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Development of a Low-Cost Dermoscope with Cross Polarization for Visual Inspection and Digital Imaging

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ABSTRACT: This paper describes the development of a digital dermoscope with cross polarization as an auxiliary instrument to help dermatologists diagnose pigmented skin lesions, allowing the visualization of skin pigmentation structures in the epidermis and dermis. The device consists of a low-cost digital microscope with a modified optical system, in which linear polarizers and a rotation system have been added to cross the transmission axes of the polarizers. As a result, this device obtains images of the skin *in situ*, greatly eliminates the specular reflection of the skin's surface layer, making it possible to visualize deeper layers such as capillary blood vessels and internal pigments.

KEYWORDS: Digital Dermoscope, Polarized light, Pigmented Skin Lesions.

INTRODUCTION

A dermoscope is used to evaluate and diagnose pigmented lesions, magnifies a pigmented lesion and allows the dermatologist to see through the stratum corneum, providing a detailed view of the skin's deep structural information. Under normal conditions, most of the light that incident on the skin's surface is reflected due to the higher refractive index of the stratum corneum. The polarized dermoscopy reduces the visualization of surface-reflected light using two polarizers [1, 2]. The basic principles and theoretical foundations are summarised below.

Light is composed of electromagnetic waves which, as observed in experimental measurements, propagate in a straight line. The electric field $\boldsymbol{E}$ of an electromagnetic wave can be described as the vector sum of two electrical field components called $E_{\parallel}$ and $E_{\perp}$, that are perpendicular to each other. The relative magnitude and phase of these $E_{\parallel}$ and $E_{\perp}$ electric fields specify the polarization status of the wave, as described in figure 1. Based on the three types of linearly polarized light, we have that [3, 4]:

1. H: The vertical wave component has zero magnitude ($E_{\perp} = 0$), and the total wave is a linearly polarized wave in the horizontal direction ($\theta = 0^0$, called H).
2. V: The horizontal wave component has zero magnitude ($E_{\parallel} = 0$), and the total wave is a linearly polarized wave in the vertical direction ($\theta = 90^0$, called V).
3. P^+: The two components $E_{\parallel}$ and $E_{\perp}$ are aligned in phase and if they are equal in magnitude, and the sum of the two waves is a $+45^0$ linearly polarized wave ($\theta = 45^0$, called P^+).

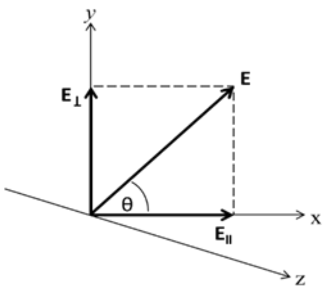

Figure 1. $E_{\parallel}$ and $E_{\perp}$ components of the total electric field are show aligned with the x and y axes, respectively. The angle θ indicates the orientation of the E field at a moment in time, viewed as the wave approaches the observer, and the wave is propagating along the z-axis.

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In other words, the three types of linearly polarized light H, P^+, and V are obtained by passing unpolarized light through a linear polarizer that is oriented at an angle $\theta = 0^0,\ 45^0$ or 90^0 respectively.

METHOD

Just as described in [4], a single H light source is used and two images are acquired, an HH image acquired through an H linear polarization filter and a HV image acquired through a V linear polarization filter. Figure 2 shows the experimental setup for such a simple polarization imaging system. The HH accepts light that is still polarized as H light. The surface glare (specular reflectance) of the tissue is also H light, so the illumination light is projected at an angle. A thin layer of gel is placed on the skin (or water, or some other medium with an equivalent refractive index) to reduce the glare from the surface away from the camera.

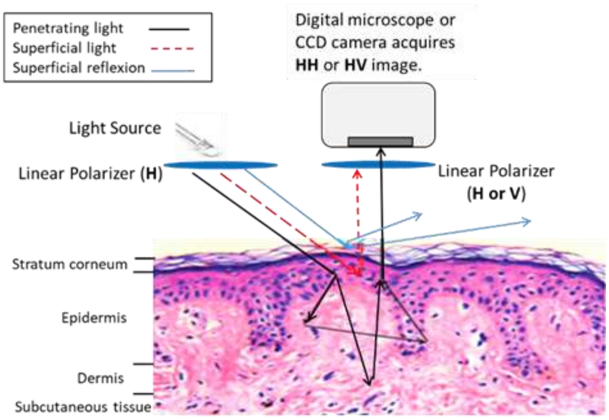

Figure 2. The trajectory of the light rays is shown, passing through the first polarizer toward the skin. The light penetrates the tissue and travels toward the second polarizer, reaching the camera sensor or digital microscope to form the image.

DERMOSCOPE WITH CROSS POLARIZATION

The procedure for assembling the dermatoscope is described in detail below so that it can be replicated by the reader. The device consists of a USB digital microscope with a resolution of 640x480 to 1600x1200 pixels, 24-bit color, and digital zoom of up to 5x, for an approximate magnification of 50x. All elements on the front are removed to expose the image CMOS sensor, allowing free use of the zoom and digital focus. Twelve ultra-bright white LEDs in a ring were used as the light source (Fig. 3.a), are connected to a 5V voltage source. A ring-cut film polarizer is placed front the light source (fig. 3.b), and both rings (LEDs and polarizer) are assembled jointly the main structure of the microscope. A second polarizer is placed on a circular base of the microscope, which allows the transmission axis to be rotated from $\theta = 0^0$ to $\theta = 90^0$ respect to the transmission axis of the first polarizer (fig 3.c).

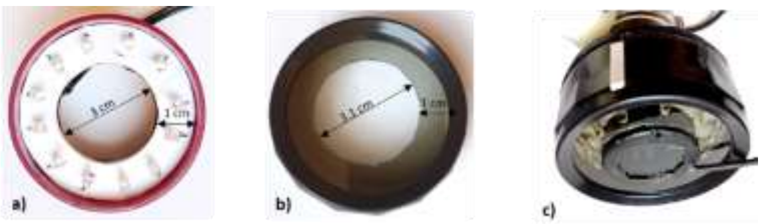

Figure 3. Assembly of light source with polarizers.

A lever is installed at the base of the second polarizer to manually rotate the transmission axis. This mechanism was not automated because it affects the image acquisition procedure, so specialists must adjust it manually. In addition, a base and an aluminum post are installed to secure the device and maintain the focal distance from the tissue to the sensor (fig. 4).

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Figure 4. Cross-polarized Digital Dermoscope prototype.

Dermoscope can be easily connected to a computer (Fig. 5.a) and allows for obtaining magnified images of the skin *in situ* [5], this device is easy to use and offers a non-invasive auxiliary diagnostic method (Fig. 5.b). This device is currently in the testing phase.

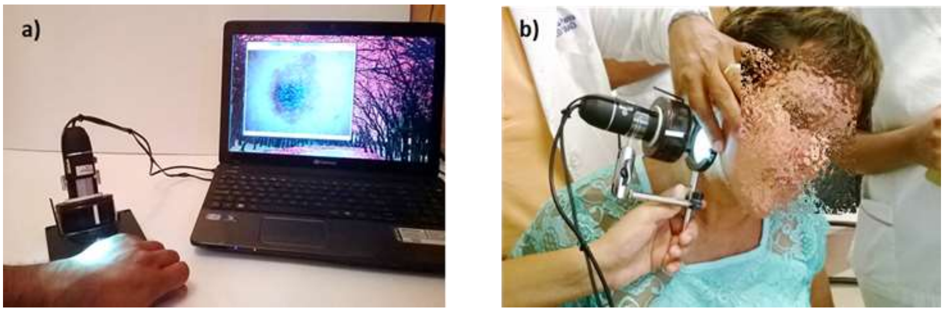

Figure 5. a) Connection of the dermoscope to the computer, b) acquisition of images of pigmented lesions.

RESULTS

A set of digital images acquired with HH polarized light and with crossed HV polarizers are shown below [4, 6], and correspond to examples of pigmented lesions diagnosed with the assistance of the developed dermoscope.

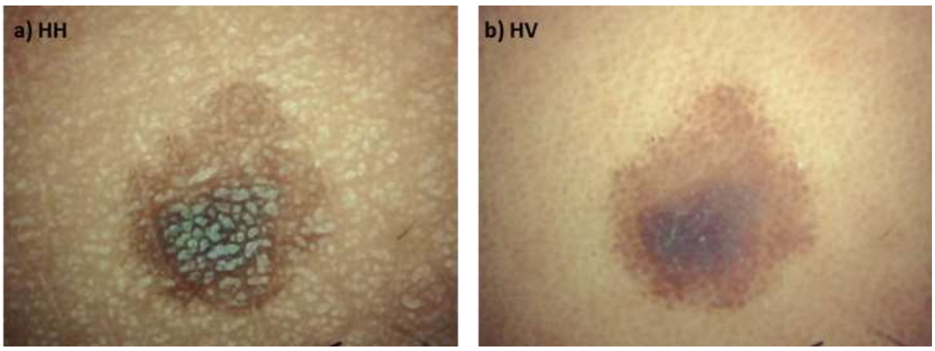

Figure 6. Benign nevus, a) uniform pigment pattern is observed, b) with crossed polarizers, a globular pigment pattern with gradual fading at the edge of the lesion is observed.

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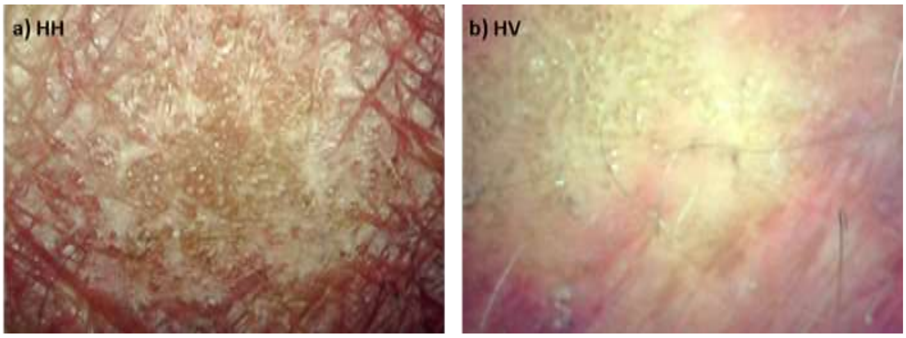

Figure 7. Ecchymosis, a lesion characterized by affecting blood vessels, a) brown coloring and skin folds are observed due to the desquamation of the cells of the stratum corneum, b) with cross polarization, the area of interest shows a pinkish color corresponding to the deposits of extravasated blood under the epidermis.

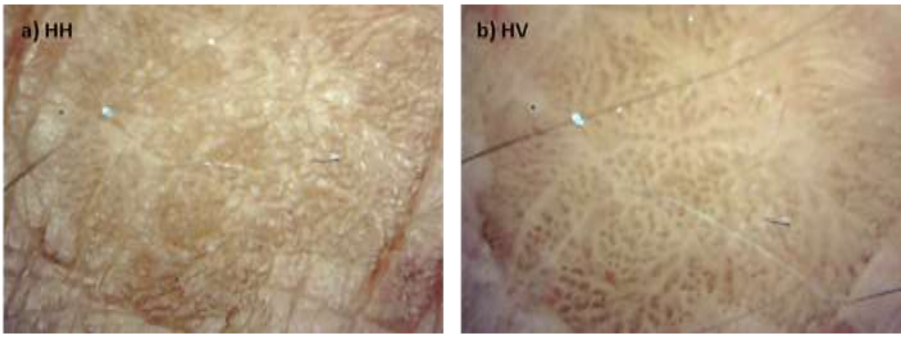

Figure 8. a) Spot corresponding to a solar lentigo, b) shows the distribution and structure of the pigment.

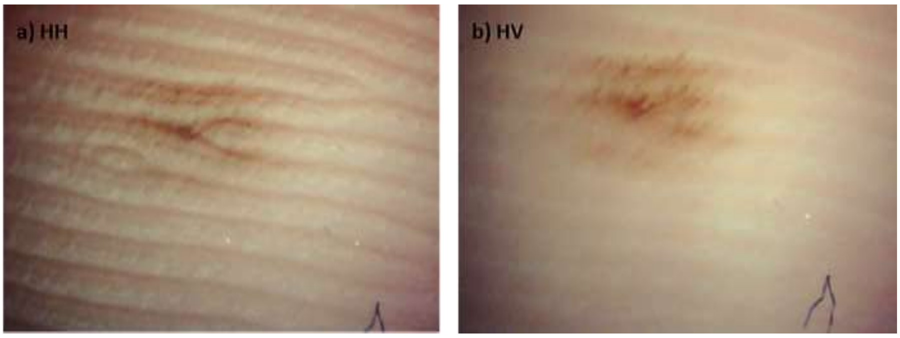

Figure 9. Intradermal nevus, a) linear appearance of pigment observed, b) presence of pigment in higher concentration.

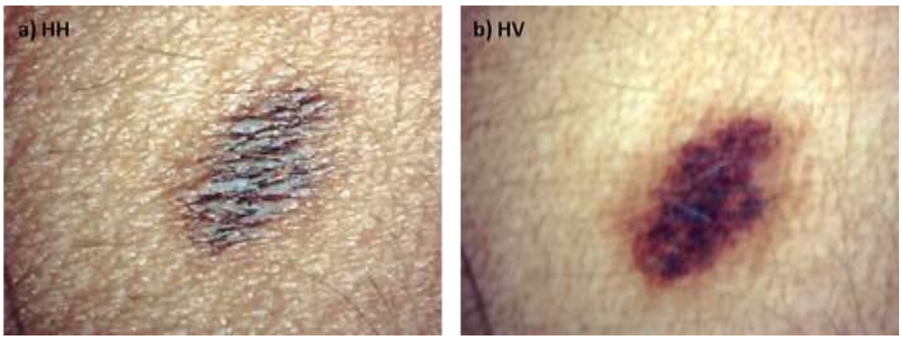

Figure 10. a) Growing compound nevus, b) with crossed polarizers, the colors of the pigment pattern are observed.

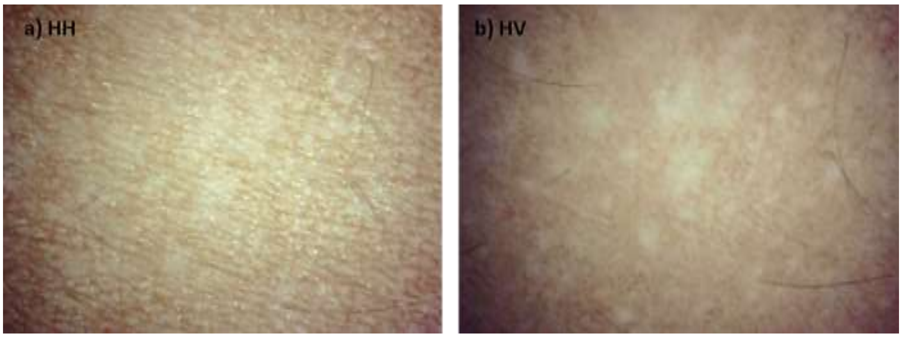

Figure 11. a) White spots corresponding to hypochromic solar dermatitis, b) with crossed polarizers the spots are more evident, confirming the previous diagnosis.

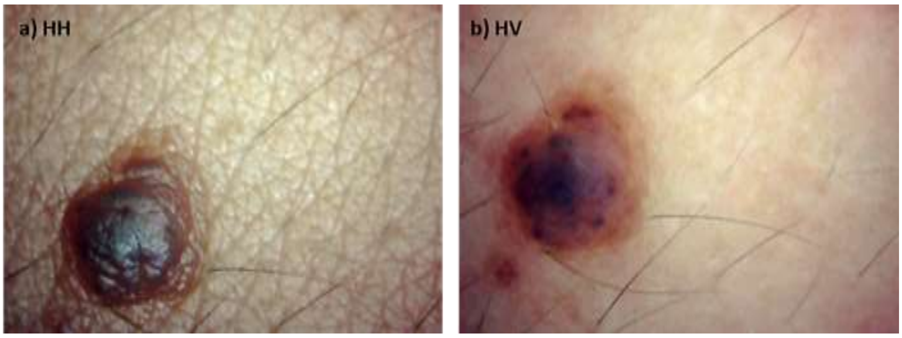

Figure 11. Melanocytic nevus, a) Pigment pattern is visible, b) brown and black globules are recognizable with cross-polarization, however, the pigmentation is not visible.

CONCLUSION

A low cost digital dermoscope was built and implemented based on commercial components. This device that can image the skin *in situ* and is used for early diagnosis of melanoma and pigmented skin lesions, verifying the effectiveness of cross polarization.

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