Pupil Ovalization After Phakic Intraocular Lens Implantation Is Associated With Sectorial Iris Hypoperfusion

Peter Fellner, MD; Bertram Vidic, MD; Yashin Ramkissoon, MD; Arthur D. Fu, MD; Yosuf El-Shabrawi, MD; Navid Ardjomand, MD

Objective: To investigate iris perfusion in patients with and without pupil ovalization after phakic intraocular lens implantation.

Methods: Comparative retrospective randomized case series of 6 participants, each with a regular pupil, and 6 participants with pupil ovalization after phakic intraocular lens implantation for high myopia were included in the study. Indocyanine green angiography was performed between 20 and 40 months (mean±SD, 26±6.1 months) after lens implantation.

Results: Iris perfusion defects were found in 5 of 6 patients with pupil ovalization. No perfusion deficits were noted in patients with round pupils.

Conclusion: Iris ovalization after phakic intraocular lens implantation may be associated with a lack of iris perfusion and with secondary ischemia. Patients with these lenses and pupil ovalization should be followed regularly.

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TREATMENT OF MYOPIA WITH ablative corneal refractive surgery is limited by the amount of tissue that can be removed secondary to risks of keratectasia resulting from corneal thinning.1-3

Implantation of phakic intraocular lenses (IOLs) is a method of correcting high refractive errors with preservation of accommodation4 while avoiding ablation of corneal tissue. Since the introduction of phakic IOLs,6 IOL types have changed and are generally safer.7,8 Three phakic intraocular lenses are now available: angle-supported anterior chamber IOLs, iris-claw lenses, and posterior chamber IOLs.7,9,10

Corneal endothelial cell loss, once a major problem early in the development of phakic IOLs, is less of a concern now.7,8,11-17 However, there is still some concern about the implantation of an IOL in a functionally healthy eye.

Complications such as cataracts, postoperative uveitis, postoperative elevated intraocular pressure, decentration, symptomatic halos, and pupil ovalization have been reported.7,8,11-18 Pupil ovalization has been reported to occur in 40% of patients using the NuVita MA20 (Bausch & Lomb Surgical, San Dimas, Calif) phakic IOLs13 and in 18% of patients with the ZSAL-4 (Morcher, Stuttgart, Germany) anterior chamber angle-supported phakic IOLs.7

Since pupil ovalization may be a result of iris ischemia,7,19 we investigated iris perfusion in 12 patients both with and without pupil ovalization after phakic IOL implantation according to indocyanine green (ICG) angiography findings.

METHODS

Twelve patients with various anterior chamber angle-supported phakic IOLs (NuVita and ZSAL-4) underwent ICG angiography. Six patients had developed varying degrees of pupil ovalization within the phakic IOL axis, while 6 patients with phakic IOLs had no obvious iris ovalization on slitlamp examination.

Institutional review board approval was not necessary, but explanation of the benefits and risks of ICG angiography were offered prior to patient consent.

Phakic IOL implantation for high myopia treatment was performed in all cases. The demographic data of the patients are presented in the Table.

The surgical technique has been previously described.16,20 Phakic IOL implantation was typically performed under retrobulbar anesthesia. Two hours prior to the procedure, the pupil was constricted with 2% pilocarpine eye drops. A 7-mm corneal incision was made and the phakic IOL was inserted into the anterior chamber after injection of viscoelastic material (Amvisc; Bausch & Lomb). The lens length

Author Affiliations:
Department of Ophthalmology, Medical University Graz, Graz, Austria (Drs Fellner, Vidic, El-Shabrawi, and Ardjomand); Moorfields Eye Hospital, London, England (Drs Ramkissoon, Fu, and Ardjomand).

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was selected by adding 1 mm to the horizontal white-to-white distance. The viscoelastic material was removed with a Simcoe irrigation-aspiration cannula, iridotomy was performed, and the corneal incision was closed with 3 interrupted stitches (10-0 nylon; Ethicon Inc, Cornelia, Ga). The pupils were constricted and appeared round at the conclusion of the procedure. Dexamethasone ointment was applied at the end of the operation and the eye was patched until postoperative day 1.

Postoperative treatment included the use of betamethasone/neomycin drops 4 times per day, and the treatment tapered over a period of 5 weeks. All patients were seen on postoperative day 1, after 1 week, 1 month, 3 months, 6 months, and then at 6-month intervals thereafter.

All procedures were performed by a single surgeon (B.V.) in the Department of Ophthalmology at the Medical University Graz in Graz, Austria.

The diagnosis and determination of the degree of pupil ovalization were done at the slitlamp. Three different degrees of pupil ovalization were recorded: grade 0 indicated no pupil ovalization, grade 1 indicated mild pupil ovalization (pupil deviation not reaching the edge of the phakic IOL optic), and grade 2 indicated severe pupil ovalization (pupil deviation reaching the edge of the phakic IOL optic in at least 1 point).17

The patients underwent ICG angiography (Heidelberg Retina Angiograph; Heidelberg Engineering, Heidelberg, Germany) of the iris. Patients received an intravenous bolus injection of 5 mL of 20% ICG (ICG-Pulsion; Pulsion Medical Systems, München, Germany). The angiograms were recorded with a digital camera (Sony Electronics Inc, Park Ridge, NJ) and analyzed in slow motion using Adobe Premiere Pro software (Adobe, Vienna, Austria) by 3 of the investigators (P.F., B.V., N.A.). A perfusion deficit was diagnosed if a sectorial absolute or early iris hypofluorescence was noted.

Three different grades of iris hypofluorescence were recorded: grade 0 indicated normal iris perfusion within 10 seconds after intravenous ICG injection, grade 1 indicated sectorial delay of filling iris vessels within the first 20 seconds after intravenous bolus injection of ICG, and grade 2 indicated a persistent lack of sectorial iris vessel perfusion.

## RESULTS

All patients had a round pupil at the end of the operation and at the follow-up at 6 months. Iris perfusion time was within 10 seconds in normal eyes and myopic eyes with phakic IOLs without iris ovalization. Three of 6 patients demonstrated iris ovalization of grade 2 from 20 to 27 months after lens implantation (Figure 1). Of these 3 patients, 1 patient had an iris perfusion defect of grade 1 (sectorial delayed iris perfusion but normal iris vessel pattern 22 seconds after intravenous ICG injection) and 2 patients had an iris perfusion defect of grade 2. Of 3 patients with mild pupil ovalization (grade 1), 2 patients demonstrated a delayed iris perfusion defect of grade 1 (sectorial delayed iris perfusion but normal iris vessel pattern 20 seconds after intravenous ICG injection; Figure 2 and Figure 3) and 1 patient had a normal iris perfusion (grade 0). None of the aforementioned patients had obvious iris atrophy.

All patients with phakic IOLs and round pupils also underwent ICG angiography and demonstrated normal iris perfusion (grade 0; Figure 4). All iris vessels were visible 10 seconds after intravenous ICG injection (Table).

## COMMENT

Whereas refractive errors of low and moderate myopia may often be treated by corneal refractive surgery, those of high myopia are often treated with phakic IOL implants or clear lens extraction.4

Anterior chamber IOLs introduced in the 1950s and 1960s were associated with damage to the corneal endothelium often resulting in corneal decompensation.5 6 Anterior chamber phakic IOLs experienced a renaissance in the 1990s with the development of better and thinner designs.11 17 Concerns about rigid anterior chamber phakic IOLs still exist since complications, including uveitis, cataracts, pigment dispersion, elevated intraocular pressure, and pupil ovalization, have been reported.18 17 19 Pupil ovalization after phakic IOL implantation has been thought to be related to iris ischemia induced by haptic compression of the iris root vessels since it is associated with iris retraction, iris atrophy, and low-grade inflammation.17 18 19 This study shows, for

### Table. Demographic Data of Patients

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>IOL Type</th>
<th>IOL Size Implanted, D</th>
<th>Ovalization Grade</th>
<th>Ischemia Grade</th>
<th>Follow-up, mo</th>
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<td>2</td>
<td>2</td>
<td>20</td>
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<tr>
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<td>1</td>
<td>20</td>
</tr>
<tr>
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<tr>
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<td>−10.5</td>
<td>0</td>
<td>0</td>
<td>25</td>
</tr>
</tbody>
</table>

*ZSAL-4 (Morcher, Stuttgart, Germany).
†NuVita MA20 (Bausch & Lomb Surgical, San Dimas, Calif).

Abbreviations: D, diopter; IOL, intraocular lens.
the first time, iris perfusion defects in patients with pha-
kic IOLs.

We described all cases of slitlamp-evident ovaliza-
tion of the pupil as pupil ovalization, whereas Alio et al17
classified pupil ovalization as pupil deviation in the me-
ridian of the placement of the phakic IOL haptic that
reaches the edge of the phakic IOL optic in at least 1 point.
No quantitative grading for pupil ovalization has been
published yet, and our grading has been adapted to dis-
tinguish between mild and severe pupil ovalization.

In this study, we used ICG angiography to investi-
gate iris perfusion in eyes with phakic IOLs with and with-
out pupil ovalization approximately 2 years after IOL im-
plantation. Indocyanine green angiography is an infrared-
based dye imaging technique introduced for retinal and
choroidal disorders. Further advances in videoangiog-
raphy have allowed for precise assessment of degree and
timing of perfusion in ocular vasculature. The use of fluo-
rescein or ICG to assess perfusion of anterior ocular struc-
tures has been previously described.21,22 The ICG was used
rather than sodium fluorescein for angiography because
fluorescein may be difficult to visualize in patients with
heavily pigmented iris tissue.23

The ICG angiograms showed mild to severe iris per-
fusion defects in 5 of 6 eyes with pupil ovalization. In 3
eyes, iris perfusion in some segments was delayed for sev-
eral seconds after intravenous injection of ICG but was
normal at the 22- to 25-second time period. In 2 other
eyes, we found permanent iris perfusion defects, espe-
cially at the pupil margin. Though the ovalization was
in the axis of the IOL, perfusion defects were not only
seen at the axis of the larger diameter of the ovalization
but also elsewhere in the iris.

The ICG angiography results were normal in 1 eye with
mild ovalization 20 months after implantation and in eyes
without pupil ovalization.

Figure 1. A, Iris perfusion in an eye with phakic intraocular lens and pupil ovalization (grade 2), 10 seconds after intravenous indocyanine green injection.
Sectorial iris perfusion defects can be seen at the iris periphery (asterisk) and at the pupil margin (arrow). B, The same eye at 22 seconds after injection shows
normal perfusion in the periphery (asterisk) but lacks sectorial iris vessel-filling at the pupil margin (arrow).

Figure 2. A, Sectorial iris perfusion defect (asterisk), 11 seconds after intravenous indocyanine green injection in an eye with pupil ovalization (grade 1). Arrow
indicates pupil margin. B, Iris perfusion is normal 20 seconds after injection.
All patients with pupil ovalization and 2 patients with round pupils showed cell deposits on the IOLs. This may be related to breakdown of the blood-aqueous barrier, as previously described in anterior segment ischemia. However, uveitis was not observed and no patient was receiving topical medication at the time of angiography.

Anterior segment ischemia has been described as occurring after different ocular surgery procedures such as strabismus or retinal detachment surgery. Iris atrophy, uveitis, and even phthisis bulbi have been described with anterior segment ischemia. Experimentally induced anterior segment ischemia results in rubeosis iridis in a rabbit model. Histopathologic examination of eyes with anterior chamber IOLs has revealed iris ghost vessels. Iris atrophy was not noticed in any of our patients, particularly not in those with sectorial iris vessel–filling defects.

One difficulty with the phakic anterior chamber IOL implantation surgical technique is the accurate measurement of phakic IOL size. The general recommendation for the IOL length is the largest corneal diameter plus 1 mm; however, this is an estimation and may not reflect the proper anterior chamber diameter. Anterior chamber depth measurement using ultrasound biomicroscopy, optical coherence tomography, or Scheimpflug photography could be useful for phakic IOL size measurement and may reduce the pressure on the iris roots through better IOL intraocular fit. New foldable phakic IOLs are commercially available now, and these lenses have the additional advantage of reducing the haptic pressure in the chamber angle.

The long-term relevance and associations of iris perfusion defects, which are demonstrated on ICG videoangiography, and subsequent development of iris ischemia are still unclear. However, these patients may require regular follow-up, and IOL explantation may be considered in patients with extensive pupil ovalization associated with symptoms of chronic anterior uveitis.

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Correspondence: Navid Ardjomand, MD, Department of Ophthalmology, Medical University Graz, Auenbruggerplatz 4, A-8036 Graz, Austria (navid.ardjomand@meduni-graz.at).

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