Fingerprint Changes and Verification Failure Among Patients With Hand Dermatitis

Chew Kek Lee, MRCP(UK); Choong Chor Chang, MRCP(UK); Asmah Johar, MMed(Mal); Othman Puwira; Baba Roshidah, FRCP(UK)

Objectives: To determine the prevalence of fingerprint verification failure and to define and quantify the fingerprint changes associated with fingerprint verification failure.

Design: Case-control study.

Setting: Referral public dermatology center.

Patients: The study included 100 consecutive patients with clinical hand dermatitis involving the palmar distal phalanx of either thumb and 100 age-, sex-, and ethnicity-matched controls. Patients with an altered thumbprint due to other causes and palmar hyperhidrosis were excluded.

Main Outcome Measures: Fingerprint verification (pass/fail) and hand eczema severity index score.

Results: Twenty-seven percent of patients failed fingerprint verification compared with 2% of controls. Fingerprint verification failure was associated with a higher hand eczema severity index score (P < .001). The main fingerprint abnormalities were fingerprint dystrophy (42.0%) and abnormal white lines (79.5%). The number of abnormal white lines was significantly higher among the patients with hand dermatitis compared with controls (P = .001). Among the patients with hand dermatitis, the odds of failing fingerprint verification with fingerprint dystrophy was 4.01. The presence of broad lines and long lines was associated with a greater odds of fingerprint verification failure (odds ratio [OR], 8.04; 95% CI, 3.56-18.17 and OR, 2.37; 95% CI, 1.31-4.27, respectively), while the presence of thin lines was protective of verification failure (OR, 0.45; 95% CI, 0.23-0.89).

Conclusions: Fingerprint verification failure is a significant problem among patients with more severe hand dermatitis. It is mainly due to fingerprint dystrophy and abnormal white lines.

Trial Registration: Malaysian National Medical Research Register Identifier: NMRR-11-30-8226


AND DERMATITIS IS A COMMON skin disease with a reported lifetime prevalence of up to 15% and a median incidence rate of 5.5 cases per 1000 person-years. It affects quality of life and results in repeated medical leaves and even job changes. Because hand dermatitis can involve the pulp of the thumb, it has been reported to cause significant fingerprint changes, which may impair fingerprint recognition, and fingerprint impairment has been reported to cause significant economic loss. The odds of 2 individuals having the same fingerprint had been estimated to be 1 in 64 billion. This uniqueness makes fingerprints a good modality for biometric identification. Furthermore, fingerprints do not change naturally over time as opposed to other physical features that may change owing to various factors.

With the introduction and increment of fingerprint use in national registration, immigration, banking transactions, building and door access, and other settings, patients with hand dermatitis are often excluded from the system and require other means of verification that are often less secure and more cumbersome. In Malaysia, fingerprint data are encoded into a computer chip in the national identity card, which is called MyKad. Because of this emerging predicament among patients with hand dermatitis, it is timely to review the magnitude of this problem as well as the factors associated with finger-
print verification failure. We sought to determine the prevalence of fingerprint verification failure, to define and quantify the fingerprint changes, and to determine the factors associated with fingerprint verification failure among patients with hand dermatitis.

### METHODS

This case-control study, which was approved by the Clinical Research Centre, Kuala Lumpur, Malaysia, was conducted in the Department of Dermatology, Hospital Kuala Lumpur, from March to August 2011. We recruited 100 patients and 100 age-, sex-, and ethnicity-matched controls and included all consecutive consented patients who were clinically diagnosed as having hand dermatitis involving the palmar aspect of the distal phalanx of either thumb and who possessed a readable MyKad. We excluded patients who had altered thumbprints due to other causes (eg, skin tumor, scars, and other abnormalities) and those diagnosed as having hyperhidrosis of the palms. The control group consisted of age-, sex- and ethnicity-matched controls who possessed a readable MyKad. We excluded those who were diagnosed as having hand dermatitis, those who had symptoms of hand dermatitis for the past 6 months, those who had altered thumbprints due to other causes (eg, skin tumor, scars, or other abnormalities), and those who were diagnosed as having hyperhidrosis of the palms.

**STUDY DEVICE**

We used a multipurpose fingerprint-processing unit (Sagem MorphoSmart MSO 350; Sagem DS) with a smart card reader (ISO [International Organization for Standardization] format) that runs on a central family processing unit (ARM9). It has a slot to read smart cards, including MyKad and a fingerprint optical sensor that is capable of both image capture and fingerprint image processing. The fingerprint sensor area, which covers a 21 × 21-mm acquisition area, is approved by Federal Information Processing Standards (FIPS 201). Acquired thumbprints undergo this biometric algorithm, which generates quality and matches score. During matching, the system compares the identification points (minutiae) and the relative distance as well as the angle between each minutiae point with its neighboring minutiae. This match is scored mathematically and produces the resultant match score. The fingerprint quality score is defined as a measurement of the clarity of ridges and valleys and the extractability features that are used for identification purposes. Higher scores indicated better match and quality, respectively. The threshold used to ascertain a match was set at a commonly used threshold: a quality score of 70 and a match score of 3500.

**STUDY PROCEDURES**

Recruits were interviewed regarding their demographics, clinical presentation, personal and family history of atopy, hand dominance, and history of failed fingerprint verification. The clinical diagnosis was obtained according to the diagnosis given by the attending physician. Thereafter, an investigator rated the severity of the hand dermatitis using the hand eczema severity index (HECSI) score. The same parameters and scoring methods were used to assess each thumb individually. For each thumb, the resultant score was termed the modified thumb severity index (mTSI) score.

The patients’ fingerprints were then matched with their MyKad using the Sagem Morphosmart MSO 350 and the Fingerprint Validator, a software package developed using the Sagem MorphoSmart SDK. Each patient was given 3 attempts on each thumb for fingerprint image acquisition and verification. If the first attempt failed, the patients applied aqueous cream over the thumb and repeated the attempt 5 minutes later. When any of the 3 attempts was successful, the thumb verification was regarded as successful. The best match score and the corresponding quality score were recorded, and the corresponding image was saved for further analysis. When verification failed but the quality score exceeded the threshold (70), the best match score and its corresponding quality score and image were used. When verification failed but the quality score was below the threshold (70), the best quality score and its corresponding match score and image were used.

Fingerprint analysis was performed by an investigator who was blinded as to the final result of the fingerprint verification. Abnormalities of fingerprints were described and defined. The area and length of the abnormalities were measured using ImageJ 1.44, a public domain Java-based image-processing software package developed by the National Institutes of Health, Bethesda, Maryland. The area of abnormality was defined as the percentage of abnormality within the acquired thumbprint surface area.

**STATISTICAL ANALYSIS**

All analyses were performed using SPSS version 19.0 (SPSS Inc). Continuous data were expressed as mean (SD) when they were normally distributed and as median and interquartile range (IQR) when they were not normally distributed. Categorical data were expressed as proportion (percentage). Comparisons of continuous data were performed with the t test when they were normally distributed and with the Mann-Whitney U test when they were not normally distributed. The correlation between 2 continuous data was expressed as r2 using the Pearson correlation. Linear regression was expressed as b. Comparisons of proportions were performed with the χ2 test or the Fisher exact test, whichever applied. P < .05 was considered significant.

### RESULTS

#### DEMOGRAPHICS AND CLINICAL CHARACTERISTICS

The mean age of patients was 44.6 years (age range, 15-78 years). Most patients (25.0%) were between 50 and 59 years old and female (Table 1), and most (48.0%) were diagnosed clinically as having allergic contact dermatitis, followed by irritant contact dermatitis (14.0%), atopic dermatitis (14.0%), endogenous dermatitis (11.0%), and unspecified dermatitis (13.0%). The median disease duration was 52.0 months (IQR, 13-130 months).

#### STUDY DEVICE

- **Recruits** were interviewed regarding their demographics, clinical presentation, personal and family history of atopy, hand dominance, and history of failed fingerprint verification. The clinical diagnosis was obtained according to the diagnosis given by the attending physician.
- An investigator rated the severity of the hand dermatitis using the hand eczema severity index (HECSI) score.
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- Linear regression was expressed as b. Comparisons of proportions were performed with the χ2 test or the Fisher exact test, whichever applied.
- P < .05 was considered significant.
The median HECSI score was 18.00 (IQR, 10.25-30.00). The patients with atopic dermatitis had less severe disease (median HECSI score, 10.50; IQR, 7.00-19.75) than those without atopic dermatitis (median HECSI score, 20.00; IQR, 14.00-34.00) (P = .001). The median mTSI score was 8.00 (IQR, 2.00-8.00). Most patients had an mTSI score of 8.00 (35.3%), with 40.0% of the patients having an mTSI score below 8.00, and 24.5% of the patients having an mTSI score above 8.00. The 2 most common presentations of hand dermatitis were erythema (89.5%) and scaling (89.5%). Most patients had mild erythema (85.5%) and mild scaling (79.5%). Only 4 patients had mild vesiculation.

COMPARISON OF FINGERPRINT VERIFICATION BETWEEN PATIENTS AND CONTROL

A significantly higher proportion of patients had a history of fingerprint verification failure (odds ratio [OR], 8.81; 95% CI, 3.51-22.13) compared with controls (Table 2). Most failures (62.0%) occurred at the immigration counter, but the highest rate of verification failure occurred at the bank counter (40.4%). When fingerprint verification was tested, a significantly higher proportion of patients failed one or both thumbprints compared with controls (49.0% vs 7.0% [ratio of patients failed one or both thumbprints was tested, a significantly higher proportion of patients had a history of verification failure (odds ratio, 12.76 [95% CI, 5.39-30.24]), respectively). The correspond-

Table 2. History of Verification Failure Among Patients With Hand Dermatitis and Controls

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patients (n = 100)</th>
<th>Controls (n = 100)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of failed fingerprint registration</td>
<td>16 (16.0)</td>
<td>4 (4.0)</td>
<td>.005</td>
</tr>
<tr>
<td>History of failed fingerprint verification at immigration</td>
<td>20/62 (32.3)</td>
<td>2/62 (3.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>History of failed fingerprint verification at the Employees Provident Fund counter</td>
<td>10/53 (18.9)</td>
<td>1/55 (1.8)</td>
<td>.004</td>
</tr>
<tr>
<td>History of failed fingerprint verification at the bank counter</td>
<td>23/57 (40.4)</td>
<td>4/59 (6.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>History of failed fingerprint verification</td>
<td>36/100 (36.0)</td>
<td>6/100 (6.0)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Table 3. Factors Associated With Thumbprint Verification Among Patients With Hand Dermatitis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Failed Verification (n = 79)</th>
<th>Passed Verification (n = 121)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HECSI score, mean (SD)</td>
<td>30.92 (26.05)</td>
<td>18.69 (12.89)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>mTSI score, mean (SD)</td>
<td>10.85 (7.51)</td>
<td>5.43 (3.94)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>42.3 (16.4)</td>
<td>46.1 (17.5)</td>
<td>.12</td>
</tr>
<tr>
<td>Duration of disease, wk</td>
<td>479.70 (574.00)</td>
<td>348.84 (448.34)</td>
<td>.09</td>
</tr>
<tr>
<td>Presence of atopy, No. (%)</td>
<td>38 (48.10)</td>
<td>62 (51.24)</td>
<td>.66</td>
</tr>
<tr>
<td>Presence of atopic dermatitis, No. (%)</td>
<td>23 (29.11)</td>
<td>33 (27.27)</td>
<td>.78</td>
</tr>
<tr>
<td>Hand dominance,a</td>
<td>42/78 (53.85)</td>
<td>56/118 (47.46)</td>
<td>.38</td>
</tr>
</tbody>
</table>

Abbreviations: HECSI, hand eczema severity index; mTSI, modified thumb severity index.

a Two patients were ambidextrous; therefore, 4 thumbprints were excluded from this analysis.

FINGERPRINT CHANGES IN HAND DERMATITIS

There were 2 distinctive fingerprint changes among patients with hand dermatitis: dystrophy and abnormal white lines. Dystrophy was defined as defects with no recognizable fingerprint pattern (Figure 1A). A variant of dystrophy had a mottled appearance, often round with a central black dot (Figure 1B). These mottled appearances often clinically correspond to scales. Occasionally, the whole fingerprint was dystrophic, showing a tree-bark appearance (Figure 1C).

Abnormal white lines were categorized by the orientation, length, and broadness of the lines. Most of the lines were either horizontal or vertical. In this study, any lines with an angle of 45° or less to the horizontal lines were classified as horizontal. Any lines with an angle of more than 45° to the horizontal lines were classified as vertical. The length of the lines was categorized as long or short. Long lines measured 50% or more of the line extrapolated across the fingerprint (Figure 2). The broadness of the lines was categorized as broad or thin. Broad lines had the broadest width, being 2 or more times the width of the broadest valley (Figure 3). The valley is the normal space between the black lines in the fingerprint. Compared with controls, patients with hand dermatitis had a significantly higher incidence of dystrophy in their fingerprints (42.0% vs 2.0%; OR, 33.48; 95% CI, 12.68-
99.29 \( [P < .001] \) but a significantly lower incidence of abnormal white lines (79.5% vs 91.5%; OR, 0.36; 95% CI, 0.20-0.66 \( [P = .001] \)).

**DYSTROPHY**

Among the patients with hand dermatitis, the OR of fingerprints with dystrophy failing fingerprint verification was 4.01 (95% CI, 2.20-7.32). On the other hand, the OR of fingerprints with abnormal white lines that failed fingerprint verification was not statistically significant (OR, 0.55; 95% CI, 0.27-1.09). Of the 84 patients with dystrophy, 15 had total dystrophy (17.9%), while 20 (23.8%) had the mottled variant of dystrophy. The median percentage of the surface area of dystrophy was 22.80% (IQR, 6.38%-60.10%). Most patients (38 of 39 [97.4%]) with an area of dystrophy of 25% or more failed their fingerprint verification, while only 41 of 161 patients (25.5%) with an area of dystrophy of less than 25% passed their verification (OR, 111.22; 95% CI, 14.80-835.92 \( [P < .001] \)). The total surface area of dystrophy was inversely correlated with the match score (\( r^2 = 0.404 \)) and the quality score (\( r^2 = 0.533 \)) but positively correlated with the mTSI score (\( r^2 = 0.380 \)) (all \( P < .001 \)).

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**Figure 1.** Fingerprint dystrophy. A, The circled area has no recognizable normal fingerprint pattern. B, The mottled variant of dystrophy, which is often round with a central black dot. C, Tree-bark total dystrophy.

**Figure 2.** Figure showing extrapolated white lines for line a and b. Line a is a long line as it measures more than 50% of the entire extrapolated line. Line b is a short line as it is shorter than 50% of the entire extrapolated line.

**Figure 3.** Broad lines and thin lines. Line a, which is a broad line, measures more than 2 times the width of the broadest valley of the fingerprint; line b, which is a thin line, measures less than 2 times the width of the broadest valley.
ABNORMAL WHITE LINES

Most patients (79.5%) with hand dermatitis had abnormal white lines. Its presence was not associated with atopic dermatitis among recruits (P = .48), and there was no increase in the number of abnormal white lines among patients with atopic dermatitis (P = .94). However, the number of abnormal white lines was significantly higher among patients with hand dermatitis (median, 12 lines per fingerprint; IQR, 5-19 lines) than among controls (median, 8 lines per fingerprint; IQR, 4-13 lines) (P = .001).

Among the patients with hand dermatitis, the total number of abnormal lines correlated well with both the fingerprint match score (r² = 0.994) (P < .001) and the fingerprint quality score (r² = 0.135) (P < .001) but not with the mTSI score (r² = 0.001) (P = .67). Short horizontal lines were most prevalent in fingerprints (146 of 200 [73.0%]) followed by short vertical lines (113 of 200 [56.5%]), long horizontal lines (105 of 200 [52.5%]), and long vertical lines (36 of 200 [18.0%]).

Broad lines and long lines were associated with fingerprint verification failure (OR, 8.04; 95% CI, 3.56-18.17 and OR, 2.37; 95% CI, 1.31-4.27), while the presence of thin line was protective of verification failure (OR, 0.45; 95% CI, 0.23-0.89). The presence of horizontal, vertical, and short lines was not associated with fingerprint verification failure (P = .49, P = .13, and P = .13, respectively). The patients who failed fingerprint verification also had a greater number of long lines and broad lines (Table 4).

This is the first study (to our knowledge) that has quantified the prevalence of fingerprint verification failure and the type of fingerprint changes among patients with hand dermatitis. In 1970, David et al defined fingerprint changes in patients with hand dermatitis, which were mainly ridge atrophy and white lines. Fingerprint changes in eczema were distinguished from celiac disease by the patchy fingerprint changes; however, severe eczema was noted to obscure fingerprint patterns completely. 4 Fingertip eczema was recognized as one of the many skin diseases that may impair fingerprint acquisition and recognition by obliterating the papillary line, causing rejection of fingerprint verification and resulting in loss of wages. 3, 4 Our findings confirm fingerprint verification failure among patients with hand dermatitis affecting the pulp of their thumbs. With the increasing use of fingerprint for verification, this problem will cause difficulties for many patients.

Our study population follows the bimodal age distribution of allergic contact hand dermatitis. 8 The long median duration of the disease was similar to that of a large Swedish population-based study. 10 However, our proportion of patients with irritant contact dermatitis was much lower than that of previous studies, 9, 11 and the type of hand dermatitis in a significant number of patients was not specified. This group of patients could have both endogenous and exogenous hand dermatitis with either allergic contact dermatitis or irritant contact dermatitis.

Overall, the median HECSI score among our patients with hand dermatitis was similar to that of other studies. 12 However, in our study, the patients with atopic dermatitis had less severe hand dermatitis in contrast to the results of other studies. 3, 12

Hand dermatitis can possibly affect the fingerprint by 3 mechanisms, ie, by causing scaling, wrinkling or fissures, and effacement of finger ridges. Scaling corresponds to fingerprint dystrophy, often the mottled type, which affects the quality score by interfering with the ridges pattern and adding artifacts to the fingerprint. If the fingerprint is not rejected at the start of the fingerprint analysis, the resultant low-quality score would impair the match score. Fissures and wrinkling correspond to the abnormal white lines in fingerprints. These lines add artifactual minutiae points and disrupt neighboring minutiae points. When severe, ridges may be destroyed, causing fingerprint dystrophy and therefore the loss of minutiae points used in fingerprint matching.

Contrary to previous literature, abnormal white lines in fingerprints were not confined to diseased fingers. In fact, more controls had abnormal white lines than did patients with hand dermatitis. However, when present, the number of abnormal white lines was higher among patients with hand dermatitis and correlated well with both fingerprint quality and match scores.

There has been controversy as to whether palmar hyperlinearity is a feature of atopic dermatitis or a manifestation of the concomitant autosomal dominant ichthyosis. 33 It is also not known whether hyperlinearity can involve the fingers in atopic dermatitis. In our study, neither the presence nor the number of abnormal white lines was associated with atopic dermatitis. Therefore, fingerprint hyperlinearity is probably not associated with atopic dermatitis or palmar hyperlinearity. The number of abnormal white lines was independent of the thumb dermatitis severity, but the lines significantly decreased the quality and match scores. Abnormal white lines may introduce artifactual minutiae points, which interfere with the matching process during fingerprint verification. They may also obscure neighboring minutiae points, thereby resulting in both reduced quality and match scores.

The presence of long lines and broad lines was a poor prognostic factor for fingerprint verification. When the line was more than half the length of the line across the fingerprint, the possibility of the line cutting across

**Table 4. The Number of Abnormal Line Subtypes in Patients With Hand Dermatitis and Their Verification Status**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pass Verification (n = 121)</th>
<th>Fail Verification (n = 79)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short lines</td>
<td>6 (1-13)</td>
<td>9 (0-16)</td>
<td>.37</td>
</tr>
<tr>
<td>Long lines</td>
<td>0 (0-1)</td>
<td>2 (0-4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Horizontal lines</td>
<td>5 (1-9)</td>
<td>7 (0-11)</td>
<td>.26</td>
</tr>
<tr>
<td>Vertical lines</td>
<td>1 (0-5)</td>
<td>3 (0-9)</td>
<td>.01</td>
</tr>
<tr>
<td>Thin lines</td>
<td>6 (1-14.5)</td>
<td>9 (0-17)</td>
<td>.68</td>
</tr>
<tr>
<td>Broad lines</td>
<td>0 (0-0)</td>
<td>0 (0-2)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviation: IQR, Interquartile range.
the central part of the fingerprint was greater. Therefore, the line has a higher probability of disrupting and interfering with the minutiae of the fingerprint, which often concentrate centrally. The broader the line, the more likely it is to disrupt neighboring ridges and therefore affect the minutiae of the fingerprint.

On the other hand, dystrophy mainly occurred in the fingerprints of patients with hand dermatitis. Almost all patients with dystrophy of 25% or more failed their fingerprint verification. Most dystrophy concentrates at a portion of the fingerprint. When more than a quarter of the fingerprint is involved, the possibility of it involving the central part of the fingerprint is higher. Most minutiae are found in the central part of the fingerprint. Therefore, any abnormalities affecting the central part of the fingerprint are more likely to interfere with the matching and verification process. The prevalence of fingerprint verification failure may have been overestimated, as the present study was conducted a tertiary center that serves as a referral center for more severe cases and is also a center of referral for patients with hand dermatitis who failed to register their thumbprints in the National Registration Department of Malaysia.

In conclusion, our study clearly highlighted the prevalence of problems with fingerprint verification and identified as well as quantified the types of fingerprint changes among patients with hand dermatitis. Fingerprint verification failure can also be a marker of disease severity. Therefore, problems with fingerprint verification should be actively sought for and anticipated in patients with hand dermatitis.

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Author Contributions: Drs Lee and Chang had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Lee, Chang, Johar, Othman, and Baba. Acquisition of data: Lee and Baba. Analysis and interpretation of data: Lee, Chang, Johar, Othman, and Baba. Drafting of the manuscript: Lee, Johar, and Othman. Critical revision of the manuscript for important intellectual content: Lee, Chang, Johar, and Baba. Statistical analysis: Lee. Obtained funding: Lee and Chang.

Administrative, technical, or material support: Lee, Chang, Johar, Othman, and Baba. Study supervision: Chang, Johar, Othman, and Baba.

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Additional Contributions: Yasmin Teknologi Sdn Bhd provided the Sagem Morphosmart MS O350, which was used in the study, and developed the Fingerprint Validator program. Kulenthran Arumugam, MRCOG, of the Medical Education and Research Development Unit, Universiti Malaya, provided advice regarding statistical methodology, and Yusob B. Mat Tais, Registrar of Criminals of the Royal Malaysian Police and the National Registration Department of Malaysia, Kuala Lumpur, assisted us on matters pertaining to fingerprint analysis.

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