Use of Crossed Polarizers to Enhance Images of the Eyelids

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Purpose: To describe imaging of the external eye with Crossed Polarizers to enhance clinically important features in digital photographs of the eyelids.

Methods: External photographs with and without crossed polarizing filters were taken of patients with blepharitis and controls with no clinical eye pathology.

Results: Photographing eyelid skin through Crossed Polarizers decreased reflections on the skin surface and improved visualization of eyelid telangiectasias and blood vessels in patients with a broad range of skin pigmentation and ethnicities.

Conclusions: The use of Crossed Polarizers in imaging the external eye reduces reflections and glare from the eyelid skin and margins, thereby allowing for a more detailed evaluation of underlying structures and analysis of images. These findings suggest that including Crossed Polarizers in clinical photography has informative applications for assessing eyelid disease.

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The use of polarized light for diagnostic imaging has been studied in dermatology,[1] pathology,[2] and ophthalmology,[3,4] in which it can reveal reflectance, polarizing, depolarizing, and/or birefringence properties of tissues under study. In dermatology, polarization methods have been applied to a variety of conditions including pigmented and nonpigmented skin lesions,[5] skin malignancies,[6] photoaging,[7] and acne.[8,9] Photography using a polarizing filter parallel to the polarization of the light source (parallel polarizers) enhances superficial structures of the skin, whereas using a filter at cross-polarization to the light source (Crossed Polarizers) improves visualization of subsurface tissue structures.[1] By reducing specular reflections from superficial epidermal tissue and skin surface lipids, imaging with Crossed Polarizers specifically enhances the assessment of blood vessels and chromophores in skin,[10,11] thus improving assessments of pigmented lesions and vascular lesions[10,11] and reducing the impact of epidermal melanin.[12]

In ophthalmology, polarization manipulations have been applied to image various parts of the human eye, including the conjunctiva,[13] cornea,[13,14] lens,[15] sclera,[13] and retinal nerve fiber layer.[16] Because approximately 90% of the cornea is composed of parallel sheets of collagen fibers, the cornea behaves as a uniaxial birefringent or anisometropic medium.[17] When imaged using Crossed Polarizers, a characteristic interference pattern develops, known as an "isogyre," which was first described in 1941 by Cogan.[18] The appearance of the corneal isogyre is due to a combination of optical properties created by curvature of the cornea and distribution of collagen fibrils.[19] Briefly, light that is parallel or perpendicular to the corneal surface is not altered, whereas light that is oblique to the surface of the cornea is rotated and retarded, thereby appearing as a dark cross shape.[19] Birefringence of the cornea is influenced by intraocular pressure, and corneal birefringence was once explored as a noninvasive measure of intraocular pressure but found to have limited utility.[20]

Although the lens similarly produces an isogyre interference pattern,[17] its birefringence is much weaker than that of the cornea.[15] Scanning laser polarimetry uses the

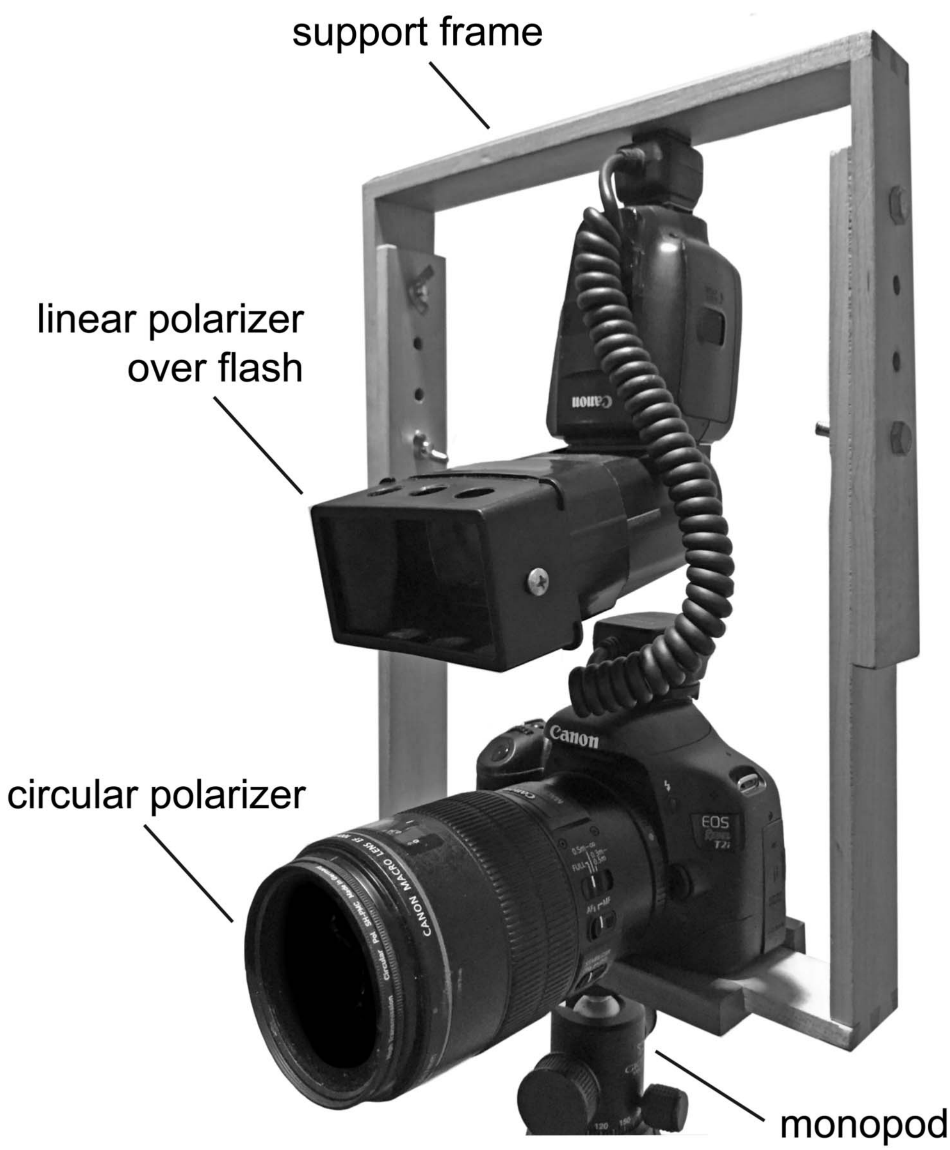

FIGURE 1. Camera setup. The wooden frame was custom-made to hold the flash above the body of the camera, so that the flash could be angled down at an appropriate 45-degree angle. A linear polarizer was inserted over the flash and a circular polarizer over the camera lens for polarized images, and they were removed for nonpolarized images.

birefringence of the retinal nerve fiber layer to estimate its thickness.[21] Polarization sensitive ocular coherence tomography can measure tissue birefringence and has been studied for several applications, including measuring scleral elasticity and retinal nerve fiber layer damage.[22]

In this study, we used Crossed Polarizers to image the eyelids. We hypothesized that photography through cross-polarizers would reduce specular reflectance and glare and thus improve visualization of subepidermal structures and the vasculature of the eyelids.

TABLE 1. Summary of Effects of Crossed Polarized Imaging on Eyelids and Anterior Segment

	Effect of Crossed Polarizers on the Image
Eyelids	Enhanced visualization of blood vessels and telangiectasias of the eyelid. Decreased reflections from the skin surface.
Conjunctiva	Decreased reflections from the conjunctival surface.
Cornea	Appearance of the corneal isogyre. Decreased reflections from the corneal surface.

MATERIALS AND METHODS

This study was approved by the University of Pennsylvania Institutional Review Board and complied with the Health Insurance Portability and Accountability Act. Informed consent was obtained from all subjects before participation, and the patients were photographed using the protocol described below (a modification of the Eyelid Photography Protocol previously published by our group).[23] The use of polarized filters with an external camera is not registered as a device with the United States Food and Drug Administration for the diagnosis of external eye disease, and its use in this study should be considered investigational.

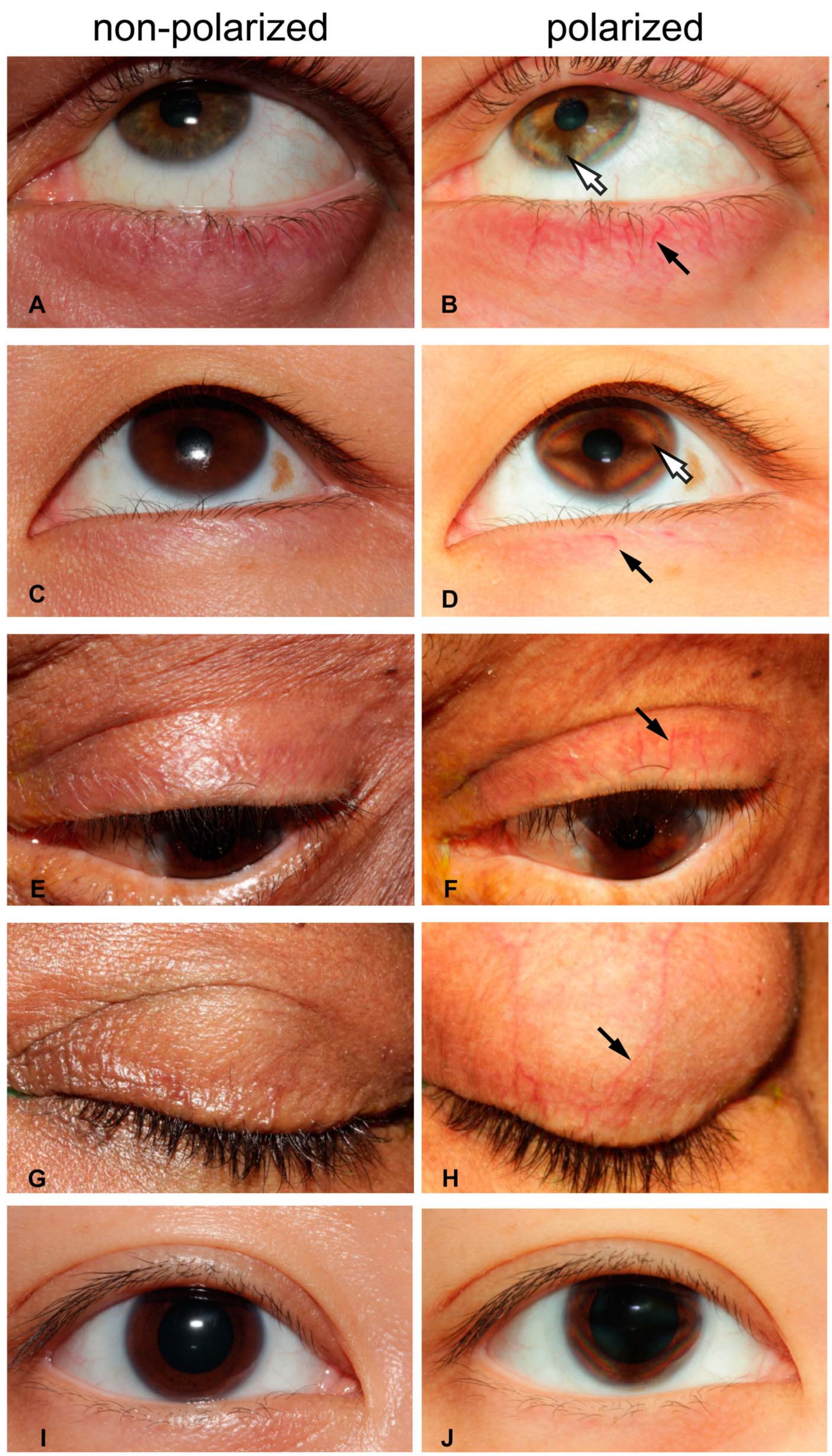

FIGURE 2. Nonpolarized and cross-polarized eyelid photographs. Conventional, nonpolarized images of the eyelids of patients with blepharitis (A, C, E, and G) and the corresponding images of the same eyes through Crossed Polarizers (B, D, F, and H). The method is illustrated in patients with blepharitis of different races (A, B: white; C, D: South Asian; E, F: lightly pigmented African American; G, H: more heavily pigmented African American). The control subject (I, J) is Asian. Black arrows indicate a representative blood vessel in each patient that is made more visible with Crossed Polarizers. One patient (E, F) has a loose eyelash visible on the upper eyelid (not highlighted). White arrows in (B, D) indicate the typical isogyre when the cornea is visualized through Crossed Polarizers. No adjustments were made to any of the images other than the insertion of arrows and labeling.

A Canon EOS Rebel T2i camera and external flash (Canon 600 EX-RT) were attached to a custom-made frame that screwed onto a monopod (Manfrotto 608B monopod with ball joint attachment) for stability. This arrangement enabled the external electronic flash to be aligned at a 45-degree angle downward toward the subject's eye. The external flash was set to the ETTL (exposure through the lens) mode, with a shutter speed of 1/60 s. A Canon 100 mm f/2.8 L macro lens, attached to the camera, was set to manual focus at 0.34 m and F22 aperture. The camera was connected through a USB cable to a laptop computer with Canon EOS Utility Software that permitted real-time viewing and management of the images.

Photographs were taken in examination rooms with fluorescent overhead lighting of approximately 320 lux. Photographs of the eyelids were taken with the patient looking straight ahead, up, or down with gentle traction of the lids to allow full visualization of the eyelid margins. For each photograph, the camera was positioned so the lens focused on the region of interest on the eyelid, with the camera repositioned for each image.

For the polarized photographs, a circular polarizing filter (Heliopan ES 67 mm SH-PMC high-transmission circular polarizer) was attached over the lens of the camera, and an orthogonally oriented piece of Techspec linear polarizing laminated film (Edmund Optics, Barrington, NJ, custom-cut to fit a filter holder) was placed over the external flash (Fig. 1).

RESULTS

Polarized and nonpolarized photographs were taken of patients with blepharitis and controls with no clinical eyelid pathology. The novel observations in this study relate to improved visualization of eyelid blood vessels and telangiectasias. These observations are summarized in Table 1.

Eyelids

Eyelid photographs with Crossed Polarizers decreased reflections from the skin surface and revealed blood vessels and telangiectasias that were either poorly visualized or not visualized in the nonpolarized photographs (Fig. 2). Crossed Polarizers improved the visualization of eyelid telangiectasias and vasculature of patients with a broad range of skin pigmentation and ethnicities.

Cornea and Conjunctiva

Use of Crossed Polarizers revealed the typical isogyre in the cornea (Figs. 2B, D). As previously described,[13,14] photographs through Crossed Polarizers decreased reflections from the corneal and conjunctival surfaces (Fig. 2).

DISCUSSION

The use of Crossed Polarizers in imaging the external eye reduces reflections and glare from the eyelid skin and margins, as well as from conjunctival and corneal surfaces.[13] Polarized digital images using commercially available photography equipment can be easily acquired in many clinical settings. The isogyre in the cornea can confirm the correct orthogonal orientation of the 2 polarizing filters[13] when the cornea is fully visible in the image.

For the eyelids, photography through Crossed Polarizers improves visualization of telangiectasias beneath the skin and lid margins that were not readily visible in nonpolarized images. Importantly, this method improves vascular visualization in subjects with both lightly and heavily pigmented skin, suggesting potentially useful applications.

For example, polarized photography could be useful for diagnosis and research in eyelid diseases such as blepharitis and meibomian gland dysfunction (MGD). Although enhancement of vessels in rosacea of the skin[1] and other disorders[6] has been described in the dermatology literature, we are not aware of previous reports describing the utility of crossed polarizing filters for imaging the eyelids. Blepharitis and MGD are underdiagnosed in ophthalmology, particularly in patients with heavily pigmented skin[24]; and patients often present with nonspecific signs or symptoms.[25] Earlier clinical diagnosis of blepharitis and MGD, along with improved research endpoints, could result from the application of crossed polarization imaging.

Although reduction of corneal and conjunctival surface reflections from photography with Crossed Polarizers has been described previously,[13] this imaging technique has not been extensively applied to investigation of conjunctival or corneal disease. Besides potential use in diagnosing eyelid pathology, removing reflections could improve the accuracy of objective assessment algorithms now being developed to quantify redness or other biomarkers from digital conjunctival and corneal photographs.

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