

Comparison of contrast sensitivity and color discrimination after clear and yellow intraocular lens implantation

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PURPOSE: To compare contrast sensitivity and color vision in patients in whom blue-light filtering and non-yellow-tinted intraocular lenses (IOLs) were implanted.

SETTING: Refractive Surgery Unit, Hospital NISA Valencia al Mar, Valencia, Spain.

METHODS: Forty eyes of 20 patients were enrolled in a blue-light filtering fellow-eye control study; patients were implanted with a yellow-tinted IOL (AcrySof Natural, Alcon) in 1 eye and a non-yellow-tinted IOL (AcrySof SA60AT, Alcon) in the fellow eye after cataract surgery. Three months postoperatively, monocular contrast sensitivity function was measured with the CSV 1000-E contrast sensitivity chart at distance and the color discrimination with the Farnsworth-Munsell 100 Hue test.

RESULTS: Eyes implanted with blue-light filtering IOLs showed similar contrast sensitivity to that in fellow eyes implanted with non-yellow-tinted IOLs ($P > .1$). Both types of IOLs showed normal contrast sensitivity values (normalized log-contrast sensitivity about 1.0). There were no statistically significant differences in chromatic discrimination between the 2 types of IOLs ($P = .56$).

CONCLUSION: The use of blue-light filtering IOLs is more advisable because they are capable of protecting the retina against ultraviolet light without disturbance of contrast sensitivity and chromatic vision, that produces subjective impairment in visual function.

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It has been reported that implantation of clear intraocular lenses (IOLs) increases the risk for retinal pathology by allowing blue light to reach the retina.^{1,2} Thus, to provide the same protection to the retina afforded by the natural lens, the use of ultraviolet light-absorbing IOLs has become the standard of practice.^{3,4} Filtering properties of most

IOLs are not comparable with those of the natural lens since the latter yellows with age while the IOLs in current use are colorless.^{5,6} A recent study by Sparrow and coauthors⁷ suggests that blue-light absorbing IOLs protect lipofuscin-containing retinal pigment epithelial cells from blue-light damage and may reduce the risk for or progression of macular degeneration. In this way, new blue-light absorbing IOLs are required. The AcrySof Natural IOL (Alcon) has been designed with a material that includes a blue-light absorbing chromophore designed to approximate more closely the light-transmittance characteristics of the natural lens at wavelengths below approximately 500 nm.

Despite of the benefits of blue-light blocking, a yellow-tinted IOL could modify the visual performance of patients implanted with these IOLs in relation to those implanted with nontinted IOLs. It has been suggested in previous works that yellow filters can improve several visual conditions such as clarity of vision, glare reduction, and contrast sensitivity medium spatial frequencies under photopic and

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mesopic conditions⁸; improve reaction time in response to stimuli⁹; and increase apparent brightness under daylight conditions.¹⁰ Thus, taking this into account, patients implanted with blue-light filtering IOLs may benefit not only from ultraviolet light blocking but also from a visual performance improvement. However, previous studies^{11,12} of the effect of yellow-tinted lenses on color vision in patients without ocular pathology concluded that these lenses cause changes in color perception. These studies point out that changes in chromatic discrimination vary depending on the yellow lens type (eg, filter spectral transmittance).

The performance index that most usefully documents human spatial vision is the contrast sensitivity function, which plots the reciprocal of the threshold contrast for sinusoidal gratings as a function of their spatial frequency. It thus gives information on visual performance for a range of object scales and is especially useful in patients who have had refractive surgery procedures, as described in detail by Montés-Micó et al.¹³⁻¹⁹ Contrast sensitivity measurement of patients implanted with IOLs thus describes completely their visual performance. Any color vision discrimination deficiency could be discarded by means of the Farnsworth-Munsell 100 Hue test, which is the most specific test to assess chromatic discrimination abnormalities.

To our knowledge, no visual performance measurements by means of contrast sensitivity and color vision testing of patients implanted with the new AcrySof Natural IOL have been published to date. Thus, the purpose of this study was to determine the visual qualities in eyes implanted with the AcrySof Natural IOL and to compare the measurements to those in eyes implanted with a non-yellow filter IOL (AcrySof SA60AT, Alcon).

PATIENTS AND METHODS

Twenty consecutive patients who had implantation of the AcrySof Natural IOL in 1 eye and AcrySof SA60AT in the fellow eye (mean age 67.5 years \pm 2.3 [SD]; range 65 to 70 years) were prospectively examined 3 months after IOL implantation. Exclusion criteria included ocular disease other than cataract and history of prior ocular surgery or inflammation. All cataracts in this study were extracted by 1 surgeon (A.R.G.) using topical anesthesia and a clear corneal 2.75 mm temporal incision. Phacoemulsification was followed by irrigation and aspiration of cortex and IOL implantation in the capsular bag. All patients were satisfied with the outcome of their surgery, showing a best spectacle-corrected visual acuity (BSCVA) of \geq 20/25 3 months postoperatively.

The AcrySof Natural IOL is optical and structurally identical to the AcrySof SA60AT except for the blue-light filtering material. The overall diameter of the lenses was 13 mm, and the optical diameter was 6 mm. Lens power varied from +21.00 diopters (D) to +22.50 D.

To evaluate the visual performance of patients implanted with these IOLs, the following tests were done: the CSV 1000-E contrast sensitivity test and the Farnsworth-Munsell 100 Hue color test.

Contrast Sensitivity Function

The contrast sensitivity function was measured monocularly with the CSV 1000-E contrast test (Vector Vision). The non-viewing eye was occluded for each measurement, and best spectacle refractive correction, if necessary, was initially used with the viewing eye, in accordance with the normal practice of the individuals concerned. This contrast sensitivity function test allows presentation of sine-wave gratings at different spatial frequencies (3, 6, 12, and 18 cycles per degree [cpd]), with contrasts changing. The manufacturer's recommended testing procedures were followed: testing distance of 2.5 m and a luminance level of 85 cd/m². Absolute values of log₁₀ contrast sensitivity were obtained for each combination of eye and spatial frequency, and means and standard deviations were calculated.

Farnsworth-Munsell 100-Hue Test

Once the contrast sensitivity function were obtained, the patients were allowed to rest 15 minutes before taking the Farnsworth-Munsell 100 Hue color test.²⁰ The color test was performed randomly and monocularly with the best spectacle correction in all patients. All caps belonging to the first box were put off and placed on a black table. Then, the patients were asked to place them in the box in the correct order. The same was done with the other 3 boxes. When the 4 boxes were completed, the results were written by the examiner and the patient was not allowed to see them. Farnsworth-Munsell error scores were calculated as described by Kinnear.²¹ Thus, the error score for each cap was calculated by adding the differences between the number of that cap and the numbers of the caps placed by the patient on both sides of it. Since with this method the score for a cap correctly placed will be 2, the error score for a particular cap will be the score less than 2. Following previous literature in this area,²²⁻²³ color vision examination was performed at photopic conditions (85 cd/m²).

All examinations were performed by 1 ophthalmic technician masked as to the IOL status of each eye. The tenets of the Declaration of Helsinki²⁴ were followed in this research. Informed consent was obtained from all patients after the nature and possible consequences of the study were explained.

RESULTS

Patient demographics are shown in Table 1. There were no statistically significant differences between the 2 IOLs with respect to corneal astigmatism, BSCVA, and spherical equivalent. Normality of data distribution was tested using the Kolmogorov-Smirnov test.

Logarithmic contrast sensitivity values were used for statistical analysis, and normalized values were used for graphical representation. Mean normalized monocular best corrected log contrast sensitivity as a function of the IOL at the 4 spatial frequencies indicated is shown in Figure 1. To evaluate the significance of the differences between the values of contrast sensitivity of both IOLs, a *t* test was performed at each spatial frequency. A *P* value less than 0.01 (ie, at the 1% level) was considered statistically significant. *P* values are shown in the figure legend for all spatial frequencies evaluated.

Table 1. Demographic characteristics of participants.

Parameter	All Patients	AcrySof Natural IOL	AcrySof SA60AT IOL	P Value
No. of eyes		20	20	—
Age (y)	67.5 ± 2.3			—
Sex (M/F)	9/11			—
Interval (months)*	3			—
Mean astigmatism (D)†	—	0.84 ± 0.43	0.96 ± 0.39	.2504
Mean BSCVA	—	0.93 ± 0.11	0.96 ± 0.13	.5169
Mean SE (D)	—	0.57 ± 1.19	0.69 ± 1.06	.4233

Means ± SD

BSCVA = best spectacle-corrected visual acuity; SE = spherical equivalent

*Elapsed time between surgery and examination

†Postoperative corneal astigmatism

Once the total Farnsworth-Munsell error scores of all patients were obtained for each of the eyes, a *t* test was performed to look for differences between the scores obtained with the AcrySof Natural IOL and the AcrySof SA60AT IOL. No statistically significant differences were found between the 2 IOLs (*P* = .56). In Figure 2, the mean total error scores and standard deviations for both IOLs are represented.

DISCUSSION

Our study showed that distance contrast sensitivity in both IOL groups achieved normal values (near to 1.0

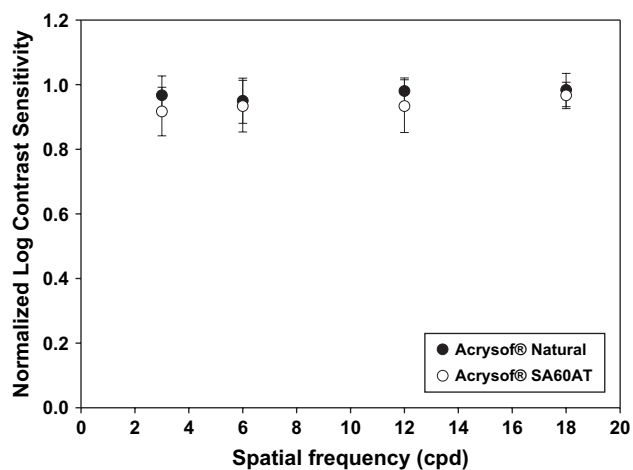


Figure 1. Normalized monocular best corrected log contrast sensitivity at the 4 spatial frequencies (cpd). Filled data points refer to the AcrySof Natural and open data points to the AcrySof SA60AT; vertical bars represent ±1.0 standard deviations. *P* values were 0.47, 0.73, 0.20, and 0.36 for 3 cpd, 6 cpd, 12 cpd, and 18 cpd frequencies, respectively.

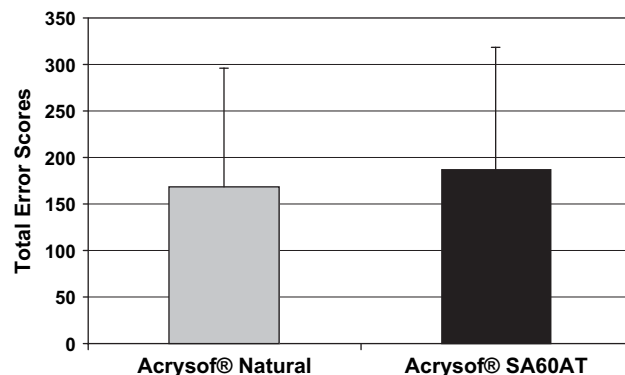


Figure 2. Mean scores (and standard deviations) of the Farnsworth-Munsell 100 Hue test for the AcrySof Natural and AcrySof SA60AT IOLs.

normalized log contrast sensitivity at all spatial frequencies); Figure 1 shows similar values of contrast sensitivity at different spatial frequencies. These results agree with those found by Montés-Micó et al.^{15,19} in patients implanted with monofocal nontinted IOLs (AMO SI-40NB, Allergan) at the same time postoperatively (photopic conditions).

When inter-IOL differences were evaluated for best corrected distance contrast sensitivity, the *t* test revealed no statistically significant differences between the AcrySof Natural IOL and the AcrySof SA60AT IOL at any spatial frequency (*P* > .1).

Previous studies⁸⁻¹⁰ report that the use of yellow filters by healthy phakic patients improved the image contrast and consequently their contrast sensitivity function. This improvement may be attributed to a decrement of the chromatic aberrations effects,^{25,26} a brightness increment,²⁷ scattering reduction,²⁸ or a decrement of lenticular fluorescence.²⁹ The effects of chromatic aberration are more noticeable in a high spatial resolution task. Considering that visual acuity, 1 of the tasks most sensitive to the presence of these aberrations, is not improved with the use of tinted lenses, the effect of the reduction in chromatic aberrations due to the filter probably will not improve the patients' performance in contrast discrimination tasks.^{25,26} Kinney and coauthors⁹ suggest that the origin of this enhancement is the response increment of the opponent chromatic mechanisms due to the removal of the negative contribution of short wavelengths. Also, the decrement of blue radiation reduces the scattering effects, which would justify the poor performance of these filters under glare and bad atmospheric conditions.²⁸ It has been found that the short wavelengths removed by the cut-off

filters produce fluorescence effects in the chromophore-containing proteins present in the eye's lens.²⁹ Thus, it is reasonable to believe that the different contributions of the phenomena discussed above result in a contrast increment. In this way, de Fez and coauthors¹² have shown that yellow filters enhance low achromatic contrast at middle and high spatial frequencies.

Why do our results not reveal any difference in contrast sensitivity between the blue-light filtering IOL and the IOL without filter? One obvious possibility is the different spectral transmittance of each filter. For example, the yellow filter used by de Fez and coauthors¹² has a short cut-off wavelength with low transmittance: about 10% at 430 nm with the AcrySof Natural IOL and about 30% at the same wavelength; Ernest³⁰ provides a full description of light-transmission-spectrum. Thus, depending on the spectral transmittance of each filter, the effect on contrast sensitivity may vary. This explains those differences found in previous literature related to contrast sensitivity and yellow filters and similarities found in contrast sensitivity between yellow and non-yellow-tinted IOL. In fact, to know the effect of a yellow filter on contrast sensitivity, it is necessary to specify its spectral transmittance.

Yellow filters reduce the transmittance of the visible spectrum and change color perception to a greater or lesser degree depending on their spectral transmittance.^{11,12} De Fez and coauthors¹² showed that yellow filters cause a tritan-like defect with discrimination losses in the yellow-purplish region. In contrast to this, our results revealed no color discrimination alterations in those eyes implanted with the AcrySof Natural IOL, results similar to those found by Kinnear and Sahraie³¹ for a population without chromatic discrimination alterations. In addition, those eyes implanted with the non-blue-light filtering IOL did not show changes in their color vision. A comparison between the 2 groups did not reveal statistically significant differences. As we have discussed previously, differences in spectral transmittance may be the source of different results between ours and those found by de Fez and coauthors.¹² In our study, different spectral transmittance of the AcrySof Natural and the non-yellow filter IOL is not enough to provoke differences in color vision between the IOLs.

In conclusion, the AcrySof Natural IOL provides excellent contrast sensitivity, comparable to that obtained with the AcrySof SA60AT after a period of 3 months of IOL implantation. The blue-light filter of the AcrySof Natural IOL does not cause any chromatic discrimination defect. Thus, the use of blue-light filtering IOLs would be more advisable because they are capable of protecting the retina from ultraviolet light without disturbance of contrast sensitivity and chromatic vision.

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