Pinhole pupilloplasty: Small-aperture optics for higher-order corneal aberrations

Priya Narang, MS, Amar Agarwal, MS, FRCS, FRCOphth, Dhivya Ashok Kumar, MD, FRCS, FICO, FAICO, Ashvin Agarwal, MS

This technique of performing pinhole pupilloplasty helps filter the straylight from the periphery of the cornea in cases with higher-order corneal aberrations. The pinhole effect blocks distorted and unfocused light rays and isolates more focused central and paracentral rays through the central aperture, thereby reducing aberrations of the optical system as a whole and enhancing visual acuity and its image quality.

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Significant irregular corneal astigmatism leads to ocular aberrations that cause tremendous unfavorable effects. These effects can be minimized by reducing the pupillary aperture, which tends to negate the effect of ocular aberrations. A small pupil diameter reduces incident straylight, which can help improve visual acuity and reduce haze and halos. Based on this, intraocular lenses (IOLs) with small apertures were developed to enhance the visual potential of patients with irregular astigmatism.1–7

A small pinhole acts as a lens that focuses light. As shown in Figure 1, after pinhole pupilloplasty, the pinhole wards off the light emanating from the peripheral cornea and allows the passage of central and paracentral rays. This enhances visual acuity and the image quality by reducing the aberrations of the optical system as a whole.

The Stiles-Crawford effect of the first kind could be another possible mechanism because it is believed that when an equal intensity of light enters near the center of the pupil, it produces a greater photoreceptor response compared with the light entering the eye near the edge of the pupil. The photoreceptor response is significantly less than expected by the reduction in the photoreceptor acceptance angle of light entering near the edge of the pupil.5,9 Therefore, when the pupil narrows, more focused light enters the eye through the narrow aperture, producing a greater photoreceptor response.

Pupilloplasty techniques have been developed to achieve an adequate pupil shape and size and pupil configuration to avoid phenomena such as glare and photophobia.10–14 We describe a pinhole pupilloplasty technique that effectively addresses the issue of achieving adequate image and visual quality while addressing the issues of glare and photophobia in cases of higher-order irregular corneal astigmatism.

SURGICAL TECHNIQUE

In the new pinhole pupilloplasty technique, single-pass 4-throw pupilloplasty is performed. Although the single-

Figure 1. The principle of pinhole pupilloplasty. A clear focused image is obtained when the rays from the central cornea are focused on the retina.
pass 4-throw technique has been described, a slight variation was adopted for pinhole pupilloplasty. A greater amount of iris tissue from the pupillary margin is incorporated into the 10-0 needle, which then is passed through the iris tissue much more centrally so that iris tissue close to the center of pupil is approximated.

In brief, under peribulbar anesthesia of 4 mL lidocaine hydrochloride (Xylocaine 2.0%) and 2 mL bupivacaine hydrochloride 0.5% (Sensorcaine), 2 paracenteses are created and a 10-0 polypropylene suture attached to the long arm needle is introduced into the anterior chamber. The anterior chamber can be maintained with an ophthalmic viscosurgical device or with fluid infusion with the help of an anterior chamber maintainer or a trocar anterior chamber maintainer. An end-opening forceps is introduced through the paracentesis, and the proximal iris leaflet is held. The suture needle is passed through the proximal iris tissue. A 26-gauge needle is introduced from the paracentesis from the opposite quadrant and passed through the distal iris leaflet after being held with end-opening forceps. Next, the tip of the 10-0 needle is then passed through the barrel of the 26-gauge needle, which is then pulled out of the paracentesis. The 10-0 needle exits the anterior chamber along with the 26-gauge needle.

A Sinskey hook is passed through the paracentesis, and a loop of suture is withdrawn from the eye. The suture ends are then cut with microscissors (Figure 2). The procedure is repeated in the other quadrant to achieve a pupil of desired configuration and to decrease the pupil to pinhole size (Video 1, available at http://jcrsjournal.org).

Results
The procedure conformed to the tenets of the Declaration of Helsinki, and institutional review board

<table>
<thead>
<tr>
<th>Eye/Age (Y)/Sex</th>
<th>Surgery</th>
<th>Lens Status</th>
<th>Cornea</th>
<th>Pupil Diameter (mm)</th>
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<td></td>
<td></td>
<td>Preop</td>
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<td></td>
<td></td>
<td></td>
<td>H</td>
</tr>
<tr>
<td>OD/64/M</td>
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<td>PC IOL</td>
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</tr>
<tr>
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<td>Pinhole pupilloplasty</td>
<td>PC IOL</td>
<td>Post PKP</td>
<td>6.20</td>
</tr>
</tbody>
</table>

CDVA = corrected distance visual acuity; H = horizontal; IOL = intraocular lens implantation; PC = posterior chamber; PKP = penetrating keratoplasty; Sim K Astig = simulated keratometry astigmatism; UDVA = uncorrected distance visual acuity; V = vertical

*Partial
approval was obtained. All patients provided informed consent.

Data were analyzed using Stata software (version 12.0, StataCorp LLC). Normality of data was checked using the Shapiro-Wilk normality test.

Five eyes of 5 patients had the pinhole pupilloplasty procedure (Table 1). There was a statistically significant difference in the pupil dimensions in the horizontal and vertical meridians between preoperatively and postoperatively. The mean preoperative pupil diameter in the horizontal meridian and vertical meridian was 4.96 mm ± 1.48 (SD) and 4.88 ± 0.55 mm, respectively. The mean postoperative pupil diameter was 1.47 ± 0.29 mm (P = .006) and 1.38 ± 0.01 mm (P = .00, paired-sample t test), respectively. The mean postoperative pupil diameter after dilation with a mydriatic (tropicamide 0.8%–phenylephrine 5%) was 1.72 ± 0.23 mm and 1.82 ± 0.33 mm, respectively. Postoperatively, following pupil dilation there was a significant difference in the horizontal diameter and vertical diameter of the pupil (P = .018 and P = .031, respectively; paired-sample t test).

There was a significant improvement in the uncorrected distance visual acuity (Snellen decimal equivalent notation) in the postoperative period (P = .04, Wilcoxon test). However, there was no significant difference in the uncorrected distance visual acuity and corrected distance visual acuity in the postoperative period (P = .189, Wilcoxon test).

All patients had a minimum follow-up of 3 months (range 3 to 9 months). There were no cases of hyphema or other postoperative complications.

DISCUSSION
The concept of pinhole or small-aperture optics is established as having a definite value in the field of ophthalmology.1–7,15–17 Small-aperture IOLs cut off the peripheral defocused rays, and the integrated small aperture increases spectacle independence by extending the depth of focus with the potential benefit of improving the image quality. Trindade et al.1 addressed corneal irregular astigmatism using an intraocular pinhole device designed to be implanted in the ciliary sulcus in pseudophakic eyes. It is of hydrophobic foldable acrylic material and has a 1.3 mm central opening with no dioptric power. The device has been found to enhance the functional vision in patients with irregular corneal astigmatism.

Miotics have been recommended because they give significant relief by immediately inducing pupillary miosis. However, miotics are associated with drawbacks, such as causing frontal headaches, nausea, and bronchospasms. Prolonged use of miotics also leads to ciliary muscle spasm, which can induce retinal detachment in myopic eyes.18 High irregular corneal astigmatism can manifest as a sequel to varied etiology. It eventually leads to a significant decrease in the visual and image quality.

Performing a surgical pupilloplasty is a viable option for achieving a pinhole effect in eyes with higher-order irregular corneal astigmatism. In all our cases, there was a significant improvement in visual acuity in the postoperative period (Figure 3). Although pinhole pupilloplasty can be performed with any technique, we performed it with a single-pass 4-throw that has an additional advantage of using a single pass through the anterior chamber, which likely causes less intraoperative inflammation because of the minimal iris tissue manipulation. An additional advantage of performing a single-pass 4-throw is that it allows adequate examination of the retina after pupil dilation.19 Also, adequate visualization of the posterior segment for routine examination is possible in eyes with pinhole pupilloplasty (Figure 4). It is often difficult to sever the suture knot of polypropylene using a neodymium:YAG laser; however, the knot can be cut with microscissors in cases that require subsequent major retinal intervention. Although any technique can be adopted for performing pinhole pupilloplasty, it is easier to undo a single-pass 4-throw, Siepser,16 or a McCannel12 technique and their modifications compared with a cerclage because of the continuous passage of the suture across the entire pupil margin.

<table>
<thead>
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<th>Table 1. (Cont.)</th>
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<tr>
<td><strong>Pupil Diameter (mm)</strong></td>
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<td><strong>Snellen UDVA</strong></td>
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<td><strong>Postop (Post Dilation)</strong></td>
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<td><strong>H</strong></td>
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<tr>
<td><strong>Preop</strong></td>
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<td>1.56</td>
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<tr>
<td>1.63</td>
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<tr>
<td>1.53</td>
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<td>2.10</td>
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<td>1.80</td>
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Centration of the pupil can be achieved by preoperatively marking the center of the cornea or intraoperatively by gauging the position of the light reflex of the microscope. The latter method, however, can lead to improper centration because the globe can rotate or deviate under the effect of peribulbar anesthesia. An intraoperative measuring caliper can be used to quantify the pupil size during surgery. Alternatively, intraoperative optical coherence tomography can also be used to optimize the pupil size, although we did not use any specific measure to do so.

A possible limitation of pinhole pupilloplasty is the presence of insufficient iris tissue to perform pupilloplasty. Another limitation would be to perform this procedure in a phakic eye. Although there are limitations to the procedure, the advantage of being able to focus and improve visual function outweighs its shortcomings.

The principle of small-aperture optics to correct presbyopia by enhancing the depth of focus has been placed at the level of the cornea and at the level of the lens. A similar principle in which the optics are placed at the level of the iris and pupil structure works efficiently by filtering the defocused rays and increasing the visual potential. Although the effect of pinhole pupilloplasty on establishing an extended range of vision remains under study, this paper puts forward the concept of performing pinhole pupilloplasty for cases with higher-order irregular corneal astigmatism. The idea is to achieve significant improvement in visual acuity by creating a pinhole effect. A study with a larger number of cases would help establish this concept.

In conclusion, surgical pupilloplasty to create the pinhole effect is a cost-effective and efficient method because no purpose-designed device is needed. Based on the significant immediate improvement in acuity and high patient satisfaction in our 5 cases, we recommend that surgeons consider performing pinhole pupilloplasty in cases with higher-order irregular corneal astigmatism.

**WHAT WAS KNOWN**
- Pinhole devices mitigate the impact of corneal aberrations.
- Pinhole visual acuity is an indicator of the visual potential of an eye and of the corrected vision a patient can perceive.
- Contact lenses, corneal inlays, and pinhole intraocular lenses help achieve the pinhole effect.
- The pupilloplasty procedure facilitates pupil reconstruction and helps achieve an adequate pupil contour, size, and shape.

**WHAT THIS PAPER ADDS**
- Pinhole pupilloplasty achieved the pinhole effect by narrowing down the pupil size.
- Pinhole pupilloplasty significantly improved visual acuity in patients with higher-order corneal aberrations by allowing the passage of light through the central pinhole area and reducing the aberrations of the optical system.
REFERENCES


9. Stiles WS, Crawford BH. The luminous efficiency of rays entering the eye pupil at different points. Proc R Soc Lond B 1933; 112:428–450


Disclosures: None of the authors has a financial or proprietary interest in any material or method mentioned.