Dysphotopsia after Temporal versus Superior Laser Peripheral Iridotomy: A Prospective Randomized Paired Eye Trial

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• PURPOSE: **To determine if the location of neodymium: yttrium–aluminum–garnet laser peripheral iridotomy (LPI) is related to the occurrence of postoperative visual dysphotopsia.**

• DESIGN: **Randomized, prospective, single-masked, paired-eye comparative clinical trial.**

• METHODS: **SETTING: Private subspecialty clinic in Mississauga, Canada. STUDY POPULATION: Patients with primary angle closure or primary angle-closure suspects were recruited and randomized to receive LPI temporally in one eye and superiorly in the other. Patients were masked to the location of treatment in each eye. INTERVENTION: Temporal or superior LPI. MAIN OUTCOME MEASURES: Occurrence of new-onset linear dysphotopsia. Other visual disturbances also were assessed using a questionnaire before and 1 month after intervention. Secondary outcome measures included eyelid position, laser parameters, and any intraoperative complications.**

• RESULTS: **A total of 208 patients were recruited to the study, of which 169 (84%) completed it. New-onset linear dysphotopsia was reported in 18 (10.7%) eyes with superior LPI versus 4 (2.4%) eyes with temporal LPI ($P = .002$). Eleven eyes (6.5%) with superior LPI reported linear dysphotopsia despite complete eyelid coverage of the iridotomy. No significant differences were found with other visual disturbances between them. There was more pain experienced by the temporal LPI (2.8 ± 2.2 vs 2.1 ± 2.0; $P = .001$), despite no difference in laser energy or number of shots. Intraoperative rates of hemorrhage were similar (8.9% vs 10.1%; $P = .71$).**

• CONCLUSIONS: **Temporal placement of LPI is safe and was found to be less likely to result in linear dysphotopsia as compared with superior placement. Temporal iris therefore may be considered a preferred location for LPI.** (Am J Ophthalmol 2014;157:929–935. © 2014 by Elsevier Inc. All rights reserved.)

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LASER PERIPHERAL IRIDOTOMY (LPI) WITH NEODYMIUM: yttrium–aluminum–garnet laser treatment is performed frequently in patients with narrow angles to relieve pupil block and to reduce the risk of acute and chronic angle-closure glaucoma. Side effects associated with LPI typically are benign and include transient blurred vision, transient intraocular pressure rise, transient uveitis, and hyphema. More severe complications can include corneal trauma, cataract, closure of the iridotomy, and retinal detachment.[1–7]

Visual disturbances or dysphotopsias have been reported in 2.7% to 4% of patients after LPI, but few studies have addressed this specific issue.[8–10] These dysphotopsias can manifest as haloes, lines, ghost images, glare, shadows, crescents, and so forth. Murphy and Trope first reported linear dysphotopsias that they described as the presence of a blurred or a colored line occurring after superior LPI in a previously asymptomatic patient.[9] Their patient had a patent iridotomy partially exposed by the upper lid, and they hypothesized that placement of the iridotomy entirely under the upped eyelid might have avoided linear dysphotopsia. After Murphy and Trope's report, Weintraub and Berke reported 4 cases with similar symptoms of linear dysphotopsia in the inferior hemifield after superior LPI, despite full coverage by upper eyelid.[11] They hypothesized that a base-up prism effect of the tear meniscus at the upper lid margin may have redirected incoming light superiorly through the LPI, despite its position behind the lid. They also found that altering the light path by either raising or lowering the upper eyelid, thereby disrupting the tear meniscus, resulted in resolution of the dysphotopsias.

However, a recent paper by Congdon and associates prospectively compared 217 subjects with superior LPI with 250 controls.[12] Some LPIs were totally covered by the lid, some were partly covered by the lid, and some were uncovered by the lid. Straylight and prevalence of visual symptoms were rare in their study and did not differ between treated subjects and controls regardless of lid coverage, size of the LPI, or iris color.

The purpose of our study was to determine if the location of the LPI, superior or temporal, affected the incidence of dysphotopsia after surgery. Specifically, we were interested in linear dysphotopsia because these are most specific to LPIs and most problematic to patients.

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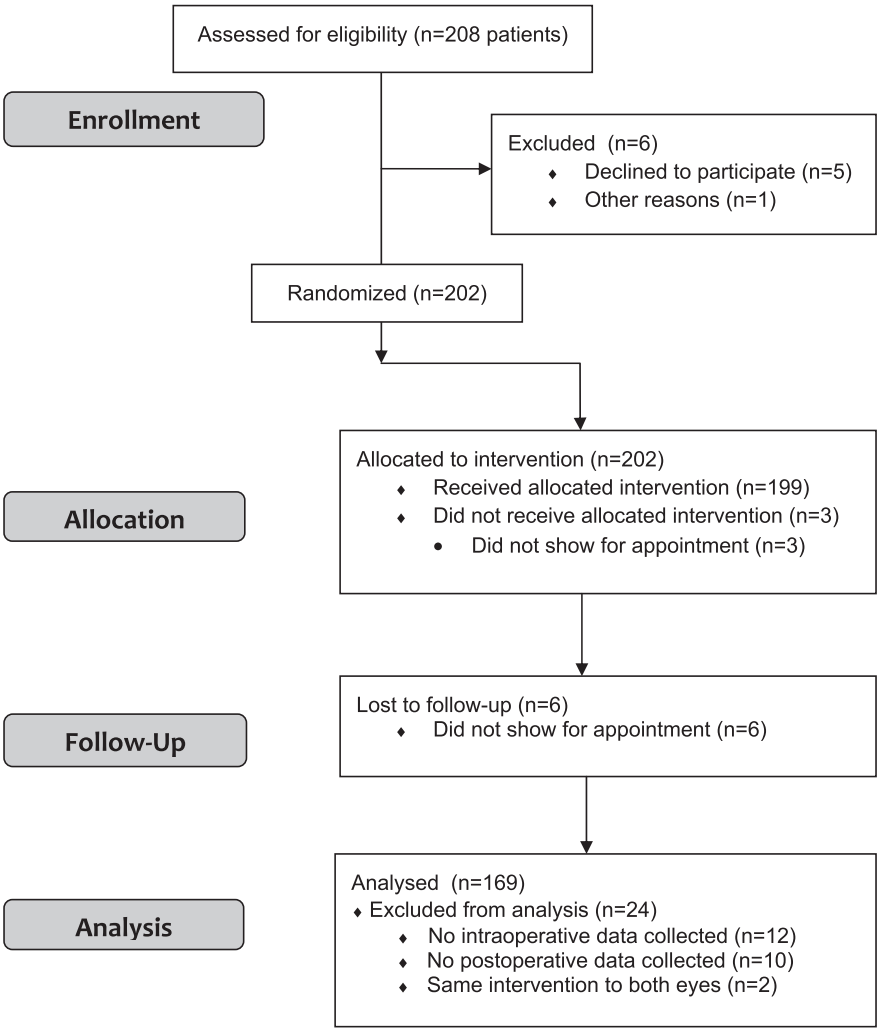

FIGURE 1. Participant flow diagram showing the number of subjects deemed eligible to enroll, the number excluded before allocation with reasons, the number randomized and allocated to intervention and reasons for not receiving intervention, the number lost to follow-up after laser peripheral iridotomy, and the number analyzed including reasons for those excluded.

METHODS

A PROSPECTIVE, RANDOMIZED, SINGLE-MASKED, PAIRED-EYE study was performed with Institutional Review Board Services (Aurora, Ontario, Canada) approval and was registered at ClinicalTrials.gov (no. NCT01758237). All primary angle-closure patients and primary angle-closure suspects seen in the subspecialty clinic in Mississauga, Ontario, Canada, were invited to participate. The inclusion criteria were patients with an indication for LPI who were older than 18 years, were able and willing to give consent, were able to follow study instructions, and were able to attend the required study visits. Patients were excluded if they had any previous intraocular surgery, corrected distance visual acuity worse than 20/40, asymmetrical ptosis of more than 2 mm, active intraocular inflammation, or a history of acute-attack angle-closure glaucoma. Before surgery, age, gender, race, and corrected distance visual acuity were recorded and a questionnaire on visual disturbance symptoms was administered (Supplemental Material, available at AJO.com).

Using a binary random number generator, one eye was selected and then randomized using the same method to an LPI in the temporal location or superior location. The other eye by default was assigned the opposite location. Patients were masked to the location of treatment performed in each eye. The LPI was performed using the neodymium:yttrium–aluminum–garnet laser using an Abraham iridectomy lens (Ocular Instruments Inc., Bellevue, Wasington, USA). Superior LPIs were place between 11 and 1 o'clock with an attempt to place as peripheral as possible and under the superior eyelid. Temporal LPIs were placed between 2 and 4 o'clock (for left eyes) or between 8 and 10 o'clock (for right eyes), being careful to avoid placing near the lid margin for patients whose lid crossed near the temporal cornea. Preference was made

for iris crypts, while avoiding iris vessels. Both LPIs were performed sequentially at the same visit. Intraoperative data collected included iris color, number of laser shots, energy used, a subjective rating of pain on a scale from 0 to 10, and the occurrence of any complications.

Each patient had a follow-up visit 1 month after LPI, during which the same visual symptom questionnaire was administered. This was followed by corrected distance visual acuity, slit-lamp, gonioscopic, and external examinations to measure palpebral fissure, margin reflex distance, presence of cataract, location and size of LPI, its distance from the limbus, and the degree of eyelid coverage. The primary outcome measure was the presence of new linear dysphotopsias. Secondary outcomes included the presence of other visual dysphotopsias, laser parameters, pain experienced during the procedure, and complications.

A sample size of 163 patients (163 eyes per group) was calculated based on an estimated of incidence of 10% linear dysphotopsias in the superior LPI group versus 3% in the temporal group (power, 80%; α, 0.05). This was based on previously unpublished pilot study data. To account for a 15% dropout rate, a total of 200 patients were planned to be recruited.

Statistical analyses were carried out using the Statistical Package for the Social Sciences version 15 (IBM, Chicago, Illinois, USA). Paired *t* tests were used for comparison of the neodymium:yttrium–aluminum–garnet laser settings. The Mann–Whitney *U* test or Wilcoxon signed-rank test were used for all other analysis. Correlation between eye color and dysphotopsia was performed using binary logistic regression. Significance was set at $P = .05$.

RESULTS

A TOTAL OF 208 PATIENTS WERE ELIGIBLE FOR RECRUITMENT into the study. Of those, 202 patients were enrolled and 199 of these underwent the intervention. There were 169 (81.3%) patients who completed their questionnaires and examinations before and after laser treatment and underwent the correct treatments in either eye (Figure 1). Two patients received the same intervention in both eyes, and so were excluded from the analysis. In total, 338 eyes from the 169 patients were included in the data analysis. Demographic characteristics for these patients are listed in Table 1.

There was no statistically significant difference in the mean laser energy used (4.99 ± 1.13 mJ vs 5.06 ± 2.07 mJ; $P = .733$), number of shots (8.1 ± 8.4 vs 8.7 ± 16.7; $P = .684$), and total energy (41.5 ± 48.2 mJ vs 47.1 ± 107.9 mJ; $P = .539$) used to perform the LPI between the superior and temporal locations. Subjective pain grading scores showed temporal LPIs were significantly more painful than superior LPIs (2.8 ± 2.2 vs 2.1 ± 2.0; $P < .001$). There was also no difference in the presence of intraoperative hemorrhage, which was graded as mild, between superior or temporal LPIs (8.9% vs 10.1%; $P = .71$).

TABLE 1. Characteristics of Patients Who Underwent Bilateral Laser Peripheral Iridotomy and Completed the Study

No. of patients	169
Mean age ± SD, y	53.4 ± 11.5
Male / female gender, n (%)	52 (30.8)/117 (69.2)
Race, n (%)	
Black	9 (5.3)
Asian	11 (6.5)
White	85 (50.3)
Hispanic	5 (3.0)
South Asian	59 (34.9)

SD = standard deviation.

Before LPI, 94 patients (55.6%) experienced 1 or more dysphotopsias (Table 2). Rates of each dysphotopsia before LPI were similar in both superior and temporal LPI eyes with no significant difference. Of dysphotopsias present before laser, glare, blurred vision, and haloes tended to more common, whereas linear dysphotopsias were present in only 3 (0.9%) of 338 eyes.

After LPI, there were no differences in reported dysphotopsia from before LPI for both superiorly treated and temporally treated eyes, with the exception of linear dysphotopsia and halos (Table 2). After LPI, 23 (6.8%) eyes demonstrated linear dysphotopsias. There were 18 eyes (10.7%) that had undergone superior LPI as compared with 5 (3.0%) eyes that had undergone temporal LPI, one of which had the same dysphotopsia before laser treatment. This was a statistically significant difference ($P = .002$; Figure 2). Thus, the number of new-onset linear dysphotopsias after laser treatment was 18 (10.7%) for superior LPI eyes versus 4 (2.4%) for temporal LPI eyes ($P = .002$). In 2 patients, linear dysphotopsia present before LPI resolved after LPI, 1 in each group. There were 2 patients who demonstrated linear dysphotopsias in both eyes after LPI. The presence of haloes and ghost images seemed to improve in a significant number of patients after LPI regardless of location (Table 2).

Most the patients who had undergone temporal LPI had completely exposed iridotomies (97.6%). Among those eyes with a superior LPI, 128 (75.5%) were covered fully by the upper lid, 28 (16.6%) were partially exposed, and 13 (7.7%) were completely exposed. In total, 11 (8.6%) of the fully covered superior LPI patients and 7 (25.0%) of the partially covered superior LPI patients specifically reported linear dysphotopsia. By contrast, none of the patients with fully exposed superior LPI experienced visual disturbances. All eyes with linear dysphotopsia in the temporal LPI group had exposed LPIs. In total, 2.8% of all fully exposed LPI's experienced linear dysphotopsias as compared with 11.3% of partially or completely covered LPI's (Table 3).

TABLE 2. Dysphotopsias Occurrence in Patients before and after Superior and Temporal Laser Peripheral Iridotomy

Variable	Superior LPI			Temporal LPI		
	Before Laser	After Laser	*P* Value[a]	Before Laser	After Laser	*P* Value[a]
Halo	23	8	.002	23	10	.007
Lines	1	18	<.001	2	5	.180
Crescent	4	2	.317	2	1	.317
Glare	33	23	.059	33	22	.048
Ghost images	14	4	.008	14	5	.013
Shadows	8	7	.763	8	8	1.00
Blurry vision	28	33	.369	28	35	.209

LPI = laser peripheral iridotomy
[a]Wilcoxon signed-rank test.

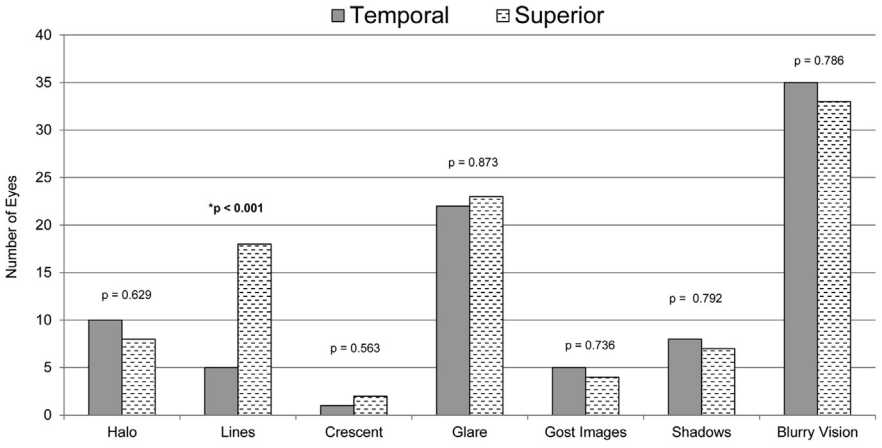

FIGURE 2. Bar graph comparing the dysphotopsias occurring after laser peripheral iridotomy between the temporal and superior groups. There was a significant difference between the groups with the presence of lines or linear dysphotopsia ($P < .001$).

TABLE 3. Dysphotopsia Frequency Based on Lid Coverage of Laser Peripheral Iridotomy in All Study Patients

Lid Coverage	No Dysphotopsia	Dysphotopsia	
		Any	Linear
LPI exposed	144	34	5
LPI partially exposed	17	12	7
LPI covered	99	32	11
Total	260	78	23

LPI = laser peripheral iridotomy.

There was no significant correlation between any of the symptoms and the color of the iris.

DISCUSSION

LASER PERIPHERAL IRIDOTOMY HAS BEEN FOUND TO BE safe and effective in the treatment of angle-closure glaucoma.[11,13,14] However, unusual visual symptoms such as diplopia, lines, crescents, shadows, and ghost images have been reported after the procedure.[8,11] Our results were consistent with those of previous studies in showing that many of these symptoms are present before LPI. Of these varied symptoms, the new onset of linear dysphotopsias after laser seems to be most specific to LPI. In some patients, these linear dysphotopsia can be a source of significant disability and concern.

In our study, linear dysphotopsia occurred in 6.8% of eyes after LPI. Overall, 10.7% of superior LPI eyes demonstrated new linear dysphotopsias, as compared with 2.4% of temporal LPI eyes. All of the superior LPI cases occurred in either fully or partially covered LPIs. Our results suggest that patients who underwent superior LPI were 3.6 more times likely to demonstrate linear dysphotopsias after laser than those with a temporally placed LPI. Partially or completely covered LPIs were 4.0 times more likely to result in new linear dysphotopsias than completely exposed LPIs.

Although it has been suggested that superior placement of the LPI ensuring full lid coverage can avoid linear

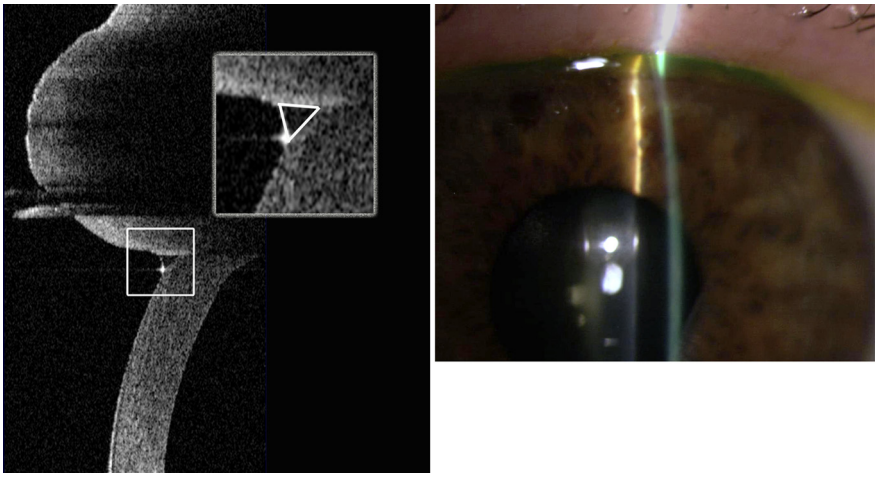

FIGURE 3. (Left) Anterior segment ocular coherence tomography and (Right) color slit-lamp photograph with fluorescein staining showing the superior tear prism that is believed to be responsible for causing the linear dysphotopsias observed in superior laser peripheral iridotomy patients.

dysphotopsia,[9] 11 of our patients (6.5%) with fully covered superior LPI still demonstrated new visual dysphotopsias after LPI, as opposed to none of the patients with superiorly exposed LPI and 2.8% of all exposed (superior and temporal) LPI. These findings are more in keeping with those of Spaeth and associates.[10]

To understand fully the development of dysphotopsias, one must delve into their underlying optics. The tear film forms a triangular lake at both the upper and lower lid margin, which can act as a base-up prism for incumbent light (Figure 3). Light passing through the air–tear interface is refracted toward the base of the tear prism, which sits at the lid margin. Refracted light therefore must be redirected superiorly by the upper lid tear meniscus. In a susceptible patient, the right combination of upper lid position and appropriately sized tear meniscus could refract light superiorly directly through the path of a superior LPI situated behind the eyelid. This is more likely to occur with a superior LPI placed just above (and partially or fully covered by) the lid margin because of the position of the tear meniscus just below the LPI. Patients would be more symptomatic in this scenario than light passing unrefracted through a fully exposed LPI. Light passing through a small aperture like an LPI will diffract or spread in a ring-like fashion before striking the retina. The longer its path, the more it will spread, and consequently the more defocused it will become. Light redirected superiorly strikes the superior peripheral retina after a relatively short path, and as such remains relatively focused (Figure 4). Focused light can be perceived in this case by the patient. In contrast, light passing through the temporal iris continues in a straight path to strike the temporal posterior pole (Figure 5). Because this path is longer, it would be relatively defocused at the retina and thus less perceptible to the patient.

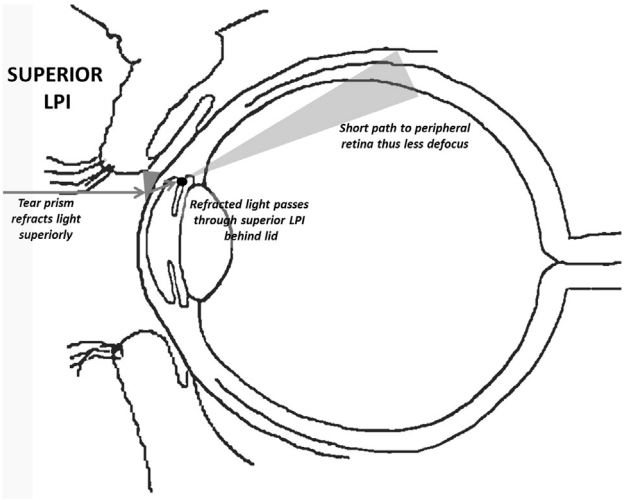

FIGURE 4. Schematic eye showing that light redirected superiorly by the tear prism could pass through a superior laser peripheral iridotomy (LPI) otherwise hidden by the upper lid and would strike the superior peripheral retina after a short path, thus remaining relatively focused.

The typical dysphotopsias described by patients with superior LPIs consists of a grey or blue horizontal or slightly curved line in the inferior peripheral visual field. The inferior location is consistent with light falling on superior peripheral retina. We believe that the horizontal or slightly curved orientation of the linear image is generated by the shape of the upper lid margin, which defines the lateral dimension of the tear meniscus and thus the shape of the image created by light refracted through the tear prism (Figure 3).

Other types of visual phenomena such as haloes, glare, and blurred vision also were described, but these often

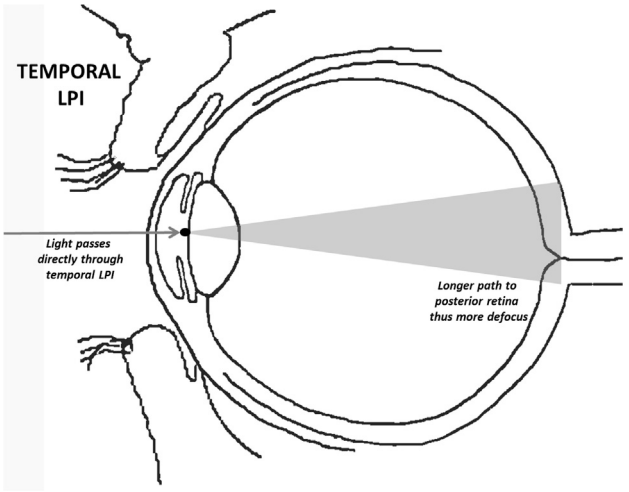

FIGURE 5. Schematic eye showing that light passing through a temporal laser peripheral iridotomy (LPI) would continue in a straight line toward the temporal posterior pole following relatively longer path, creating a defocused image.

occurred before LPI and therefore were likely less specific to LPI itself. Interestingly, the presence of haloes and ghost images seemed to improve significantly after the LPI was performed, regardless of location. It is possible that some of these patients had halos or blurred vision as a result of intermittent intraocular pressure spikes resulting from angle closure that improved after LPI.

Despite similar laser energy and shots between groups, LPI performed in the temporal location resulted in 1.5 times more pain based on our subjective scale when compared with the superior location. This may have resulted from increased stimulation of the long ciliary nerves by laser energy delivered to the temporal peripheral iris. Our study did not show any increased risk of intraoperative hemorrhage—which was mild in all reported cases—but one must be careful to avoid the vessels at 3 and 9 o'clock when performing temporal LPIs.

Visual dysphotopsias in general, and more specifically linear dysphotopsias, occur frequently after laser iridotomy. Although most of these phenomena resolve or are well tolerated by most patients, for some patients it can be aggravating and disabling. Thus, dysphotopsia should be discussed with patients undergoing LPI.

Coverage of a superior LPI by eyelid does not prevent the occurrence of linear dysphotopsia and may increase the risk because of the base-up refraction of light by the tear meniscus at the superior lid margin. Temporal placement of peripheral iridotomy may cause greater discomfort at the time of the procedure, but is safe and seem to reduce the occurrence of postoperative linear dysphotopsias significantly.

In conclusion, the results of this study suggest that the ideal location of an LPI is in the temporal iris versus superiorly for the average patient. This is supported both by theoretical optics and the results of this clinical trial. It is likely that nasal placement would result in similar findings as temporal placement. Because eyelid positions vary among ethnicities and in older versus younger patients, one must customize the position of LPI to the individual patient's anatomic features. For example, if the temporal aspect of the superior lid drops down steeply in a given patient, even a temporal LPI may induce dysphotopsia. In that case, placing the LPI more inferotemporally should be considered or placing it nasally. Care should be taken to examine the patient's eyelids before and ensure that the upper eyelid does not cover or partially cover the temporal LPI location.

ALL AUTHORS HAVE COMPLETED AND SUBMITTED THE ICMJE FORM FOR DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST and none were reported. Involved in Design of study (A.N., I.A., V.V.); Conduct of study (A.N., D.K.V., I.A., V.V.); Collection (A.N., D.K.V., G.W.B., I.I.K.A., V.V.), management (A.N., G.W.B., I.I.K.A., V.V.), AND analysis and interpretation (A.N., D.K.V., G.W.B., I.I.K.A., V.V.) of data; and Preparation, review, or approval of manuscript (A.N., D.K.V., G.W.B., I.I.K.A., V.V.). This study was registered with the National Institute of Health maintained site http://www.clinicaltrials.gov (identification no.: NCT01758237).

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Biosketch

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Symptoms	Right eye	Left eye
Halo		
Lines		
Crescent		
Ghost images		
Glare		
Shadows		
Blurry vision		
Other…(specify)		

Scale:

0 = none existing
1 = mild barely noticed
2 = mild not interfering with vision
3 = moderated, interfering with vision but tolerated
4 = severe, interfering with vision, not tolerated

SUPPLEMENTAL FIGURE 1. Questionnaire that was administered to each patient at preoperative and postoperative visits to determine the subjective presence of each type of dysphotopsia.