Dermatol Ther (Heidelb) (2024) 14:361–390
https://doi.org/10.1007/s13555-024-01104-4

REVIEW

Applications of Ultraviolet and Sub-ultraviolet Dermatoscopy in Neoplastic and Non-neoplastic Dermatoses: A Systematic Review

Paweł Pietkiewicz · Cristian Navarrete-Dechent · Yaei Togawa · Piotr Szlązak · Natalia Salwowska · Ashfaq A. Marghoob · Agnieszka Leszczyńska-Pietkiewicz · Enzo Errichetti

Received: December 19, 2023 / Accepted: January 17, 2024 / Published online: February 15, 2024

ABSTRACT

Dermatoscopy is a non-invasive and cost-efficient imaging technique augmenting clinical examination in neoplastic and non-neoplastic dermatoses. Recently, novel dermatoscopic techniques based on principles of reflectance/absorption and excited fluorescence have been developed. However, comprehensive data on their applications are sparse, and terminology is inconsistent. In this systematic review, we addressed the principles of ultraviolet (UV) imaging and proposed categorization based on spectral characteristics and signal acquisition, as well as discussed documented and potential clinical applications, safety measures during examination, and limitations associated with reflectance and fluorescence dermatoscopy. A literature search was conducted in the PubMed medical database until 2 December 2023 according to PRISMA guidelines, and 28 papers fit the scope of this review, whereas additional relevant articles were included to provide broader context regarding the chosen terminology, chromophores described, safety of sub-UV/UV, and regulations for light-emitting devices. UV and sub-UV dermatoscopy, categorized into different methods on the basis of the emitted wavelength and signal acquisition process (reflectance versus fluorescence), augment conventional dermatoscopy by optimizing safety margins in melanoma, facilitating early

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13555-024-01104-4.

P. Pietkiewicz (✉)
Zwierzyniecka Medical Center, Zwierzyniecka 30/28, 60-814 Poznań, Poland
e-mail: pietkiewicz.pp@gmail.com

P. Pietkiewicz · P. Szlązak · N. Salwowska · A. Leszczyńska-Pietkiewicz
Polish Dermatoscopy Group, Poznań, Poland

C. Navarrete-Dechent
Melanoma and Skin Cancer Unit, Department of Dermatology, Escuela de Medicina, Pontificia Universidad Católica de Chile, Santiago, Chile

Y. Togawa
Department of Dermatology, Chiba University Graduate School of Medicine, Chiba, Japan

P. Szlązak
Dermedica, Gdansk, Poland

N. Salwowska
Department of Dermatology, School of Medicine, Medical University of Silesia, Katowice, Poland

A. A. Marghoob
Dermatology Service, Department of Medicine, Memorial Sloan Kettering Cancer Center, New York, USA

E. Errichetti
Institute of Dermatology, "Santa Maria Della Misericordia" University Hospital, Udine, Italy

detection of tumor recurrence, and enhancing visualization in non-neoplastic conditions, including pigmentation disorders, intertrigo, papulo-desquamative dermatoses, and beyond. The review highlights the limitations of these techniques, including difficulty in differentiating melanin from hemoglobin, challenges in evaluating uneven surfaces, and artifacts. Although UV dermatoscopy complements conventional dermatoscopy, clinicians should be aware of their peculiarities, artifacts, limitations, and safety concerns to optimize their diagnostic accuracy and ensure patient's safety.

Keywords: Absorption; Dermatoscopy; Entomodermatoscopy; Imaging; Infectoscopy; Reflectance; Skin cancer; Skin diseases; Ultraviolet radiation

Key Summary Points

Dermatoscopy is a non-invasive and cost-efficient imaging technique, useful in augmenting the diagnosis of neoplastic and non-neoplastic dermatoses. Ultraviolet and sub-ultraviolet light dermatoscopy are innovative auxiliary diagnostic modalities capable of visualizing clues not discernible with conventional dermatoscopy.

The literature on this topic is limited, and the terminology used is inconsistent and misleading, necessitating systematization based on the emitted wavelength and the major physical principle behind each method (fluorescence versus reflectance).

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and involved a comprehensive literature search in the PubMed medical database, focusing on papers related to fluorescence or reflectance dermatoscopy using ultraviolet and sub-ultraviolet radiation.

Apart from major clinical applications, the review addresses the photobiological safety, limitations of each method, and possible artifacts.

Fluorescence and reflectance dermatoscopy complement the diagnostic armamentarium in dermatology, may shorten the diagnostic path, narrow the differential diagnosis, and drive therapeutic decisions.

INTRODUCTION

Dermatoscopy stands as a useful, non-invasive, and cost-efficient diagnostic tool, revolutionizing dermatologic clinical practice by enhancing diagnostic accuracy in both neoplastic and non-neoplastic dermatoses, reducing unnecessary excisions and diagnostic biopsies. Moreover, it may guide the management of inflammatory skin diseases and serve as an aid in monitoring response to therapy and the early detection of treatment-related side effects [1].

Within the realm of dermatoscopy, ultraviolet (UV) and sub-UV dermatoscopy have recently emerged as innovative modalities employing high-energy, short-wavelength light-emitting diodes. Nevertheless, comprehensive data on the extent of their applications is lacking and the terminology surrounding those novel methods is often inconsistent and misleading, contributing to confusion, as various imaging methods claim the term "UV dermatoscopy."

In this systematic review, we focused on several key aspects, including the basics of UV imaging, the mechanisms of signal reception, the categorization of these methods based on their spectral characteristics, their documented and potential clinical applications, and the safety measures required during examinations. Additionally, we explored the limitations associated with both UV and sub-UV dermatoscopy techniques.

METHODS

This systematic review was structured in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist. A comprehensive search was conducted in the PubMed medical database on 2 December 2023, using the following keywords: ("ultraviolet" OR "UV" OR "fluorescence" OR "reflectance" OR "violet" OR "purple") AND ("dermatoscopy" OR "dermoscopy" OR "trichoscopy"). We focused on all types of papers related to fluorescence or reflectance dermatoscopy using UV and sub-UV (called purple or violet light by some authors) in general dermatology and dermato-oncology. All records were independently screened by the first two authors for relevance. From a total of 1060 records identified, 26 were found directly relevant to the scope of this review: 7 studies, 2 case series, 15 case reports, and 2 narrative reviews. We excluded papers focusing on fluorescence-assisted videodermatoscopy and UV-enhanced visualization, as these methods were deemed not closely related enough neither to fluorescence nor reflectance dermatoscopy for the purpose of this review.

To ensure the comprehensiveness and currency of our study selection, a full forward and backward citation search was performed on all included papers until 2 December, leading to the addition of two extra papers (one narrative review and one study in press by some of the coauthors). The flow diagram for the papers' selection is illustrated in Fig. 1. Another 41 references were included to provide a broader context regarding the terminology, chromophores, safety considerations of sub-UV/UV, and regulations for light-emitting devices.

This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

The Basic Principles of UV Dermatoscopy

The primary wavelength of light emitted by UV dermatoscopes/videodermatoscopes falls into either close, low-energy UV (UVA spectrum: 320–400 nm) or sub-UV (violet-blue light spectrum: 400–425 nm). There are currently no UVB dermatoscopes available. UVB exposure would pose significant risks to both the skin and the eyes, necessitate higher energy consumption resulting in faster battery drain, and produce significantly weaker reflection signals due to greater scattering, causing radiation in this spectral range to penetrate very shallowly into the skin and ultimately diminishing image clarity and limiting its clinical use.

Sub-UV/UV dermatoscopy relies on five fundamental interactions of the radiation with the skin: reflection, penetration, absorption, scattering, and the Stokes shift phenomenon. The Stokes phenomenon corresponds to the emission of visible fluorescent photons by sub-UV/UV-excited chromophores (Table 1). This energy creates a "shift" toward longer wavelengths, usually belonging the visible light spectrum [2].

Although various methods have been categorized as "UV dermatoscopy," it should be recognized that these methods differ significantly from a technical standpoint. For precise categorization, we propose a simplified nosological system to distinguish between them on the basis of the physical properties of the emitted wavelength (UV versus sub-UV) and the process of signal acquisition (fluorescence versus reflectance as a predominant phenomenon): sub-UV reflectance dermatoscopy (sUVRD), sub-UV-induced fluorescence dermatoscopy (sUVFD), UV reflectance dermatoscopy (UVRD), and UV-induced fluorescence dermatoscopy (UVFD) (Figs. 2, 3).

These distinctions are in line with the terminology already used in photography (UV-induced fluorescence photography [3–6] and UV reflected/reflectance photography [7, 8]. We intentionally added the "sUV/UV-induced" prefix to fluorescence dermatoscopy to emphasize that no UV signal is received by the eye. This serves to underline that there are no UV-related safety concerns associated with this method. It also helps to specifically distinguish this method from other possible diagnostic modalities based on blue light-induced fluorescence. Even though we are aware that physical reflection/absorption are common phenomena

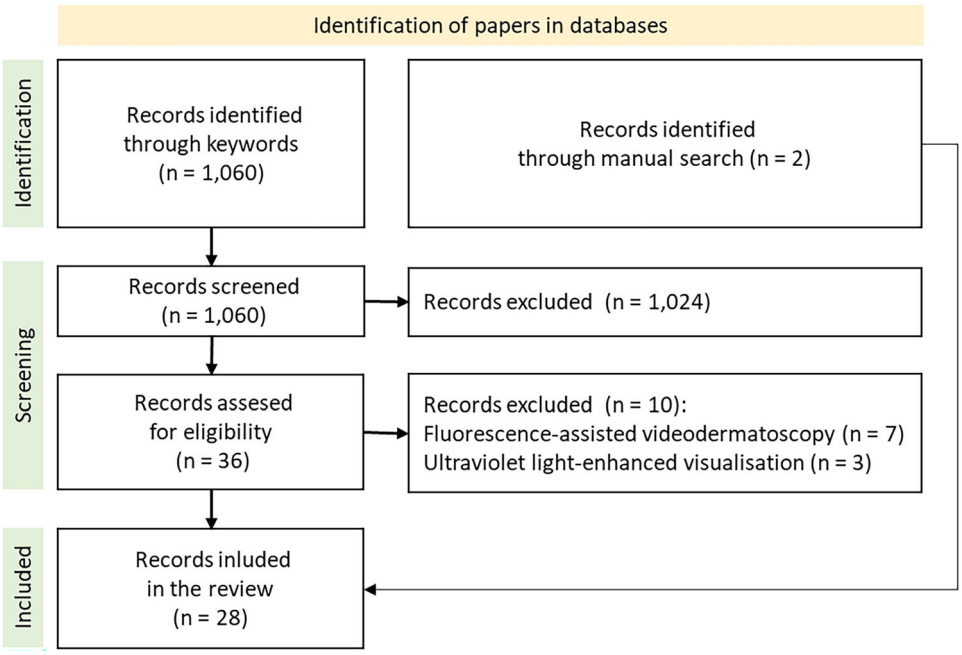

Fig. 1 Flow diagram showing the process of data extraction, screening, and eligibility check of all the records, following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines

in fluorescence dermatoscopy, these do not play a key role in producing images and are not responsible for the unique character of each of these methods.

While sUVFD fills a gap in our model, at present, there are no reports of the existence or usage of sUVFD devices. This imaging technique seems feasible. However, it is expected to involve fewer chromophores capable of generating excited emissions.

Reflectance Dermatoscopy

sUVRD In sUVRD, the dermatoscope's light source emits visible violet–blue light. This diagnostic method is based on physical differences in absorption spectra among skin chromophores. Sub-UV radiation is sometimes misleadingly referred to as near-UV [9, 10], although according to the ISO 21348:2007 Standard, true near-UV spans from 300 nm to 400 nm, encompassing UVA and a portion of UVB [11], while sub-UV belongs to the visible light spectrum and has lower energy than UV. It is absorbed by main chromophores (namely hemoglobin and melanin), and reflected by others (e.g., keratin) (Fig. 4). After filtering out other wavelengths, the camera's internal sensor records the intensity of the reflected sub-UV signal and converts it into a grayscale image displayed on the digital screen. The use of a physical sensor is designed to minimize the risk of eye damage. Currently, D'z -D100 dermocamera (peak wavelength 405 nm; Casio, Japan) is the only device offering sUVRD capabilities.

Applications of sUVRD

Dermato-oncology

In a study comparing a number of features in pigmented lesions, the demarcation of melanomas and melanocytic nevi was better with sUVRD than in polarized dermatoscopy [10]. This ability to distinguish areas with enhanced/decreased pigmentation allowed the use of sUVRD in the optimization of safety margins in patients with acral lentiginous melanoma [9, 12]. Such a use has the potential to reduce the costs associated with surgical procedures, potentially leading to fewer stages in Mohs micrographic surgery or other staged excision techniques (e.g., square technique). Furthermore, it may assist in the early detection of

Table 1 Major ultraviolet-excited fluorochromes and associated conditions

Color	Responsible fluorochrome	Condition (causal factor)
Pink to red	Protoporphyrin IX	Psoriasis (unknown)
Orange to red	Coproporphyrin III	Comedonal acne, alopecia areata, progressive macular hypomelanosis (*Cutibacterium* ssp.), erythrasma, pitted keratolysis (*Corynebacterium minutissimum*)
Yellow	Unknown	Trichobacteriosis axillaris (*Corynebacterium* ssp.)
Yellow	Unknown	Scabies feces (*Sarcoptes scabiei*)
Yellow to green	Pteridine	Tinea corporis and tinea of the glabrous skin (*Microsporum canis, Microsporum gypseum*)
Light green	Pityrialactone	Pityriasis versicolor (*Malassezia furfur*)
Green	Pyoverdine	Skin and nail infections (*Pseudomonas aeruginosa*)
Green	Bilirubin	Serum (erosion, visicle)
Green to blue	Unknown	Scabies mite (*Sarcoptes scabiei*)
Blue	Keratin	Malassezia folliculitis (*Malassezia furfur*), milia
Bright blue	Calcifications	Basal cell carcinoma, trichoepithelioma

melanoma recurrence by revealing vascular structures or faded structureless areas at surgical scar margins (Fig. 5) [12]. On the contrary, sUVRD did not highlight the delineation of pigmented BCCs and seborrheic keratosis [10].

In one study, sUVRD (P405 dermocamera, peak wavelength 405 nm) was compared with UVRD (P385 prototype dermocamera, peak wavelength 385 nm). In slightly pigmented skin types, the P385 model generally outperformed sUVRD in terms of exposition and visual perception of borders and lines (Fig. S1) [13].

In our experience, sUVRD enhances visualization of hyperreflective keratin cysts [(milia-like cysts/white dots and clods better seen in non-polarized dermatoscopy; common in seborrheic keratosis [SK]) and calcifications (multiple aggregated yellow globules/grouped yellow-white dots and clods; common in trichoepitheliomas and relatively common in BCC; unpublished data), whereas dermatoscopically hard to perceive hyporeflective superficial erosions can be appreciated in pigmented BCC or intraepithelial carcinomas (Figs. 6, 7). In a recent study on 207 pigmented skin lesions, sUVRD enhanced the visibility of erosions, crusts, and white dots/clods better seen in non-polarized dermatoscopy in BCC, as well as keratin plugs and thick brown curved lines in SK [10]. The authors also demonstrated that sUVRD was superior to conventional dermatoscopy in visualizing all erosions in melanomas and SK, thick brown curved lines in melanocytic nevi, white dots/clods better seen in non-polarized dermatoscopy in BCC, and crusts in SK. The authors underlined that more feasible identification of erosions in melanomas might contribute to more precise pathology descriptions. The following features were best seen with sUVRD: erosions, followed by keratin plugs, crusts, and thick lines curved (possibly due to uneven surface), whereas thick brown lines reticular (pseudo-network) in melanoma and SK and pigmented dots/clods in BCC were usually absent in sUVRD imaging, followed by blue/blue–gray clods (ovoid nests) in BCC (likely due to shallow penetration of 405 nm light into the skin). Interestingly, pigmented lines reticular (pigment network) and dots/clods were often not highlighted with sUVRD compared with polarized dermatoscopy, but equally visualized in nevi [10]. Nevertheless, we expect that sUVRD has a potential to highlight pigmented clues in hypopigmented tumors (e.g., early lentiginous melanomas) (unpublished

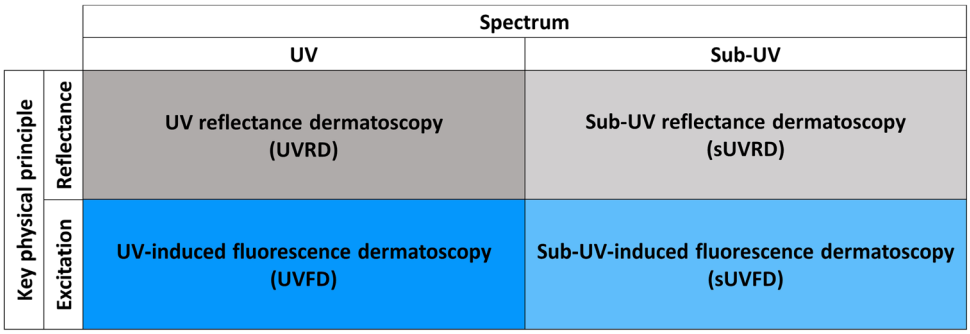

Fig. 2 Proposed nosological system for ultraviolet dermatoscopy: classification based on wavelength and underlying physical principles

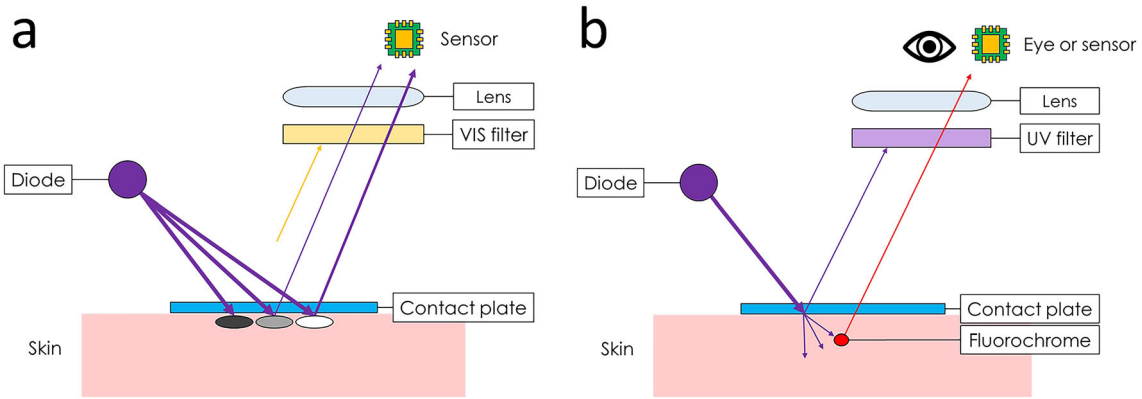

Fig. 3 Simplified schematics of signal acquisition in reflectance (**a**) and fluorescence dermatoscopy (**b**). In reflectance dermatoscopy, signal intensity is digitally recorded by the camera sensor and converted into a grayscale image on the basis of the absorption/reflection characteristics of the chromophore exposed to the emitted wavelength (white, high reflection/low absorption; black, low reflection/high absorption). Any visible light, either originating from the background or from excitation, is filtered out by the visible light (VIS) filter and not recorded. In fluorescence dermatoscopy, most of the emitted light is absorbed or dispersed in the skin, and the reflected fraction is effectively filtered out by the ultraviolet (UV) filter. The energy absorbed by the chromophore is partially emitted as excited fluorescence (within the visible light spectrum) and recorded either with the eye or with a smartphone/camera sensor

data; see Fig. 4), yet these observations require confirmation in larger series.

Non-neoplastic Conditions

Wound Healing The additional value of sUVRD was investigated in a series of studies on wound healing after pressure injury. The authors reported that sUVRD clues (darker dots and clods imperceptible in conventional dermatoscopy, corresponding to microhemorrhages) may predict spontaneous healing or development of ulceration on rat models [14, 15].

Cutaneous Collagenous Vasculopathy Cutaneous collagenous vasculopathy is a rare, progressive, and asymptomatic cutaneous telangiectatic disorder characterized by endothelial instability. It often mimics conditions such as generalized essential telangiectasia or pigmented purpuric dermatoses. Hyporeflective linear serpentine reticular/polygonal vessels with indistinct contours (higher absorption of

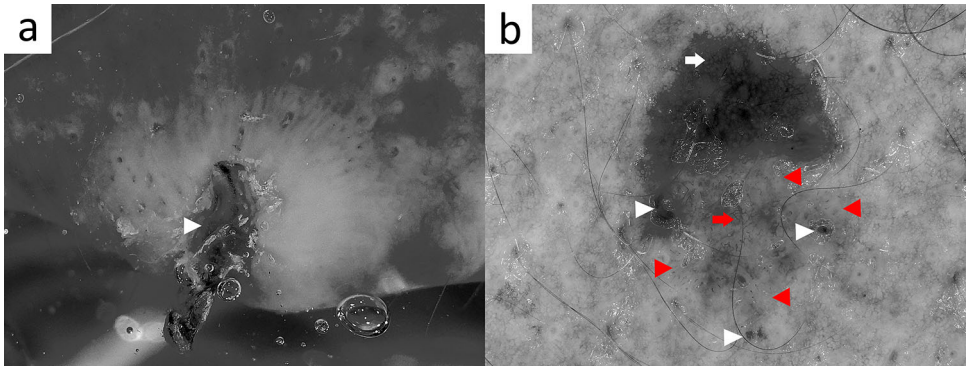

Fig. 4 Examples of sub-ultraviolet reflectance dermatoscopic imaging: hyperreflective area and circles corresponding to keratinization in squamous cell carcinoma. Central hyporeflective crust is a consequence of high absorption by hemoglobin (white arrowhead) (**a**); hyporeflective structures in a nevus/basal cell carcinoma collision: lines reticular (melanin) (white arrow), clods (erosions) (white arrowheads), linear vessels (red arrow), and poorly delineated areas (hemoglobin) (red arrowheads) (**b**)

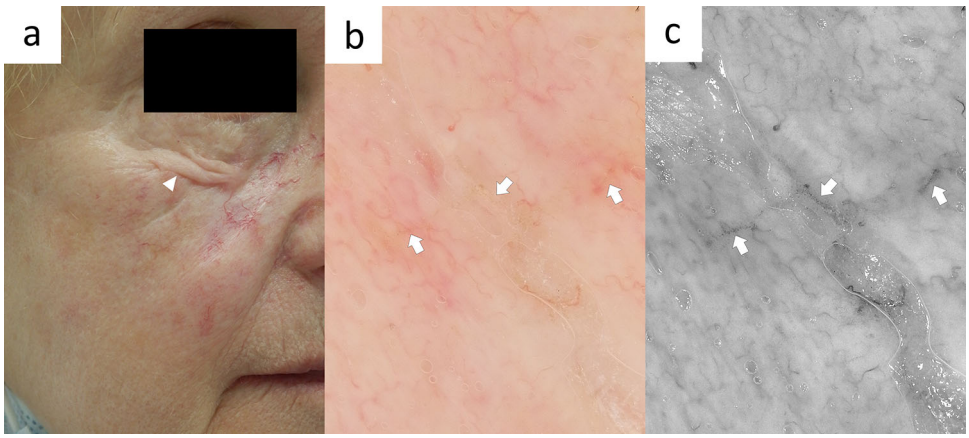

Fig. 5 Clinical presentation of a patient with recurrent facial lentiginous melanoma in situ (white arrowhead) (**a**). Comparison of conventional contact non-polarized dermatoscopy (**b**) and sub-ultraviolet reflectance dermatoscopy (sUVRD) (**c**). Hyperreflective angulated lines extending from both sides of the scar can be better appreciated with sUVRD (white arrows)

sub-UV spectrum by hemoglobin) suggestive of underlying endothelial dysfunction and erythrocyte extravasation were demonstrated in sUVRD [16].

Photoaging, Vascular, and Pigmentary Disorders Similarly to UV-reflectance photography, sUVRD could be potentially of aid in evaluation of vascular and pigmentary disorders (including vitiligo, melasma, photoaging, ochronosis, tattoos) and monitoring the treatment effects (peelings, lasers, high-frequency ultrasound procedures, etc.). Demonstrating the therapeutic effects in reflectance dermatoscopy to the patient could be used to increase their adherence to the treatment.

Porokeratosis In our experience, sUVRD can enhance the visibility of cornoid lamella and the surrounding vessels [17].

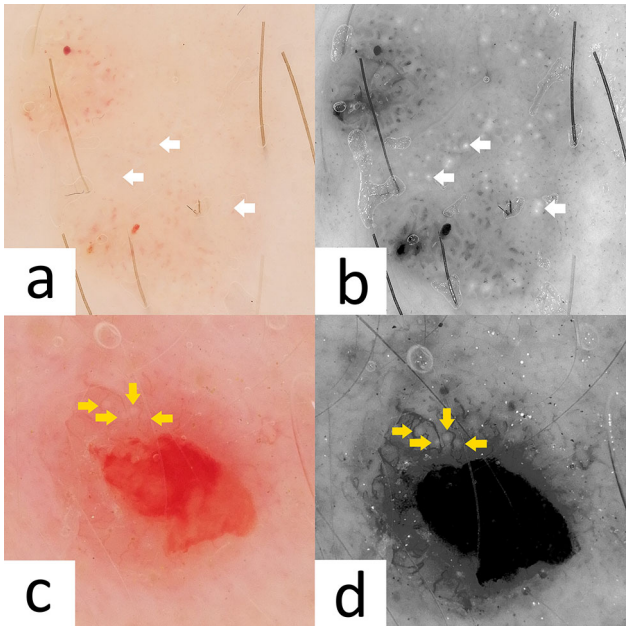

Fig. 6 White dots/clods (milia-like cysts; white arrows) and multiple aggregated yellow clods (yellow arrows) are better seen in sUVRD (hyperreflective dots/clods) (**b**, **d**) than in conventional dermatoscopy (**a**, **b**)

UVRD

The physical basis of emission and sensing in UVRD is similar to sUVRD, with UV diodes and UV sensors. Reflected UV light is responsible for producing gray-scale digital images on the basis of the absorption/reflection of the examined area. Currently, only the P385 dermocamera prototype (385 nm, Casio, Japan) offers UVRD, but has not been introduced to the market yet. A single study in slightly pigmented skin types proved its usefulness [13].

Applications of UVRD

Dermato-oncology

A single study on the use of UVRD in a Casio P385 prototype dermocamera (peak wavelength 385 nm) in dermato-oncology was identified [13]. Device performance in enhancing the clues in keratoacanthoma-like squamous cell carcinoma (SCC), facial lentiginous melanoma in situ, and melanocytic nevus in patients with albinism was compared with the Casio D'z-D100 model. In darker skin types it seemed to provide better visibility and contrast for better margin identification. It is not commercially available thus far.

UVFD

In UVFD, a UV diode serves as the emitter, while the signal receiver can either be the human eye or the visible light sensor of a smartphone camera. The optical system employed in UVFD functions to filter out all the reflected UV signals, allowing only visible light to pass through. This visible light is generated through an excited emission process induced by UV light, a phenomenon known as the Stokes shift [2]. In this phenomenon, chromophores exposed to UV light get excited, moving their electrons from a stable ground vibrational level to a higher, unstable vibrational level. The energy accumulated in the electrons is subsequently released as a new photon (typically of longer wavelength and falling within the visible spectrum of light) as the particle returns to its original ground vibrational level. Dark regions in UVFD images result from the high absorption of UV light by melanin and hemoglobin, which leads to the absence of any background fluorescence in these areas (all light absorbed, no reflected light visible). The method also appears in the literature as UV-enhanced trichoscopy (UVET) [18, 19].

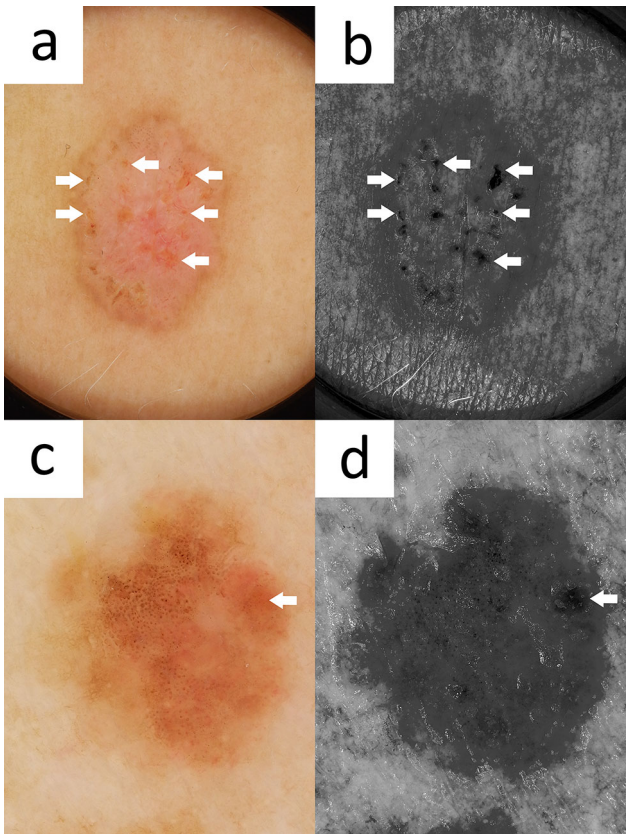

Fig. 7 Superficial erosions can be appreciated better in superficial basal cell carcinoma and pigmented intraepithelial carcinoma with sUVRD (small hyporeflective areas; white arrows) (**b**, **d**) than contact-polarized dermatoscopy (**a**, **c**)

Currently, several manufacturers offer UVFD devices: DL5 dermatoscope (peak wavelength 365 nm, Dermlite, USA); SKIARY Sk-3 smartphone dermatoscope (peak wavelength 365 nm, Beijing Xiangzhen Technologies Co. Ltd., Beijing, China); several non-medical Dino-Lite microscope models featuring 395 nm LEDs: AM4013MT-FVW, AM4013MTL-FV, AM4113FVT, AM4113T-FVW, AM4113TL-FVW, AM4115-FVW—EDGE, and 375 nm LEDs: AM4113FVT2, AM4113T-FV2W, AM4115-FUT—EDGE, AM4115-FUW—EDGE, AM4115-FVW—EDGE, AM7115MT-FUW (Dino-Lite Europe, Netherlands); MicroCAMERA (390 nm, Dermotricos SRL, Coccaglio, Italy); CH-UVDS30 (wavelength range 360 < 390 nm, Chuanghong Science and Technology Company, China); SmartV 150DF (wavelength 370–400 nm, JEDA, Nanjing, China); and Ultracam TLS (no data on wavelength, Dermaindia, Tamil Nadu, India).

Applications of UVFD

Dermato-oncology

Biopsy Site Identification The precise identification of biopsy sites is pivotal for the success of dermatological surgeries and to prevent wrong-site surgery. The exact surgical site can be hard to identify if the biopsy was performed some time ago or due to other variables such as sun damage and multiple scars, among others. Various strategies have been employed to address this problem, including the use of photographs, anatomical maps, and reflectance confocal microscopy (RCM). Of note, photography and mapping techniques are straightforward but offer only a limited window of opportunity for effective use. Furthermore, RCM, although regarded to be highly effective, is usually available only in highly specialized centers and requires extensive training, which

limits its widespread use. Interestingly, UVFD is a simple and inexpensive method that has proven to be useful in the presurgical identification of biopsy sites. UVFD highlights the biopsy site by making it darker (Fig. S2). UVFD also significantly increases the physician's confidence for surgical site identification when compared with conventional polarized dermatoscopy (93% versus 72%). The darker areas observed in UVFD likely correspond to inflammation and angiogenesis within the scar tissue after a biopsy (hemoglobin absorbs UV light). Future studies are needed to determine the exact time frame when these UVFD features are still present in biopsied sites [20].

Post-treatment Site Identification In the authors' experience, UVFD might also be used to identify the sites treated with topical chemotherapeutics (e.g., 5-fluorouracil 5% cream), which still seem darker than the healthy skin. This allows for precise delineation of the site where subtle neoplastic clues can still be present in conventional dermatoscopy. Moreover, it could potentially be used to screen for totally regressed tumors, e.g., primary cutaneous melanoma (Fig. S3).

In the authors' experience, UVFD is also useful in delineating melanoma and basal cell carcinoma margins (Fig. S4). In microinvasive/in situ tumors, that task can be challenging with either naked eye or even with conventional dermatoscopy. Presence of melanin or a scar-like depigmented area in melanoma results in darker or lighter areas in UVFD, respectively, whereas areas of neovascularization in general become darker than the normal skin with UVFD.

Diagnostic Clues in Neoplastic Diseases UVFD has the potential to visualize relatively fresh erosions due to the presence of bilirubin in dried-out crust [21]. Thus, it could be of aid in confirming the presence of ulceration in both melanoma and non-melanoma skin cancer (e.g., indicating the diagnosis of basal cell carcinoma in flat ulcerated pigmented skin lesions, as in the authors' experience, unlike the further, thin melanomas that rarely develop ulcerations). Moreover, it may confirm the presence of multiple aggregated yellow globules/dots and clods in trichoepithelioma and basal cell carcinoma that feature strong bright white fluorescence (unpublished data) (Fig. 8).

Glomus Tumor A pink glow of the stroma has been observed with UVFD of the glomus tumor located under the proximal nail fold [22]. Nonetheless, this was a single observation, and the pinkish glow seen in the images in the aforementioned paper might have been an artifact due to incomplete adhesion of the contact plate to the tumor surface (see the Limitations of UVFD, sUVRD and UVRD dermatoscopy section).

Apocrine Hidrocystoma Apocrine hidrocystoma is a BCC simulator. This benign, bluish- or skin-colored cyst with linear serpentine and branching vessels usually localizes on the eyelid margin or in the periorbital area. UVFD can be used to differentiate both tumors, as BCC is usually darker, whereas apocrine hidrocystoma is bright due to its translucency (unpublished data) (Fig. 9).

Non-neoplastic Conditions

Vitiligo UVFD allows for the identification of well-defined depigmented and pigmented areas, as well as perifollicular pigmentation in a series of patients with vitiligo [23]. In a study on UVFD comparing hypopigmented dermatoses of the trunk, vitiligo did not exhibit any specific fluorescence pattern, yet this study did not address border abruptness [24]. It has been suggested that the character of demarcation seems to be stage dependent, with perifollicular pigmentation and poorly demarcated margins in progressive lesions, and well-demarcated borders and perifollicular depigmentation in stable lesions (Fig. S5) [23, 25]. In one patient in re-pigmentation phase, telangiectasias and pigmentation reservoirs were visualized with UVFD [23]. Nonetheless, diagnostic accuracy with UVFD was shown to be inferior to conventional non-contact polarized dermatoscopy (well-defined borders) [24].

Progressive Macular Hypomelanosis Progressive macular hypomelanosis is an acquired

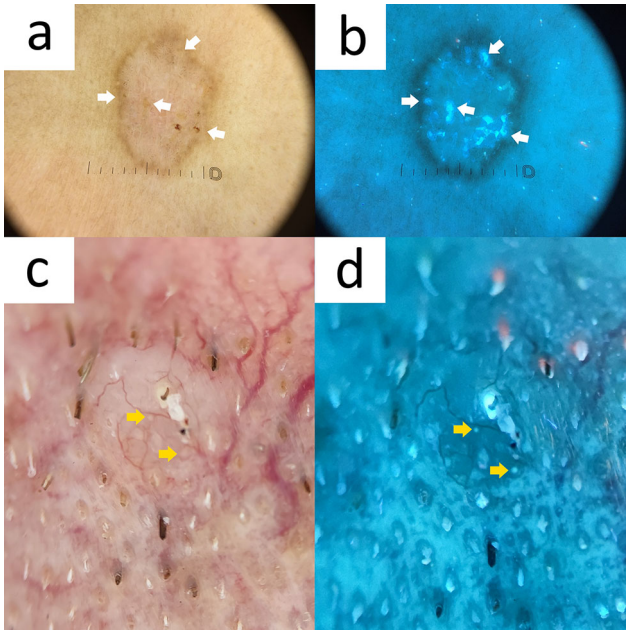

Fig. 8 Conventional non-contact polarized dermatoscopy (**a**) is inferior to ultraviolet-induced fluorescence dermatoscopy (UVFD) (**b**) in visualization of fresh crusts (white arrows). Bright yellow–green crusts easily identify superficial erosions in basal cell carcinoma. Multiple aggregated yellow clods present in nodular basal cell carcinoma (c) are easily detected as bright blue in UVFD (yellow arrows)

perifollicular depigmentation, usually occurring in young adults with skin of color. Due to association with *Cutibacterium acnes*, central red follicular fluorescence related to coproporphyrin III can be observed within the hypopigmented area in UVFD [24]. Thus, UVFD provides a more reliable diagnosis than conventional non-contact polarized dermatoscopy [24].

Idiopathic Guttate Hypomelanosis The disorder is not characterized by any excited fluorescence in UVFD, yet there are no data on border abruptness. In terms of diagnostic accuracy, conventional non-contact polarized dermatoscopy (perilesional patchy brown reticular lines) outperforms UVFD [24].

Pityriasis Versicolor Pityriasis versicolor is a common superficial fungal infection [26]. Atypical manifestations may require additional workup. UVFD enables the visualization of light and dark green structureless areas in hypo- and hyperpigmented lesions, respectively (Fig. 10)

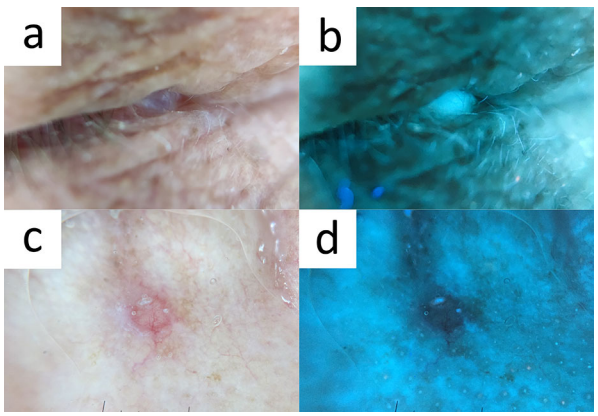

Fig. 9 Comparison of dermatoscopic and ultraviolet-induced fluorescent dermatoscopic (UVFD) presentation of apocrine hidrocystoma (AH) and nodular basal cell carcinoma (nBCC). Both AH (**a**) and nBCC (**c**) present as facial shiny nodules with linear serpentine branching vessels. UVFD is able to discriminate bright AH (**b**) from dark nBCC (**d**)

[24, 26]. Additionally, the physiological cutibacterial orange–red follicular fluorescence is notably interrupted in affected seborrheic

areas (blackout areas), likely due to the antiseptic properties of azelaic acid produced by the *Malassezia* fungus [24, 26]. This fluorescent clue was a strong predictor of archomic pityriasis versicolor, responsible for superiority of UVFD against conventional non-contact polarized dermatoscopy [24]. The method also enhances the visibility of light green scales within the skin furrows (that may be double-edged) and perifollicular scaling, even in less apparent lesions, thus confirming the propensity of the fungus to localize within the hair follicle openings [26]. Certain hypopigmented PV lesions exhibit a darker rim resembling a "contrast halo sign" occasionally seen with conventional dermatoscopy [26]. Fading of fluorescence and scaling, as well as reemergence of background cutibacterial follicular fluorescence, should occur once the production of azelaic acid ceases with elimination of the fungus. Thus, UVFD can prove diagnostically valuable in monitoring the response to treatment [26]. Nevertheless, there are currently no observations specifying the exact time frames when these changes occur.

Other Pigmentary Disorders

It is likely that UFVD could be useful in other common hypopigmented dermatoses, e.g., pityriasis alba, nevus depigmentosus, and nevus anemicus, but the data are lacking [27].

Seborrheic Dermatitis

In our experience, this *Malassezia*-driven dermatosis presents blackout areas in UVFD due to anti-cutibacterial activity of the fungus [26]. In seborrheic areas in adults, fine yellowish-white scaling seen in non-contact polarized dermatoscopy is matched by blackout areas without red follicular fluorescence (Fig. 11).

Malassezia Folliculitis

Malassezia folliculitis displays blue follicular fluorescence in UVFD, likely due to fungus-induced hyperkeratosis and production of azelaic acid that inhibits the growth of *Cutibacteria* [24, 26]. Moreover, UVFD was superior to non-contact polarized dermatoscopy in regard to differentiation with inflammatory acne lesions that show no fluorescence (follicular blackout areas) [24].

Acne

Comedonal acne hosts *Cutibacterium acnes*, responsible for background orange-to-red follicular fluorescence in seborrheic areas. Coproporphyrin III is a major chromophore responsible for UV-induced excited fluorescence [2, 24, 26]. In inflammatory acne lesions (e.g., papulopustular or nodular acne) this fluorescence is interrupted, leading to the development of follicular blackout areas (Fig. S6) [24]. It was shown that UVFD provides better diagnostic accuracy than non-contact polarized dermatoscopy, and can reliably differentiate the lesions from *Malassezia* folliculitis with blue follicular fluorescence [24]. Red fluorescence might be absent in prepubertal children and in non-seborrheic areas.

Psoriasis

Certain psoriatic plaques exhibit pink–red fluorescence in 365 nm, especially in more severe cases [28–30]. This phenomenon develops due to the presence of protoporphyrin IX in stratum corneum, yet the exact mechanism responsible for this deposition remains unknown [28, 30, 31]. Although in the case of intertrigo of major skin creases both psoriasis and erythrasma display red excited fluorescence, previously reported peripapillar distribution was shown to be indicative for inverse psoriasis and against other causes (candidiasis, tinea) [24, 30]. Uniform dotted vessels visualized with conventional non-contact polarized dermatoscopy was shown to be a stronger predictor of inverse psoriasis than UVFD clues [24]. Nonetheless, in our experience, UVFD can be of aid in the atypical forms (e.g., follicular variant or in isolated psoriatic plaques) and add diagnostic confidence to conventional non-contact polarized dermatoscopy (uniform dotted vessels) as its common clinical differentials (e.g., lichen planus, seborrheic keratosis, eczema, lichen simplex, keratosis pilaris, pityriasis rubra pilaris, mycosis fungoides, tinea corporis, syphilis, etc.) do not exhibit any porphyrin-related fluorescence (Fig. 12). However, in regard

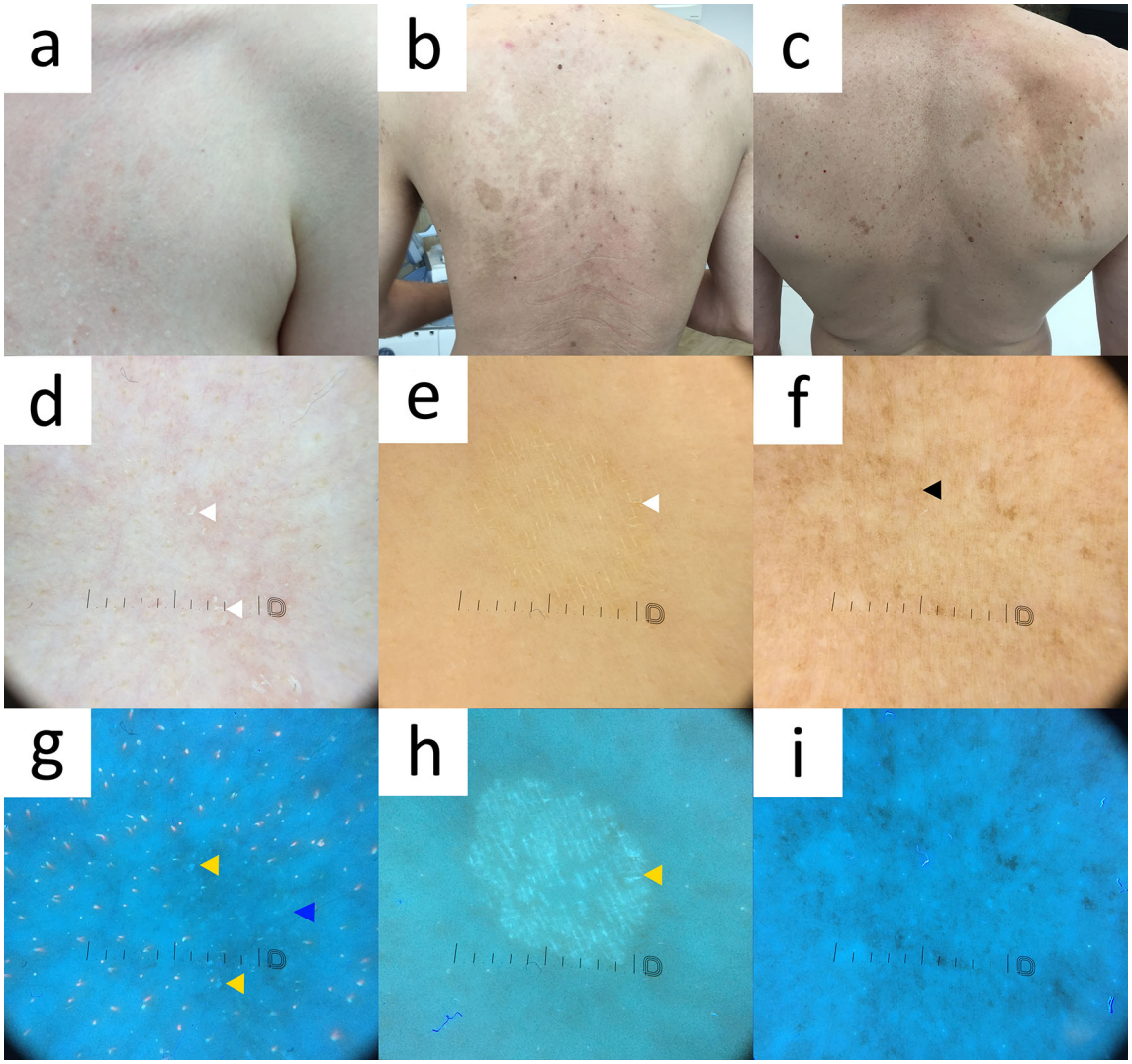

Fig. 10 Pityriasis versicolor (PV) may present as hypo- (**a**) and hyperpigmented (**b**) macules, which in some instances can be differentiated with Becker's nevus (**c**). Conventional non-contact polarized dermatoscopy of PV exhibits poorly demarcated hypo- (**d**) or hyperpigmened (**e**) areas covered with fine scales often following skin furrows (white arrowheads). Furthermore, in Becker's nevus, hyperpigmented physiologic areas of brown lines reticular do not display any scaling (black arrowhead) (**f**). PV scaly areas become light to dark green under ultraviolet-induced fluorescence dermatoscopy (UVFD), with enhanced delineation and more perceptible scaling (yellow arrowheads) (**g**, **h**). In seborrheic areas, such areas are usually mostly deprived of cutibacterial pink/orange follicular excited fluorescence (blackout areas), which is particularly helpful in achromic lesions (blue arrowhead) (g). Becker's nevus does not exhibit any fluorescence under UVFD (**i**)

to special sites—umbilicus and intergluteal fold—it should be kept in mind that erythrasma may also evoke that phenomenon.

Psoriatic nails exhibited bright nail longitudinal crumbling and enhanced visibility of dark subungual splinter hemorrhages, while the relatively flat area of the nail remained blurred [32]. That modality can be used for treatment monitoring to observe subtle nail surface clues [32]. In our experience it can be used to enhance diagnostic confidence in

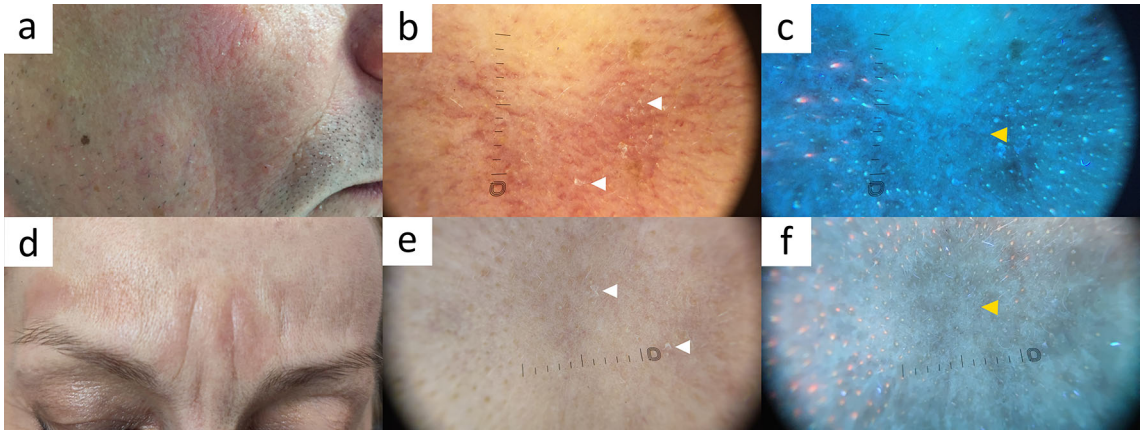

Fig. 11 Seborrheic dermatitis. Erythematous macules with fine scaling (**a**, **d**). Non-contact polarized dermatoscopy showing areas with delicate scaling (white arrowheads) (**b**, **e**). Ultraviolet-induced fluorescence dermatoscopy displays areas deprived of physiological orange-to-red follicular fluorescence (blackout areas) typical for *Cutibacterium*-colonized seborrheic areas (yellow arrowheads) (**c**, **f**)

differentiation of psoriatic and non-psoriatic pitting (irregular and regular, respectively) (Fig. 13).

Pityriasis Rosea

Even though pityriasis rosea was reported not to display any fluorescent clues in UVFD, and be inferior to conventional non-contact polarized dermatoscopy in terms of diagnostic accuracy [24], this imaging method was able to confirm the presence of peripheral bright blue scale with an inner free edge ("hanging curtain sign") in a series of cases, even where the scale was not present in conventional non-contact polarized dermatoscopy (Fig. S7) [33].

Pityriasis Lichenoides Chronica

UVFD was reported to display no UVFD clues, and be diagnostically inferior to conventional non-contact polarized dermatoscopy (orange structureless areas) [24].

Eczema

Even though there are no reports on UFVD of eczema, in the authors' experience, a predominant blue-to-yellowish/greenish excited fluorescence of the serum crusts (dots/clods) [21, 34], along with darker diffuse dotted vessels, can be appreciated (Fig. 14). This fluorescence of the dried-out serum is associated with excessive amounts of bilirubin, whereas yellowish/greenish tint is noted with higher concentrations and higher rate of unconjugated bilirubin. Notably, the yellowish tint disappears with sun exposure, but not with indoor lighting [21].

Lichen Planus

This dermatosis does not display any fluorescent clues in UVFD and the method is inferior to conventional non-contact polarized dermatoscopy (Wickham striae) [24]. Poorly demarcated UVFD-dark lines in genital lichen planus correspond to non-polarizing-specific white structures, whereas the method is not able to visualize any structure corresponding to polarizing-specific white lines. Erythematous areas peripheral to the white lines of lichen planus, in UVFD, are seemingly larger and darker (likely due to upper dermal lymphocytic infiltrate and dilated dermal vessels) (Fig. S8) [2].

Porokeratosis

Translucent, white, yellow, brown or gray, annular, single- or double-edged continuous or interrupted keratin rim (cornoid lamella) is a dermatoscopic hallmark of porokeratosis. Even if subtle in conventional dermatoscopy, the keratin rim becomes bright blue in UVFD

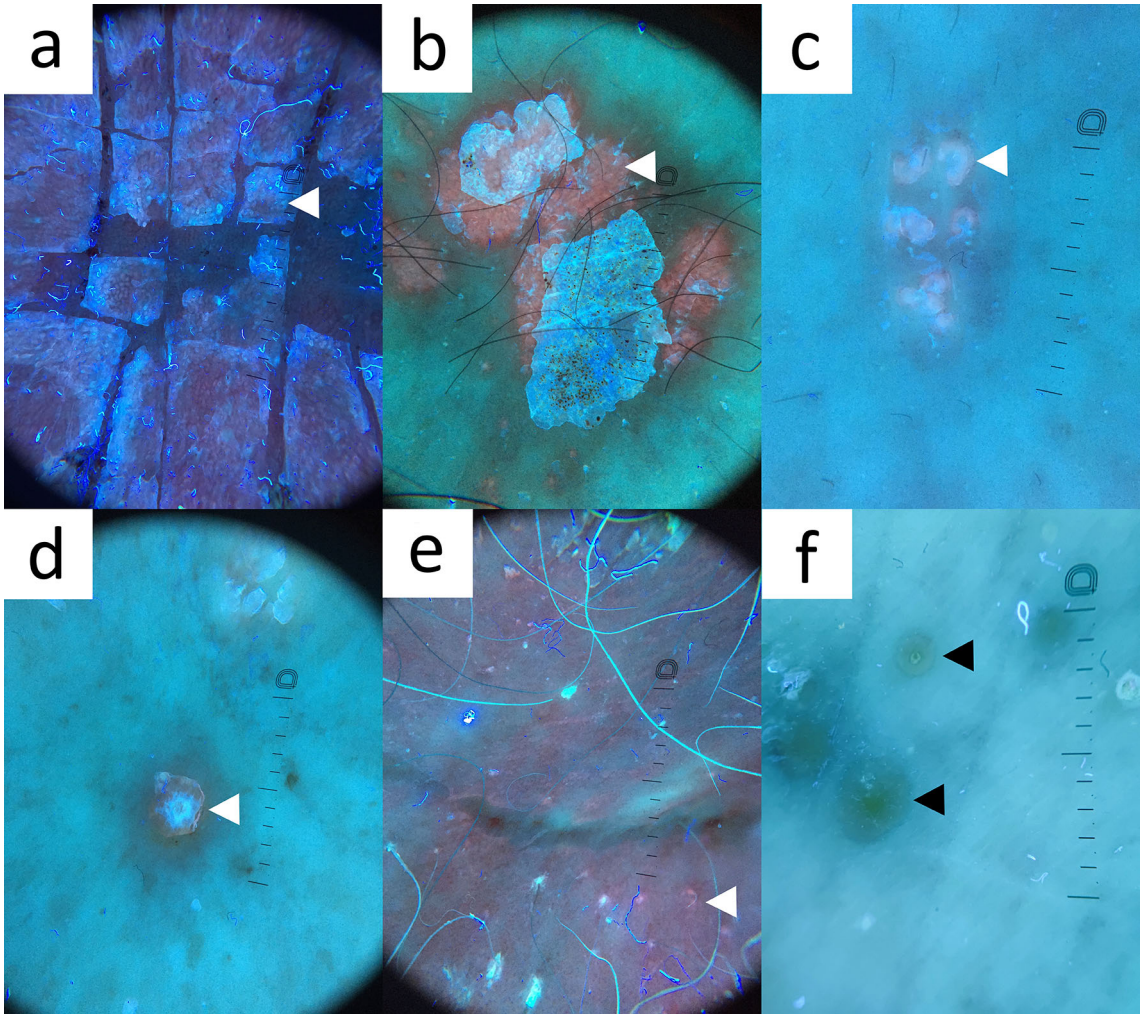

Fig. 12 Pink–red fluorescence in the stratum corneum under non-contact ultraviolet-induced fluorescence dermatoscopy (white arrows): plaque psoriasis (**a**), guttate psoriasis (**b**, **c**), follicular psoriasis (d), inverse psoriasis of the groin (**e**). Of note, palmoplantar pustular psoriasis does not exhibit red fluorescence, but presents green roundish neutrophilic pustules (black arrows) (**f**)

("diamond necklace" appearance) (Fig. 15) [35]. Such observations have been reported in disseminated superficial actinic porokeratosis [36], and a case clinically corresponding to verrucous/genitogluteal porokeratosis [2, 37]. Furthermore, pigmented cornoid lamella becomes darker under UVFD [17].

Transient Acantolytic Dermatosis

In the author's experience, UVFD of Grover's disease exhibits bright green-to-blue central polygonal scale (serous crust) and peripheral darker area (Fig. 16).

Terra Firma-Forme Dermatosis

Bright blue polygonal scales can be appreciated in UVDF (author's personal observation) (Fig. 17).

Cutaneous Collagenous Vasculopathy

Alternated constrictions and dilations of the blood vessels, giving a "sausage-string appearance" were noted in UVFD. The vessels were distributed in a reticular/polygonal manner and the perivascular areas were darker. These findings correlated to endothelial dysfunction and erythrocyte extravasation [16].

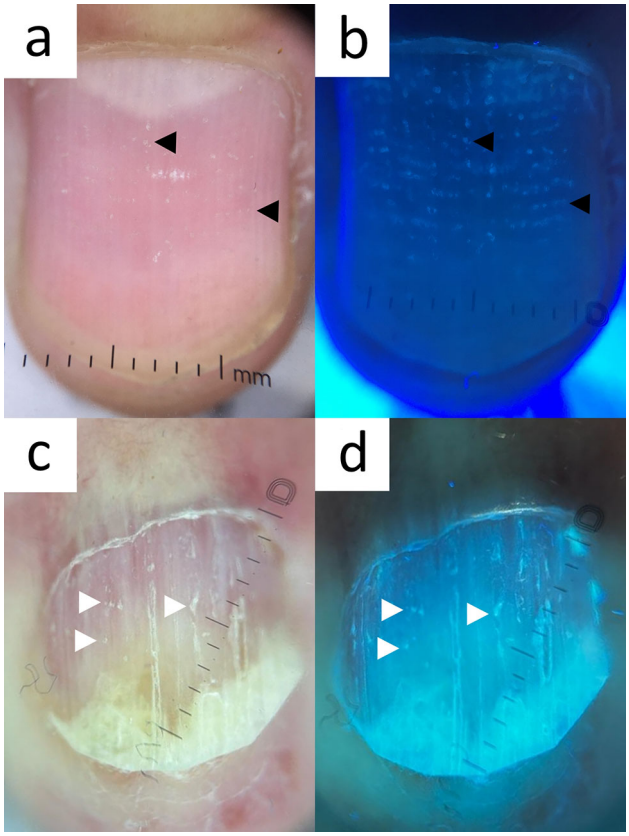

Fig. 13 Comparison of conventional polarized dermatoscopy and ultraviolet-induced fluorescence dermatoscopy (UVFD) in assessment of nail pitting in eczema (**a**, **b**) and psoriasis (**c**, **d**). UVFD enhances the surface clues, revealing regular character of pits in eczema (black arrowheads) and irregular pitting in psoriasis (white arrowheads)

Sebaceous Glands

Sebum appears yellow to green under UVFD. Thus, heterotopic sebaceous glands, regardless of whether they are involved in Fordyce spots, Montgomery glands, sebaceous hyperplasia, sebaceous induction in dermatofibroma, or nevus sebaceous, appear as poorly to well-demarcated yellowish-green roundish structures with central brighter ostium (Fig. 18) [2].

Pearly Penile Papules

Pearly penile papules are a common physiological variant that is commonly mistaken for genital warts. In polarized dermatoscopy, they present as whitish clods with centered glomerular vessels. In UVFD they appear neutral in color (Fig. S9) [2].

Trichobacteriosis Axillaris

Yellow–green, luminescent conglomerates adhering to the hair shafts can be seen in trichobacteriosis axillaris, a corynebacterial infection. This clue may not only narrow the clinical differentials, but also be of aid in confirming disease resolution or identify early recurrence (Fig. 19). Admixture of the sweat and bacterial products is suspected to be responsible for the fluorescence, but no specific chromophore has been identified so far [38].

Erythrasma

Specific coral–red diffuse fluorescence of corynebacterial coproporphyrin III present in the intertriginous areas confirms the diagnosis and can be used to monitor the treatment.

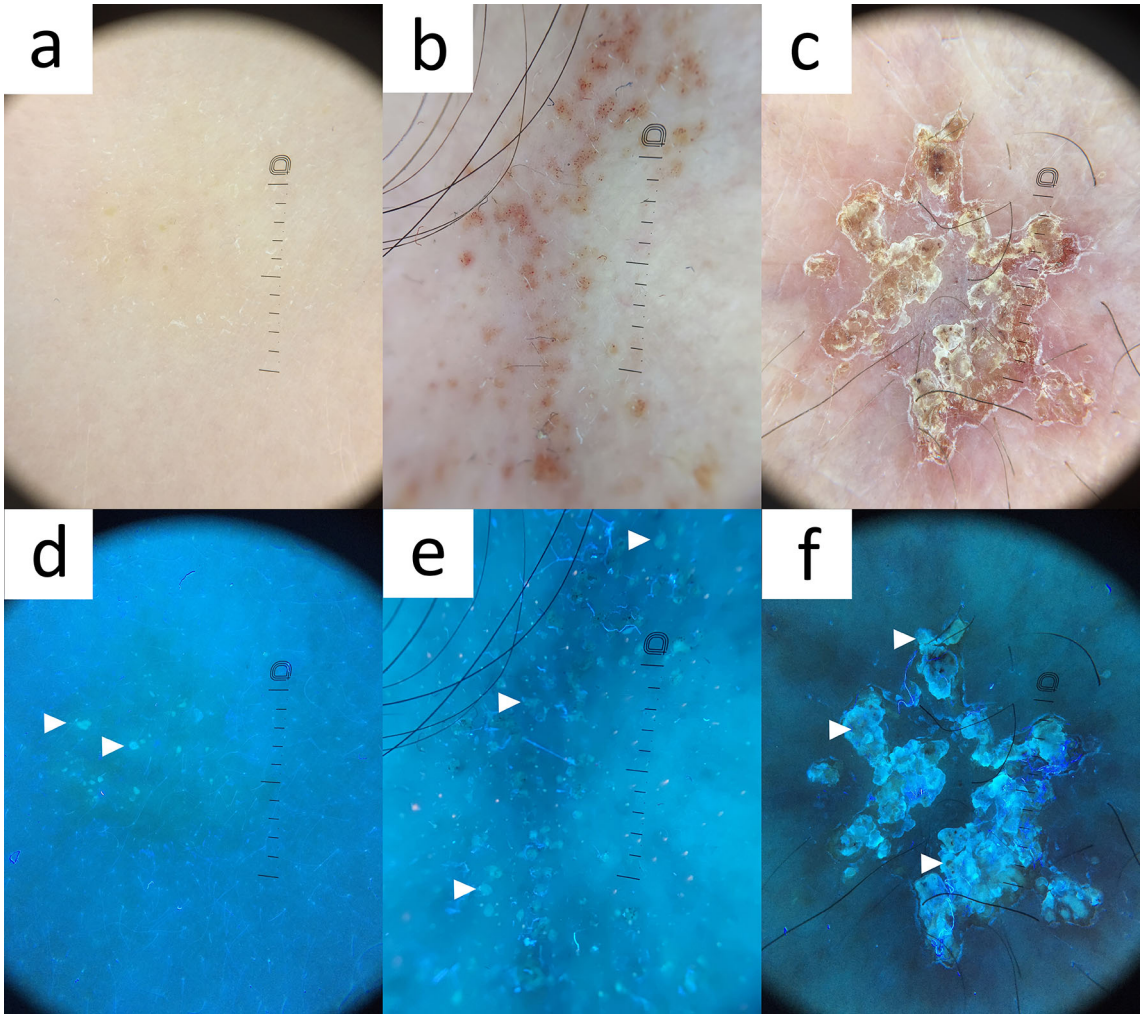

Fig. 14 Comparison of non-contact polarized dermatoscopy (NCPD) (**a**–**c**) and ultraviolet-induced fluorescence dermatoscopy (UVFD) (**d**–**f**) in eczema. Yellowish-green fluorescence of bilirubin can be seen even in early, dermatoscopically non-obvious cases (**d**), and intensifies in more advanced stages (white arrowheads) (**e**, **f**)

[39, 40]. In our experience, axillary lesions may also demonstrate periapocrine/peripilar red clods. If erythrasma coexists with trichobacteriosis axillaris, both dermatoscopic patterns (yellow–green or blue peripilar concretions over the coral–red fluorescence and blue background) combine, resembling the colors of Netflix series posters (dubbed a "Stranger Things pattern" by one of the authors [ALP]) (Fig. 19) [24, 38]. Coral–red fluorescence in UVFD, especially of diffuse or polygonal distribution (versus peripapillar in inverse psoriasis), is specific for interdigital corynebacterial intertrigo (Fig. 12, Fig. 20) and can confidently differentiate it from non-fluorescent candidiasis or dermatophytosis (Fig. S10) and green pseudomonas intertrigo (Fig. 21) [24]. In regard to diagnostic accuracy, UVFD was superior to non-contact polarized dermatoscopy in both corynebacterial intertrigo and erythrasma [24]. Of note, in our experience the chromophore can be partially or completely washed out by shower or bath.

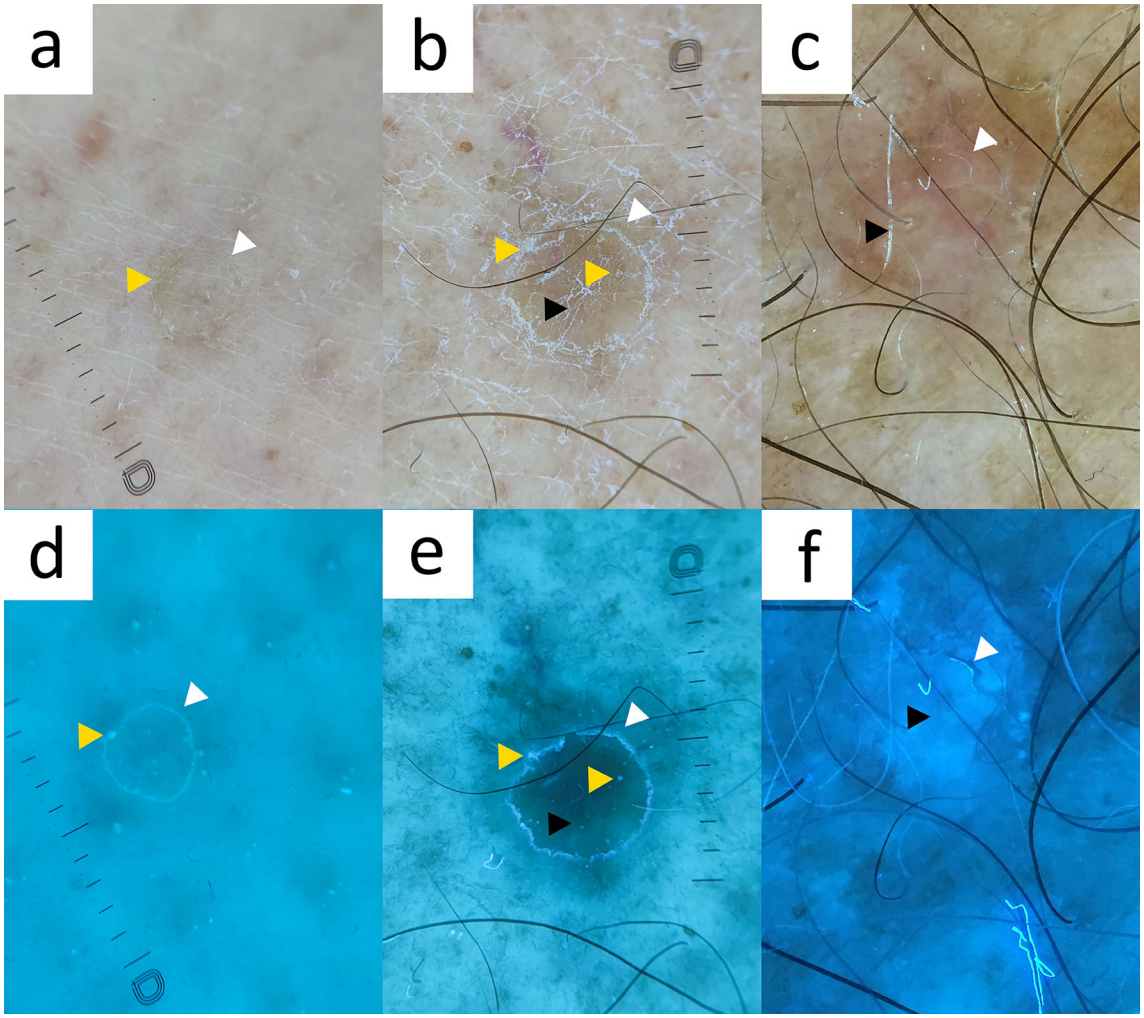

Fig. 15 Comparison of non-contact polarized dermatoscopy and ultraviolet-induced fluorescence dermatoscopy (UVFD) in disseminated superficial actinic porokeratosis. The disease is characterized by the presence of cornoid lamella—annular keratin rim (white arrowheads). Depending on the pigmentation status (**a**–**c**), this rim can become either bright (**d**, **e**) or dark (**f**) blue. Moreover, UVFD enhances follicular keratin plugs (yellow arrowheads) (**a**, **b**), allowing more confident confirmation of folliculocentric character of the lesions, and highlights pigmentation status of the central area (black arrowheads) (**e**, **f**)

Pitted Keratolysis

UVFD reveals coral–red eccrine dots and perieccrine clods corresponding to crateriform pits in the interdigital spaces that can be appreciated clinically and with conventional dermatoscopy [24, 41]. Plantar lesions also show pale coral–red pits with a free edge of scale, as well as a pale coral–red parallel ridge pattern and pale coral–red clods in the ridges [41]. We believe that the method could serve as a test-of-cure. Red dots/clods at the sweat duct ostia present both in PK and erythrasma (Figs. 19, 20) [24] and might suggest that in both disorders could be classified as Periacrosyringial Cutaneous Corynebacteriosis with side-dependent variability in presentation. In a single study, UVFD proved superior to non-contact polarized dermatoscopy in diagnosing corynebacterial intertrigo [24].

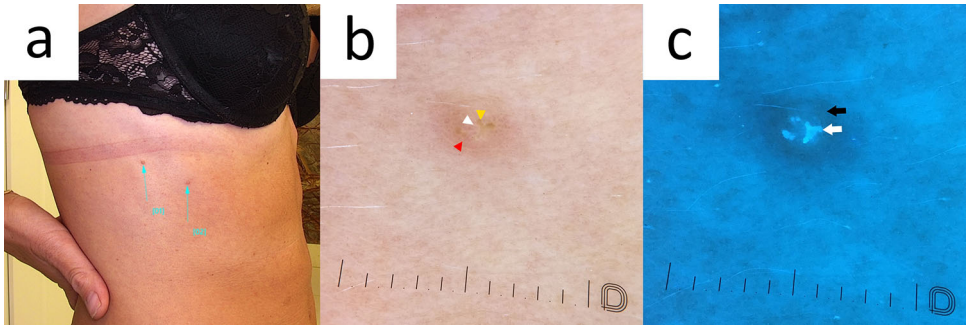

Fig. 16 Transient acantolytic dermatosis: clinical presentation (**a**); non-contact polarized dermatoscopy showing three-zonal aspect: central polygonal yellow–brown scale (yellow arrowhead) surrounded with a white area (white arrowhead) and outer pink rim (red arrowhead) (**b**); ultraviolet-induced fluorescence dermatoscopy displays blue polygonal crust (white arrow) surrounded with a darker area (black arrow) (**c**)

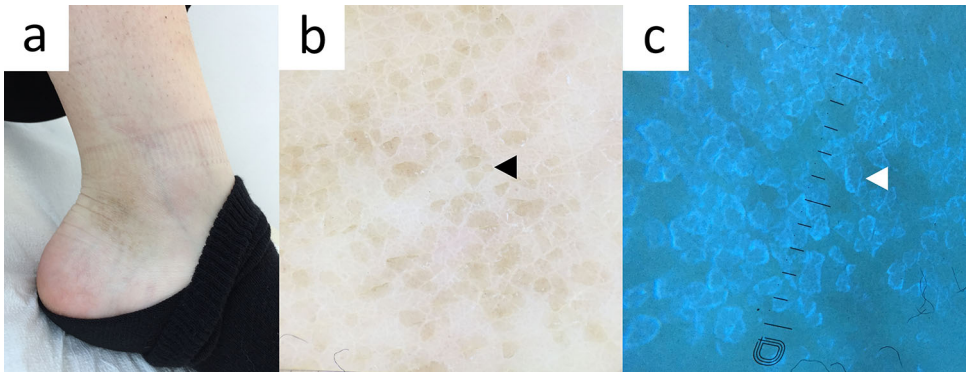

Fig. 17 Terra firma-forme dermatosis: clinical presentation (**a**); non-contact polarized dermatoscopy exhibits tan polygonal scales (black arrowhead) (**b**); ultraviolet-induced fluorescence dermatoscopy reveals polygonal scales with bright blue margins (white arrowhead) (**c**)

Candidal Intertrigo

UVFD shows no fluorescent clues in intertrigo caused by *Candida*, which differentiates it from psoriasis and erythrasma, but not tinea (which may often display no fluorescent clues) [24]. Nonetheless, UVFD was demonstrated to be superior to conventional polarized dermatoscopy in diagnosing candidal intertrigo (with the inverse approach) [24].

Tinea Pedis

UVFD shows no fluorescence in dermatophytic intertrigo, apart from enhancing the visibility of a free edge of scaling that reliably differentiates this entity from interdigital erythrasma, pseudomonas intertrigo, and pitted keratolysis (Fig. S10) [24]. Diagnostic accuracy with UVFD was shown to be superior to that of conventional non-contact polarized dermatoscopy [24].

Pseudomonas Skin and Nail Infections

Pseudomonas aeruginosa is known for producing pigmented by-products: blue pyocyanin, black melanin, red pyorubin, and green pyoverdine. The latter substance is responsible for disease-specific green fluorescence of infected tissue, e.g., foot intertrigo (Fig. 21) [24]. UVFD was shown to be superior to non-contact polarized dermatoscopy in diagnosis of *Pseudomonas* intertrigo [24].

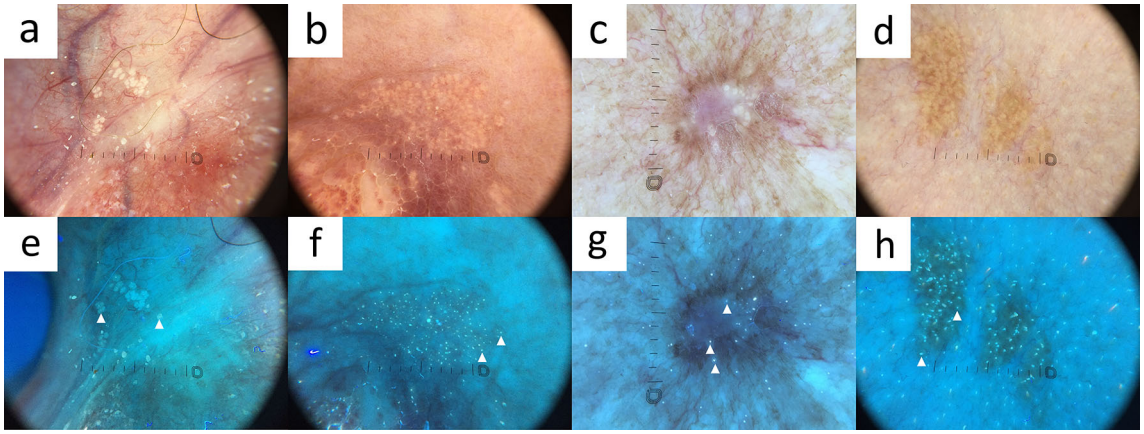

Fig. 18 Comparison of polarized dermatoscopy and ultraviolet-induced fluorescence dermatoscopy (UVFD) in Fordyce spots (**a**, **d**), sebaceous induction in dermatofibroma (**b**, **e**), and nevus sebaceous (**c**, **d**). In each case a poorly to well-demarcated roundish clods of sebaceous gland with a central bright ostium can be appreciated (white arrowhead)

Molluscum Contagiosum

Umbilicated molluscum papules are dark in UVFD (likely due to increased vascularity), whereas some of the central pores present faded yellowish fluorescence (Fig. S11) [2].

Viral Warts

The presentation of viral warts in UVFD depends primarily on pigmentation status and the affected site. Nonpigmented lesions appear neutral, while pigmented warts appear dark. Extragenital locations typically exhibit perivascular bright halos or fluorescence of the keratinized tips of the elongated papillae. Mucosal or genital lesions lack this feature [2].

Demodicosis

UVDF was able to visualize a single *Demodex* mite (with a bright bluish trunk) wandering through the facial skin [42]. In our opinion, the ingested sebum might be the source of the fluorescence, yet it requires further confirmation.

Scabies

Scabies is a common mite infestation. Atypical cases may require the use of dermatoscopy. Nevertheless, UVFD was shown to further increase the diagnostic accuracy by accentuating the burrows (serpiginous bright blue lines corresponding to dry keratin scales of stratum corneum) [43–46] and evoking the bright green fluorescence of the mite (Fig. 22) [43, 47]. The exact chromophore responsible for the green color of the parasite is unknown. Occasional greenish tint of the burrows is likely caused by the scratching-provoked eczematous reaction (see *Eczema* section). In a case report using a prototype of high-power field UV-induced fluorescence dermatoscopy, it was possible to visualize yellowish feces inside the burrow responsible for the "glittering trail" appearance [46].

Tinea Capitis and Tinea Corporis

UVFD was reported to be of use in the diagnosis of *Microsporum canis*-induced tinea, including tinea auricularis presenting as tinea incognito. The microorganism is associated with endothrix infection of the hair shaft, including vellus hair. UVFD reportedly shows bright white coiled and curly vellus hair [18, 48–50]. These observations may facilitate monitoring therapeutic response and follow-up [50]. Normally, non-contact polarized dermatoscopy of *Microsporum*-induced tinea of the glabrous skin usually shows Morse-code-like hairs (hairs with interrupted black and white bands), bent hairs, zig-zag hairs, and diffuse whitish scaling [51]. In a case caused by *Microsporum gypseum* (ectothrix), 400 nm UVFD uncovered subtle erosions and follicular

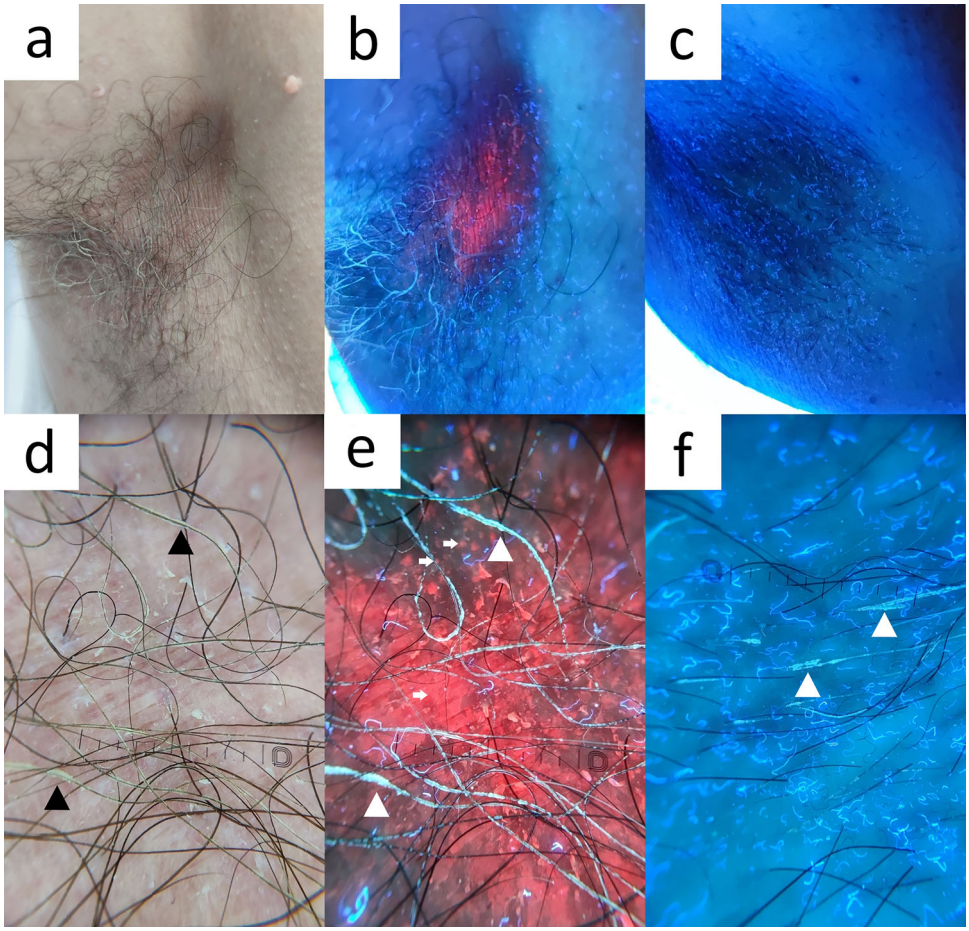

Fig. 19 Overlap of trichobacteriosis axillaris (TA) and erythrasma. Creamy white concretions on axillary hair and subtle hyperpigmentation in clinical examination (**a**) is matched by coral–red fluorescence of the armpit erythrasma and greenish fluorescence of the hair under Wood's lamp examination (**b**). No fluorescence seen with Wood's lamp after 2-week treatment with 2% fucidic acid cream and axillary hair shaving (**c**). Dermatoscopic examination at baseline reveals sparse scaling and yellowish translucent continuous and interrupted concretions adhering to axillary hair shafts typical for TA (black arrowheads) (**d**). Ultraviolet-induced fluorescence dermatoscopy (UVFD) reveals fluorescent clues to erythrasma and TA combined into a "Stranger Things" pattern: intense diffuse coral–red structureless area and dots (white arrows), discernible on a blue background, and yellowish-greenish concretions adhering to axillary hair shafts (white arrowheads), respectively (**e**). UVFD in a follow-up visit confirms absence of clues to erythrasma, whereas still displays interrupted yellowish–greenish concretions adhering to short regrowing axillary hair (white arrows) (**f**). Despite full clinical clearance in clinical and Wood's lamp examination, these fluorescent clues suggest incomplete clearance of TA, requiring prolonged treatment

pustules at the proximal hair shaft of the vellus hair that exhibited bright green excited fluorescence [52]. In the presented case, 365 nm UVFD displayed diffuse bright blue scaling with foci of green scale, bright blue and dull green hair: broken hair, bent hair, and bright blue fluorescent Morse-code-like hair (Fig. 23). The fluorophore responsible for the green color present in *M. canis* and *M. gypseum* is pteridine [53, 54].

Dermatophytic intertrigo of major skin creases is usually characterized by no fluorescent clues in 365 nm UVFD, contrary to inverse psoriasis and erythrasma (both red). Even though conventional non-contact polarized dermatoscopy is superior to UVFD in prediction

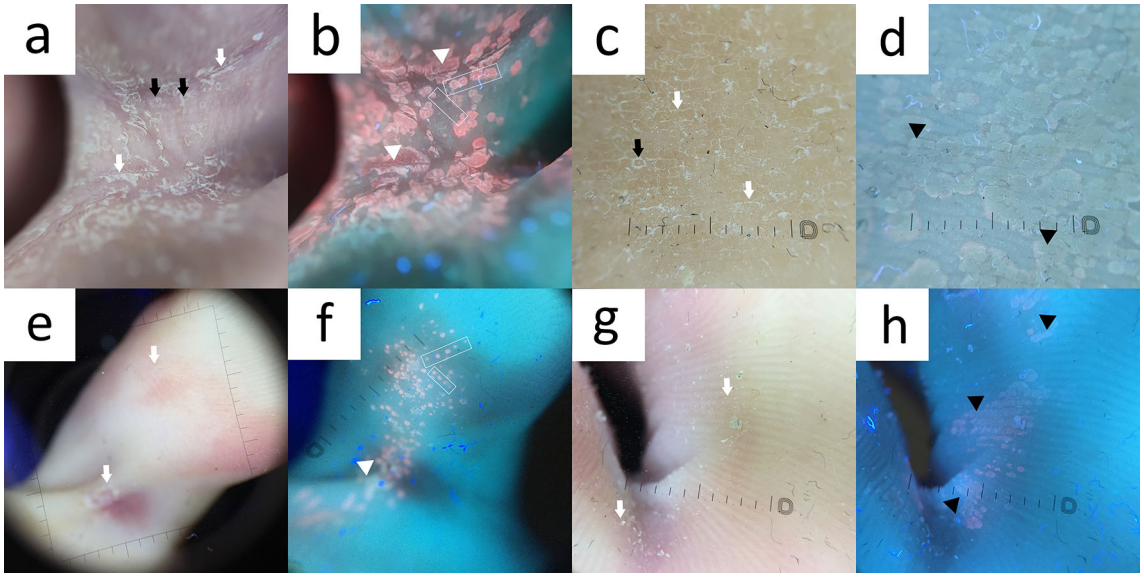

Fig. 20 Comparison of non-contact polarized dermatoscopy and ultraviolet-induced fluorescence dermatoscopy (UVFD) of pitted keratolysis (PK) and interdigital erythrasma (IE). Dermatoscopy of PK displays subtle scaling in the furrows (white arrows) and crateriform pits (black arrows) in interdigital spaces (**a**) and at plantar site (**c**). Dermatoscopy of IE presents a subtle interdigital scaling (white arrows) (**e**, **g**). UVFD of PK shows a fine coral-red scale (white arrowhead) (**b**), vague coral–red parallel ridge pattern (black arrowheads) (**d**), and peripheral linearly arranged coral–red eccrine dots and clods (white frame) (**b**) (possibly corresponding to the presence of *Corynebacterium* in eccrine duct openings and perieccrine area, respectively), strikingly similar to patterns of UVFD in IE (**f**, **h**)

of dermatophytic intertrigo (peripheral dotted vessels versus no fluorescence), some cases may display light green fluorescence (likely due to peripheral and peripilar serous crusts rich in bilirubin—see *Eczema* section) that might differentiate it from candidal intertrigo that may share the same UVFD presentation [24].

Frontal Fibrosing Alopecia

One prospective study in 12 patients showed that the presence of physiological cutibacterial orange–red coproporphyrin III fluorescence of the hair follicle ostia in frontal fibrosing alopecia ("starry night sky sign") was a predictor of hair regrowth or stabilization after 6 months of treatment to oral dutasteride 0.5 mg, clobetasol propionate 0.05% foam, and topical 5% minoxidil daily. No regrowth was observed in five patients lacking fluorescence. The authors suggested that the *Cutibacterium* colonization was maintained exclusively within viable hair follicle units [19]. Hair follicle regrowth is dependent on viable hair follicle progenitor cells that are normally located in a bulge region, just between the arrector pili muscle and intrafollicular opening of the sebaceous duct [55]. As Gram-positive *Cutibacterium* can develop only in a lipophilic environment, only follicular units with preserved perifollicular sebaceous glands may become colonized. We believe that this observation supports the role of intact sebaceous glands as an indirect clue to preserved follicular stem cells reserve. We have noted similar uniform variably intense red follicular excited fluorescence in alopecia areata patches, where the inflammatory process damages deeper follicular structures. Thus, we hypothesize that such an association should likely be true to any subtype of cicatricial alopecia (Fig. 24).This clue is likely age-dependent and might not be seen in prepubertal children.

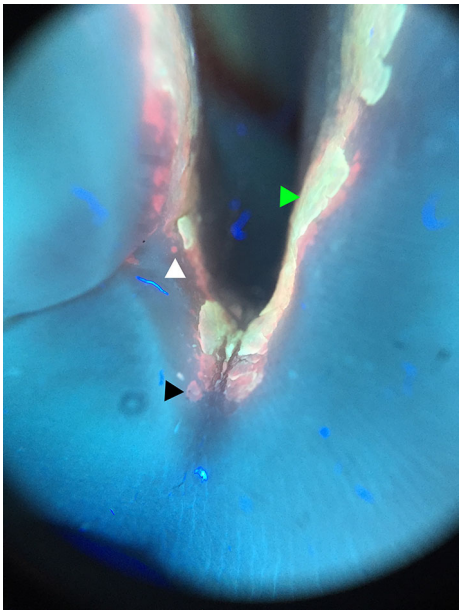

Fig. 21 Ultraviolet-induced fluorescence dermatoscopy of mixed intertrigo showing specific clues to interdigital erythrasma (coral–red excited fluorescence of scale and coalescing perieccrine dots and clods) (black and white arrowhead, respectively) and *Pseudomonas* infection—green excited fluorescence of the scale (green arrowhead)

Safety Concerns of UV Dermatoscopy

The IEC 62471:2006 standard is dedicated to addressing the issue of photobiological safety associated with light-emitting devices, including dermatoscopes [56]. These standards categorize light emitters into four risk groups, ranging from R0 (no risk) to R3 (high risk). The D'z-D100 Casio sUVRD dermocamera falls under the R0 risk group, while Dermlite's DL5 dermatoscope, utilizing UVFD, belongs to the R1 group (low risk). The data on the other devices are lacking.

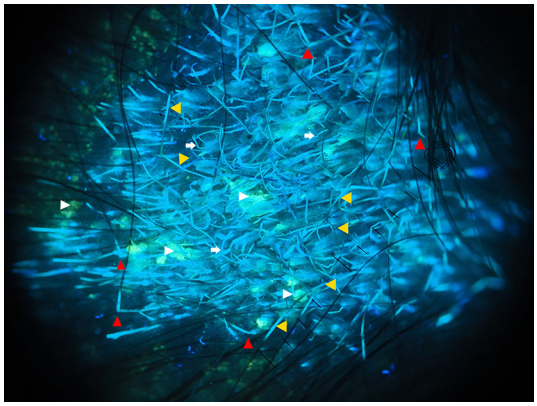

Fig. 23 Ultraviolet-induced fluorescence dermatoscopy (UVFD) of the tinea of the scalp caused by *Microsporum canis*. Standing out, bright blue and dull green hair, including broken hair (red arrowheads) and bent hair (white arrows), along with diffuse bright blue scales with green areas (white arrowheads) can be seen in UVFD. Note the bright blue fluorescent alternated band indicating Morse-code-like hair (yellow arrowheads) (**b**). Courtesy of Daria Luchinina, MD (Yoshkar-Ola, Russia)

Although UVA has a cancerogenic potential on the skin, the radiation intensity of 11 W/m^2 in DL5 is similar to the one achieved with the nail UV lamps, which have time exposure limits for each hand ranging from 59 min to 112 min [57]. Thus, even a few minutes of UVFD should be considered medically negligible. In our experience, the examination of a specific area rarely exceeds 30 s. Nevertheless, it is worth noting that the FDA recommends limiting exposure to nail UV lamps to no more than

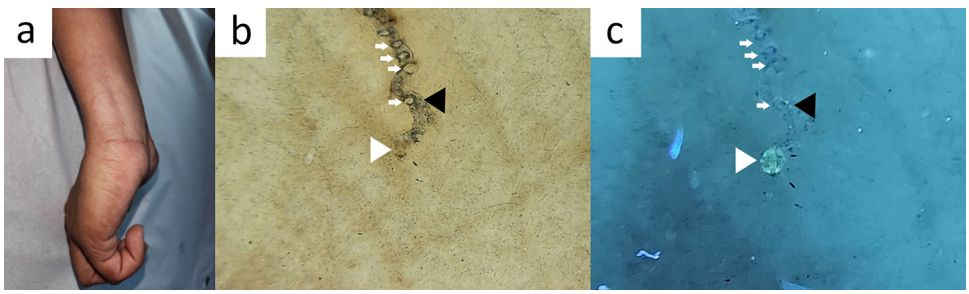

Fig. 22 Scabies. Clinical presentation (**a**). Ultraviolet-induced fluorescence dermatoscopy increases the visibility of the burrow (normally bright; black arrowhead) and the mite (greenish; white arrowhead) (**c**) compared with conventional contact polarized dermatoscopy (**b**). Progeny mites (white arrows) do not exhibit any fluorescence

10 min per hand per session in healthy individuals, with further restrictions for those using specific antibiotics, oral contraceptives, estrogens, and dietary supplements [57]. While UVA irradiation does not cause sunburn, it may contribute to the development of photosensitivity reactions, such as polymorphous light eruptions.

Both sub-UV and UVA radiation may pose some danger to the human retina and skin [58–61]. A R1 group was assigned to Dermlite's DL5 due to blue-light hazard, as the UV filters utilized in the device, and almost completely filtering out the remaining low percentage or reflected UVA, have minimal impact on the emitted sub-UVA. In addition, currently approved topical chemical sunscreens provide no protection to the skin against blue light and cannot not be recommended for that purpose [61]. Whereas a maximal time of a single, direct blue-light exposure to the eye is < 1.27 h for a R1 device, this scenario is technically unlikely with a dermatoscope. Nonetheless, these standards apply primarily to acute blue-light exposure, not chronic or repeated exposure [62, 63].

Low visual brightness of sub-UV/UV evokes low aversion response and does not provoke squinting and pupil constriction, especially in response to reflected radiation, estimated to be responsible for about 50% of eye exposure [64]. Consequently, healthcare professionals, due to chronic and repeated direct and indirect exposure in clinical settings, may choose to use UVA eye protection for their personal comfort and cataract prevention. It is worth noting that using even professional protective glasses without side covers can be associated with UV back reflection from the anti-reflective coating (counting for about 39% of UVA and 4% of sub-UV exposure) [65].

Most of the UV from a dermatoscope is absorbed [66], and almost all of it is filtered out by the device before it reaches the observer's eye. In addition, wearing polycarbonate UV-protective glasses can further minimize any risk of cataract formation for the observer. Furthermore, from a diagnostic point of view, blue-blocking protective glasses will impair the perception of colors. Of note, the studies investigating the effectiveness of blue-blocking protective measures in relation to eye diseases, including age-related macular degeneration, are lacking [62, 67]. During the examination, patients should be asked to close their eyes or use protective goggles to prevent direct sub-UV/UV exposure. The use of eye protection might be specifically recommended in children who have a natural curiosity and tend to look directly into the LEDs [68]. Alternatively, using a smartphone/digital camera as a signal receiver can completely eliminate the risk of cataract formation.

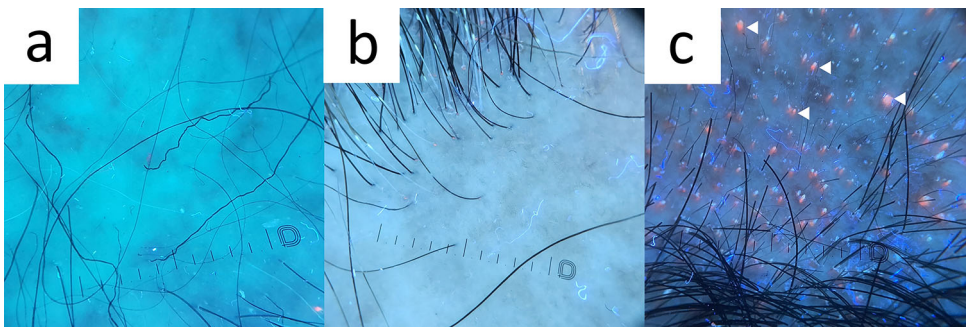

Fig. 24 Comparison of lichen planopilaris (LPP) (**a**), frontal fibrosing alopecia (FFA) (**b**), and alopecia areata (AA) (**c**) naive to the treatment in ultraviolet-induced fluorescence dermatoscopy. Of note, AA features uniform red follicular fluorescence in alopecic patches (white arrowheads), suggestive of preserved peripilar sebaceous glands with a hair regrowth potential. This clue is lost in both presented cicatricial alopecias. AA case is a courtesy of Verce Todorovska, MD (Skopje, North Macedonia)

Limitations of UVFD, sUVRD, and UVRD dermatoscopy

Discrimination of Pigment Source

The major limitation of UV and sub-UV dermatoscopy is the inability to reliably differentiate between melanin and hemoglobin (Fig. S12). While this distinction is often clear for linear vessels, interpreting the role of pigmented structures, such as structureless areas, clods, and dots, can be challenging, especially in the grayscale of sUVRD/UVRD. Furthermore, in sUVRD/UVRD, pigmented keratin scales on the face may mimic angulated lines, which are a clue to malignancy. Therefore, it is essential to emphasize that both fluorescence and reflectance dermatoscopy should always be complemented by conventional dermatoscopy and remain an integral part of clinical examination. The use of other dermoscopy modes, such as toggling between polarized and non-polarized light, might also be of help to correctly discern between structures.

Device-Dependent Variability in Imaging

Even a slight alteration in the emitted wavelength, as observed with UVRD (385 nm) and sUVRD (405 nm), can influence signal acquisition, leading to noticeable variations in the images [13]. It is plausible that various UVFD devices might generate excited fluorescence with differing hues and/or levels of brightness.

Sun Damage Status

It should be considered that the presence of various pigmentation and keratinization disorders resulting from chronic sun damage may interfere with both UVFD and sUVRD/UVRD, which may be due to compromised sub-UV/UV absorption, reflexion, and fluorescence patterns.

Excessive Pressure

Just as in conventional dermatoscopy, applying excessive pressure to the lesion may force the blood out of vascular structures, leading to the formation of a central paler area and the absence of vascular clues in both UVFD and sUVRD/UVRD (Fig. S13).

Uneven Surfaces

Evaluating irregular surfaces, e.g., on the face, periareolar, anogenital, and acral regions, can pose challenges when using UVFD dermatoscopy. We have encountered this issue mainly on the dorsum of the nose, ears, and internal canthus. This is primarily due to the difficulty of achieving proper contact plate adherence, which can lead to the loss of a dark, sealed environment, leading to visible light infiltration and a loss of focus (Fig. S14). In these scenarios, fading the room lights might be of aid, if possible.

Of note, utilizing contact UVFD may bias surface visualization and deprive the image of the clues of scale. Conversely, non-contact UVFD has the potential to reduce the visibility of vascular and pigment clues.

In sUVRD/UVRD, the existence of uneven skin surfaces and the presence of hair intensifies the reflection signals originating from the stratum corneum, restricting deeper penetration of sub-UV/UV light (Fig. S15). Thus, it is vital that both reflectance dermatoscopy techniques are used with contact medium (such as water, paraffin, 70% alcohol solution, silicone gel, etc.) to obtain the images exhibiting crisp structures and accurate shades, and avoid air bubbles, unless the operator intentionally aims to investigate the surface clues or the clues of scale with non-contact sUVRD/UVRD.

Given the innovative nature of both methods, no optimal contact medium for fluorescence or reflectance dermatoscopy can be recommended at this point, as it is possible certain media may compromise the signal quality.

Exposure and White Balance

In certain cases, reducing the intensity of radiation can paradoxically improve the visibility of fluorochromes (Fig. S16). This likely occurs because a lower contrast between the background dermal fluorescence and the chromophore's excited fluorescence is achieved when the irradiation density is set to its maximum. Additionally, in some imaging devices connected to the UV-induced fluorescence

dermatoscope, the embedded software automatically adjusts exposure and white balance. This adjustment might result in the excited fluorescence color fading or in reduced contrast in UVFD.

Patient Preparation

When performing UV dermatoscopy, a detailed medical history should be taken concerning the following aspects to avoid false positive and false negative results. In cases where the method is expected to provide added diagnostic value, the patient should be advised to abstain from any topical substances listed below and schedule a follow-up appointment a few days or weeks later.

The Use of Sunscreens

Patients should take certain preparations before undergoing UV dermatoscopy. The application of sunscreens impacts diagnostic accuracy (see Figs. S17, S18). In UVFD, the filters, which are designed to absorb and/or reflect UV radiation, lead to the formation of dark or bright areas (increased UV absorption or bright UV-induced fluorescence, respectively) that can obscure the underlying fluorescent clues. In sUVRD/UVRD these areas present as hyperreflective.

The Use of Drugs, Cosmetics, and Other Miscellaneous Substances

The use of topical and systemic drugs, emollients, lacquers, deodorants, soaps, hair cosmetics, honey, and various other substances, including herbal remedies and plant-derived substances (e.g., fruit juices, greater celandine juice), even if they were applied several days prior to the examination, might be potentially responsible for artificial UV-induced fluorescence or signal reduction/absence (Fig. S17) [34, 69]. Textiles and dirt may interfere with skin fluorescence. Colored markers, lipsticks, and nail polishes may also contribute to artificial fluorescence, especially in malingering patients, including children.

Age and Site

Cutibacterial colonization of seborrheic areas develops in puberty. Thus, *Cutibacterium*-associated red fluorescence might be absent in prepubertal children, in non-seborrheic areas, or be affected by systemic or topical antibacterial treatment.

Washing

Patients should not take a shower/bath directly before the visit. Excessive hygiene (e.g., frequent showers) may wash out the luminescent chromophores and result in the absence of fluorescent clues in UVFD, a phenomenon that we observed in corynebacterial dermatoses (Fig. S19).

Sun Exposure

Sun exposure might likely be responsible for burnout of UV-induced fluorescence. Thus, exposed areas may manifest minimal-to-none UVFD fluorescent clues (Fig. S20). This specifically applies to porphyrin- and bilirubin-related excited fluorescence, yet may be potentially true also for other fluorophores [21].

Skin of Color

Increased melanin density in the skin of color results in higher absorption of UV light. This phenomenon might impair the visibility of melanin and hemoglobin clues in darker skin types. This issue was partially addressed by UVRD with a P385 Casio dermocamera prototype, which was reported to provide better contrast in skin of color than sUVRD.

CONCLUSIONS

Fluorescence and reflectance dermatoscopy based on UV and sub-UV can identify clues that are not discernible with conventional dermatoscopy, thereby enhancing diagnostic confidence in both neoplastic and non-neoplastic dermatoses. Of note, these methods should not replace, but rather should complement, the

diagnostic armamentarium, serving as valuable adjuncts in the broader context of clinical examination and patient history. Importantly, clinicians using these techniques must be aware of possible artifacts and limitations inherent in UV and sub-UV imaging to ensure accurate interpretation and avoid diagnostic pitfalls.

ACKNOWLEDGEMENTS

Medical Writing and Editorial Assistance. ChatGPT 4.0 was used for language editing purposes.

Author Contributions. Conceptualization: Paweł Pietkiewicz; Methodology: Paweł Pietkiewicz, Cristian Navarrete-Dechent; Formal analysis and investigation: Paweł Pietkiewicz, Cristian Navarrete; Writing—original draft preparation: Paweł Pietkiewicz, Cristian Navarrete-Dechent; Yaei Togawa, Enzo Errichetti; Writing—review and editing: Paweł Pietkiewicz, Cristian Navarrete-Dechent; Yaei Togawa, Piotr Szlązak, Natalia Salwowska, Ashfaq A. Marghoob, Agnieszka Leszczyńska-Pietkiewicz, Enzo Errichetti; Supervision: Paweł Pietkiewicz.

The authors wish to thank the following colleagues for contributing the images and sharing their observations: Dr. Darya Luchinina (Department of Health in the Republic of Mari El; Republican Dermatovenereological Clinic; Yoshkar-Ola, Russian Federation). Dr. Verce Todorovska (Dermatology Private Practice; Skopje, North Macedonia) Dr. Marian Voloshynovych (Department of Dermatology and Venereology, Ivano-Frankivsk National Medical University, Ivano-Frankivsk, Ukraine).

Funding. No funding or sponsorship was received for publication of this article.

Declarations

Conflict of Interest. Paweł Pietkiewicz has received DL5 dermatoscope free of charge from DermLite Inc. Cristian Navarrete-Dechent, Yaei Togawa, Piotr Szlązak, Natalia Salwowska, Ashfaq A. Marghoob, Agnieszka Leszczyńska-Pietkiewicz, Enzo Errichetti have nothing to disclose.

Ethical Approval. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

REFERENCES

1. Lallas A, Errichetti E, Ioannides D. Dermoscopy in general dermatology. 1st ed. Boca Raton: CRC Press; 2018. p. 374.

2. Pietkiewicz P, Navarrete-Dechent C, Goldust M, Korecka K, Todorovska V, Errichetti E. Differentiating fordyce spots from their common simulators using ultraviolet-induced fluorescence dermatoscopy-retrospective study. Diagnostics (Basel). 2023;13(5):985.

3. Mustafic A, Li C, Haidekker M. Blue and UV LED-induced fluorescence in cotton foreign matter. J Biol Eng. 2014;8(1):1–11.

4. Tuxworth B. Getting Started with UV Fluorescence Photography. [Internet]. Adaptalux.com. 2017. https://adaptalux.com/getting-started-uv-fluorescence-photography/. Cited 5 Nov 2023.

5. Mojeski JA, Almashali M, Jowdy P, Fitzgerald ME, Brady KL, Zeitouni NC, et al. Ultraviolet imaging in dermatology. Photodiagnosis Photodyn Ther. 2020;30: 101743.

6. Crowther J. Ultraviolet fluorescence photography—choosing the correct filters for imaging. J Imaging. 2022;8(6):162.

7. Crowther JM. UV reflectance photography of skin: what are you imaging? Int J Cosmet Sci. 2020;42(2): 136–45.

8. De Angelis D, Mapelli G, Mazzullo FL, Lorenz MT, Cattaneo C. Possible applications of reflected UV photography in forensic odontology: food for thought. Leg Med (Tokyo). 2020;42: 101641.

9. Sano T, Minagawa A, Suzuki R, Koga H, Okuyama R. Dermoscopy with near-ultraviolet light highlights the demarcation of melanin distribution in cutaneous melanoma. J Am Acad Dermatol. 2021;84(1): e23–4.

10 Minagawa A, Meling MT, Koga H, Okuyama R. Near-ultraviolet light dermoscopy for identification of pigmented skin tumours. Acta Derm Venereol. 2023;103: adv00876.

11. International Organization for Standardization. ISO 21348:2007 Space environment (natural and artificial). Process for determining solar irradiances. [Internet]. Geneva; 2007. https://www.iso.org/standard/39911.html. Cited 8 Dec 2023.

12. Shu J, Yamamoto Y, Aoyama K, Togawa Y, Kishimoto T, Matsue H. Assessment of malignant melanoma lesions using violet-light dermoscopy: a case report. J Dermatol. 2022;49(7):710–3.

13. Togawa Y, Yamamoto Y, Matsue H. Clinical study on the comparison of dermoscopic images using two wavelengths of near-ultraviolet-visible light. JEADV Clin Pract. 2023;1–5. [ahead of print].

14. Xu H, Wang Y, Takashi E, Kamijo A, Miura D, Karasawa K, et al. Predicting the different progressions of early pressure injury by ultraviolet photography in rat models. Int Wound J. 2021;19(4): 834–44.

15. Fang X, Wang Y, Maeda R, Kitayama A, Takashi E. Early prediction of pressure injury with long short-term memory networks. Sens Mater. 2022;34(7): 2759.

16. Pietkiewicz P, Adhikari A, Kowalska K, Malińska A, Bowszyc-Dmochowska M. Could conventional, ultraviolet-induced fluorescence and sub-ultraviolet reflectance dermatoscopy assist the diagnosis of cutaneous collagenous vasculopathy?—a case report. Dermatol Pract Concept. 2024 [in press].

17. Pietkiewicz P, Korecka K, Salwowska N, Kohut I, Adhikari A, Bowszyc-Dmochowska M, et al. Porokeratoses—a comprehensive review on the genetics and metabolomics, imaging methods and management of common clinical variants. Metabolites. 2023;13(12):1176.

18. Rudnicka L, Olszewska M, Rakowska A, Slowinska M. Trichoscopy update 2011. J Dermatol Case Rep. 2011;5(4):82–8.

19. Rodrigues-Barata AR, Moreno-Arrones OM, Corralo DS, Galvan SV. The 'starry night sky sign' using ultraviolet-light-enhanced trichoscopy: a new sign that may predict efficacy of treatment in frontal fibrosing alopecia. Int J Trichology. 2018;10(5): 241–3.

20. Navarrete-Dechent C, Pietkiewicz P, Dusza SW, Andreani S, Nehal KS, Rossi AM, et al. Ultraviolet-induced fluorescent dermoscopy for biopsy site identification prior to dermatologic surgery: a retrospective study. J Am Acad Dermatol. 2023;89(4): 841–3.

21. Kearse KP. Ultraviolet fluorescent detection of elevated bilirubin in dried blood serum. J Foren Sci Res. 2022;6(1):049–52.

22. Thatte SS, Chikhalkar SB, Khopkar US. 'Pink glow': a new sign for the diagnosis of glomus tumor on ultraviolet light dermoscopy. Indian Dermatol Online J. 2015;6(Suppl 1):S21-23.

23. Yuan M, Xie Y, Zheng Y, Zhang Z, Yang C, Li J. Novel ultraviolet-dermoscopy: early diagnosis and activity evaluation of vitiligo. Skin Res Technol. 2023;29(1): e13249.

24. Errichetti E, Pietkiewicz P, Bhat YJ, Salwowska N, Szlązak P, Stinco G. Diagnostic accuracy of ultraviolet-induced fluorescence dermoscopy in non-neoplastic dermatoses (general dermatology): a multicentric retrospective comparative study. J Eur Acad Dermatol Venereol. 2024. https://doi.org/10.1111/jdv.19795. (**in press**).

25. Thatte SS, Khopkar US. The utility of dermoscopy in the diagnosis of evolving lesions of vitiligo. Indian J Dermatol Venereol Leprol. 2014;80(6):505–8.

26. Łabędź N, Navarrete-Dechent C, Kubisiak-Rzepczyk H, Bowszyc-Dmochowska M, Pogorzelska-Antkowiak A, Pietkiewicz P. Pityriasis versicolor—a narrative review on the diagnosis and management. Life. 2023;13(10):2097.

27. Bae JM, Lee RW. 365-nm narrowband Wood's lamp for vitiligo and hypopigmentation disorders. J Am Acad Dermatol. 2020;83(4):e283–4.

28. Bissonnette R, Zeng H, McLean DI, Schreiber WE, Roscoe DL, Lui H. Psoriatic plaques exhibit red autofluorescence that is due to protoporphyrin IX. J Invest Dermatol. 1998;111(4):586–91.

29. Wang B, Xu YT, Zhang L, Zheng J, Sroka R, Wang HW, et al. Protoporphyrin IX fluorescence as potential indicator of psoriasis severity and progression. Photodiagn Photodyn Ther. 2017;19: 304–7.

30. Pietkiewicz P, Navarrete-Dechent C, Mayisoğlu H, Jolly G, Kutlu Ö, Errichetti E. Pink-red fluorescence observed in ultraviolet-induced fluorescence dermoscopy of psoriatic plaques. Dermatol Pract Concept. 2023;13(3): e2023243.

31. Xie Y, Zheng Y, Yuan M, Zhang Z, Yang C, Li J. Specific features of psoriasis vulgaris under the ultraviolet dermoscopy. Photodiagn Photodyn Ther. 2022;40: 103100.

32. Gao RY, Pradhan S, Ran YP. Nail psoriasis in a child observed under ultraviolet dermoscopy treated by a topical biological agent cream: a case report. Int J Dermatol Venereol. 2021;4(4):251.

33. Thomas M, Yadav T, Khopkar U. The role of dermoscopy using a triple light source in the diagnosis of pityriasis rosea: an observational pilot study. Int J Dermatol. 2017;56(7):e147–8.

34. Kearse KP. Ultraviolet 365 as an alternative light source for detection of blood serum. J Forensic Sci. 2020;65(5):1716–21.

35. Sun R, Chen H, Zhu W, Lian S. Wood's lamp image of porokeratosis. Photodermatol Photoimmunol Photomed. 2017;33(2):114–6.

36. Thatte SS, Kharkar VD, Khopkar US. 'Diamond necklace' appearance in superficial porokeratosis. J Am Acad Dermatol. 2014;70(6):e125-126.

37. Chi C, Liu J. Image Gallery: porokeratosis under the dermoscopic furrow ink test and ultraviolet light. Br J Dermatol. 2017;177(4): e159.

38. Al-Nasiri M, Navarrete-Dechent C, Korecka K, Salwowska N, Goldust M, Pietkiewicz P. Ultraviolet-induced fluorescence dermatoscopy of trichobacteriosis axillaris reveals peripilar yellow-green luminescent concretions. Dermatol Pract Concept. 2023;13(2): e2023169.

39. Brown J. Erythrasma and identification with Wood's light. J Am Podiatry Assoc. 1970;60(8): 322–3.

40. Garcia-Souto F. Visual dermatology: erythrasma fluorescence under wood's lamp. J Cutan Med Surg. 2020;24(1):94.

41. Pietkiewicz P, Navarrete-Dechent C, Salwowska N, Cantisani C, Goldust M, Errichetti E. Ultraviolet-induced fluorescence dermatoscopy reveals fluorescent clues in pitted keratolysis. Dermatol Pract Concept. 2023;13(3): e2023242.

42. Singh N, Yang H, Pradhan S, Ran X, Ran Y. Image gallery: wandering demodex mite in vivo under ultraviolet dermoscopy of rosacea. Br J Dermatol. 2020;182(1): e2.

43. Pietkiewicz P, Navarrete-Dechent C. Scabies mite is bright green under UV dermatoscopy. Dermatol Pract Concept. 2023;13(2): e2023135.

44. Nie J, Gou T, Xu L, Wang W, Zhang L, Lu Y. Misdiagnosed scabies correctly diagnosed by dermoscopy using ultraviolet light mode. Clin Exp Dermatol. 2021;46(8):1601–3.

45. Yürekli A, Muslu İ, Pektaş SD, Alataş ET, Aydoğdu CT, Daşgin D. Using ultraviolet dermoscopy in diagnosing scabies. Exp Dermatol. 2023;32(11): 1996–9.

46. Fujimoto M, Sakai H, Watanabe R, Fujimoto M. Glittering trail: Feces of scabies indicated by high-power–field dermatoscopy using UV-A light. J Am Acad Dermatol. 2023; 8:S0190–9622(23)01018–6.

47. Yürekli A. A new sign with UV dermoscope in the diagnosis of scabies: ball sign. Skin Res Technol. 2023;29(5): e13336.

48. Zhi HL, Xia XJ, Liu ZH. Tinea auricularis: a neglected tinea incognito. Clin Exp Dermatol. 2022;47(6): 1179–80.

49. Liu ZH, Zhi HL, Xia XJ. Combination dermoscopy highlights fungal invasion of vellus hair in tinea vellus. Clin Exp Dermatol. 2022;47(1):138–9.

50. Zhi HL, Xia XJ, Liu ZH. Combination dermoscopy for initiation and monitoring of systemic antifungal therapy for paediatric tinea faciei with invasion of vellus hair owing to *Microsporum canis*. Clin Exp Dermatol. 2023;48(3):249–50.

51. Waśkiel-Burnat A, Rakowska A, Sikora M, Ciechanowicz P, Olszewska M, Rudnicka L. Trichoscopy of tinea capitis: a systematic review. Dermatol Ther (Heidelb). 2020;10(1):43–52.

52. Tang J, Ran Y. Polarized and ultraviolet dermoscopy for the diagnosis of dermatophytosis of vellus hair. Indian J Dermatol Venereol Leprol. 2020;86:607.

53. Wolf FT. Chemical nature of the fluorescent pigment produced in microsporum- infected hair. Nature. 1957;180(4591):860–1.

54. Wolf FT, Jones EA, Nathan HA. Fluorescent pigment of microsporum. Nature. 1958;182(4633):475–6.

55. Joulai Veijouye S, Yari A, Heidari F, Sajedi N, Ghoroghi Moghani F, Nobakht M. Bulge region as a putative hair follicle stem cells niche: a brief review. Iran J Public Health. 2017;46(9):1167–75.

56. International Electrotechnical Commission. IEC 62471 Ed. 1.0 b:2006, First Edition: Photobiological safety of lamps and lamp systems. Edition 1.0, IEC. Distributed through American National Standards Institute; 2014. p. 98.

57. Ford H, Horsham C, Urban D, Tinker R, Hacker E. Quantifying the ultraviolet radiation emitted by nail curing devices: a descriptive study. Australas J Dermatol. 2021;62(2):e311–3.

58. Glickman RD. Ultraviolet phototoxicity to the retina. Eye Contact Lens. 2011;37(4):196–205.

59. Cherrie JW, Cherrie MPC. Workplace exposure to UV radiation and strategies to minimize cancer risk. Br Med Bull. 2022;144(1):45–56.

60. Yu Z, Correa VSMC, Efstathiou NE, Albertos-Arranz H, Chen X, Ishihara K, et al. UVA induces retinal photoreceptor cell death via receptor interacting protein 3 kinase mediated necroptosis. Cell Death Discov. 2022;8(1):1–11.

61. Kumari J, Das K, Babaei M, Rokni GR, Goldust M. The impact of blue light and digital screens on the skin. J Cosmet Dermatol. 2023;22(4):1185–90.

62 International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP statement on light-emitting diodes (LEDS) and laser diodes: implications for hazard assessment. International Commission on Non-Ionizing Radiation Protection. Health Phys. 2000;78(6):744–52.

63. Krigel A, Berdugo M, Picard E, Levy-Boukris R, Jaadane I, Jonet L, et al. Light-induced retinal damage using different light sources, protocols and rat strains reveals LED phototoxicity. Neuroscience. 2016;339:296–307.

64. Behar-Cohen F, Baillet G, de Ayguavives T, Garcia PO, Krutmann J, Peña-García P, et al. Ultraviolet damage to the eye revisited: eye-sun protection factor (E-SPF®), a new ultraviolet protection label for eyewear. Clin Ophthalmol. 2014;8:87–104.

65. Citek K. Anti-reflective coatings reflect ultraviolet radiation. Optometry. 2008;79(3):143–8.

66. Cader A, Jankowski J. Reflection of ultraviolet radiation from different skin types. Health Phys. 1998;74(2):169–72.

67. Cougnard-Gregoire A, Merle BMJ, Aslam T, Seddon JM, Aknin I, Klaver CCW, et al. Blue light exposure: ocular hazards and prevention—a narrative review. Ophthalmol Ther. 2023;12(2):755–88.

68. Herro EM, Cosan T, Jacob SE. Ultraviolet protective eyewear for Wood's light use. Pediatr Dermatol. 2011;28(3):351–2.

69. Huang X, Asawanonda P, Oon HH. Molnupiravir-associated nail and hair fluorescence on Wood's lamp examination. Clin Exp Dermatol. 2023;48(4):381–2.