

Original article

Comparison of smartphone photography and dermoscope-assisted photography in evaluation of color changes of bruise in forensic patients

Anchalin Techarungpaisarn, Pongpon Traithepchanapai*

Department of Forensic Medicine, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand

Abstract

Background: The dermoscope has been widely developed for enhancing diagnostic capabilities. However, its application within the medicolegal aspect remains limited. This study explored the potential of dermoscope-assisted imaging in improving the bruises assessment for forensic purposes.

Objective: This study aimed to evaluate and compare the efficacy of smartphone photography and cross-polarized dermoscope-assisted photography in assessing bruise color in forensic patients.

Methods: Thirty bruises of varying durations (1 - 7 days) and sizes (1 - 12 cm²) were analyzed in a forensic clinic. Bruises were photographed using a Samsung Galaxy Note 20® with and without a DermLiteV® cross-polarized dermoscope (PD) attached. The colorimetric parameters from the color space developed by the International Commission on Illumination (CIELAB), namely, L* (relative luminance), a* (change in red to green) and b* (change in blue to yellow) were measured and color difference (ΔE) was calculated. Statistical analyses were conducted to assess the differences of the mean ΔE of the two imaging modalities.

Results: Both modalities demonstrated clear differentiation between normal skin and bruised areas ($\Delta E > 5$). The cross-polarized dermoscope showed higher ΔE values for purplish-blue (17.7 vs. 14.0, $P < 0.001$) and yellowish bruises (9.6 vs. 5.4, $P < 0.001$), indicating superior color distinction. Dermoscopy-assisted images exhibited greater consistency and less variability in L*, a*, and b* values, particularly for older or faint yellow bruises.

Conclusion: Cross-polarized dermoscopes enhance bruise visualization and documentation. While smartphones suffice for vivid bruises, dermoscopes are recommended for detailed assessments of faint or older bruise.

Keywords: Bruise, dermoscope, dermoscope in forensic medicine, forensic medicine, forensic photography.

***Correspondence to:** Pongpon Traithepchanapai, Department of Forensic Medicine, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand.

E-mail: pongpon.tr@gmail.com

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It is crucial to thoroughly evaluate and document the appearance of bruises in forensic clinics. As they are guides for forensic pathologists in giving opinion upon the duration and sometimes cause of the injuries. Bruises can appear in different color due to force applied, severity and configuration of a bruise depends on multiple factors such as laxity and vascularity of the connective tissue, age, underlying conditions, previous medication, and skin pigmentation. Moreover, the color also alters over time. A bruise becomes visible after applying blunt force to the skin causing hemorrhage into soft tissue.⁽¹⁾ The first colors seen on the skin are red, purple, or blue depending on the oxidative state of the hemoglobin and the depth of skin. As the hemoglobin starts to degrade, the colors will change following the products of degradation. By the action of hem-oxygenase, hemoglobin turns into biliverdin (green), carbon monoxide and iron atom. The iron atom then forms a complex with ferritin to produce hemosiderin (brown). The hemosiderin will eventually be metabolized to bilirubin (yellow).⁽²⁾ Several studies were conducted aiming to aid the pathologist evaluate the bruises both by naked eyes and by assisting tools including scoring system, colorimeter, spectrometer, microscopic examination, or even artificial intelligence.⁽³⁻⁸⁾ However, in setting of forensic clinic where time is limited, pathologists usually evaluate wound characteristics by naked eyes as it is the simplest, non-destructive, and less time-consuming way.

Nowadays, smartphone photography plays an important role in general practice.⁽⁹⁾ Since most of the practitioners own one smartphone and it is the

most convenient way for documenting wound for consultation. Although smartphone photographing technology is advancing, photographing the same bruise can be interpreted into different grades of visibility and color depending on the interpreter's perception, experience, and lighting of the place.⁽³⁾

Throughout the past decades, dermoscope has been widely used among the dermatologists as a non-invasive technique to visualize epidermal and dermal layers of the skin.⁽¹⁰⁾ It has demonstrated great diagnostic abilities in various types of skin lesion.⁽¹⁰⁻¹²⁾ The principle of dermoscope is to alter the reflection, scattering and absorption of light of the skin to allow the visualization of epidermal, dermo-epidermal junction and papillary dermis. There are two techniques of dermoscope, non-polarizing and polarizing dermoscope.⁽¹⁰⁾

Non-polarizing dermoscope (NPD) is a technique in which the dermoscope contacts skin with a layer of immersion oil or ultrasound gel as a medium between the instrument and the skin surface, making the stratum corneum more translucent to reduce light reflection and increase refraction, revealing deeper structures.⁽¹⁰⁾

In polarizing dermoscope or cross-polarized technique (PD), two polarizing filters are positioned perpendicular to each other. The first polarizing filter is placed between the light source and the skin while the second one is placed between the skin and the detector (**Figure 1**). When the light travels through the first filter, part of the polarized light is reflected by the stratum corneum and then blocked by the second filter. Meanwhile, the remaining part will penetrate

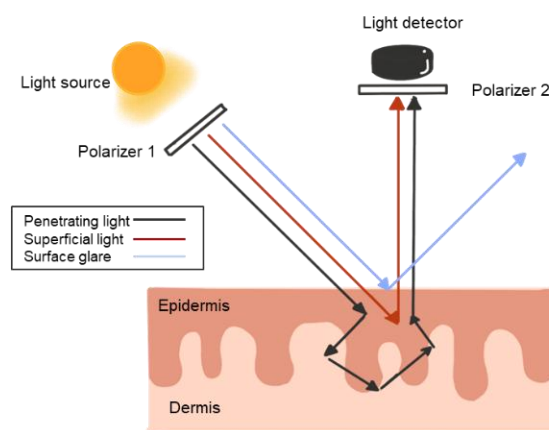


Figure 1. Comprising of two polarizing filters, the cross polarized technique allows visualization of dermis.

the deeper layer and backscatter. After multiple scatterings, it will lose its polarization, this backscattered light will finally travel through the second detector and reach the detector. This explains why the liquid medium is not required by the polarizing technique.⁽¹³⁾

Although dermoscope has been developed for a greater diagnostic ability and broadly studied in other fields, its implementation in medicolegal aspect is only scarce. The first use of dermoscope in forensic medicine was reported in the Department of Forensic Medicine at the University Hospital of Rouen in France in 2019, describing its role in fingerprints identification, gunshot wounds and stab wounds.⁽¹⁴⁾ This study will propose the use of dermoscope on aiding bruise assessment in at forensic medicine clinics, compare its diagnostic abilities to the smartphone photography and point out its limitations in forensic field by comparing the difference of colorimetric values between both modalities.

Materials and methods

Subjects

Patients in forensic clinic presenting with bruises at King Chulalongkorn Memorial Hospital. The inclusion criteria were 18 to 45 years old patients⁽¹⁵⁾ with bruises size ranging between 1 cm² to 25 cm²

(limitation of the dermoscope size) and the duration of injuries between 1 to 7 days. Patients with extremely dark skin tone (Type V-VI in Fitzpatrick Scale), coagulopathy, current anticoagulant or steroid use⁽¹⁵⁾, bruises in sensitive areas such as face or genitalia, bruises in an area which other skin disorder co-existed were excluded from the study. This study has been approved by institutional review board (IRB), Faculty of Medicine Chulalongkorn University (IRB no. 0644/67)

Photography method

After routine examination in forensic clinic, informed consent process was performed. The following basic information are obtained: age, sex, nationality, underlying medical conditions and medication, time of injuries, object causing blunt force trauma. Bruises were assessed colors by principal investigator, size and color of the bruises were recorded.

Smartphone photography was performed under ambient light in forensic clinic with a Samsung Galaxy Note 20[®], auto setting, with built-in flash. When photographing, the 3 x 3 grid was always on the display screen to assure that the bruise was placed in the central grid to reduce the difference of distance between the camera and the bruise of each subject (**Figure 2**).

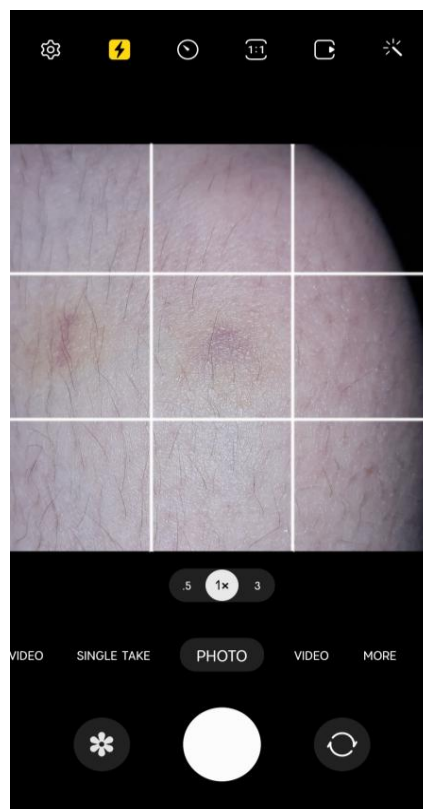


Figure 2. An example of the screenshot showing the adjustment of the bruise at the central grid.

Dermoscope-assisted photography was performed using DermLiteV® in cross-polarized mode, with the same Samsung Galaxy Note 20® (auto setting, 1x zoom) attached to it. The tool was gently placed on the skin for photography. Bruises larger than 2 x 2 cm were divided into four quadrants, each quadrant was photographed to cover the whole bruises and adjacent skin.

Color parameter analysis

The color space used in this study is the CIELAB color space specified by Commission Internationale de l'éclairage (CIE). It is the most complete color space and the most used in skin pigment color measurement.⁽¹⁶⁾

There are three axes of CIELAB as displayed in **Figure 3**.⁽¹⁷⁾

L^* = lightness (values from 0 to 100, 0 means totally black and 100 means diffuse white)

a^* = range of color from green to red (negative a^* means green and positive means red)

b^* = range of color from blue to yellow (negative b^* means blue and positive means yellow)

Each image from the smartphone was transferred to a PC for color analysis. Using Image J software, each bruise was divided into four quadrants. The color picker tool was to measure the value L^* , a^* and b^* of the area of normal skin and area of the bruises in each quadrant (**Figure 4**). L , a^* and b^* of the four quadrants were averaged and calculated for ΔE in Microsoft Excel® Software using this formula.⁽¹⁷⁾

$$\Delta E = \sqrt{(L_c - L_b)^2 + (a_c - a_b)^2 + (b_c - b_b)^2}$$

(c – control skin, b – bruise)

ΔE indicates differences of color between 2 point. ΔE in CIELab color space (ΔE_{lab}) is calculated from this formula.⁽¹⁷⁾

Ranging from 0 to 100, the greater value indicates the more difference of two colors. Hence, the more noticeable changes. The two colors of ΔE more than 1 starts to be noticeable by naked eyes. A range of ΔE that standard observer notices the difference are as follows.⁽¹⁷⁾

0 - 1.0	Unnoticeable
1.0 - 2.0	Noticeable to experienced observers
2.0 - 3.5	Noticeable difference to unexperienced observers
3.5 - 5.0	Clear difference
> 5.0	Two different colors

When yellow color is visible. The color difference between normal skin and yellowish border will also be calculated and analyzed separately to evaluate the ability of dermoscope in detecting older bruises and faint bruises (**Figure 4**).

Statistical analysis

All measurements were recorded and calculated in Microsoft Excel®. The data were expressed as mean $\pm$ standard deviation (SD). The paired t - test was performed to compare significant differences of ΔE between each pair of modalities (cross-polarized dermoscope vs smartphone photography) using IBM SPSS software version 29.0.2®. $P < 0.05$ was indicated statistical significance.

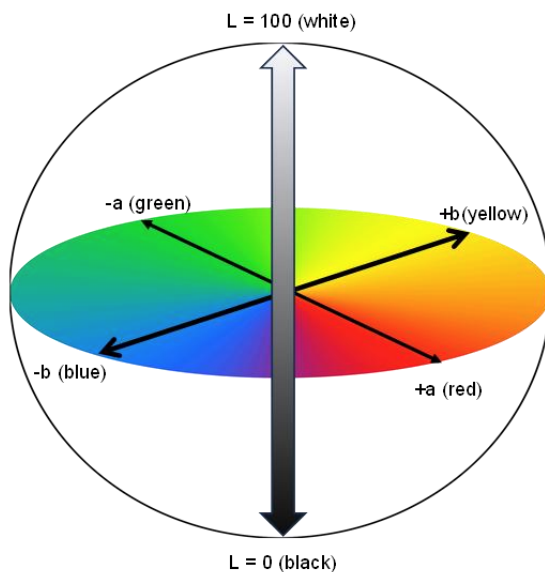


Figure 3. CIELAB color space axes.

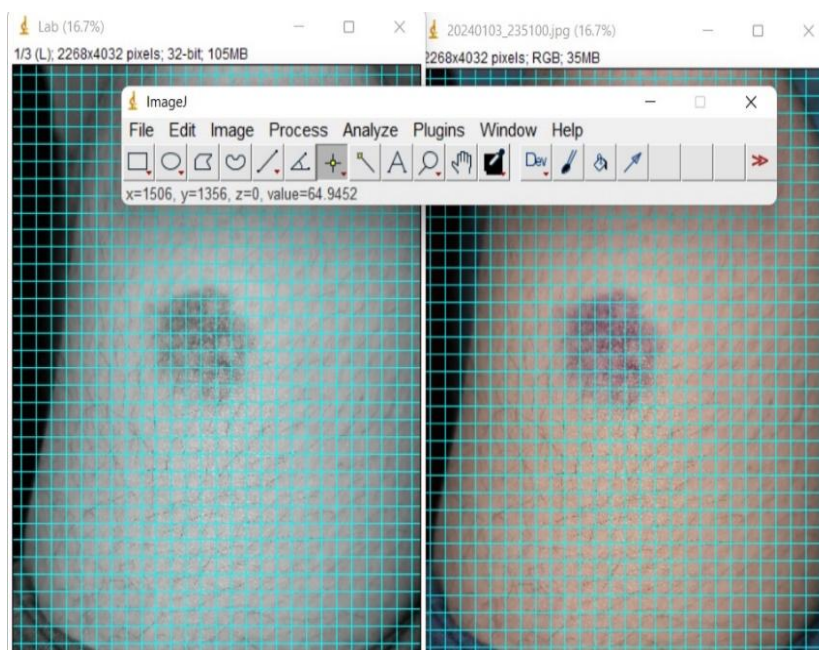


Figure 4. Screenshot from ImageJ® software showing grid and the value L detect from the image.

Table 1. Minimal, maximal, mean and SD of L*, a* and b* value measured on control skin in smartphone photography alone and with cross-polarized dermoscope.

	L*		a*		b*	
	Smartphone Photography	Cross-polarized dermoscope	Smartphone Photography	Cross-polarized dermoscope	Smartphone Photography	Cross-polarized dermoscope
Min	64.8	73.8	3.3	-5.9	-7.6	-4.6
Max	76.0	79.3	13.5	0.8	14.5	-5.8
Mean	70.8	77.1	9.3	-1.2	5.7	0.1
SD	3.1	1.4	3.1	1.5	3.5	2.4

Results

Sample characteristics

A total of 30 bruises were recruited into this study. Duration of wound ranged from 1 to 7 day (mean 3.5 ± 1.8 days); size ranged from 1 to 12 cm² (mean 3.1 ± 2.5 cm²). Most of the bruises were located on the lower extremities. All the bruises were caused by accidentally being hit by blunt objects.

The L*, a* and b* values measured on control skin are summarized in **Table 1**. Cross-polarized dermoscope images yielded a higher mean L value, lower mean a* value and lower b* value. Lower standard deviation was shown in all three parameters.

Purplish-bluish bruises

The L*, a*, and b* values observed in purplish to bluish bruises exhibited a consistent trend: higher L* values accompanied by lower a* and b* values. Using a cross-polarized dermoscope, the mean L* value was

77.6 ± 6.4 , whereas smartphone photography yielded a lower mean L* value of 64.0 ± 6.0 . For the a* values, smartphone photography recorded a mean of 14.3 ± 5.9 , while the cross-polarized dermoscope displayed a significantly lower mean of 8.6 ± 5.0 . Similarly, the mean b* value measured with standard smartphone photography was 5.7 ± 5.4 , whereas the cross-polarized dermoscope showed a lower mean of -0.3 ± 4.6 (**Figure 5**).

The mean ΔE of both modalities were more than 5 which means a clear difference between the two colors.⁽¹⁷⁾ Cross-polarized dermoscope showed a slightly higher mean ΔE of 17.7 ± 7.8 while the mean ΔE of smartphone photography was 14.0 ± 6.2 . The mean ΔE value of smartphone photography was significantly different from the cross-polarized dermoscope-assisted photography ($P < 0.001$).

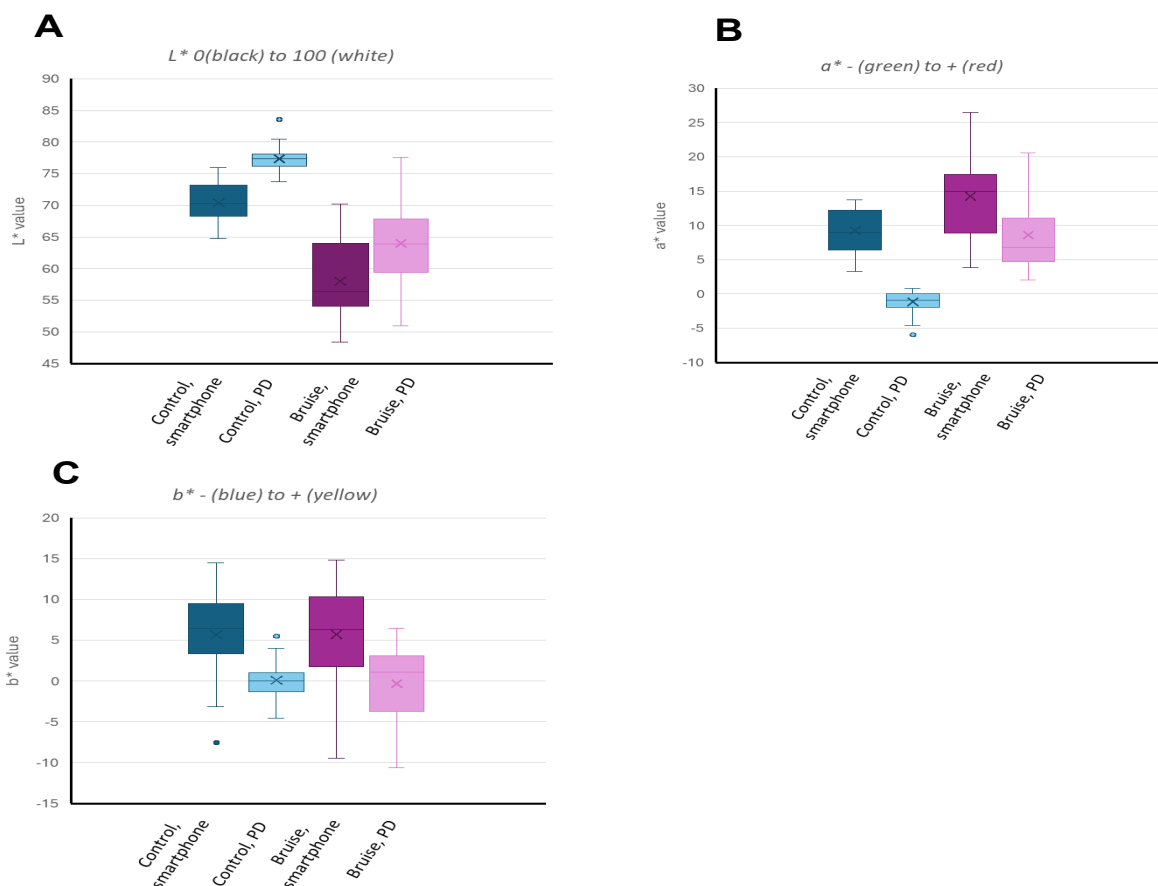
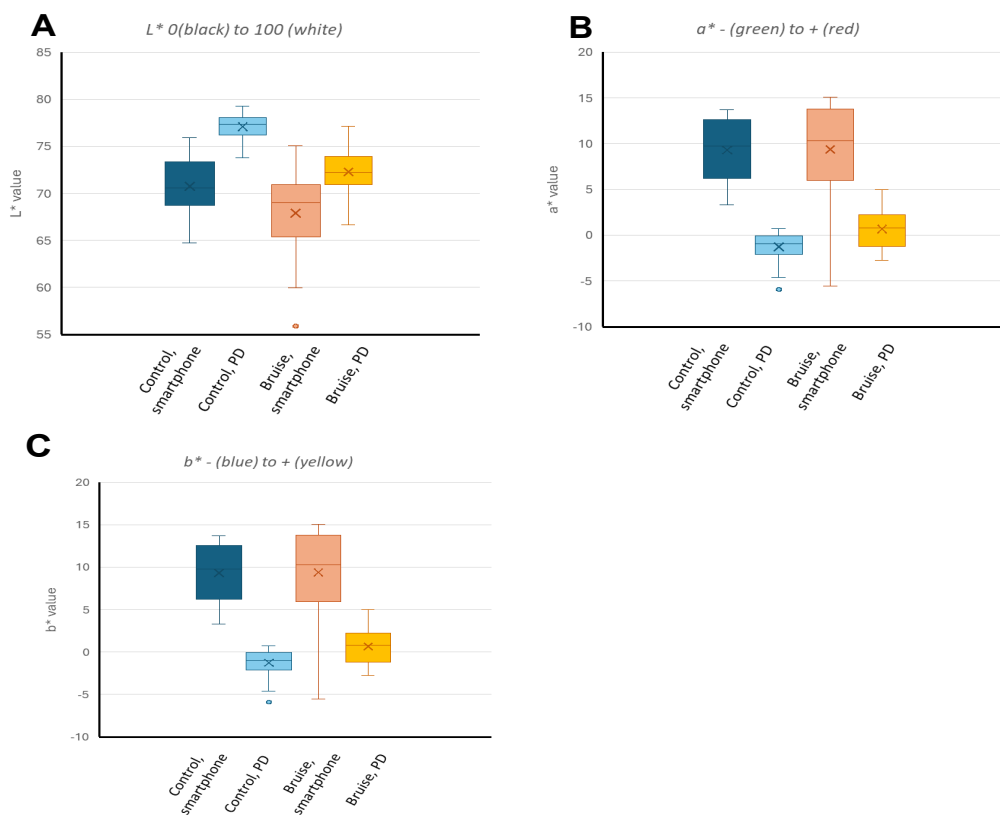


Figure 5. Box plots demonstrate the trend of each color parameter L* (A), a* (B) and b* (C) of the control skin and bruises captured by smartphone and crossed-polarized dermoscope (PD) as labeled



Figures 6. Box plots demonstrate the trend of each color parameter L* (A), a* (B) and b* (C) of the control skin and peripheral yellowish area of bruises captured by smartphone and peripheral dermoscope (PD) as labeled.

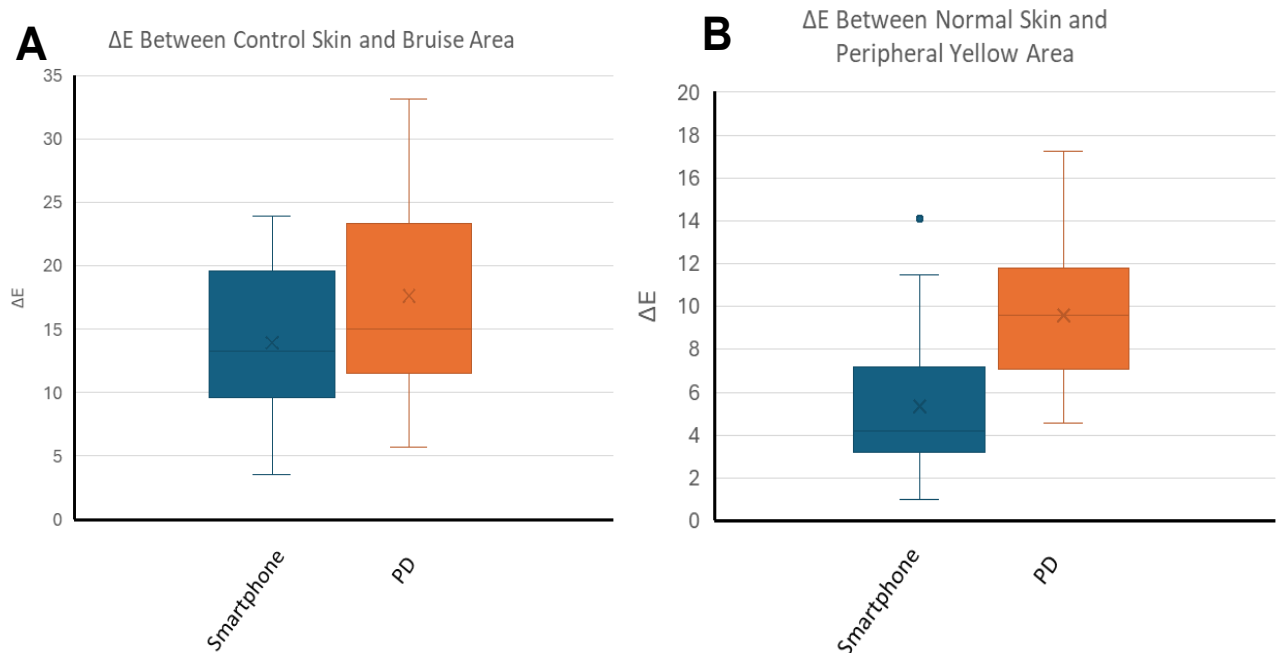


Figure 7. Box plots comparing the ΔE values of smartphone photography and cross-polarized dermoscope (PD) when visualizing the bruise area (A) and peripheral yellow area (B).

Yellowish bruises

Out of 30 bruises, 26 displayed a yellowish hue at their borders. The peripheral areas of these bruises were analyzed to compare ΔE values, all of which exhibited a consistent pattern. The cross-polarized dermoscope produced a mean L^* value of 77.2 ± 2.3 , whereas smartphone photography yielded a lower mean L^* value of 67.9 ± 4.5 with greater variability. The a^* and b^* values recorded by the cross-polarized dermoscope were consistently lower. Specifically, the mean a^* values were 0.7 ± 2.0 for the cross-polarized dermoscope and 9.4 ± 4.6 for smartphone photography. Similarly, the mean b^* values were 6.3 ± 3.4 and 9.1 ± 4.3 for the cross-polarized dermoscope and smartphone photography, respectively (Figure 6).

The mean ΔE of smartphone photography and cross-polarized dermoscope were 5.4 ± 3.2 and 9.6 ± 3.2 respectively. The mean difference is 4.2. There was a statistically significant difference between the ΔE of smartphone photography and cross-polarized dermoscope-assisted photography ($P < 0.001$) (Figure 7).

Discussion

In this study, we focused on comparing images from normal smartphone and cross-polarized smartphone photography in terms of colors parameters differences by using ΔE as an indicator. Both modalities

demonstrated the satisfying average ΔE of more than 5 which indicated an obvious color difference between normal skin and area of bruises. Cross-polarized dermoscope showed a significantly higher ΔE in both purple-blue and yellow bruise analyses. This can be implied that its ability to distinguish colors difference is superior to normal smartphone photography.

When documenting purplish-bluish bruises, the average ΔE of smartphone photography and cross-polarized dermoscope were 14.0 and 17.7 respectively. Both modalities can effectively visualize the bruises. Although the average ΔE of cross-polarized dermoscope were significantly higher, smartphone photography alone is efficient in documenting bruises when purple or blue are vivid.

On the other hand, cross-polarized dermoscope is superior to smartphone photography in documenting yellow bruises. As shown in the result, cross-polarized dermoscope demonstrated an average ΔE of 9.6 while in smartphone photography demonstrated 5.4 which is close to the cut-off of two different colors. Hence, we recommended cross-polarized dermoscope as an assistant tool in documenting faint bruises and older bruises.

Cross-polarized dermoscope demonstrated a less variant range of values. When visualizing purplish to bluish bruises with assistance of cross-polarized dermoscope, the images appeared lighter (Higher L value) with more greenish (lower a^* values) and bluish (lower b^* value). A similar trend also showed on visualizing normal skin. The ranges of all parameters appeared shorter in cross-polarized dermoscope with the higher mean L value, lower a^* value and b^* value. This may be due to its built-in light source placed closer to the skin affecting the image to be lighter. In addition, according to the box plots, the mean value of the color parameters of normal were obviously different and may result in a significantly higher ΔE in cross-polarized dermoscope.

This study purposes a comparison between smartphone and dermoscope photography. The result showed that dermoscope might improve quality of images while documenting older bruises which their color differences decline.⁽³⁾ Moreover, clearer images suggest increased effectiveness of consultation, case reviewing and evidence in jurisdiction. The utilization of dermoscope with smartphones might be an alternative assistant tool in bruise age prediction with its ability to reduce the variation of images quality and color caused by different ambient light. Future prospective works applying dermoscope might improve results of using CIELAB parameters by colorimeter alone. Thus, dermoscope is a convenient portable tool, the images can easily be captured and processed within a smartphone. A previous work on deep learning demonstrated a satisfying precision and accuracy of bruises age prediction; however, the accuracy tends to decline as the bruise age increases.⁽⁷⁾ Further innovative studies on combining both dermoscope and deep learning could result in a more precise bruise age prediction especially in these older bruises.

This study has several limitations. The adjacent normal skin was used as a control point, which may not fully account for individual variations in skin tone. Additionally, the study population was relatively homogeneous, as individuals with extremely dark skin were excluded. Consequently, the findings might apply to populations with lighter or darker skin tones. The study also focused on bruises with duration between 1 to 7 days, and it is possible that older bruises may produce different results. Furthermore, the number of bruises with yellowish borders included in this study

was limited. Previous research has shown that bruises may take up to two to four weeks to resolve.⁽¹⁸⁾ We recommend further studies that include individuals with darker skin tones and examine bruises beyond the initial two weeks. The use of a dermoscope may enhance the visualization and documentation of faint bruises in later stages.

Conclusion

The results indicate a significant difference in ΔE between smartphone photography and cross-polarized dermoscope-assisted photography, highlighting the potential of the dermoscope in documenting bruises. While smartphones are sufficient for capturing vivid purplish-blue bruises, dermoscopes may be more effective in photographing faint or older bruises with a yellowish hue. Further prospective studies could explore the dermoscope's ability to visualize faint bruises that are challenging to capture by an unaided smartphone.

Due to its integrated light source, magnification, and filters, images captured with the cross-polarized dermoscope appeared brighter, with reduced red and blue hues, resulting in more consistent image coloration. In contrast, smartphone photography, especially when using a built-in flash, tended to produce more variable color results. This advantage suggests that the cross-polarized dermoscope be particularly beneficial for color analysis, which has important implications in forensic medicine, such as in the evaluation of livor mortis, bruise aging, and discoloration during the decomposition process.

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Conflict of interest statement

All authors have completed and submitted the International Committee of Medical Journal Editors Uniform Disclosure Form for Potential Conflicts of Interest. All authors declare that they have no conflicts of interest.

Data sharing statement

All data generated or analyzed in the present study are included in the published article. Further details are available for non commercial purposes from the corresponding author upon reasonable request.

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