Modern cataract surgery allows surgeons to customize and tailor the refractive outcome to the visual needs of individual patients and this has led to increased patient expectation for spectacle independence following cataract surgery. Presbyopia-correcting intraocular lenses (IOLs) have been shown to provide good unaided vision at distance, intermediate, and near vision when implanted binocularly. However, due to issues such as glare, halos, and decreased contrast associated with diffractive optics, other options including presbyopic laser in situ keratomileusis and corneal inlays are available for treating presbyopia. The small-aperture corneal inlay (KAMRA; Acufocus, Inc., Irvine, CA) employs the principle of small-aperture optics and has been shown to improve unaided intermediate and near vision with minimum to no effect on distance vision when implanted monocularly. Recently, the same principle of small-aperture optics has been applied at the lenticular plane to develop a new small-aperture IOL. The IC-8 (Acufocus, Inc.) is a single-piece, hydrophobic acrylic, monofocal, small-aperture IOL with a small-aperture corneal inlay (KAMRA; Acufocus, Inc., Irvine, CA) employs the principle of small-aperture optics and has been shown to improve unaided intermediate and near vision with minimum to no effect on distance vision when implanted monocularly. Recently, the same principle of small-aperture optics has been applied at the lenticular plane to develop a new small-aperture IOL. The IC-8 (Acufocus, Inc.) is a single-piece, hydrophobic acrylic, monofocal, small-aperture IOL with a
diameter of 12.5 mm, 6-mm optics, and “C” loop haptics (Figure 1). Embedded within the optic is a mask made of polyvinylidene fluoride and nanoparticles of carbon with an overall diameter of 3.23 mm and a central aperture of 1.36 mm. This IOL is implanted monocularly in the non-dominant eye for the correction of presbyopia and has been shown to provide a continuous range of good unaided distance, intermediate, and near vision.\textsuperscript{7,8}

The purpose of this study was to evaluate posterior segment visualization in eyes that had undergone IC-8 IOL implantation.

\textbf{PATIENTS AND METHODS}

In this prospective fellow eye comparative study, 15 eyes of 15 patients were included. All had bilateral cataracts except for one (patient 10) who had a unilateral cataract. All except one underwent clear corneal phacoemulsification with implantation of the small-aperture IOL in the non-dominant eye and a colorless monofocal IOL (409 MP; Carl Zeiss Meditec AG, Jena, Germany) in the fellow eye. The patient with unilateral cataract underwent phacoemulsification with implantation of the small-aperture IOL. There was no other ocular morbidity in the study group. Two months following cataract surgery, a trained ophthalmic staff nurse performed the following standard posterior segment examinations bilaterally in all patients: fundus photography with a non-mydriatic fundus camera (Canon CR-2 Plus; Canon, Tokyo, Japan), 24-2 threshold automated perimetry (Humphrey Field Analyzer 3, automated visual field analyzer; Carl Zeiss Meditec AG), and optical coherence tomography (OCT) of the posterior pole and optic nerve head with two commercially available devices (Cirrus 5000; Carl Zeiss Meditec AG, and Spectralis; Heidelberg Engineering, Heidelberg, Germany). All investigations were performed in scotopic conditions without topical mydriatic agents. An independent ophthalmologist (ZK) who was masked to the laterality and type of IOL used then evaluated and scored the digital images of the above-mentioned investigations based on a scoring scale (Table 1).

\textbf{SURGICAL TECHNIQUE}

Cataract surgery was performed by a single surgeon (SS) under topical and intracameral anesthesia. Following 1.8-mm clear corneal phacoemulsification, a colorless, single-piece, preloaded, hydrophilic plate

![Figure 1. High-magnification photograph of the IC-8 small-aperture intraocular lens (Acufocus, Inc., Irvine, CA) with the central mask.](image-url)

\begin{table} [H]
\centering
\caption{Grading Scale Used by the Masked Observer to Grade the Quality of the Images} \label{tab:1}
\begin{tabular}{|c|c|c|c|c|}
\hline
\textbf{Grade} & \textbf{Non-mydriatic Fundus} & \textbf{24-2 Automated Perimetry} & \textbf{OCT of the Macula} & \textbf{OCT of the ONH} \\
\hline
4 & Very clear view of the posterior pole & Very clear view of the entire visual field, with no field defects & Very clear view, all layers of retina and foveal pit visible & Very clear view, all margins of the ONH and all four quadrants of the NFL visible \\
3 & Mild peripheral shadowing with glare & Mild, peripheral artifacts, causing ring scotomas & Mild obstruction and shading but retinal layers and foveal pit visible & Mild, peripheral artifacts, ONH visible but NFL view obstructed \\
2 & Moderate shadowing, obscuring the details of the retinal vessel & Moderate paracentral ring scotomas & Moderate obstruction and shading, retinal layers not visible but foveal pit visible & Moderate obstruction and shading, no NFL visibility but ONH visible \\
1 & Severe shadowing, obscuring view of the macula and optic disc & Severe ring scotomas with no view of the physiological blind spot & Severe paracentral defects, with no clear view of the retinal layers or foveal pit & Severe obstruction, ONH just visible \\
0 & No clear view, unable to make out any details & Central “black out” with no normal field plot & No clear view, unable to make out any details & No clear view, unable to make out any details \\
\hline
\end{tabular}
\end{table}

\textit{OCT} = optical coherence tomography; \textit{ONH} = optic nerve head; \textit{NFL} = nerve fiber layer
haptic IOL (409 MP; Carl Zeiss Meditec AG) was injected into the capsular bag through a 1.8-mm clear corneal wound in the dominant eye of the patient. For the non-dominant eye, following 1.8-mm clear corneal phacoemulsification, the wound was enlarged to 3 mm to facilitate insertion of the small-aperture IC-8 IOL in the capsular bag. A digital caliper (CALLISTO Eye; Carl Zeiss Meditec AG) set at 5.5 mm and centered on the patient-fixated coaxially sighted corneal light reflex from the operating microscope (Lumera 700; Carl Zeiss Meditec AG) was used to center the capsulorhexis. The IC-8 IOL was centered in the capsular bag over this reflex with a slight nasal bias. There were no intraoperative complications. At the end of the procedure, all eyes received intracameral administration of 0.1 mL of preservative-free cefuroxime (Aprokam; Thea Pharmaceuticals, Clermont-Ferrand, France) and postoperatively all were treated with topical corticosteroid (Pred forte 1%; Allergan, Irvine, CA) for 4 weeks.

RESULTS

The trained ophthalmic nurse was able to perform non-mydriatic fundus photography (Figure 2), 24-2 automated threshold perimetry (Figure 3), and OCT scan of the macula and the optic nerve head using two commercially available OCT machines. There were no cases of image capture failure in the small-aperture IOL eye with any of the investigative tools. The masked observer (an experienced retinal surgeon) could not detect any difference in the image quality between the standard monofocal IOL and the small-aperture IOL eye and marked a score of grade 4 (ie, clear view, able to clearly view and interpret the test results) bilaterally for all posterior segment investigative tools. Moreover, patient 11, who underwent unilateral implantation of the IC-8 IOL, developed postoperative endophthalmitis 4 weeks following an uncomplicated cataract surgery. Vitreous biopsy showed no organisms on Gram stain and culture. Six weeks following the intravitreal antibiotic injection, he underwent pars plana vitrectomy for severe vitreous opacities. A non-contact fundus viewing system (RESIGHT 500; Carl Zeiss Meditec AG) was used during vitrectomy. Intraoperatively, the retinal surgeon (ZK) was able to visualize the posterior pole and the peripheral retina through the IC-8 IOL and was able to perform all maneuvers, including a thorough and complete posterior vitrectomy, inducing a complete posterior vitreous detachment, shaving the vitreous base, and examining the peripheral retina for any entry site tears. Subjectively, the retinal surgeon believed that the IC-8 small-aperture IOL did not com-

Figure 2. Fundus photographs captured with a non-mydriatic fundus camera. (A) Phakic eye showing paracentral light scatter from the natural lens (blue arrow). (B) Eye with IC-8 small-aperture intraocular lens (IOL) (Acufocus, Inc., Irvine, CA) showing a crisper paracentral image due to the small-aperture IOL blocking the stray light with no compromise of the posterior pole view. (C) Anterior segment view through the fundus camera showing the small-aperture IOL. (D) Side profile view of the non-mydriatic fundus camera.
promise his intraoperative view. The entire technique is shown in Video 1 (available in the online version of this article).

**DISCUSSION**

The impact of loss of accommodation on the quality of life has placed presbyopia treatment in the forefront of clinical research. The surgical options for the treatment of presbyopia can be broadly classified as treatments at the corneal plane with either presbyopic laser treatment creating a multifocal corneal profile or corneal inlays and interventions at the lenticular plane with lens-based surgery combined with implantation of multifocal, trifocal, or extended depth of focus IOLs.

Diffractive and refractive multifocal/trifocal lenses work by splitting the incident light, thereby inducing light scatter. This forward scattered light from a glare source forms a veil of luminance over the retina. This results in disc halos on the retina because the out-of-focus image has a greater diameter than the sharp image on the retina. The unwanted effect of light on the out-of-focus image may be visually disturbing, especially when the relative energy distribution between the distance and near images is altered following pupil dilation. There are reports highlighting the issues encountered by retinal surgeons when performing vitrectomy in eyes with multifocal IOLs, which range from loss of intraoperative focus to constant need of readjustment of intraoperative focus, decreased intraoperative contrast/ghost images, and problems during fluid–air exchange.

The IC-8 small-aperture IOL received Conformité Européenne (CE) approval in 2015. It works on the same principle as the KAMRA corneal inlay based on small-aperture optics. Previous reports where surgeons have undertaken cataract surgery and pars plana vitrectomy in eyes with the KAMRA corneal inlay have reported no issues in relation to the intraoperative view. The diameter of the mask on the IC-8 IOL is 15% smaller than that of the KAMRA corneal inlay (overall diameter: 3.23 mm, central aperture: 1.36 mm compared to the KAMRA corneal inlay with an overall diameter: 3.8 mm, central aperture: 1.6 mm) and is flat with no curvature compared to the KAMRA corneal inlay, which has a curvature of 7.5 mm. There has been no previous report evaluating the posterior segment view both clinically and intraoperatively with the small-aperture IC-8 IOL. In this prospective, observer-masked comparative case series, we were

Figure 3. (A) Automated perimetry from the pseudophakic right eye with a monofocal intraocular lens (IOL). (B) Automated perimetry from the pseudophakic left eye with a small-aperture IOL.
able to demonstrate that the small-aperture IOL does not seem to interfere with any of the clinical tools used for posterior segment investigations. Moreover, intraoperatively, the retinal surgeon was able to perform all standard vitrectomy steps including inducing a posterior vitreous detachment, performing complete vitrectomy with shaving of the vitreous base, and examining the peripheral retina by indentation to check for entry site tears. However, we appreciate that this does not demonstrate how the intraoperative view would be affected in other vitreoretinal procedures such as membrane peeling. The physiological magnification induced by the human cornea combined with the use of an indirect viewing system for vitrectomy provides a good magnified view through the central aperture of the IOL to visualize the posterior pole. There was no distortion or ghosting of the intraoperative view as previously reported with refractive and diffractive IOLs.

This initial case series demonstrates that standard posterior segment examination can be safely and effectively performed through a small-aperture IOL. This study is limited by the lack of data examining the peripheral retina with or without scleral indentation in eyes with small-aperture IOL implantation.

AUTHOR CONTRIBUTIONS

Study concept and design (SS); data collection (SS, ZK); analysis and interpretation of data (SS, LWK); writing the manuscript (SS, LWK); critical revision of the manuscript (SS, LWK, ZK)

REFERENCES