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Long-Term Endothelial Cell Loss in Patients with Artisan Myopia and Artisan Toric Phakic Intraocular Lenses

5- and 10-Year Results

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Purpose: To evaluate the long-term change in endothelial cell density (ECD) after the implantation of 2 types of rigid iris-fixated phakic intraocular lenses (pIOLs) for the treatment of myopia and astigmatism.

Design: Prospective, clinical cohort study.

Participants: A total of 507 eyes of 289 patients receiving the Artisan Myopia or Artisan Toric (Ophtec B.V., Groningen, The Netherlands) iris-fixated pIOL for the treatment of myopia or astigmatism at the University Eye Clinic Maastricht as of January 1998.

Methods: A total of 381 myopic and 126 toric pIOLs were implanted. Five- and 10-year follow-ups were completed by 193 and 127 eyes implanted with the myopic pIOL and by 40 and 20 eyes implanted with the toric pIOL, respectively.

Main Outcome Measures: Chronic endothelial cell (EC) loss, percentage of eyes with a decrease of $\geq$25% in ECD, and percentage of eyes with an ECD $<$1500 cells/mm^2.

Results: Chronic EC loss was calculated from 6 months postoperatively to the end of follow-up and showed an annual ECD decline of 48 cells/mm^2 (standard error, 3.14) and 61 cells/mm^2 (standard error, 6.30) in the myopic ($P < 0.001$) and toric ($P < 0.001$) groups, respectively, resulting in a total EC loss of 16.6% and 21.5% from 6 months to 10 years postoperatively, respectively. Ten years after implantation, ECD had decreased by $\geq$25% in 7.9% and 6.3%, whereas ECD was $<$1500 cells/mm^2 in 3.9% and 4.0% in the myopic and toric groups, respectively. Explantation of the pIOL occurred in 6.0% in the myopic group and 4.8% in the toric group. Risk factors for increased EC loss were a shallow anterior chamber depth (ACD) ($P \leq 0.005$) and a smaller distance between the central and peripheral pIOL edge to the endothelium ($P \leq 0.005$).

Conclusions: A significant linear chronic EC loss was reported after implantation with myopic or toric iris-fixated pIOLs. A smaller ACD and smaller distance between pIOL edge and endothelium were risk factors for EC loss. Modification of preoperative age-related ECD thresholds is indicated to maintain an ECD that warrants safe future combined pIOL explantation and cataract surgery. *Ophthalmology 2017;■:1–9 © 2017 by the American Academy of Ophthalmology*

Implantation of phakic intraocular lenses (pIOLs), whether angle supported, iris fixated, or positioned in the posterior chamber, is associated with an accelerated decrease in endothelial cell density (ECD).[1–9] The magnitude of endothelial cell (EC) loss after pIOL implantation surpasses the physiologic annual decrease of 0.6% as reported in 42 adults in a 1997 benchmark study.[10] The importance of EC loss for assessing the safety of pIOLs was emphasized in 2006 when the French Health Products and Safety Agency (l'Agence Française de Sécurité Sanitaire des Produits de Santé [AFSSAPS]) withdrew the foldable angle-supported Vivarte pIOL (Ioltech S.A., Perigny, France) from the market because of excessive EC loss. More recently, the American Academy of Ophthalmology (AAO) Task Force has formulated guidelines that define the percentage of eyes with a total EC loss equal to or more than 25% after 3 years as an end point for clinical investigation of a new pIOL. In addition, the AFSSAPS guidelines describe an ECD of less than 1500 cells/mm^2 as an explantation criterion.[11,12] However, so far none of the published studies have used these newly established EC loss criteria as outcome measures. In this study, we applied these criteria as outcomes measures in our patient cohort of myopic and toric pIOLs that was followed over a 10-year period using the same specular microscope and ECD measurement protocols.

Methods

Design

From January 1998 to June 2016, 507 eyes of 289 patients received a myopic or toric iris-fixated pIOL implant at the University Eye

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Clinic Maastricht, Maastricht University Medical Center, The Netherlands. Patients were prospectively evaluated preoperatively and at 1 day, 1 week, and 1, 3, 6, and 12 months postoperatively in the first postoperative year. Regular follow-up continued with annual visits. The rigid myopic pIOL was implanted in 381 eyes of 209 patients, and 193 and 127 eyes completed the 5- and 10-year follow-ups, respectively. The rigid toric pIOL was implanted in 126 eyes of 80 patients, with 40 and 20 eyes completing the 5- and 10-year follow-ups, respectively.

The current study was performed in adherence to the tenets of the Declaration of Helsinki. The Maastricht University Medical Center Institutional Review Board stated that approval was not required for this study.

Implantation Criteria

Before pIOL implantation, patients had to be aged ≥18 years and have a stable refraction for at least 2 years. Anterior chamber depth (ACD) from the corneal endothelium to the anterior plane of the crystalline lens had to be at least 2.8 mm with a maximal clear lens rise of 600 μm.[1,13,14] Preoperative minimal ECD depended on age with >2800 cells/mm^2 required for patients aged 21 to 25 years, >2650 cells/mm^2 for patients aged 26 to 30 years, >2400 cells/mm^2 for patients aged 31 to 35 years, >2200 cells/mm^2 for patients aged 36 to 45 years, and >2000 cells/mm^2 in patients aged more than 45 years.[1,15]

This article does not contain data of patients treated with iris-fixated pIOLs in keratoconus or irregular astigmatism or patients treated with iris-fixated pIOLs after corneal transplantation. Data from a subset of patients from the present study were reported in previous studies.[16–19]

Phakic Intraocular Lenses and Surgical Technique

The Artisan Myopia pIOL is a 1-piece, polymethyl methacrylate, rigid lens with a convex-concave optic and a total diameter of 8.5 mm. The optic diameter is variable and depends on the required refractive correction; pIOLs from −1.0 to −15.5 diopters (D) are available in a 6.0-mm optic diameter, whereas a 5.0-mm optic diameter is available for pIOL powers from −1.0 to −23.5 D.

The Artisan Toric pIOL is a 1-piece, polymethyl methacrylate, rigid lens with a convex-concave optic, a spherical power ranging from +14.0 to −22.0 D, and a cylindrical power of up to −7.5 D. The total diameter is 8.5 mm with an optic diameter of 5.0 mm. Lens power calculations were performed by the manufacturer using the formula of van der Heijde et al.[20]

All surgeries were performed by the same surgeon (R.M.M.A.N.) at the University Eye Clinic Maastricht under general or local anesthesia. Previous reports by our group have described the surgical procedure and postoperative medication regimen.[16–19]

Evaluation

Preoperative examination consisted of subjective and cycloplegic refraction, Snellen uncorrected distance visual acuity (VA) and corrected distance VA measurements, and slit-lamp examination, including Goldmann applanation tonometry and fundoscopy. Additional measurements consisted of corneal topography (Orbscan [Bausch & Lomb, Rochester, NY, USA], Pentacam HR [OCULUS Optikgeräte GmbH, Wetzlar, Germany], Sirius [Schwind eye-tech-solutions GmbH & Co. KG, Kleinostheim, Germany]), biometry (A2500 [SonomedEscalon, New Hyde Park, NY, USA], IOLMaster [Carl Zeiss AG, Oberkochen, Germany]), anterior segment optical coherence tomography (OCT) (Visante [Carl Zeiss AG, Oberkochen, Germany]) and specular microscopy (NONCON ROBO PACHY SP9000 S/N PK1-1137; [Konan Medical Inc., Nishinomiya, Japan]). All preoperative measurements were performed 1 week after removal of soft contact lenses and 2 weeks after removal of rigid gas-permeable contact lenses.

From 2006 onward, OCT was used to perform preoperative pIOL simulation to measure the ACD, the vault between the pIOL and crystalline lens, the distance between the anterior pIOL and the endothelium, and the clear lens rise as reported previously.[1,13,14,18,21,22] Annual postoperative follow-up visits consisted of subjective refraction, Snellen uncorrected distance VA and corrected distance VA measurements, slit-lamp examination, tonometry, corneal topography, anterior segment OCT, and specular microscopy.

In respect of the known variation between specular microscopes and the influence of this variation on the correct calculation of EC loss, all eyes continued their measurements with the same specular microscope.[23–26] Per protocol, the mean ECD in each eye was calculated by determining the mean of 3 consecutive measurements of 50 central ECs using the manual center-to-center method.[27]

Outcome Measures

The definitions of outcome measures were based on the recent guidelines of the AAO and AFSSAPS, describing the percentage of eyes reaching the AAO end point (i.e., EC loss ≥25% compared with the preoperative measurement) and AFSSAPS explantation criterion (i.e., ECD <1500 cells/mm^2).[11,12] We calculated the mean ECD 5 and 10 years after pIOL implantation, as well as the annual EC loss. To adhere to the AAO-defined guidelines, we not only presented the percentage of eyes meeting the AAO-defined end point after 5 and 10 years but also added the percentage of eyes meeting this end point after 3 years.[12]

Statistical Analysis

Statistical analysis was performed using SPSS for Windows (version 23, IBM, Armonk, NY). All VA measurements were converted from Snellen VA to logarithm of the minimum angle of resolution VA before statistical analysis. Descriptive analyses were performed to compute mean and standard deviation (±standard deviation) in primary outcome measures and preoperative characteristics. Longitudinal changes were analyzed using a linear mixed-model analysis with an eye identification number as a grouping variable and time as a covariate. The best fitted covariance structure was selected using the Bayesian information criterion. Similar to previous reports on EC loss, the effect of pIOL implantation on the endothelium (i.e., acute EC loss) was assessed from preoperatively to 6 months postoperatively, whereas long-term changes (i.e., chronic EC loss) were assessed from 6 months postoperatively to the end of follow-up. Kaplan–Meier and multivariate Cox regression analyses were performed to assess survival from implantation to the occurrence of the AAO-defined end point (i.e., total EC loss ≥25%) and the AFSSAPS-defined explantation criterion (i.e., ECD <1500 cells/mm^2). P values were considered significant if the P value was <0.05.

Results

From January 1998 to June 2016, 381 eyes of 209 patients were implanted with the myopic pIOL and 126 eyes of 80 patients were implanted with the toric pIOL. Mean follow-up was 94.9±56.5 months in the myopic group and 50.4±46.8 months in the toric