The multiple radial stromal deep corneal incisions placed in radial keratotomy (RK) lead to higher-order aberrations and pose a surgical challenge to performing any further corrective procedure on the cornea because of fear of inducing an incisional dehiscence. A method to perform pinhole pupilloplasty (PPP) in the setting of previous RK is presented. Application of pinhole optics by performing PPP leads to significant improvement in image quality and helps to optimize visual potential in post-RK cases.

Radial keratotomy (RK) was the most commonly performed refractive surgery in 1980s that involved placing deep stromal incisions to flatten the central cornea, but its aftermath still continues in the form of irregular astigmatism, resultant hyperopic shift, unpredictable visual outcomes with diurnal fluctuating vision, and glare and halos resulting due to biomechanically unstable cornea.1 Because of alteration in corneal shape, patients have higher-order aberrations (HOAs) that are difficult to treat with any corneal ablative procedure. The patients who undergo RK currently present with presbyopia or early cataract formation. This subset of patients poses a challenge for intraocular lens (IOL) power calculation, for the consideration of type of IOL to be implanted, or to the type of surgical procedure that can be considered to enhance the visual outcome.

Principles of small-aperture optics can be applied to cases with HOAs, which are refractory to other forms of currently available treatment.2–5 The placement of an IC-8 IOL (Acufocus, Inc.) in post-RK case has been demonstrated to help achieve spectacle independence at distance, intermediate, and near.1 In this study, we describe a safe and an effective technique of performing pinhole pupilloplasty (PPP) with single-pass 4-throw (SFT) method in the setting of previous RK using Purkinje 1 (P1) image as the marker for centration.6

Internal Ethics Committee approval was obtained, and patients were informed about the surgical procedure and provided written consent. This was a prospective, noncomparative case series that included patients having PPP for HOAs induced after RK. The PPP procedure was performed in 6 eyes of 5 patients under peribulbar anesthesia. The radial corneal RK incisions in all the eyes did not extend into the central 3 to 4 mm zone, and the central axis was clear. All the eyes that were subjected to PPP did not undergo any other corrective procedure except RK in both eyes. Visual acuity (logarithm of the minimum angle of resolution [logMAR]) for all cases was recorded under photopic and mesopic conditions for all distances (distance 4 m, intermediate 66 cm, and near 44 cm) with the Clinical Trial Suite Machine (M & S Technologies, Inc.), which offers standardized method of recording visual quality and helps to avoid variation and inaccuracy in threshold measurements as specified in ANSI, ISO, and Consensus Statement of the Accommodative IOL Task Force.2–11 The Clinical Trial Suite system can be calibrated for various viewing distances, and the tests were performed at specified light levels of 85 cd/m² (photopic) and 3 cd/m² (mesopic). The defocus curve was tested by using corrected distance vision and measuring visual acuity in steps (+1.50 diopter [D] to −2.50 D) in 0.50 D defocus steps and in between +0.50 D and −0.50 D in 0.25 D steps. The mean, standard deviation, and CI for each point on the curve were plotted.

**SURGICAL TECHNIQUE**

Surgical planning of the placement of paracenteses incisions was performed prior to the commencement of the
procedure. Paracentes incision was placed between the 2 RK marks, and ophthalmic viscosurgical device was introduced inside the anterior chamber to coat the endothelium. A 9-0 polypropylene suture attached to a long needle was introduced, taking care not to imbibe the corneal tissue into it. The needle was passed through the proximal iris tissue along the pupillary edge and subsequently from the distal iris tissue (Figure 1, A and B). A 30-gauge needle was introduced from the opposite quadrant in between the 2 RK marks, and the suture needle was threaded into it and withdrawn from the eye. A Sinskey hook was passed, and a suture loop was withdrawn. The suture end was passed through the loop 4 times in the same direction (Figure 1, C). Both suture ends were pulled that led to sliding of the loop inside the eye, thereby approximating the pupillary edges. Microscissors were introduced, and the suture knot was cut (Figure 1, D). The procedure was repeated in the other quadrants (Figure 1, E and F) until the desired shape and size of pupil was achieved, and care was taken to center the pupil on the P1 reflex that falls on the anterior surface of cornea and emanates from the coaxial light of the microscope. A vitrectomy probe can be used to center the P1 reflex wherein the iris tissue is found to obliterates the centration of pupil on P1 reflex because of overriding of the iris tissue (Figure 2). The paracentes incisions were sealed with corneal sutures to prevent any inadvertent leakage (Supplemental Digital Content 1, Video 1, available at http://links.lww.com/JRS/A199).

Figure 1. Surgical procedure of single-pass 4-throw technique in a case with radial keratotomy. A: A 9-0 suture needle (long arm) is introduced from the paracentesis incision placed in the space between 2 radial incisions. The needle engages the proximal part of the iris around the pupillary edge. B: A 30-gauge needle is introduced from another paracentesis incision placed similarly in the opposite quadrant. The suture needle engages the distal part of iris tissue around the pupillary edge and is threaded into the 30-gauge needle. C: The suture loop is withdrawn with the Sinskey hook, and the suture end is passed through the loop 4 times in the same direction. D: Both suture ends are pulled. This leads to sliding of the loop inside the anterior chamber. The knot is cut with microscissors. E: The 9-0 suture needle is passed again in the opposite quadrant, and the procedure is repeated. F: Pupil size is narrowed down, and pinhole pupil is achieved.

Figure 2. Centration of pupil on Purkinje 1 (P1) image. A: A 25-gauge vitrectomy cutter is introduced from the paracentesis incision. B: The pupillary edge overriding on the P1 reflex is cut with the vitrectomy cutter. C: Centration of pupil on P1 reflex is achieved.
The patients who had associated cataract underwent phacoemulsification procedure, followed by PPP in the same setting. The cataract removal was performed carefully with phacoemulsification parameters set at low level to prevent any inadvertent fluctuations in the anterior chamber. All the maneuvers for performing a routine phacoemulsification procedure were performed gently. The paracenteses incisions created for cataract surgery was used for performing PPP to limit the number of side incisions as far as possible.

RESULTS
The technique was performed in 6 eyes of 5 patients. The mean age of the cases was 59 ± 9.77 years. All the cases had a minimum follow-up of at least 6 months. The preoperative pupil size was 2.96 ± 1.66 mm, whereas the postoperative pupil diameter was 1.66 ± 0.21 mm (Figure 3), as measured with anterior segment optical coherence tomography.

There was significant improvement in preoperative and postoperative uncorrected and corrected distance visual acuities in photopic and mesopic light conditions for distance, intermediate, and near (Table 1) (Wilcoxon signed-rank test). The patient satisfaction rate was very high in the immediate postoperative period and persisted on all follow-ups. The defocus curve in the postoperative period demonstrated an extended depth of focus and a range of vision that extended from +1.50 D to −2.50 D. All cases maintained visual acuity that was better than 0.26 logMAR over the entire range of defocus (Figure 4).

DISCUSSION
Post-RK cases demonstrate corneal instability with frequent hyperopic shifts and fluctuation of visual acuity after an otherwise uneventful procedure. Disatisfied cases often consult for additional refractive interventions that might help them to overcome the downside of the initial RK procedure. The effect of total ocular aberrations experienced by the patient has a direct relationship with the size of the pupil. With a decrease in the pupil aperture, the effect of HOAs decreases because the peripheral rays are barred from entering the eye and the central/paraxial rays are impervious to the imperfections of the optical system. The benefits of small-aperture optics can be availed either through the application of miotics or implantation of a small-aperture IOL. Prolonged use of miotics is often associated with nausea, frontal headache, and bronchospasm and is, therefore, not recommended. We considered application of miotic drops to apprise the patient of the type of vision quality that can be attained in the postoperative period. Intermittent application of miotic drugs can be advised to the patient either if there is a contraindication to undergo surgery or if the patient is unwilling. Small-aperture IOLs have been designed to address cases with irregular corneal aberrations and have been documented to enhance the functional vision and impart extended depth of focus. These IOLs can be placed intraocularly; however, their

<table>
<thead>
<tr>
<th>Visual Acuity</th>
<th>Photic</th>
<th>Mesopic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance 4 m</td>
<td>Intermediate 66 cm</td>
</tr>
<tr>
<td>UDVA Preop</td>
<td>0.95 ± 0.23</td>
<td>0.88 ± 0.21</td>
</tr>
<tr>
<td>Postop</td>
<td>0.32 ± 0.21</td>
<td>0.30 ± 0.21</td>
</tr>
<tr>
<td>P value</td>
<td>0.028</td>
<td>0.043</td>
</tr>
<tr>
<td>CDVA Preop</td>
<td>0.61 ± 0.34</td>
<td>0.66 ± 0.27</td>
</tr>
<tr>
<td>Postop</td>
<td>0.21 ± 0.19</td>
<td>0.46 ± 0.28</td>
</tr>
<tr>
<td>P value</td>
<td>0.027</td>
<td>0.03</td>
</tr>
</tbody>
</table>

CDVA = corrected distance visual acuity; preop = preoperative; postop = postoperative; UDVA = uncorrected distance visual acuity

P < .05.
availability is often an issue in many countries. Under such circumstances, PPP can be performed, and the benefits of pinhole optics can be availed.

The stromal deep radial incisions in RK never heal. Therefore, it is imperative to preferably place the paracentesis incision equidistant from the consecutive radial marks. IOL power calculation poses a major challenge in post-RK patients because of the irregularity of cornea. The ASCRS calculator was used to calculate IOL power in cases that underwent cataract extraction along with PPP. Performing PPP helps to overcome the aspect of residual refractive power that this subset of patients might experience during the postoperative period because pinhole optics confers a better range of vision at distance, intermediate, and near (Figure 4).

Intraocular maneuver induces temporary hyperopic shift due to swelling of radial incisions and a resultant flattening of the central corneal surface. The fluctuations in the refractive state were not obvious in our case series, and we presume that it could be due to PPP that imparted pinhole optics to the patients. We also feel that minor refractive errors were also taken care by PPP, and we did not encounter the need to perform any additional corrective procedure. The technique of SFT pupiloplasty procedure was adopted to achieve a pinhole pupil although PPP can be performed with any other method of pupiloplasty.6 The surgeons chose SFT because minimal passes are necessary to achieve the desired pupil size, thereby rendering the procedure as fast, effective, and one that can be accomplished with minimal intraocular manipulations. A maximum of 3 to 4 passes were needed to perform the PPP procedure with SFT technique. Centration was performed on P1 reflex that is considered to be the main reference marker for assessing centration intraoperatively.26

The limitation includes the small number of study patients, and future research is necessary to confirm the effectiveness of the procedure with large number of cases and a longer follow-up. Another limitation is that the procedure cannot be performed in eyes with large iris defect. In addition, we would not recommend performing the procedure in cases with preexisting abnormality in the posterior segment because they might need posterior segment intervention in future. Although PPP narrows down the pupil size, ablating the knot with Nd:YAG laser can reverse the procedure, and it can also be undone by cutting off the suture knot with intraocular scissors. However, caution is necessary while cutting the knot because it is an intraocular maneuver, and the surgeon needs to be careful and very precise while releasing the iris knot. All the cases that we chose for the surgical maneuver were either pseudophakic or had an associated cataract. We would extend a word of caution to perform the procedure in phakic eyes because it can induce or accelerate cataract formation in the eye.

To summarize, PPP is a safe procedure, and it obviates the need to use a specially designed pinhole IOL. The technique can be used as a corrective measure to enhance the visual potential of cases with previous RK. The predictability and efficacy of PPP for visual acuity outcomes is satisfactory, and the additional benefit of extended range of vision is remarkable.

**WHAT WAS KNOWN**
- Radial keratotomy (RK) induces higher-order aberrations (HOAs).
- Pinhole pupiloplasty (PPP) helps achieve improved visual and image quality in cases with HOAs.

**WHAT THIS PAPER ADDS**
- PPP could be adopted as a surgical technique in cases with previous RK because it enhanced the visual potential by allowing patients to focus through the central clear cornea.
- Pinhole optics imparted by PPP helped to overcome residual refractive errors and imparted extended depth of focus in post-RK cases.

**REFERENCES**


Figure 4. The defocus curve in the postoperative period demonstrates an extended depth of focus and range of vision from +1.50 D to –2.50 D. All the cases maintained visual acuity that was better than 0.26 logMAR over the entire range of defocus (logMAR = logarithm of the minimum angle of resolution).
10. Harris PA, Roberts LE, Grant R. Comparison of backlit and novel automated ETDRS visual acuity charts. Optom Vis Perf 2018;6:62–68

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