

# Intraocular Optical Quality of Phakic Intraocular Lenses: Comparison of Angle-Supported, Iris-Fixated, and Posterior Chamber Lenses

JORGE L. ALIO, PABLO PEÑA-GARCÍA, KETEVAN PACHKORIA, JORGE L. ALIO II, AND AMR EL ASWAD

- **PURPOSE:** To evaluate internal aberrometric profiles following phakic intraocular lens (PIOL) implantation.
- **DESIGN:** Retrospective and consecutive case series.
- **METHODS:** One hundred and five eyes of 65 patients were included. The optical aberrations were measured with the Topcon KR-1W aberrometer. Comparisons of internal aberrations for different models were made. Comparisons at 4 and 6 mm were made also within the same model for all the lenses. Comparisons regarding the implantation site were also performed: angle-supported (AS) anterior chamber (AC) ( $n = 47$ ), iris-fixated (IF) ( $n = 27$ ), and posterior chamber (PC) ( $n = 31$ ).
- **RESULTS:** Root mean square (RMS) of internal optical higher-order aberrations (HOAs) changed significantly to higher values from 4-6 mm aperture diameter in each PIOL, as should be expected. However, this significant change was not detected in spherical aberration for Kelman Duet ( $P = .753$ ) and in trefoil for Acrysoft ( $P = .059$ ). Kelman lens showed significantly lower values of spherical aberration compared to Acrysoft at 4 mm ( $P = .022$ ) and at 6 mm ( $P = .042$ ). Acrysoft showed the lowest values at central zone for trefoil ( $P = .043$ ) and tetrafoil ( $P = .002$ ) in AC group. In the IF group, Artisan and Artiflex showed similar results for all internal aberrations. In the comparison between Visian Implantable Collamer Lens (ICL; STAAR Surgical Co, Monrovia, California, USA) and phakic refractive lens (PRL), both for posterior chamber, significantly lower values of coma were observed for ICL ( $P = .033$ ). IF lenses showed clinical evidence, but not significant, of better centering capability than AS lenses ( $P = .096$ ).
- **CONCLUSIONS:** The study of intraocular aberrations is an adequate method to identify the clinical optical behavior and could help the surgeon to identify the most frequent problems related with each model. (Am J Ophthalmol 2013;156:789-799. © 2013 by Elsevier Inc. All rights reserved.)

**P**HAKIC INTRAOCULAR LENSES (PIOLS) ARE TODAY AN accepted alternative for the correction of high refractive errors. Three types of phakic intraocular lenses are currently used in clinical practice: (1) angle-supported lenses (AS); (2) iris-fixated lenses (IF); and (3) posterior chamber lenses (PC). Different PIOL models with different characteristics and specific complications have been designed.<sup>1</sup>

Over the last decades, considerable attention has been given to the understanding of the physical optics of the eye and assessing the optical and visual quality after PIOL implantation, since photic phenomena and glare perception are still a concern in some patients.<sup>2-6</sup>

The assessment of high-order wavefront aberration patterns may allow us to identify the diverse optical quality of PIOLs. The changes in the internal aberrometric profile induced by PIOLs might alter the visual performance of the patient. Previous studies have investigated this issue: a previous study<sup>7</sup> analyzed the aberrometric pattern in myopic eyes implanted with a posterior chamber PIOL model lens (PRL) (Carl Zeiss/Meditec AG, Jena, Germany), reporting a slight reduction of third- and fourth-order aberrations for 5-mm pupils. Another recent study evaluating the aberrometric outcomes after Visian Implantable Collamer Lens (ICL; STAAR Surgical Co, Monrovia, California, USA) and AcrySof Cachet (Alcon Laboratories Inc, Fort Worth, Texas, USA) PIOL implantation showed fewer ocular high-order aberrations postoperatively.<sup>5,6</sup>

Different PIOLs, with different designs, implanted at different anatomic locations may induce different changes in the aberrometric profile of the eye. If differences exist, the clinical study of the aberrations caused internally by these lenses may be relevant as it could lead to differences in the quality of vision after implantation. The aim of this study is to evaluate the aberrometric internal profile of different PIOL models so that surgeons may have a better understanding of their impact on visual acuity, thus enabling them to make comparisons.

## PATIENTS AND METHODS

THIS STUDY INCLUDED 105 EYES FROM 65 PATIENTS WHO underwent PIOL implantation at Vissum Corporation, Alicante, Spain. Each PIOL model was implanted using

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From Vissum Corporation, Alicante, Spain (J.L.A., J.L.A.II., A.E.A.); Division of Ophthalmology, Universidad Miguel Hernández, Alicante, Spain (J.L.A., P.P.G.); and Hospital Ramón y Cajal, Madrid, Spain (K.P.).

Inquiries to Jorge L. Alio, Avda de Denia s/n, Edificio Vissum, 03016 Alicante, Spain; e-mail: jlalio@vissum.com

the specific protocol described for its implantation.<sup>1</sup> The study followed the tenets of the Helsinki Declaration and all patients provided written informed consent to use the data obtained for scientific purposes. The study was approved by the Ethical Board Committee of Visum Corporación Oftalmológica Alicante. For the purpose of the study, the PIOLs were divided into 3 main groups according to the site of implantation.

Group 1 included AS PIOLs: Baikoff ZB5M (Bausch & Lomb Surgical/Chiron Vision, Rochester, New York, USA) (n = 10 eyes), Kelman Duet (Tekia, Irvine, California, USA) (n = 14 eyes), AcrySof Cachet (Alcon Laboratories Inc, Fort Worth, Texas, USA) (n = 11 eyes), and ZSAL-4 (Morcher GmbH, Stuttgart, Germany) (n = 12 eyes). Group 2 included IF PIOLs: Artisan (Ophtec BV, Groningen, Netherlands) (n = 16 eyes) and Artiflex Veriflex (Abbott Medical Optic, Inc, Santa Ana, California, USA) (n = 15 eyes). Group 3 included PC PIOLs: Visian ICL (STAAR Surgical Co, Monrovia, California, USA) (n = 16 eyes) and PRL (Carl Zeiss/Meditec AG, Jena, Germany) (n = 11 eyes).

• **MATERIALS, PATIENTS, AND METHODS:** This retrospective study comprised consecutive patients who had implantation of different models of PIOLs at different anatomic sites: 42 eyes (40%) belonged to male patients and 63 (60%) to female. Mean patient age was  $38.34 \pm 9.04$  years (range, 23-55). The mean age for the AS group was  $41.07 \pm 8.71$  years (range, 26-55): for Baikoff  $48.80 \pm 2.94$ , for Kelman  $40.06 \pm 6.96$ , for ZSAL  $41.00 \pm 7.51$ , and for Acrysof  $32.09 \pm 7.66$ . The mean age for the IF group was  $35.35 \pm 9.36$  (range, 23-52): for Artisan  $32.00 \pm 11.46$  and for Artiflex  $36.81 \pm 8.28$ . The mean age of PC PIOLs was  $36.28 \pm 8.18$  (range, 25-51) years: for PRL  $39.55 \pm 6.15$  and for ICL  $35.71 \pm 8.85$ . Spherical equivalent for the patients in the whole group was  $-12.60 \pm 5.26$  diopters (D) (range,  $-27.00$  to  $-4.50$ ). Spherical equivalent for AS lenses was  $-15.16 \pm 5.82$  D (range,  $-4.50$  to  $-27.00$ ):  $-13.83 \pm 2.19$  for AcrySof,  $-21.28 \pm 4.09$  for ZSAL,  $-13.36 \pm 4.93$  for Baikoff, and  $-12.59 \pm 6.54$  for Kelman. Spherical equivalent for IF lenses was  $-10.17 \pm 3.65$  D (range,  $-17.25$  to  $-4.75$ ):  $-13.38 \pm 4.33$  for Artisan and  $-11.32 \pm 3.10$  for Artiflex. Spherical equivalent for PC lenses was  $-10.57 \pm 3.34$  D (range,  $-16.63$  to  $-5.00$ ):  $-10.64 \pm 4.62$  for PRL and  $-10.51 \pm 1.82$  for ICL.

All groups were comparable in age ( $P = .075$ , Kruskal-Wallis test), except Baikoff, with patients significantly older. Moreover, all groups were comparable in primary astigmatism ( $P = .201$ , Kruskal-Wallis test) and in spherical equivalent ( $P = .078$ , Kruskal-Wallis test), except ZSAL, used in patients with significantly higher ametropia.

Exclusion criteria were previous intraocular surgery, anterior chamber depth less than 3 mm, history of glaucoma or uveitis, crystalline lens opacity, scotopic pupil diameter more than 7 mm, ocular disease, or active retinal

disease. At the moment of intervention all cases fulfilled the requirements for PIOL implantation.

All PIOLs included in the current study were evaluated under slit-lamp examination as properly centered for clinical purposes. All patients had best-corrected visual acuity of 20/20 and at least 20/25 of uncorrected vision. Other signs that could suggest decentration or tilt, such as severe halos and glare or abnormal retinoscopic pattern, were also considered as exclusion criteria.

• **PHAKIC INTRAOCULAR LENSES INCLUDED IN THIS INVESTIGATION:** The Baikoff (ZB, ZB5M, NuVita) PIOL is a rigid, polymethyl methacrylate (PMMA), Z-shaped, 5 mm optical zone AS lens similar to the Kelman 4-point-fixation multiflex implant. These models required a 5- to 6-mm-long incision for them to be implanted. Despite good anatomic and optical results, glare, halos, and pupil distortion prompted Baikoff to design a new lens called NuVita. The real optic diameter was increased to 4.5 mm and the total diameter to 5 mm. A new concave form was given to the posterior surface to increase the distance from the natural lens. The thickness of the edge was decreased by 20% to reduce potential peripheral contact on the corneal endothelium.<sup>1</sup>

The Kelman Duet is a rigid, 2-part AS phakic PIOL. It has a 3-point angle-support PMMA haptic angulated from 11.1 to 9.6 degrees, a foldable silicone optic 6 mm in diameter, and overall lengths from 12-13 mm. It can be implanted through a 2-mm incision: first the haptic and then the optic. The main advantage of this model is the exchangeability of the lens haptic and optic.<sup>1,8</sup>

The ZSAL-4 Plus is a rigid, 4-point-fixation PMMA lens with a diameter of 5.5 mm and an effective optic zone of 5 mm. The optic has a flat anterior and concave posterior surface and the overall lengths vary from 12.5-13 mm. The haptic geometry has been changed to a thinner connecting bridge between the optic and the first footplate and a thicker connecting bridge between both footplates to increase haptic flexibility and disperse compression forces against angle structures. The angulation of the haptics is 19 degrees, reduced compared to previous models to obtain less contact between the lens and the endothelium.<sup>1</sup>

The AcrySof Cachet PIOL is a single-piece, AS, foldable, all-soft acrylic and hydrophobic lens. It has a 6.0-mm meniscus optic and can be inserted through a 2.6-mm incision. The overall length varies from 12.5-14 mm. It is available from -6.00 D to -16.5 D in half-diopter increments. Its optic is connected to 2 flexible haptic arms by the bridge on either side. The haptics are designed to allow the compression within the angle for IOL stability, without creating the excessive force that could cause angle tissue damage or pupil ovalization.<sup>1</sup>

The Artisan IF lens is a 1-piece all-PMMA lens with a convex-concave optic. Since 1999, the Artisan lens has also been available for astigmatism correction and is a concave-convex lens. The total length is 8.5 mm with

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