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New Instruments

Use of Circularly Polarized Light in Fundus and Optic Disc Photography

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• Circularly polarized light was used in fundus and optic disc photography to reduce reflected glare and photographic artifacts originating from the ocular media and the lenses of the fundus camera. A standard fundus camera was used, with circular polarizers placed in the illumination and observation paths. The quality of fundus photography was improved significantly in eyes with intraocular lenses, cataract, vitreous haze, or high myopia as well as in normal eyes, in fundus photography of the retinal periphery, and in optic disc photography.

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Circular polarizers have been used for different ophthalmic applications, such as ophthalmoscopy,[1] lens photography,[2] and corneal endothelial microscopy.[3] To the best of our knowledge, circular polarizers have not been applied to fundus photography.

A linear polarizer polarizes light in a plane. In fundus photography, it has been used to show the birefringence of the nerve fiber layer[4] and macula.[5,6]

A circular polarizer is constructed using a linear polarizer laminated to a retarder. The latter transforms linearly polarized light into two orthogonal components and retards one component in relation to the other. When the retardance equals a phase angle of 90°, one quarter wavelength, the resulting beam is circularly polarized[7,8] (Fig 1).

When a beam of circularly polarized light is specularly reflected by a smooth surface, polarization is reversed, ie, a beam of right-circularly polarized light becomes left-circularly polarized. This beam is blocked when it reaches a right-circular polarizer. This principle is the basis of many uses of circularly polarized light in ophthalmology and fundus photography.

In this article we describe applying circular polarizers to fundus and optic disc photography to demonstrate their value in improving the quality of fundus photographs.

MATERIALS AND METHODS

Fundus photography was performed with an unmodified, standard 30° fundus camera (FF-3C, Zeiss, Oberkochen, West Germany) with a xenon light flash. The flash intensity setting for regular fundus photography is F-I, and for optic disc photography, F-II. However, because circular polarizers transmit only a fraction of the incident light, an increase in power to F-III or F-IV was required. In optic disc photography, F-IV or F-V was needed. A left-circular polarizer was placed in front of the xenon light flash, and a similar one was placed in front of the camera filmback. A special adapter was used for this purpose (Fig 2). For optic disc photography, ×2 magnification was used.

The light levels were unmodified from those of a standard Zeiss camera and are generally accepted as safe. Furthermore, the patients received only half of the increased light output, because filters were placed in the illumination path.

The polarizer was positioned so that the retarder faced the patient. The orientation was tested by holding the circular polarizer in front of a mirror. The side facing the mirror, which blocks reflected light, is the one containing the retarder.

The polarizer was optimized to $\lambda = 460$ nm, which is approximately the wavelength of the main spectral lines of xenon light ($U_2 = 467$ nm, $U_3 = 462$ nm, $U_4 = 450$ nm).[9]

The one-way transmission was tested for different wavelengths, and a relatively constant transmission was found.

A series of fundus photographs of the same retinal area was taken in 31 subjects (42 eyes) with and without circular polarizers. Different subjects with clear media were used for the optic disc photographs (18 subjects, 21 eyes). The fundus photographs were of normal eyes and eyes with intraocular lenses, cataracts, high myopia, or vitreous haze.

To compare photographs taken with and without the circular polarizer, we chose 35 pairs of the original fundus photographs and 16 pairs of optic disc photographs with approximately the same color saturation. The remainder were discarded because of the impossibility of matching pairs of photographs that had the same color saturation and identical retinal areas. The masked retinal photographs and the optic disc photographs were shown to four and nine trained observers, respectively, in a forced-choice paradigm to compare the quality of fundus photographs of the same retinal area made with and without circular polarizers. The results were analyzed statistically using the sign test for paired comparisons.[10]

RESULTS

The fundus photographs taken with circular polarizers were judged to be significantly better than those taken without circular polarizers ($z = 5.07$, $P < .0001$) (Table 1). Similar results

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Reprint requests to Eye Research Institute, 20 Staniford St, Boston, MA 02114 (Dr Fariza).

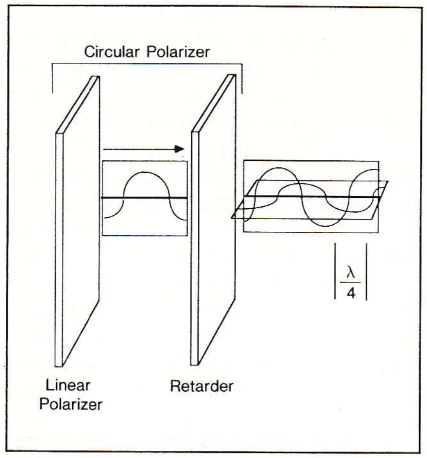

Fig 1.—Circular polarizer. Retarder transforms linearly polarized light into two orthogonal components and retards one of these components by phase angle of 90°, one quarter wavelength.

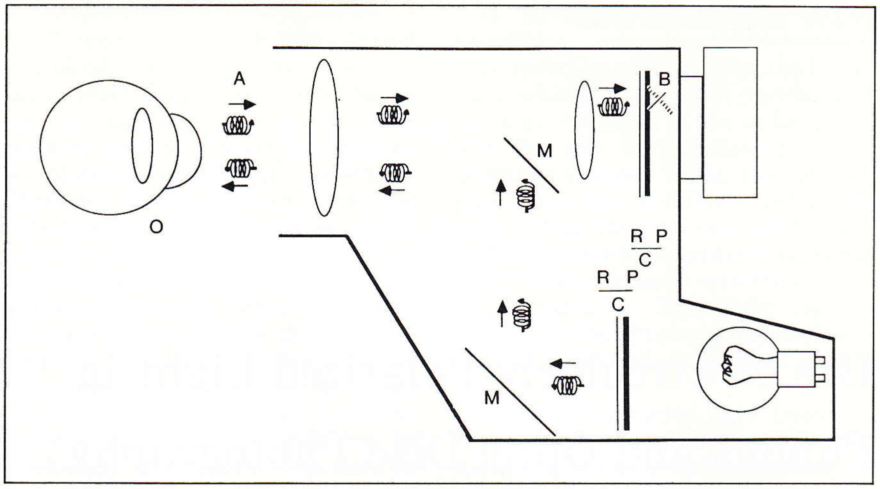

Fig 2.—Two circular polarizers (C) in fundus camera. Retarder (R) always faces away from observer. When circularly polarized light is reflected by ocular structures (O), polarization is reversed (A). Such light is blocked by circular polarizer in front of camera (B). P indicates linear polarizer; M, mirror.

Table 1.—Comparison of Fundus Photographs With and Without Circular Polarizers

Photograph No.	Description	No. of Observers Who Judged Photographs Taken With Circular Polarizers to Be Superior to Those Taken Without Polarizers (n = 4)
1	Cataract	1
2	Vitreous haze	1
3	Vitreous haze	1
4	Normal	4
5	Normal	3
6	Cataract	3
7	Vitreous haze	0
8	Myopia/cataract	4
9	Intraocular lens	3
10	Cataract	3
11	Extreme periphery/vitreous haze	3
12	Cataract	4
13	Vitreous haze	2
14	Extreme periphery/vitreous haze	2
15	Vitreous haze	3
16	Intraocular lens	4
17	Vitreous haze	2
18	Normal	1
19	Cataract	4
20	Cataract	4
21	Intraocular lens	4
22	Periphery/normal	4
23	Normal	2
24	Normal	4
25	Cataract	4
26	Cataract	3
27	Myopia	3
28	Intraocular lens	4
29	Normal	2
30	Normal	2
31	Normal	2
32	Vitreous haze	4
33	Vitreous haze	4
34	Vitreous haze	2
35	Vitreous haze	4

Table 2.—Comparison of Optic Photographs With and Without Circular Polarizers

Photograph No.	No. of Observers Who Judged Photographs Taken With Circular Polarizers to Be Superior to Those Taken Without Polarizers (n = 9)
1	8
2	9
3	7
4	8
5	6
6	5
7	4
8	4
9	8
10	9
11	5
12	5
13	4
14	2
15	9
16	8

were obtained for optic disc photographs ($z = 4.33$, $P < .0001$) (Table 2).

In eyes with intraocular lenses, reflected glare was reduced (Fig 3). In eyes with cataracts or vitreous haze, retinal details of the posterior pole were visualized better with polarized light. In eyes with high myopia, there was less glare, and artifacts from the surface of the fundus camera lens (dust particles and stains) were less apparent. Improvement in the visibility of the choroid was seen in normal eyes, and, in particular, the retina in peripheral fundus photography was visualized better (Fig 4).

In optic disc photography, the disc retina boundary, the optic disc cup, and the blood vessels in the disc were visualized better (Fig 5).

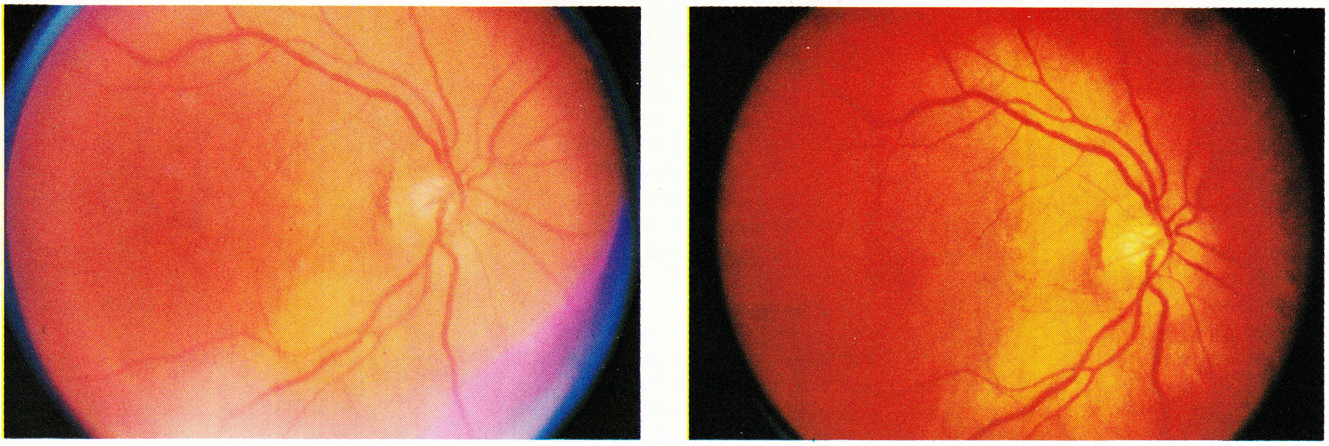

Fig 3.—Patient with intraocular lenses. Left, Photograph without circular polarizer. Right, Photograph with circular polarizer. Note reduction of glare from intraocular lens with circular polarizer.

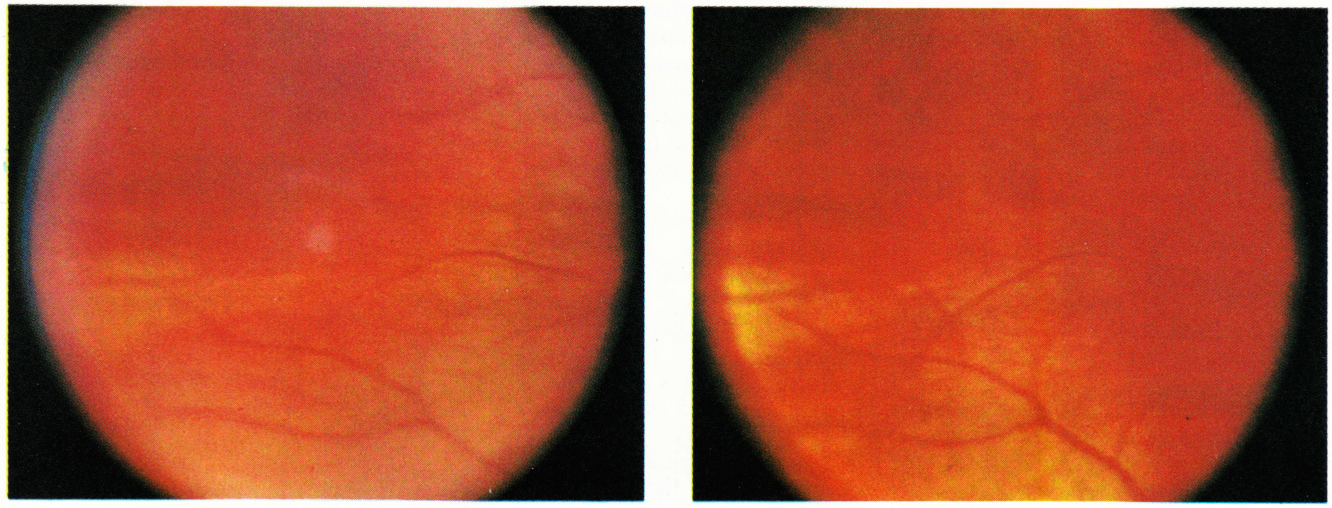

Fig 4.—Periphery of normal eye. Left, Photograph without circular polarizer. Right, Photograph with circular polarizer. Note improvement in quality of photograph with circular polarizer.

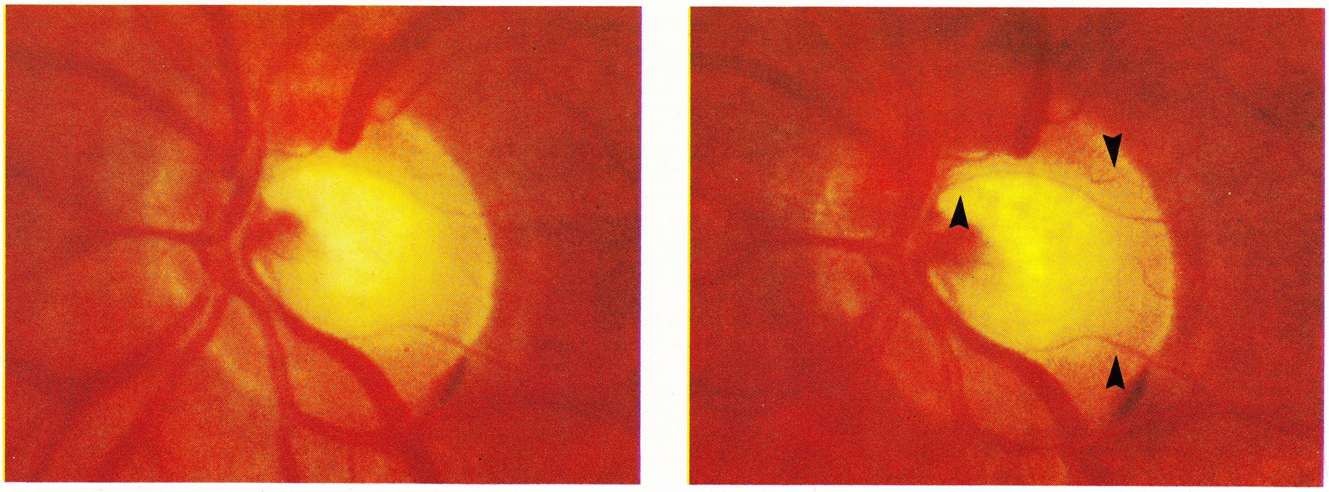

Fig 5.—Left, Photograph without circular polarizer. Right, Photograph with circular polarizer. Note better visibility of lamina cribrosa and optic cup vessels (arrowheads) with circular polarizer.

COMMENT

The glare problem in fundus imaging is well known; it has been partially solved by separating the paths of illumination and observation (Gullstrand's requirement).[11,12] Using two similar circular polarizers in front of the xenon light flash and the camera eyepiece, we produced improved fundus photographs of some specific clinical conditions and normal eyes.

In fundus photography, light is specularly reflected from the different smooth surfaces in the eye, primarily the cornea, the lens, and the internal limiting membrane of the retina. This light can impair the visibility of fundus details and reduce the quality of fundus photographs. When a circular polarizer is placed in the path of the incident light beam reaching the eye, the beam becomes circularly polarized. When this light is reflected by the specular surfaces in the eye, polarization is reversed. A circular polarizer placed in front of the fundus camera prevents passage of the beam (Fig 2) and blocks the undesirable specular reflections originating from the different smooth surfaces within the eye, resulting in improved fundus photographs.

The exact mechanism of action of polarized light in the eye is not well understood. According to Blockland[13] and Charman,[14] the degree of polarization of light scattered within the eye is largely preserved in all wavelengths except that of red light. Red light, which is reflected from the ocular fundus, choroid, and blood vessels, is less polarized than light of other wavelengths and, therefore, is less blocked by circular polarizers. This may explain the improved visibility of the fundus, particularly the choroid and blood vessels. However, specular light reflected by smooth surfaces in the eye and by intraocular lenses remains circularly polarized and can be blocked by circular polarizers. Therefore, the glare produced by the reflection of light from these structures can be reduced.

The specular reflections from intraocular lenses often result in poor-quality imaging in ophthalmoscopy[15] and fundus photography. The reflections, which usually are produced by reflected light from the anterior surface of the lens, can be blocked by the circular polarizer. In high myopia, the image plane of the fundus is closer to the focusing lens of the camera,[16] often resulting in poor-quality fundus photographs due to reflected glare, dust particles, and other imperfections on the lens surface of the fundus camera. Circularly polarized light reduces these artifacts and reflected glare and improves the quality of fundus photographs of myopic eyes.

In the presence of cataracts, changes in the refractive index between the clear and cataractous portions of the lens[17] create specularly reflected light[18] that is blocked by a circular polarizer. The improvement in the photographs of subjects with vitreous haze and in peripheral fundus photography is difficult to explain. Light back-scattered by hazy vitreous and by the periphery of a normal lens[19] and cornea in peripheral fundus photography may be more polarized than light reflected from the retina and choroid and, therefore, may be more blocked by circular polarizers.

In optic disc photography, the internal limiting membrane is particularly thick at the edges of the optic disc,[20] and the area of attachment of the posterior vitreous to the disc (martegiani area) has a different refractive index than the vitreous gel.[21] This difference creates specularly reflected light[18] that interferes with the quality of photography. This light can be blocked by the circular polarizer, leading to improved optic disc photographs.

Specularly reflected light from the internal limiting membrane is seen along the retinal vessels, especially in young individuals.[22] Its presence can be helpful for photography in diseases such as preretinal macular fibrosis, cystoid macular edema, macular cysts, disciform detachment of the neuroepithelium,[23] and papilledema,[24] but in most instances it is an unnecessary artifact that can be eliminated by a circular polarizer.

The exact mechanism by which circularly polarized light improves fundus photography is not well understood; however, better visibility seems to be achieved by decreasing specular reflections and glare from the ocular media and from the imperfections of the lenses in the fundus camera.

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