring (L)	40.0 ± N.A.	32.9 ± 16.1	28.2 ± 12.6
Little (L)	34.0 ± 5.7	28.8 ± 14.0	31.1 ± 16.3
Thumb (L)	73.0 ± 33.9	75.1 ± 21.1	76.9 ± 23.5
Index (R)	23.0 ± 7.1	36.7 ± 16.7	37.0 ± 16.6
Middle (R)	47.5 ± 9.2	52.1 ± 24.1	53.5 ± 21.4
Ring (R)	19.5 ± 7.8	31.2 ± 16.3	28.4 ± 14.3
Little (R)	23.0 ± 4.2	29.1 ± 15.2	27.6 ± 14.8
Thumb (R)	77.0 ± 25.5	78.3 ± 18.4	84.7 ± 18.3

Abbreviation. L, left; R, right; N.A.; not applicable; S.D., standard deviation.

Ⅳ. DISCUSSION

Fingerprints, impressions of the friction ridges of all or any part of a human finger, have often been and still are considered as one of the most widely used biometric methods.

The identification of individual based on the fingerprinting deals with a lot of diverse matters associated with missing parts of the accidents as well as affairs associated with the crime. It should be noted that fingerprinting is one of the four primary identification criteria that can be used in isolation to identify a deceased individual. Fingerprinting is one of the four primary identification criteria that can be used in isolation to identify a deceased individual. It is also related to many procedures performed even in the most unexpected places, such as for the bodies in social institutions, elderly dead bodies, putrefactive dead bodies, submerged dead bodies and mummified dead bodies. All those whose ridge line is unclear, having ridges of fingertip eroded or damaged or reveal the difficulty of fingerprint extraction (Davide *et al.*, 2007).

In extraction field and algorithms for estimation fingerprints, ink method with paper based approaches are relatively inaccurate and provides computationally low data. In this paper, a model-based method for the fingerprints of extraction field is proposed. When the coarse field is computed by using polyester film with print powders-based algorithm, the error from the noise can be eliminated using the model for a reconstruction and chemical character method.

The conventional type of fingerprint ink is considerably insufficient for clear extraction across a variety of situations. This often bears numerous problems.

Furthermore, the excessive contamination of red stamp ink or that of fingerprint ink also make the identification of individuals difficult. This phenomenon could be understood as the same as the smudged appearance when the fingerprint is sealed using a red stamp ink on the certificate.

Experimental results show that the high-temperature moisturized method and polyester film with print powders method have a better performance on robustness, accuracy and computational data for extraction field estimation fingerprints than the previous works. The application in a fingerprint recognition system also shows that an evident improvement can be obtained by using polyester film with print powders method in transcription and the high temperature-moisturized method in fingertip reconstruction.

In order to accurately identify the characteristics of fingerprinting paper and fingerprinting results, the quality of fingerprinting images must be improved. Considering the direction of fingerprint, the thickness of ridge line and the depth of groove, in extracting the first fingerprint, such factors as the accurate location of hands, the ingenuous technique of extractor and the method of regeneration are utmost vital.

In this study, two innovated methods for individual identification with fingerprints were developed. First, high temperature-moisturizing method which was designed to restore fingertip from which fingerprints could not be obtained by the conventional method using paper with ink. Second, polyester film with print powders which extracted a ridge of fingerprints much easily, compared to the existing method was applied to fingerprinting.

With these methods, the excellent outcomes were produced even in putrefactive dead bodies, submerged dead bodies or mummified dead bodies, which could not be easily handled until now. Polyester film with print powders method can be used in both a sanitized and an efficient manner in the process of interpretation as well as the accuracy of the process of fingerprint

extraction in various environments.

The convenient features of these model for implementation of a fast identity verification system based on the fingerprinting have also been focused. Data about a comparison between paper with ink method (A, C) and the newly-developed polyester film with print powders method (B, D) demonstrated that the fingerprints extracted using polyester film with print powders method (B, D) had more clearer ridge line and more minutiae than paper with ink method (A, D) as shown in Figure 6 and 7.

The fingerprints extracted using polyester film with print powders method(B, D, F) had more clearer ridge line with delta and more minutiae numbers than paper with ink method as shown in Figure 9.

All of the minutiae numbers of fingerprints on polyester film with print powders was increased highly significantly (p <0.01) compared with those of paper with ink in general people (Table 1, Figure 8).

The minutiae numbers of fingerprints were not statistically different among different sex and age groups between paper with ink and polyester film with print powders method.

The temperature and time effects on fingerprint quality are shown in Table 3. Excellent fingerprints were obtained in 95℃, 3 to 5 seconds compared to those below 90℃ and beyond 95℃. The prolonged exposure to intense heat would harm the skin. The hot water would restore the friction ridge skin and remove any contaminants still present. After the skin is exposed to hot water, it would be inflated to have friction ridges clearly visible on the fingers. This observation indicates that the friction ridge skin had been sufficiently restored.

To show a transcription of fingerprints using paper with ink and polyester film with print powders, fingerprinting performed after restoration as shown in Figure 9. In the recording of fingerprints from submerged, putrefactive or mummified dead bodies, there were no visible ridge detail on the finger with

paper and ink, while there were visibly more clearer ridgeline at all the figures of cadavers with polyester film with print powders.

Not only minutiae comparison through polyester film with print powders method for sex and age but also the state of dead bodies had no significant difference in cadavers.

In human identification, minutiae number needs at least for 15 in iAFIS. Fingerprint minutiae obtained through polyester film with print powders method after restoration of finger tissue by the high temperature-moisturizing method present 32 to 82 numbers.

The conventional type of ink-based transcription of fingerprints on the paper has caused the unnecessarily complex methods and the much less clear development of fingerprinting in various physical environments, where the ridge line is unclear, including charity patients, laborer, elderly people and patients with disability whose fingerprint were much eroded. The newly developed method of polyester film with print powders is proven to resolve the various problems of the conventional type of fingerprinting method, and it is undoubtedly effective in obtaining the development of clearer fingerprint.

Thus, it can be logically confirmed that the ridge line became more clearer and more characteristic as compared to the conventional type of paper with ink method.

Ⅴ. CONCLUSION

Preexisting fingerprint method uses paper with ink to transfer fingerprints. But many minutiae of fingerprints were usually spoiled with spots due to the diffusion of ink. In this study, polyester film with print powders method was developed and used in extracting fingerprints to get rid of such diffused condition. With this new method fingerprints that had more minutiae with much clearer image could be obtained. Moreover, the high temperature-moisturizing technique was used to restore fingertips of dead bodies founded in various environments. With the combination of high temperature moisturizing for restoration of fingertips and polyester film with print powders extraction method, the accuracy for fingerprint extraction was guaranteed. This innovated new method can also be used for the process of interpretation in both a sanitized and an efficient manner, considering the fact that fingerprinting is commonly destitute of the safety measure. The fingerprints extracted polyester film was covered with a transparent plastic bag and then transferred. Thus, the problem previously mentioned was resolved. The minutiae numbers of thumb finger and middle finger among ten fingers were remarkably higher than that of other fingers in both paper with ink method and also in polyester film with print powders method. The satisfactory minutiae numbers were much higher using polyester film with print powders method than paper with ink method for fingerprinting. The high temperature-moisturizing method was suitable for restoration of finger tissue of dead bodies found in various environments. There was a remarkable interrelation in restoration, transcription for fingerprints, and satisfactory numbers of fingerprint minutiae. In conclusion, the combination of polyester film with print powders method and the high temperature-moisturizing method

can be successfully applied to all human identification as an alternative and reliable fingerprinting method in terms of economic cost and convenience. Therefore, these findings suggest that the high temperature-moisturizing method and polyester film with print powders method may be useful for accurate fingerprinting in human identification.

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국문요약

신원확인을 위한 새로운 지문 현출방법

지문은 전 세계적으로 공용화된 신원확인 방법의 선두적인 기술이다. 대한민국에서는 17세 이상의 국민은 누구라도 주민등록증을 발급하기 위하여 지문을 채취한다. 이러한 제도로 인하여 우리나라는 지문감식분야가 오래전부터 월등하게 발달하게 되었으며, 모든 지문 자료를 통합적으로 관리함으로써 범죄현장 뿐만이 아니라 신원불상자의 확인 과정에 매우 효과적으로 이용되고 있다. 다양한 환경에서 변형이 발생되는 지문의 정확한 채취는 과학적 방법들로 행하여지고 있다. 이들 연구 대부분이 생체인식 기술과 관련된 측면에서 진행되고 있어, 조직의 복원과 지문 채취, 자료의 보관 및 자료의 전달과 같은 관련된 연구가 부족한 실정이다. 본 연구에서는 고온습열법과 폴리에스터 필름 분말법을 사용하여 획기적인 지문 현출법을 개발하였다. 종이와 잉크를 이용한 기존의 방법과 비교를 통해 고온습열법을 통한 지문복원 후 폴리에스터 필름 분말법을 사용한 경우에서 보다 많은 지문 특징점들을 얻을 수 있었다 새롭게 개발된 이들 방법이 차후 과학수사와 개인 신원확인에 있어 보다 편리하고 경제적이며 효율적인 지문현출방법으로 이용할 수 있을 것으로 생각한다.

Key words : 지문, 특징점, 폴리에스터 필름.