J Forensic Sci, March 2006, Vol. 51, No. 2
doi:10.1111/j.1556-4029.2006.00076.x
Available online at: www.blackwell-synergy.com

Technical Note

Mie E. Kristensen, med. stud.[1]*; Niels Lynnerup, M.D., Ph.D.*[1]*; and Birgitte Sejrsen, D.D.S, Ph.D.*[1]

Comparison of Handmarks in Manual Strangulation: An Experimental Study

ABSTRACT: A police case with a strangulated woman with fingermarks on the neck and two suspects identifying each other as the perpetrator set off a laboratory experiment. Twenty-one males participated in the study. Blue paint was applied to their fingers, after which they grasped a neck dummy and pressed hard as if strangulating someone. The imprint was removed from the dummy, and their hands were photographed. Five imprints were randomly chosen and superimposed on the hand photographs in blind trials. In no cases did we match an imprint to the correct hand. However, in four cases we matched the imprint with several hands, one of which was the correct one. This means we were able to exclude nonmatches in 4/5 cases. Overall, matching of hands and fingermarks is difficult and inconclusive. Objective criteria for matching are difficult to establish, and matching is probably best suited for cases with specific anatomical features.

KEYWORDS: forensic science, forensic anthropology, strangulation, identification

In November 2004, a woman was manually strangled. Both at the initial crime scene investigation, as well as at the external examination at autopsy, bruises distinctively shaped as four fingers were found on the left side of her neck. Two suspects were apprehended, but both identified the other as the perpetrator. The police asked us whether it would be possible to perform comparative analyses of the bruises and the hands of the two suspects in order to identify the correct perpetrator. An initial morphological appraisal was made, but the comparative analysis was inconclusive. Also, there was no experience with such matters at the institute. Likewise, a search in the literature provided no information. Even though the above case thus ended inconclusively (in this respect), it did make us start a series of experiments.

We wanted to determine whether we could pair the correct hand with the correct imprint, and exclude a number of the nonfitting hands using an overlay technique on digital images of the hands and imprints. Adopting the techniques from forensic odontology, we carried out an experiment in a controlled set-up (1–8).

Materials and Methods

A neck dummy was constructed from a cylindrical measuring beaker with a diameter of 10 cm, covered with a 1 cm thick layer of foam rubber and a 2 mm thick layer of a latexlike material (Mosgummi®, Panduro Hobby, Copenhagen, Denmark). Based on preliminary studies, as well as similar contraptions made for experimental bitemark analyses (B. Sejrsen, personal communication), we found that the dummy had approximately the same compliance and consistency as a human neck. Furthermore, the artificial "skin layer" has a certain elasticity similar to human skin. When fingers are pressed into the latexlike material, an imprint will remain for some time in the material, and nail marks are clearly demarcated. To further enhance, and to preserve, the imprint of the fingers, blue paint was applied with a sponge to the fingers of the volunteers (just enough to leave an imprint without smearing). A separate piece of the latexlike material was used for each volunteer (Fig. 1).

Twenty-one males participated in the experiment. After applying paint to their fingers, they were asked first to clasp the dummy with a natural grasp with their right hand and then press hard for 5 sec. A second imprint was then made, and this time they were asked to press the fingertips and nails of the second, third, fourth, and fifth finger of the right hand with a 90° flexion in the proximal finger joints into the dummy for 5 sec. The volunteer's right hands were then photographed with an Olympus digital camera (C-900 Zoom, Olympus Optical Co., Ltd., Tokyo, Japan), in four different positions. Position one had the hand lying flat on the background, palm upwards, and the fingers stretched, position four showed a 90° flexion in the proximal finger joints, and positions two and three showed intermediate flexion of the fingers. The imprints were also photographed, and photographs of imprints and hands were taken with graph paper as background, serving as a scale, and identification tags with numbers (Fig. 2*a* and *b*).

All images were uploaded on a computer, sorted in imprints and hands. Subsequently, the identification tags included in the photographs were erased, and all the single image files were renamed in a random fashion.

One of us (M. K.) then performed matching analyses in blind trials. Five imprints were randomly selected, and each was compared with all 21 hands. This was done by opening the image of an imprint and the image of a hand in Adobe Photoshop® (Adobe Systems, Inc., San Jose, CA). The image of the hand was mirrored so that it made an overlay on the image of the imprint. Then one image was dragged into the other, creating a second layer. By making the top layer semitransparent both layers are visibly simultaneously, and can then be brought to scale using the graph paper

[1] Institute of Forensic Medicine, Frederik d. 5's vej 11, DK-2100 Copenhagen, Denmark.

Received 4 June 2005; and in revised form 1 Sept. 2005; accepted 1 Oct. 2005; published 14 Feb. 2006.

FIG. 1—*Dummy, and one piece of Mosgummi with imprints.*

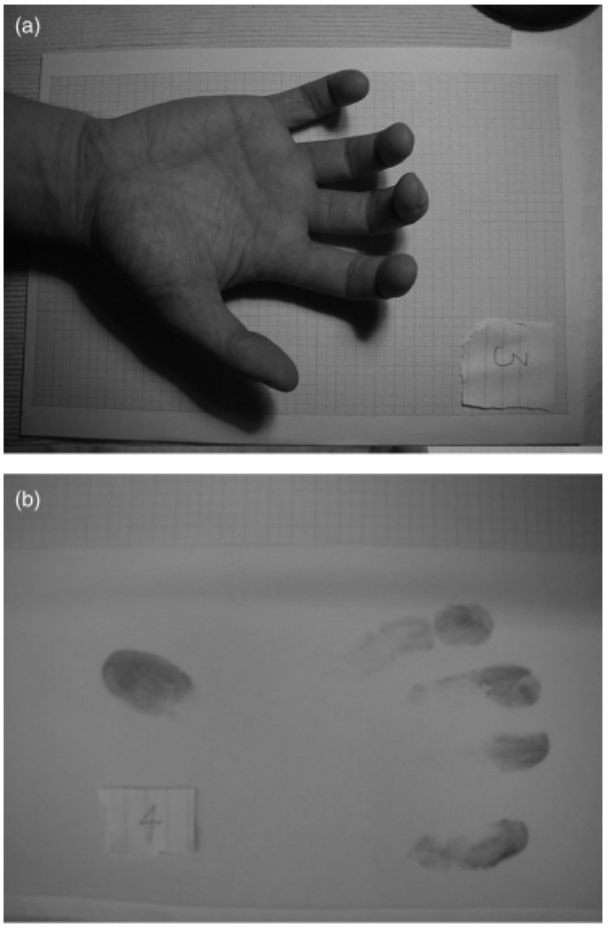

FIG. 2—*(a) Photograph of hand in position four. (b) Photograph of an imprint with graph paper as background and identification tags.*

background. The two layers were then placed on top of each other by rotating and moving them. The imprints made by grasping the dummy were matched to the hands with intermediate flexing of the fingers, and the imprints made by fingertips and nails were matched to the hands with a 90° flexing of the fingers.

The comparisons were scored as (1) good fit (+), (2) possible fit (?), and (3) poor fit (−), based on the following criteria:

- *Size*: Comparison of the finger length on the hand and imprint, and comparison of the width of the hand and the imprint at the metacarpophalangeal level. Width of fingers compared with imprint.
- *Shape and pattern*: Space between fingers, e.g., large gap between fourth and fifth fingers, and smaller equal gaps between second and third and third and fourth fingers. Do fingers match bent/crooked fingers on the imprint?
- *Special features:* Marks from rings, missing fingers, or parts of fingers, markedly crooked fingers, etc.

TABLE 1—*Cross tabulation of images of imprints and hands.*

	I 2^1	I 2^2	I 2^{1+2}	I 9^1	I 9^2	I 9^{1+2}	I 10^1	I 10^2	I 10^{1+2}	I 12^1	I 12^2	I 12^{1+2}	I 15^1	I 15^2	I 15^{1+2}
H 1	−	−	−	+	+	+	−	−	−	−	−	−	−	−	−
H 2	+	?	+	+	?	+	+	+	+ *	+	+	+	?	+	+
H 3	?	+	+	?	?	?	+	+	+	+	+	+	−	−	−
H 4	−	−	−	−	−	−	−	−	−	−	?	−	−	−	−
H 5	?	−	?	−	−	−	−	−	−	+	+	+	?	+	+
H 6	+	+	+	?	?	?	−	−	−	?	?	?	?	?	?
H 7	?	+	+	+	?	+	−	−	−	−	−	−	−	−	−
H 8	−	?	−	+	?	+	+	?	+	+	−	?	+	−	? *
H 9	−	?	−	−	−	−	−	−	−	?	−	?	−	−	−
H 10	−		−	?		?	+		+	?		?	−		−
H 11	+	−	?	+	+	+ *	?	+	+	+	+	+	+	?	+
H 12	−	−	−	−	−	−	?	?	?	−	+	?	−	?	−
H 13	−	−	−	?	+	+	−	−	−	−	?	−	−	?	−
H 14	+	+	+ *	+	?	+	−	+	?	?	?	?	+	−	?
H 15	?	−	?	+	−	?	?	−	?	+	+	+*	?	−	?
H 16	−	?	−	−	−	−	−	−	−	−	−	−	−	−	−
H 17	+	+	+	+	?	+	?	?	?	+	−	?	−	−	−
H 18	+	+	+	?	−	?	+	?	+	?	−	?	?	−	?
H 19	−	−	−	−	−	−	−	−	−	?	?	?	−	−	−
H 20	−	−	−	−	+	?	−	−	−	−	−	−	−	?	−
H 21	?	+	?	+	−	?	−	−	−	?	?	?	?	?	?

The shaded area indicates the true relationship. Asterisks denote what was chosen as best fit. 1+2 is the overall impression of the hand imprint and the fingertip imprint together. In case of discrepancy between 1 and 2, the following guidelines are asserted. + and ? gives +, + and – gives ?, and in cases of ? and –, 1 outweighs 2.
H, hand; I, imprint.

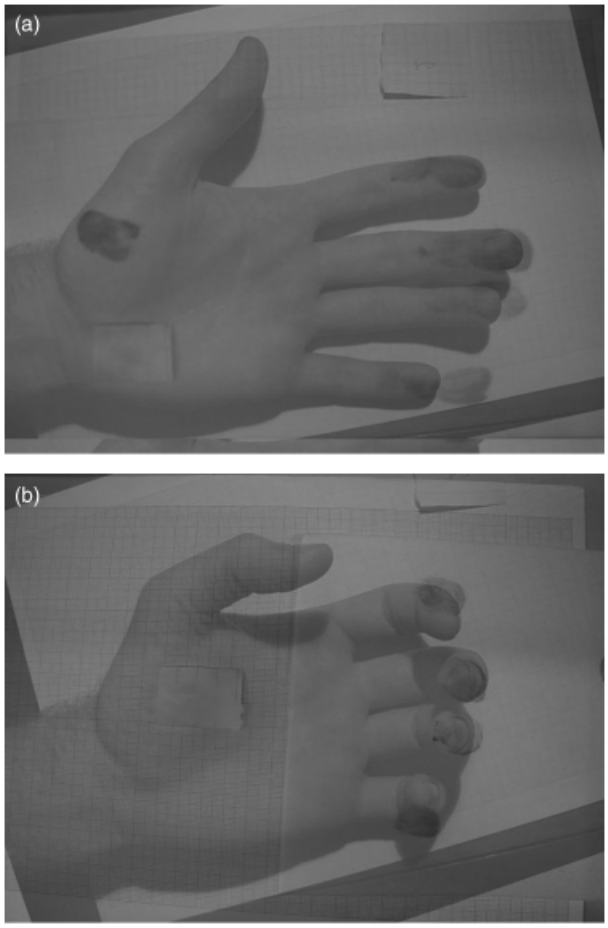

FIG. 3—*Hand 2—Imprint 2 (denoted a good fit). (a) This was denoted as a good fit because of the close fit between the second, third, and fourth fingers on the hand and imprint. The fifth finger is slightly short, but points in the same direction. The width of the hand at the base of the fingers matches the imprint. The width of the fingers matches the width of the imprint. (b) This was a possible fit because the second and fifth fingers do not fit closely with the imprint. The size of the fingers fits the imprint. There are no marks from nails.*

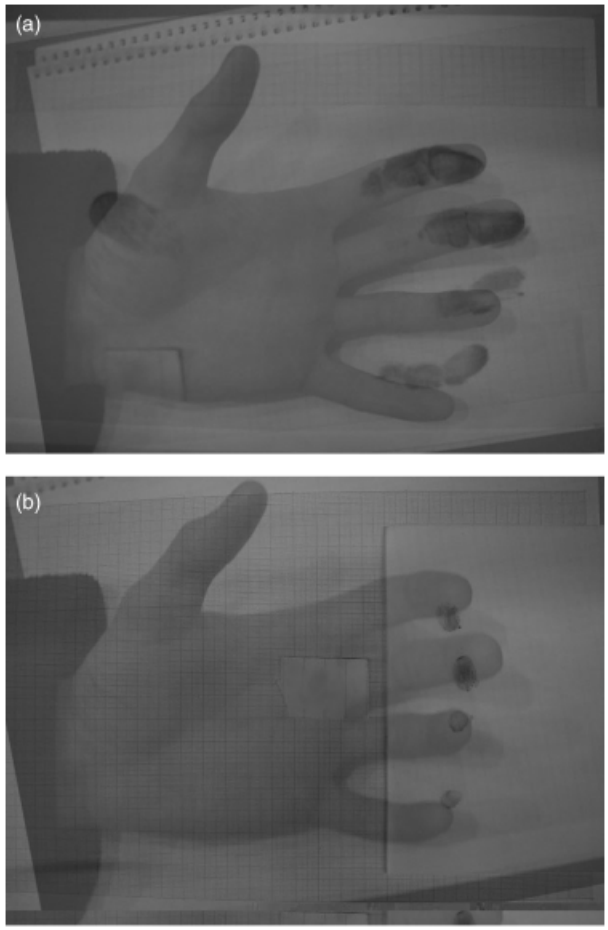

FIG. 4—*Hand 9—Imprint 9 (denoted a poor fit). (a) This was denoted a poor fit because the hand seems too wide compared with the imprint, despite the close match between the shape of the fingers and the imprint. (b) This was denoted a poor fit because only one finger fits in the imprint at a time, and the imprints seem small compared with the fingers.*

- *Nails*: Presence of nail marks; e.g., does the hand present long nails or bitten nails? If nail marks are present, does orientation match the nails on the photographs of the hands?
- *Fingertips*: How well is the overlay between the fingertips and fingertip imprint?

For each imprint a best fit was chosen, based on the above criteria.

Results

Table 1 shows the results of the comparisons. Each imprint was compared with all 21 hands (1–21). The imprint was not assigned to the correct hand as a best fit in any of the five cases. In other words, we did not identify the perpetrator in any one of the five cases.

The imprint was assigned correctly as a good fit in two cases, but only as one among several good fits. The imprint was assigned correctly as a posible fit in two cases, but only as one among many. In the last case the imprint was assigned wrongly as a poor fit. This means that in four cases (#2, #10, #12, and #15), the perpetrator would remain among the suspects, and the rest would be correctly excluded. But, in one case (#9), the perpetrator would be among the people excluded from suspicion, and he would thus have been incorrectly excluded. In the four cases with correct exclusion the number of excluded was 10, 11, 6, and 12, out of 21.

Discussion

We wanted to determine experimentally whether a correct match could be made between hand and hand imprint, and whether a number of people could be correctly excluded from suspicion. Comparisons between digital images of imprints and hands were made in blind trials, and matches were scored as good, possible, or poor fits.

To each imprint, approximately 1/3 of the hands were graded as good fits, 1/3 as possible fits, and 1/3 as poor fits. One of the true matches was graded as a poor fit, two as possible fits, and two as good fits. None of the true matches was chosen as the best fit. Figures 3–5 show three of the true matches, and Fig. 6 shows a match denoted as the best fit. Reasons for the gradings are given in the figure texts.

We note that there is variation of the grading; this is probably because of the arbitrariness of the matching criteria. In addition to the arbitrary nature of the criteria, we also found them to be inconsistent. The width of the hand was a correct measure in some cases, whereas in others (Fig. 4*a*) it was not. The shape of an imprint matched more hands, in spite of individual positions of the

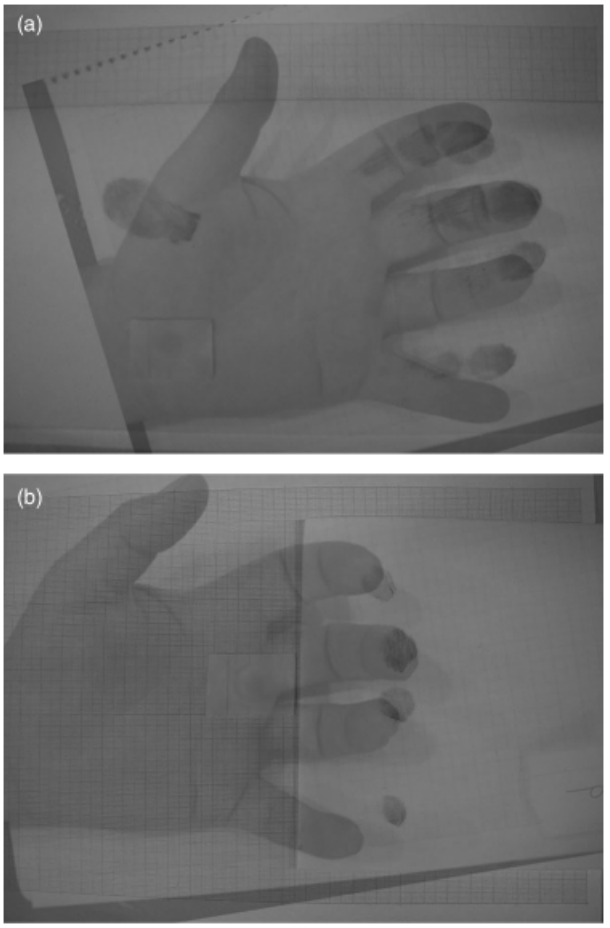

FIG. 5—*Hand 15—Imprint 15 (denoted a possible fit). (a) This was rated as a possible fit because the imprint and the hand do not correlate completely, but the overall shape is comparable, the width of the hand at the base of the fingers match, and finger width matches the imprint. (b) This was rated as a poor fit because none of the fingers truly overlays the imprint, and the imprints are small compared with the fingers. The nail mark from the second finger is not informative.*

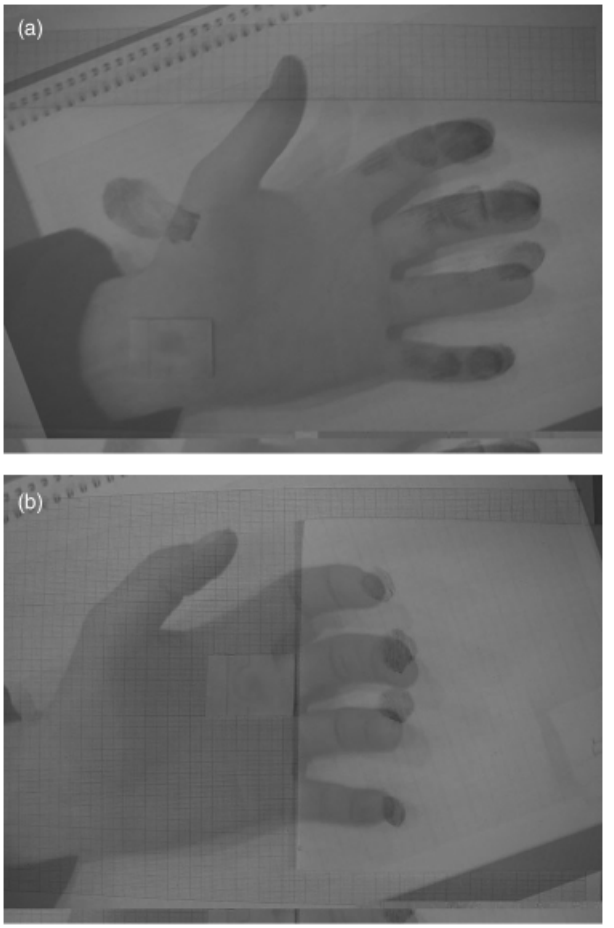

FIG. 6—*Hand 11—Imprint 9 (denoted a good fit). (a) This was denoted a good fit because of the close correlation between all four fingers on the hand and the imprint. The width of the hand at the base of the fingers matches the imprint as does the width of the fingers. (b) This was denoted a good fit because the second, third, and fifth fingers match the imprint, and the fourth is very close. The size of the fingers fits the imprint.*

fingers. The image of fingertips sometimes matched the wrong imprint, and sometimes not the correct imprint (Fig. 5*b*). Nail marks were often absent in the fingertip imprint and always absent in the imprints with all fingers. If present, they were not informative, which was also the conclusion in a previous study (9). However, in one case report, fingernail abrasions were used to positively identify the murder of two children (10), even though the method was criticized (11).

It seems that some hands have a universal fit. Hands of case #2 and #11 were denoted good fit or possible fit in all five matches. On the contrary some hands seem unique. The hand in case #19 seemed very small and was denoted poor in four cases and possible in one. Hands in cases #4 and #16 were both denoted poor in all five cases. This indicates that in spite of the arbitrary judgment, a correct match can possibly be made with the existence of some special features of the hand. Studying case reports, these also show that a positive identification is often possible because of some individual irregularity, and to a minor extent on the basis of the overall fit (1–3,10). In our study the number of excluded was 10, 11, 6, and 12 out of 21, in the four cases with correct exclusion. This gives an exclusion rate between 29% and 57%, meaning that using this method in an investigation would free between one third and one half of the innocent suspects from suspicion and narrow down the number of suspects.

One reason for the uncertainty and inconsistency may be that comparisons are made between imprints and hands, and not between several sets of imprints. The way a person holds his hand naturally may be very different from the way it is positioned while clasping a cylindrical beaker. Another reason may be that the registration of the imprint in the material is not accurate. Variation in imprints could arise because hands are applied with different pressure, which is also the case when applying a dentition to a dental wax with increasing pressure (4). With human skin, the inaccuracy increases because of its highly visco-elastic characteristics, and the edematous response to trauma, which is one of the main reasons that the use of bitemarks as hard evidence has been brought into question (4).

When working with bitemarks, it is generally accepted that the human dentition is unique (4). The human hand is also probably unique, but this uniqueness will not be transferred to an imprint because of the soft tissue and the many positions that the hand and fingers can possibly assume when grasping an object. The matching of a hand to an imprint will therefore be far more uncertain than when matching teeth and bite marks. The literature describes one paramount problem with bitemark evidence: the subjective judgment of a comparison. The overlays are made using an objective technique, among which the computer-generated overlays are considered the golden standard (4,5,8). Still, the comparison

process is subjective, and there is no consensus of opinion or definitive research on this area, as four different groups of dentist have claimed to be qualified in bite mark analysis based on four different sets of standards and guidelines (6). By using a computerized process, the subjective part could be minimized, but an imprint from a hand compared with a hand simply contains too many variables for a computer to handle (4).

Overall, we found that matching of the hand and imprint is somewhat unreliable, at least in our experimental setting. The technique will never be the first choice but could be considered as a last resort. The technique is not usable for a positive match of a perpetrator (7), the number of variables and the uncertainty being too great. Probably, the matching is best suited for cases with specific anatomical features. Under the right circumstances, it could be used as an exclusion method, just like it is emphasized that bitemarks should be used (4,6).

A future approach could be to compare two imprints: one from the neck of a victim and one made on a neck dummy. The comparison would thus be between two similar imprints, improving the comparability. Finally, we note that the distance between the tip of the thumb and the tip of the second finger could be measured on the imprints (or imprint and hand). Even with skin distortion and oedema, it would provide a more fixed measure compared with the criteria used.

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Additional information and reprint requests:
Niels Lynnerup, D.D.S., Ph.D.
Institute of Forensic Medicine
Frederik d. 5's vej 11
DK-2100 Copenhagen
Denmark
E-mail: n.lynnerup@antrolab.ku.dk