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A novel, inexpensive, portable, and wireless dermoscopic unit and qualitative demonstrations on the versatility of the device

Antonio Chuh[1,2], **Vijay Zawar**[3], **Regina Fölster-Holst**[4], **Albert Lee**[2]

[1]Department of Family Medicine and Primary Care, The University of Hong Kong and Queen Mary Hospital, Pokfulam, Hong Kong
[2]JC School of Public Health and Primary Care, The Chinese University of Hong Kong and Prince of Wales hospital, Shatin, Hong Kong
[3]Department of Dermatology, Godavari Foundation Medical College and Research Center, DUPMCJ, India
[4]Universitätsklinikum Schleswig-Holstein, Campus Kiel, Dermatology, Venerology and Allergology, Germany

Abstract

Dermoscopes are increasingly being applied to non-cancer skin diseases. However, establishing a high-quality, versatile, and inexpensive dermoscopy system could be difficult. We described how we assembled a novel, portable and wireless digital epiluminescence dermoscopic unit. The total cost was around 2,200 USD. If we leave out the unessential components, the total cost would be 1,200 USD only. We present images taken by our unit on the skin, hairs, nails, and capillaries of our patients. The quality of images was adequate. Twelve levels of polarization allowed versatility in viewing different skin depths. Connection to a camera was unnecessary. Images and videos were stored by pressing a button. A backup wired digital epiluminescence dermoscope ensured smooth examination should any interruption occur in the wireless signal transmission. A second hard drive was in place to back up all the data, preventing data loss and corruption. The patients could view the dermoscopic images concomitantly during clinical examinations. It is feasible to assemble an epiluminescence dermoscopic unit with inexpensive cost, high image qualities, portability, and secure backups. We believe that this type of unit would be suitable and cost-effective for hospitals and medical facilities served by multiple clinicians.

Keywords: Contact dermoscopy, Cross-polarization, Dermatoscope, Dermoscope, Digital epiluminescence dermoscope, polarized light

*Corresponding Author: Dr. Antonio Chuh, Jockey Club School of Public Health and Primary Care, The Chinese University of Hong Kong and the Prince of Wales Hospital, Shatin, Hong Kong. Email: antonio.chuh@yahoo.com.hk

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Introduction

Dermoscopes are being increasingly applied to a wide range of skin diseases, [1-3] including diseases and signs on the hairs, [4-6] nails, [6-8], and capillaries. [7] A wide variety of dermoscopes are available.

Contact dermoscopes deliver excellent images. They are light and highly portable. However, optical magnifications for most units are usually around 10X only. [10] Parts of the images at the four angles could be blurred. The field of viewing could be narrow. Some contact dermoscopes necessitate immersion fluids, thus introducing air bubbles. [11] Longer time would be necessary to examine multiple lesions, as fluids have to be applied to successive lesions. [12] Moreover, adaptors might be required for connection to cameras, which might adversely affect the quality of images.

Contact dermoscopy also inherently carries a risk, albeit small, of cross-infection. [13, 14] Various measures can minimize such risk. [15] However, such would consume time and human resources. Moreover, the images can usually be visible for the clinician only. The patients and other persons might not be able to have a glance.

Digital dermoscopes mostly utilize cross-polarization to achieve epiluminescence. Newer

epiluminescence dermoscopes also offer a range of polarities, rendering a choice of depths of the skin to be examined.

For digital dermoscopes, the clinician, the patient, and other people can view the images together. A head is usually the part of the scope that comes into contact with the skin. This achieves a fixed distance between the lens and the skin, allowing for precision in focusing by the viewer. No fluid is necessary. Moreover, some models have image and video capturing components on board, which would not affect the quality of images captured.

However, the site of the monitor is usually fixed. The patient might not be able to look at the images when some body parts, such as the back, are being examined, unless the cable between the scope and the monitor is exceptionally long. Moreover, cables are necessary to connect the various components of the unit. At the very least, a power cable is necessary. These limit the portability of the unit.

Our aim in this report is to explore whether it is feasible to assemble a novel and inexpensive epiluminescence dermoscopy unit with high image qualities, the images being visible to clinicians and patients in most circumstances, the unit being mobile within a hospital or a medical facility without the need for re-wiring, and the data being securely stored.

We shall denote *portable* as being able to be moved around a hospital or a medical facility swiftly, not referring to a scope that can be put into the pocket. We shall then demonstrate the results for a range of conditions affecting the (i) skin, (ii) hairs, (iii) nails, and (iv) capillaries.

Materials and methods

We attained a medical cart with a steel skeleton (Figure 1). The maximum load weight was 26 lbs. The wheels were 10 cm in diameter for stability as well as for easy maneuvering. Brakes on all four wheels prevented accidental tumbling. We also plotted the specifications of its size against the construction plans of our surgery, ensuring that the unit could pass through the corridors and doors of our consulting suites and procedure rooms.

We then attained a wireless digital epiluminescence dermoscope. The resolution was two megapixels. Twelve levels of polarization were available. It provided 50X optical magnification and 150X digital magnification, and could record in real time with 30 frames per second.

We connected the receiver of the scope to a laptop computer via a USB 2.0 port. The screen on the laptop was of 15-inch only, and could not be clearly viewed by the clinician and the patients at distances longer than around one meter. We thus installed a 24-inch LCD monitor onto the cart, and connected such to the laptop via HDMI.

The rechargeable battery of the laptop could not provide enough power to the monitor. We estimated the total energy necessary for the monitor, the laptop, and the accessories for a typical working day, and multiplied such by a 1.5X safety factor. We then incorporated a rechargeable power generator with 110V AC out at 300 watts, having ensured that charging overnight would render the generator delivering adequate energy as calculated by us.

In common with other wireless electronic devices, there carries a risk of interruptions in data transmission from the dermoscope to the receiver. We thus also acquired a backup wired dermoscope, and connected such to the laptop. We viewed the images via a generic image and video capture program at the same frame rate of 30 per second.

Dermoscopic images are part and partial of clinical records. To guarantee the reliability of the unit for data storage, we integrated a physically separate hard disc drive as a backup device. We also protected access to the data in the laptop and the separate hard disc drive by regularly updated passwords known to our staff only.

The total cost of our unit turned out to be around 2,200 USD. If we cut off the basket for holding accessories, another basket and handle kit, an adapter for the wired dermoscopy, the wired dermoscope, the HDMI selector, and the second hard-disc, and use a manufacturer-refurbished laptop, the amount would be around 1,200 USD only. This would be an acceptable cost for hospitals and health facilities with at least several clinicians. Such system will still be totally wireless, portable, no re-wiring necessary, with images saved by pressing one bottom. This functional difference would only be the absence of the second hard disc, which can be less conveniently, but still be easily, replaced by a USB 2.0 drive.

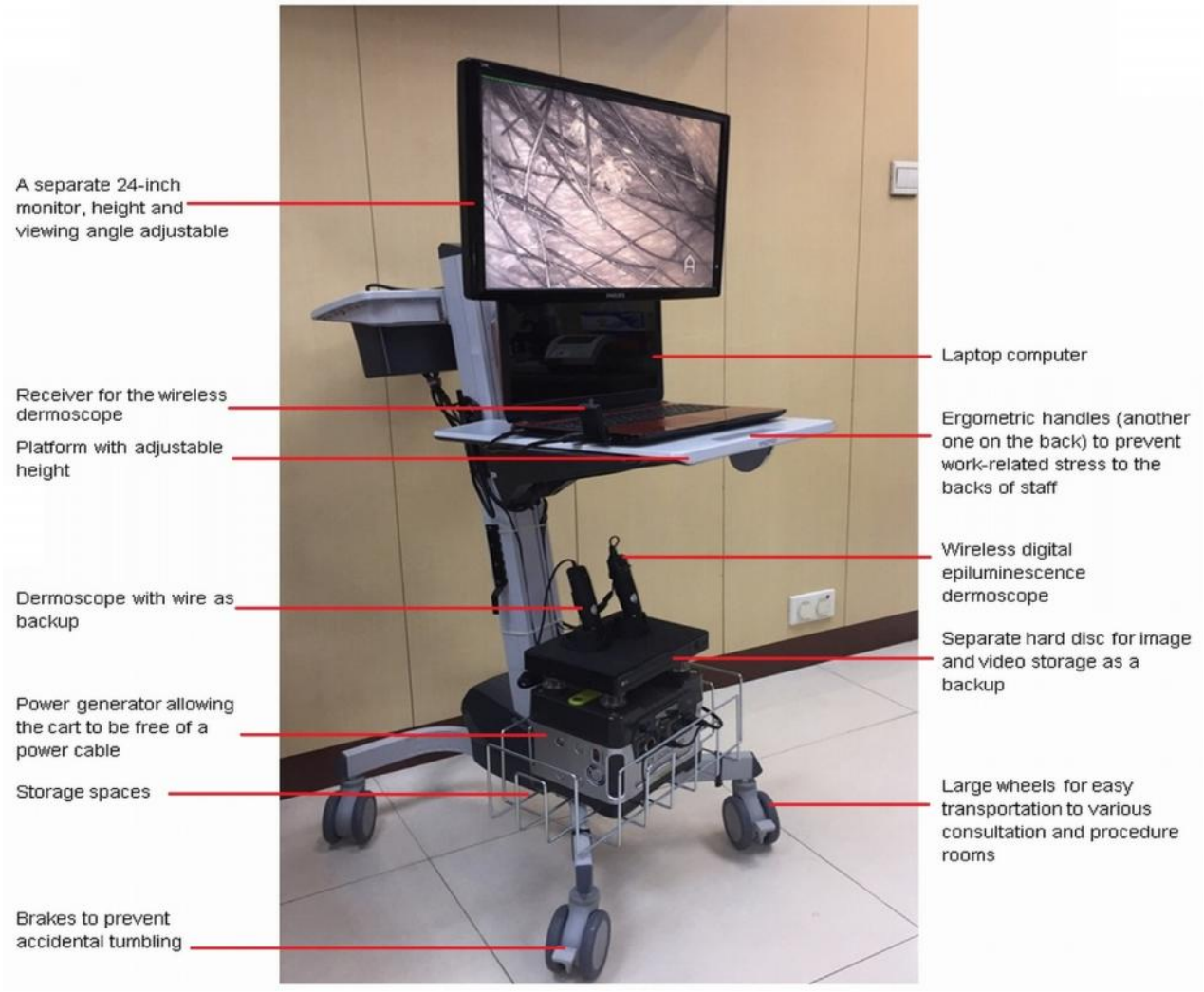


Figure 1: A portable, wireless, and economical dermoscopic unit.

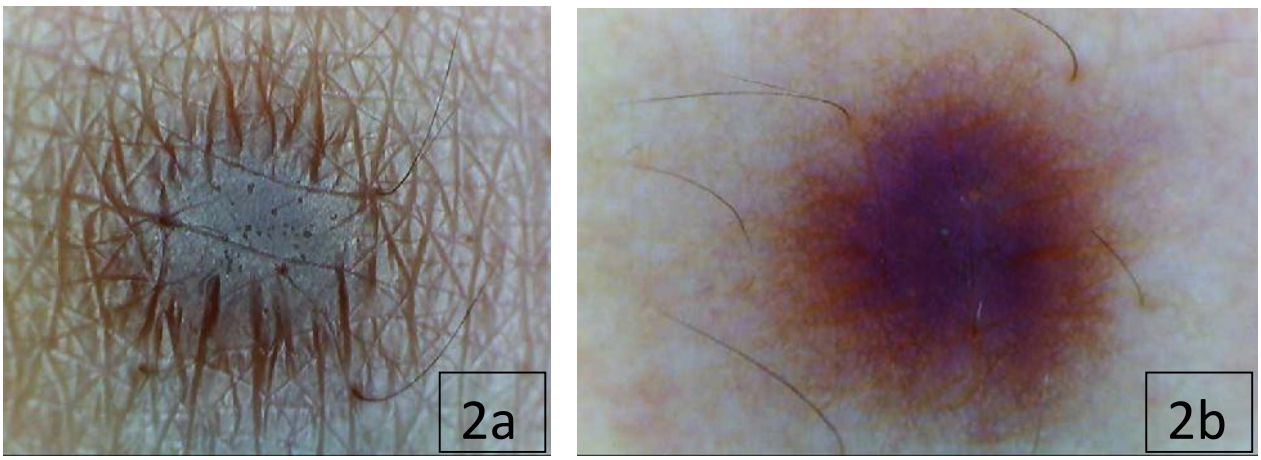


Figure 2a: Image of pigmented melanocytic naevus on the upper back of a 23-year-old male taken by dermoscope without polarized light. Little detail is visible owing to the focus only on the outermost stratum corneum and the distracting lines of skin creases. **Figure 2b:** Image of the same lesion as for Figure 2a taken by epiluminescence dermoscopy. The depth was around the dermal-epidermal junction, and lines of skin creases are obliterated. The colour, reticular pattern of pigmentation, symmetry, margin, and lack of perilesional induration were much clearer than in Figure 2a.

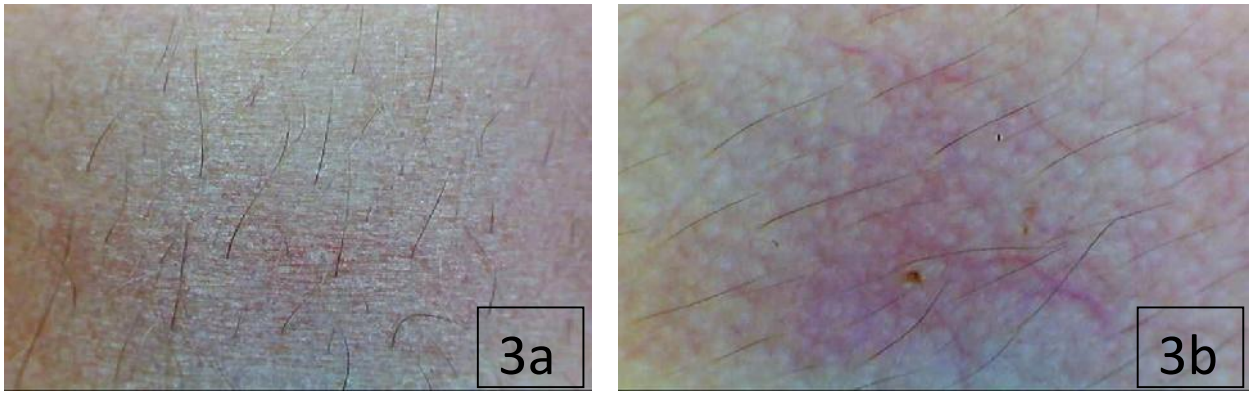


Figure 3a: Image on the cheek on a 12-year-old girl with virologically confirmed erythema infectiosum due to parvovirus B19 infection taken by dermoscopy without polarization. Only erythema was notable. **Figure 3b:** Image on the cheek of the same patient in Figure 3a, taken by epiluminescence dermoscopy. Telangiectasia in a reticular configuration was clearly portrayed. This is a characteristic clinical feature for the slapped-cheek area.

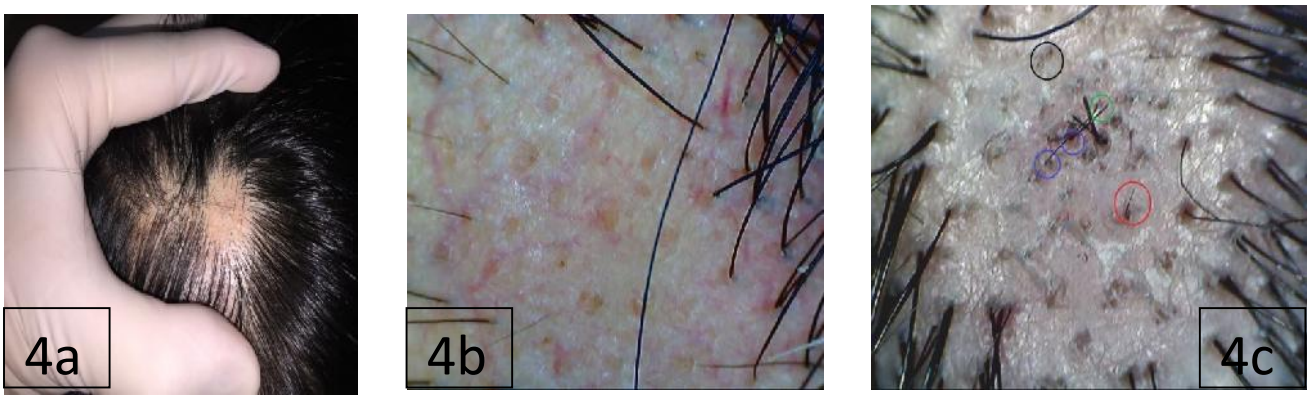


Figure 4a: Alopecia areata on the vertex of a 32-year-old female with alopecia areata. **Figure 4b:** *Yellow spots* which were reported to be highly characteristic of alopecia areata [5] under digital epiluminescence dermoscopy, from the boy as in Figure 5a. **Figure 4c:** *Black dots* which were remnants of hair follicles (encircled in black), *broken hair* (encircled in red), and suspected *tapering hairs* [5] (follicular ends encircled in blue, broken ends encircled in green).

We applied our dermoscopic unit to our patients with dermatological diseases. We demonstrated the images, taken with or without epiluminescence, on the (1) skin, (2) hair, (3) nails, and (4) capillaries of these patients.

Results

The dermoscopic images below could be captured with a dermoscope and a computer only. However, we still elected to present dermoscopic images taken by our unit on patients because: (i) The wireless transmission of signals could adversely affect the quality of the images, and (ii) The unit as a whole would be driven by the electricity regenerator. This generator was supplying power to five devices via 110W AC and USB 2.0. Fluctuations in the power supply could also have adversely affected the stability of the images.

(i) Skin

We used our dermoscopic unit without polarization to examine a pigmented lesion on the upper back of a 23-year-old male patient (Figure 2a). Our provisional diagnosis was junctional or compound melanocytic naevus. We noted little new information comparing Figure 2a to examination by our naked eyes. However, upon application of polarized light set at fairly high level (Figure 2b), the pigmented network, symmetry, shades of colors, and margins of the lesion were depicted much more clearly. We and the patient viewed the lesion on the screen concomitantly. We reassured the patient that no malignant and no pre-malignant change was present,

examined his other skin areas, and arranged a follow-up visit six months later.

We then examined the cheek of a 12-year-old girl with suspected erythema infectiosum. Figure 3a was the dermoscopic view taken without polarized light. Only erythema was noted. However, under polarized light set at a moderately high level (Figure 3b), the characteristic reticular configuration of dilated blood vessels became clearly seen. Such pattern was well known for the truncal rash. The presence of such also on the cheeks (within the *slapped cheek* region) was reported previously. [16] Without any cable between the girl and the unit, the girl herself could see the images concomitantly when we examined her.

We called the class mistress of the girl, and advised sick leave for two days only, as (i) the clinical and dermoscopic signs were quite characteristic of erythema infectiosum, and (ii) virus shedding is virtually negligible once the skin eruption is seen. [17] The diagnosis was later confirmed by PCR for parvovirus B19 DNA and seroconversion for IgG against this virus in her acute and convalescence sera as investigated in parallel.

(ii) Hairs

Figure 4a depicts lesions for a 32-year-old female with alopecia areata. Known dermoscopic findings in alopecia areata are vast. [5] We attempted to demonstrate a few features here only. Figure 4b demonstrated *yellow dots* under epiluminescence dermoscopy. Figure 4c demonstrated skin atrophy. Remnants of hair follicles were sparse and small (*black dots*, encircled in black). A *broken hair* [5] was seen, encircled in red. Two hairs in the middle of the lesion might be demonstrating the *tapering hair* sign (*exclamation mark*) ,[5] with the proximal ends near the follicles (in two blue circles) being thinner and the distal parts (in one green circle) being thicker.

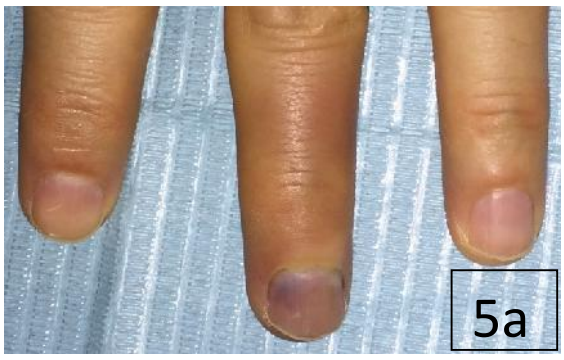
We viewed the dermoscopic images with the patient together, and explained these features to her. Based on these findings and other factors, we explained that the organ-specific autoimmune activity was still high then, and that further hairless lesions could be expected in the near future, which did happen subsequently. The use of epiluminescence dermoscopy had thus secured the trust of the patient on the clinician. Such might enhance the doctor-patient relationship and facilitate future treatments.

(iii) Nails

Polarized light was adopted to achieve epiluminescence in Figure 5b, showing subungual changes of hematoma formation and paronychia after an accidental blunt injury to the right middle finger of a patient. These changes were much clearer than the original clinical photo (Figure 5a).

Figure 6 shows totally dystrophic toenail onychomycosis. Adopting polarized light at any level or not was of lesser importance here, as the thickened nail was *dermoscopically opaque*. Our aim was to exploit the high magnification of a dermoscope to document the clinical features before treatment.

Figure 7 depicts coalescence of fingernail pits to form gloves and canals, from a 24-year-old lady. She was systemically well. We noted no sclerodactyly, no psoriatic plaques, no myalgia, and no polyarthralgia. We reassured the patient that pitting was rarely associated with underlying medical diseases, [18] and did not investigate any further.



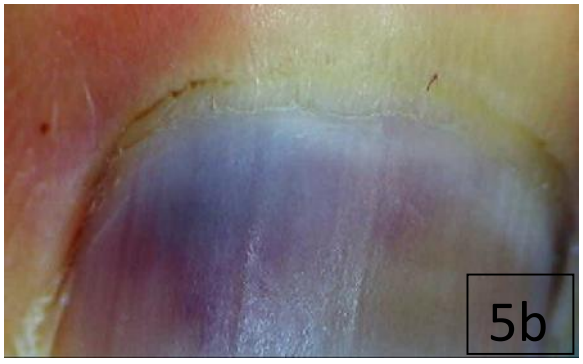


Figure 5a: Clinical photography emphasizing changes in the distal phalange of the right middle finger of a 23-year old female after a blunt compression injury. **Figure 5b**: Epiluminescence dermoscopic view showing subungual hematoma formation and paronychia. The patient subsequently developed an abscess for which incision and drainage had to be performed.

(iv) Capillaries

We present here the application of our dermoscopy unit to two patients. We did not incorporate a formal capilloscope for nailfold capilloscopy.

Figure 8a shows a 24-year-old male consulting us for a three-week history of pruritic papules and pustules on his neck, upper chest, and upper back. The lesions would flair up as highly pruritic wheals intermittently, with no precipitating factor identified.

Figure 8b taken without epiluminescence depicted perilesional erythema and induration only. Figure 8c, taken with polarized light, captured features at a level around the dermo-epidermal junction. Intra- and inter-lesional dilated capillaries were lucidly demonstrated. Complete blood picture revealed eosinophilia (1.4 X 10^9/L; reference: less than 0.2 X 10^9/L). HIV-1 and -2 antibodies and P24 antigen were negative. The patient declined a lesional biopsy for histopathology. Based on the symptoms, the urticarial flares, the epiluminescent dermoscopic findings, and the eosinophilia, we diagnosed eosinophilic folliculitis, and treated the patient accordingly.

The entire unit ran smoothly during all the stages of examination, data storage, and data retrieval. The qualities of all the images were adequately high for diagnostic and severity assessing purposes. The backup dermoscope and backup hard drive performed as intended during testing, although these were not necessitated at all during the clinical encounters with all the patients reported above.

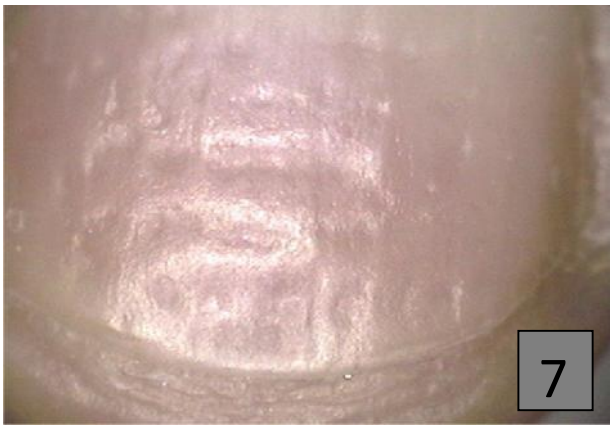
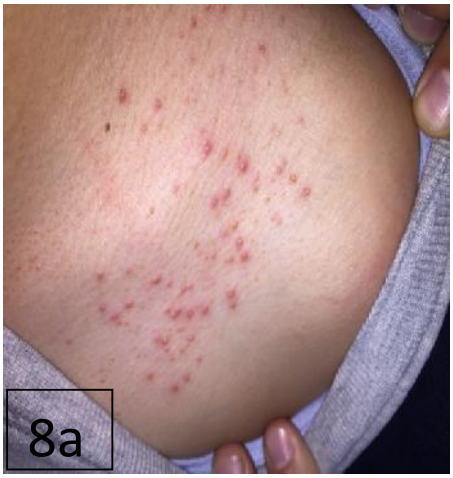
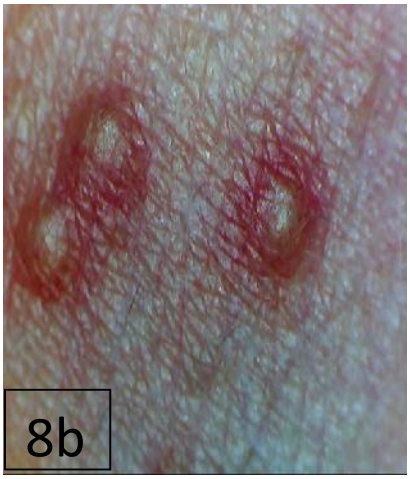


Figure 6: Left big toenail of a 47-year-old man with toenail onychomycosis. The severity was totally dystrophic. The role of dermoscopy would be for documentation only. Differences between images taken with or without polarized light would be minimal and would not modify clinical decisions. **Figure 7**: Pitting on a fingernail of a 24-year-old female.





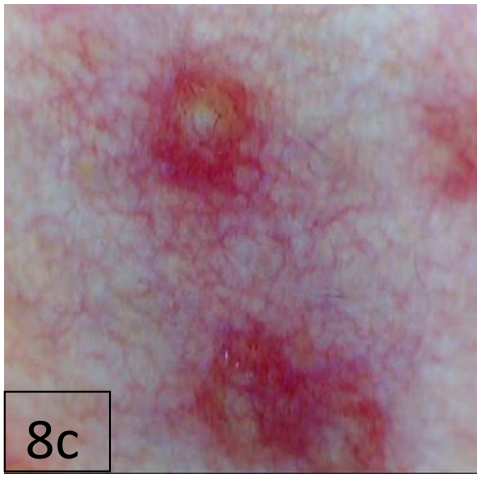


Figure 8a: A 15-year-old body with eosinophilic folliculitis. **Figure 8b:** Dermoscopic image without polarized light for the boy in Figure 9a revealed perilesional erythema and induration. **Figure 8c:** Digital epiluminescence dermoscopy of the same patient revealed intra-lesional and inter-lesional dilated capillaries.

Figure 9: Digital epiluminescence dermoscope-guided operation by one of the authors (AC). The magnification allows for high precision to achieve complete excision of lesions and minimum damage of the peri-lesional tissues and structures

Discussion

Dermoscopes were originally introduced to diagnose melanoma and other skin cancers. Currently, dermoscopes have been reported to be applicable in a wide range of skin diseases. The application of digital epiluminescence dermoscopy on pityriasis rosea [19], pseudofolliculitis barbae and ingrown hairs, [20] vitiligo, [21] pearly penile papules, [22] and pediculosis pubis [23] were originally reported by us.

We soon realized that there existed no system which offered a view for the patients, provided high quality images, had camera on board, was mobile within a hospital or a medical facility, incorporated devices against interruptions in signal transmission and against data loss, and was relatively inexpensive.

These represented the challenges for us to overcome in assembling our unit. Our unit displayed the images on a relatively large LCD monitor. Such would allow concomitant viewing by the clinician, patients, their family members, medical students, and specialist trainees. The qualities of the images and videos were adequate for clinical decision-making. Multiple polarity settings allowed the clinician to select the depths of the skin to be visualized.

The patients can follow our examination as we progress to examine their various skin surfaces. When we scope the back, we would place the wireless dermoscope onto the back (Figures 2a and 2b). The clinician and the scope move, but the patient and the unit do not. The patient can fix his eyes on the screen while we keep on describing the dermoscopic findings and the impacts of such on their managements. The same goes true when the faces of patients are being examined (Figures 3a, 3b).

The incorporation of a large-capacity AC generator allows us to abbreviate a power cord. The unit can thus be tugged through relatively narrow corridors and corners to various rooms conveniently. The platform is adjustable in height, therefore suiting the height and postures of the clinicians and the patients. The handles on the front (Figure 1) and back are also ergometrically designed, minimizing stress to the back of our staff while maneuvering the unit around.

Clinical imaging of any nature can be part of the official medical record. Our unit does not necessitate a separate camera or adaptors to be connected to a camera. The images and videos start to be stored once we press a button. We also put focus to prevent instrumental failure, data loss, data corruption, and data leakage.

As a contingency measure for instrumental failure, we incorporated a second dermoscope wired to the laptop. This ensures continuity of the dermoscopic examination should any interruption occur in the transmission of the wireless signals. Against data loss and data corruption, we incorporated a second hard drive to back up all the data. Against data leakage, we connected no external device to the laptop and the hard disc through signal cables or Wi-Fi. Moreover, access to the laptop and the separate hard disc drive are password-protected.

To our best knowledge, our dermoscopy unit with the aforementioned capabilities and costs has not been assembled or reported. We believe that our dermoscopic unit would be most suitable for medical centers with multiple clinicians. The unit can readily be moved into various rooms. Upon adequate training, these clinicians such as general practitioners would reach higher diagnostic accuracies, and would deliver appropriate and timely managements to patients. Moreover, teledermatology via dermoscopes is a current trend in telemedicine. [24, 25] With our unit, several clinicians within a hospital or a medical facility might consult each other, or consult a dermatologist outside the facility conveniently.

A future dimension of our dermoscopic unit would be DED-guided operations for delicate

surgical procedures (Figure 9). With this approach, the magnification would assist for the complete excision of pathological skin lesions with adequate margin, as well as minimizing collateral damage to adjacent tissues. We shall cover DED-guided surgical procedures in forthcoming reports.

A significant limitation in our setup is the image resolutions not being optimal. We believe that the qualities of the images here are already adequate for usual diagnostic and documentation purposes. However, images with higher qualities are always better for the detection of fine dermoscopic details. One further weakness is the absence of indications of sizes or magnifications in the images.

Another limitation is that we have not yet incorporated a capilloscope. Dermoscopy at its very best could not replace the value of capilloscopy for the examination of features in nailfold capillaries to assist in the diagnoses of systemic diseases. [25] Along the same veins, we have not incorporated a proper trichoscope to examine patients with hair loss and connective tissue diseases. [26]

Lastly, we should remind ourselves that dermoscopes, in any form and at any price range, remain to be clinical tools only. All clinicians using dermoscopes should be properly trained. Technological advances and sophistications in skin imaging can never replace our diagnostic acumen, clinical experience, and care for patients with skin diseases.

Conclusion

We conclude that it is feasible to assemble a novel epiluminescence dermoscopic unit with high image qualities, the images being visible to clinicians and patients, the unit being portable within a medical facility without the need for re-wiring, the data being securely stored with back-up, and the unit being affordable. We believe that this type of unit would be most suitable and most cost-effective for hospital and medical centers to be used by multiple clinicians.

Declaration on conflict of interests

We hereby declare that there are no known conflicts of interest associated with this publication. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. We received no subsidy and no financial support for all the equipments used or appeared in this article. The equipments can be replaced or substituted by other items of similar or compatible functionalities of any certified manufacturer. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property. We understand that the corresponding author, Antonio Chuh, is the sole contact for the editorial process (including Editorial Manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by Antonio Chuh and which has been configured to accept email from all the authors.

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