New preventative approach for negative dysphotopsia

Bonnie A. Henderson, MD, David Hyungjun Yi, MD, John B. Constantine, MD, Ivayla I. Geneva, MD, PhD

PURPOSE: To evaluate whether positioning the intraocular lens (IOL) to decrease the entry of inferotemporal light would decrease the incidence of negative dysphotopsia.

SETTING: Private practices, Boston and Chelmsford, Massachusetts, USA.

DESIGN: Prospective randomized case study.

METHODS: Patients had cataract surgery with implantation of either a silicone IOL inferotemporally or vertically (randomly assigned) or a 1-piece acrylic IOL with the optic–haptic junction inferotemporally or vertically (randomly assigned). Other patients received acrylic IOLs bilaterally and inferotemporally without randomization. Patients were asked about negative dysphotopsia symptoms postoperatively. Data were analyzed using the z test and a chi-square test for comparing the incidence of negative dysphotopsia between the 3 groups.

RESULTS: The study comprised 305 patients (418 eyes). A silicone IOL was implanted inferotemporally in 39 eyes and vertically in 60 eyes. An acrylic IOL was implanted with the optic–haptic junction inferotemporally in 163 eyes and with the junction vertical in 114 eyes. Forty-two eyes had bilateral inferotemporal implantation of an acrylic IOL. For the acrylic IOL on the first postoperative day, the incidence of negative dysphotopsia was smaller for the inferotemporal IOL orientation (6%) than in the control group (14%) (P = .026). The rate of persistent negative dysphotopsia decreased in both groups over time, and the difference 1 month after surgery was no longer statistically significant. The negative dysphotopsia rate for the silicone IOL was 0%.

CONCLUSIONS: Positioning the optic–haptic junction of an acrylic IOL inferotemporally resulted in a 2.3-fold decrease in the incidence of negative dysphotopsia after cataract surgery. When implanted in the vertical position, Acrylic IOLs seemed to lead to a higher incidence of negative dysphotopsia than silicone IOLs.

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One of the last few remaining challenges faced by cataract surgeons are the phenomena of positive and negative dysphotopsia, which continue to hamper patient satisfaction.1 Shortly after surgery, more than 70% of patients experience some type of dysphotopsia,2 with significant variability in the reported incidence in the literature.1,3

Positive dysphotopsia manifests in the form of bright arcs, streaks, or halos originating from the center or in the midperiphery of the retinas. The focus of our study was the second and much less understood photic phenomenon known as negative dysphotopsia. Its incidence is up to 15% in cataract surgery patients, with the affected individuals perceiving a dark shadow in the form of an arc (Figure 1, A) or a crescent (Figure 1, B) in their temporal visual field.4 Although some patients are able to ignore the shadow, for others the symptoms are severe and similar to those of retinal detachment or vascular occlusion.5 The symptoms tend to disappear over time; however, approximately one fifth of the patients remain permanently symptomatic.6–13

The study of negative dysphotopsia remains challenging because of the many variables contributing to its etiology.1 Furthermore, the visual disturbance often forces patients to consider a second, and sometimes...
even a third, surgical procedure to achieve resolution.9,13–16 Although the etiology of negative dysphotopsia is currently the focus of debate, there is theorectic evidence showing that light entering the eye inferotemporally and hitting the edge of the implanted intraocular lens (IOL) results in a discontinuity among the rays that reach the nasal retina, thus causing the shadow of negative dysphotopsia (Figure 1, C).17 Numerous other etiologies exist, including the relationship between the position of the IOL to the anterior capsule and posterior surface of the iris, which was recently reviewed by Henderson and Geneva.1

Regardless of whether only 1 or more etiologies combined are the root cause, we assessed whether a surgical method that blocks the entry of inferotemporal light would be useful for the prevention of negative dysphotopsia. We used the IOL type that is most often associated with negative dysphotopsia, the square-edged 1-piece high-index-of-refraction acrylic IOL (Acrysof SN60WF, Alcon Laboratories, Inc.). In this acrylic IOL, the optic edge is covered by the optic–haptic junction (2.42 mm) for one third of the circumference (Figure 1, D). Therefore, by aligning the covered optic–haptic junction in the inferotemporal location, we hypothesized that there would be at least 30% less available edge for light from that quadrant to strike the IOL and, therefore, a smaller chance of creating the negative dysphotopsia shadow.

PATIENTS AND METHODS

This prospective randomized patient-blinded clinical trial was performed at 2 surgical centers with 1 surgeon in Center A (B.A.H) and 2 surgeons in Center B (D.H.Y., J.B.C.). Each patient signed an informed consent form that described the risks associated with cataract surgery and consented to have their postoperative outcomes tracked and studied in an unidentified manner.

Patients had cataract surgery between February and November 2014. The Acrysof SN60WF acrylic IOL, which has a high index of refraction of 1.55,18 is square edged, and has been associated with the development of negative dysphotopsia,11,19 was used (Center A and by D.H.Y. at Center B). The eyes were randomized to have the acrylic IOL positioned with the optic–haptic junction in the inferotemporal position at 2 o’clock and 8 o’clock in the right eye and 4 o’clock and 10 o’clock in the left eye (Figure 2, A) to block light entering from this angle (study group) or to have the acrylic IOL implanted vertically at 6 o’clock and 12 o’clock (control group) (Figure 2, B). Using randomization, an additional group of eyes was implanted with the LI61A0 silicone IOL (Bausch & Lomb, Inc.) inferotemporally or at 6 o’clock and 12 o’clock (Center B by J.B.C). Being round-edged and made of the low-refractive material silicone (refractive index of 1.43, as
The demographics (age and sex) were noted for each patient. The data were analyzed using the χ² test for comparing the incidence of negative dysphotopsia between the acrylic group and the silicone group at the various timepoints. The combined multicenter data for the square-edged acrylic IOL showed that the incidence of negative dysphotopsia was lower in the acrylic group compared to the silicone group. The results also indicated that the incidence of negative dysphotopsia was lower in the inferotemporal orientation compared to the 6 o'clock and 12 o'clock control positions. Additionally, the study found that patients who had cataract surgery at Center A more often had inferotemporal IOL implantation, whereas patients at Center B had more occurrences of inferotemporal implantation due to the specific surgical techniques employed.

**RESULTS**

The study included 305 patients (418 eyes). The acrylic IOL was implanted in 319 eyes (228 patients), of which 163 were randomly selected to have the IOL positioned with the optic–haptic junction in the inferotemporal position at 2 o'clock and 8 o'clock in the right eye and 4 o'clock and 10 o'clock in the left eye. The acrylic IOL was implanted vertically at 6 o'clock and 12 o'clock in the remaining 144 eyes, which served as the control group. In addition, a randomly selected group of 99 eyes (77 patients) had implantation of a silicone IOL inferotemporally in 39 of the eyes and at 6 o'clock and 12 o'clock in 60 of the eyes. An additional group of 42 eyes (21 patients) received acrylic IOLs bilaterally and inferotemporally without randomization.

Table 1 shows the patient demographics (sex and age), which were similar at the 2 surgical centers. No patient dropped out of the study until the last timepoint of evaluation 1 month postoperatively.

The cataract surgery in all eyes was uneventful. All 3 surgeons attempted to create continuous central 5.5 mm capsule openings. Because the surgeries were performed manually without the use of the femtosecond laser or other capsulorhexis aids, the sizes and shapes of the anterior capsule openings varied somewhat. However, all capsule openings were continuous with no tears in the anterior or posterior capsules.

Table 2 and Figure 3 show the incidence of negative dysphotopsia and the statistical comparisons between the inferotemporal and the 6 o'clock and 12 o'clock control orientations. On the first postoperative day, the combined multicenter data for the square-edged acrylic IOL showed that the incidence of negative dysphotopsia was lower in the acrylic group compared to the silicone group.
was significantly lower than in eyes with the IOL positioned inferotemporally (10 [6%] of 163 randomized eyes and 11 [5%] of all 205 studied eyes) compared with the randomized controls (16 [14%] of 114 eyes) (P = .026 and P = .008, respectively). The rate of persistent negative dysphotopsia symptoms decreased in both groups over time, and at 1 week and 1 month there was no longer a statistically significant difference. Similar results were obtained when analyzing the data from the individual surgical centers separately. The incidence of negative dysphotopsia 1 day after the surgery was similar between the right eyes and left eyes; that is, 7.7% (12 of 155 right eyes) and 9.1% (15 of 164 left eyes). All surgeries in which the square-edged acrylic IOL was implanted resulted in complete coverage of the optic by the anterior capsule throughout the 1-month follow-up. No eye with the round-edged silicone IOL developed negative dysphotopsia on the first postoperative day or at the 3-to-4 week office visit. In 3 of the 39 inferotemporal cases, the anterior capsule did not cover the optic, with incomplete overlap from 7 to 9 o’clock or 6 to 8 o’clock or with an exposed nasal edge. Also, in 1 of the 60 control eyes, there was incomplete overlap from 1 to 2 o’clock.

Table 2. Incidents and statistical analysis for the individual surgical centers and the combined 2-center data where the acrylic IOL was used. The data from the randomized group and the larger mixed (randomized and nonrandomized) group are presented.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Square-edged acrylic IOL (randomized data only)</th>
<th>Round-edged silicone IOL</th>
<th>Square-edged acrylic IOL (all data)</th>
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<tr>
<td></td>
<td><strong>Center A POD1</strong></td>
<td><strong>Center C POD1</strong></td>
<td><strong>Center A POD1</strong></td>
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<tr>
<td>Incidence, %, Eyes (n)</td>
<td>6.43 (140)</td>
<td>0.00 (39)</td>
<td>5.49 (182)</td>
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<td></td>
<td>6.35 (23)</td>
<td>0.00 (39)</td>
<td>4.35 (23)</td>
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<tr>
<td></td>
<td>Combined POD1</td>
<td>Combined POD1</td>
<td>Combined POD1</td>
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<tr>
<td>Incidence, %, Eyes (n)</td>
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<td>14.04 (114)</td>
<td>14.36 (205)</td>
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<td></td>
<td>10.14 (45)</td>
<td>8.89 (45)</td>
<td>8.89 (45)</td>
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<td><strong>Center A POW1</strong></td>
<td><strong>Center A POW1</strong></td>
<td><strong>Center A POW1</strong></td>
</tr>
<tr>
<td>Incidence, %, Eyes (n)</td>
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<td>7.25 (69)</td>
<td>7.25 (69)</td>
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<tr>
<td></td>
<td>0.71 (140)</td>
<td>0.71 (140)</td>
<td>0.71 (140)</td>
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<td>Combined POW1</td>
<td>Combined POW1</td>
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<tr>
<td>Incidence, %, Eyes (n)</td>
<td>2.22 (45)</td>
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<td>1.84 (163)</td>
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</tbody>
</table>

IOL = intraocular lens; NA = not available; POD1 = postoperative day 1; POM1 = postoperative month 1; POW1 = postoperative week 1
*2-tailed z test
†Statistically significant, P < .05

Figure 3. Incidence of negative dysphotopsia. The asterisk represents a significant difference between the inferotemporal and the 6 o’clock and 12 o’clock control IOL orientation 1 day postoperatively (P < .05).
Table 3. Two-tailed chi-square analysis comparing the incidence of negative dysphotopsia between eyes with the silicone IOL and eyes with the acrylic IOL for the matching orientations and postoperative times. The data from the randomized group and the larger mixed (randomized and nonrandomized) group are presented.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Randomized</th>
<th>Data Only</th>
<th>All Data</th>
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<tr>
<td>Round-edged silicone IOL</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>inferotemporal or 6 o'clock and 12 o'clock control</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>With combined POD1</td>
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<td>.1388</td>
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<tr>
<td>With combined POM1</td>
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<td>.4472</td>
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<td>.2503</td>
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<tr>
<td>With Center A POM1</td>
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<td>.0334*</td>
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<tr>
<td>With combined POD1 6 o'clock and 12 o'clock control acrylic</td>
<td></td>
<td></td>
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<tr>
<td>With combined POM1 6 o'clock and 12 o'clock control acrylic</td>
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<tr>
<td>With combined POD1 6 o'clock and 12 o'clock control acrylic</td>
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<tr>
<td>With combined POM1 6 o'clock and 12 o'clock control acrylic</td>
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<table>
<thead>
<tr>
<th>IOL = intraocular lens; POD1 = postoperative day 1; POM1 = postoperative month 1; POD1 = postoperative week 1</th>
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<tr>
<td>*Statistically significant, ( P &lt; .05 )</td>
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</table>

DISCUSSION

Negative dysphotopsia was first described 15 years ago by Davison. Since that time, more than 50 articles have been published on the topic and recently reviewed by Henderson and Geneva. The importance of this disturbing photic phenomenon is further underscored by the frequent appearance of negative dysphotopsia cases in the Consultation section of the Journal of Cataract & Refractive Surgery. However, the persistent challenge of negative dysphotopsia arises from the multifactorial nature of this surgical side effect, which complicates the ability to predict its occurrence and its treatment.

Our clinical trial aimed to evaluate a surgical approach that might decrease the incidence of negative dysphotopsia in 3 eyes with the commonly used Acrysof SN60WF IOL. The 2 features of this IOL that are known to predispose to negative dysphotopsia are its high refractive index and its sharp-edged design. The results in our study support the theory that light entering the pupil inferotemporally and hitting the edge of the IOL results in discontinuity in the light rays reaching the nasal retina, which is perceived as the temporal shadow of negative dysphotopsia. We observed a 2.3-fold decrease in the incidence of negative dysphotopsia when the optic–haptic junction of the implanted IOL was placed in the inferotemporal quadrant, which blocks light entering at that angle. The Acrysof SN60WF IOL has an optic–haptic junction shoulder of 2.42 mm in diameter, which accounts for approximately one third of the circumference of the optic edge. Therefore, by positioning the optic–haptic junction in the inferotemporal quadrant, approximately one third of the available edge was covered and the observed 2.3-fold decrease in incidence was predicted.

As mentioned, in all eyes with the acrylic IOL, there was complete overlap of the optic by the anterior capsule and the only difference between the eyes was the IOL orientation, which resulted in a difference in the incidence of negative dysphotopsia. Therefore, our findings contradict the hypothesis by Masket and Fram that the anterior capsulorhexis is the cause of negative dysphotopsia. Furthermore, the lack of negative dysphotopsia in any of the 99 eyes with the round-edged silicone LI61A0 IOL, despite the imperfect coverage of the optic by the anterior capsule in 4 of the cases, supports the hypothesis suggested in a number of published studies that the refractive index of the IOL material and the design play a major role in negative dysphotopsia development, whereas the anterior capsulorhexis seems to be of less importance. We also showed that the silicone IOL performed better in terms of negative dysphotopsia prevention. This was statistically significant compared with the acrylic IOL when it was implanted in the 6 o'clock and 12 o'clock positions. The same statistical analysis showed that the surgical outcomes were similar between the silicone IOL and the acrylic IOL when the latter was implanted inferotemporally; however, we suspect that this result could have been influenced by the smaller sample \( n = 39 \) in the inferotemporal silicone IOL group compared with the larger sample \( n = 60 \) in the 6 o'clock and 12 o'clock silicone IOL group.

In our study, the patients with negative dysphotopsia reported an improvement during the 1 month after the surgery, which is consistent with results in previous studies. Even though the negative dysphotopsia incidence in the inferotemporal group was still 2-fold lower 1 week after surgery, the difference did not reach statistical significance. This was most likely because of the smaller sample; only the patients who had surgery at Center A were evaluated at the 1-week timepoint, and the rate of negative dysphotopsia decreased in both groups. The decrease in symptoms over time could be attributed to neuroadaptation. This adaptation likely...
occurs similarly to the adaptation to vitreous floaters. The rate of negative dysphotopsia decrease was similar in both patient groups after 1 month, leaving the same proportion of patients with permanent symptoms, irrespective of IOL orientation. This indicates that light discontinuity caused by light rays entering inferotemporally exacerbates only transient negative dysphotopsia, whereas long-term symptomatology might involve different mechanisms. Suspected, yet often debated, additional risk factors for negative dysphotopsia might include the presence of a prominent globe and shallow orbit, in-the-bag IOL placement with anterior capsule coverage of the optic, edema around a temporal corneal incision that is not covered by the eyelid, and possibly pupil size. Except for the in-the-bag placement, which was the case for all eyes in our study, and for the lack of corneal edema at an exposed corneal incision, we did not assess whether these additional risk factors occurred. However, given the large samples in our study, we believe that these remaining possible risk factors were naturally randomized between the inferotemporal and the 6 o’clock and 12 o’clock groups and thus that the only remaining difference between the groups was the IOL orientation.

Last, studies of inter-eye differences have found that left eyes were more likely than right eyes to develop negative dysphotopsia. Osher reported a 23% incidence for negative dysphotopsia in left eyes and an 8.3% incidence in right eyes, and Davison reported 8 cases, all of which were left eyes. However, our study showed no such preponderance. We consider it illogical to expect a difference in the incidence if there was no difference in the surgical technique for right eyes and left eyes and if the optic was completely covered by the anterior chamber, as was the case for all eyes with the acrylic IOL in our trial. However, in the study by Osher, the potential reason for the observed left-side preponderance was because in the right eye the corneal incision was superotemporal and in the left eye the incision was placed temporally, with the latter orientation known to be associated with negative dysphotopsia. Similarly, in the study by Davison, the capsulorhexis spiral was asymmetric between the left eyes and right eyes; in both eyes it was reported to start centrally, expand to the left and then toward the surgeon, and to be finally torn counterclockwise to finish. Also, they found incomplete overlap of the optic by the anterior chamber in the affected eyes, which is a known risk factor for negative dysphotopsia.

In conclusion, positioning the optic–haptic junction of the IOL inferotemporally resulted in a 2.3-fold decrease in the incidence of negative dysphotopsia after cataract surgery. Our clinical trial validates this simple surgical approach for the prevention of negative dysphotopsia during the first postoperative month. Larger and longer-term studies are necessary to corroborate these early findings.

WHAT WAS KNOWN

- Negative dysphotopsia poses a great challenge to cataract surgeons because of the highly multifactorial nature of its occurrence and the unpredictable response to treatment, often resulting in multiple surgeries.

WHAT THIS PAPER ADDS

- Positioning a 1-piece acrylic IOL to decrease inferotemporal light entry resulted in a 2.3-fold decrease in the incidence of negative dysphotopsia after cataract surgery.

REFERENCES


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