Age-related behavior of posterior chamber lenses in myopic phakic eyes during accommodation measured by anterior segment partial coherence interferometry

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PURPOSE: To evaluate age-related position shifts of the crystalline lens and the implantable contact lens (ICL, Staar Surgical) by a new, commercially available, anterior segment partial coherence interferometer, the ACMaster (Carl Zeiss Meditec), during accommodation in myopic eyes.

SETTING: ALZ Augenklinik, Munich, Germany.

METHODS: Fifty-three eyes of 29 consecutive patients were measured after myopic ICL implantation before and during subjective accommodation to a stimulus of 3 diopters (D) by anterior segment partial coherence interferometry (PCI). Nine eyes were also measured with a 5.00 diopters (D) stimulus; 14 eyes were measured repeatedly at different visits. The mean patient age was 33 years $\pm$ 9 (SD) (range 21 to 59 years). The preoperative mean sphere was -7.6 ± 1.9 D (range -5.0 to -11.5 D) and the cylinder, -1.4 ± 1.1 D (range 0 to -4.25 D).

RESULTS: Older patients had a tendency toward smaller vaults on desaccommodation between the ICL and the crystalline lens compared to younger individuals. In younger patients, there was a decrease of the vault on accommodation, whereas it increased in older persons ($P = .005$). During accommodation, the more the anterior lens surface shifted forward, the more the ICL bulged ($P = .005$). The change in vaulting was significantly larger at 5.00 D than at 3.00 D accommodation stimulus ($P = .012$).

CONCLUSIONS: The behavior of ICLs in relation to the crystalline lens during accommodation varied with age and could be shown by PCI. The position shift of the ICL depended on the initial vault at desaccommodation and the ability of the anterior lens surface to bulge forward. Even though the crystalline lens stiffened, and therefore accommodation deteriorated with age, there was still a movement of the ICL, pointing to the role of the ciliary muscle movement in accommodation.

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As refractive surgery becomes widely accepted among patients, ophthalmologists have to deal not only with mild or moderate ametropia, but they also have to seek other solutions when corneal refractive surgery reaches its limits.

In young patients, implantation of a supplementary artificial lens in the phakic eye allows preservation of accommodation after surgery. Different types of phakic intraocular lenses (IOLs) have been designed for that purpose and are placed in the anterior chamber, clipped to the iris, or placed in the posterior chamber.

Posterior chamber IOLs were developed in different shapes and materials, such as silicone.[1,2] One is the thin and flexible ICL (implantable contact/corrective lens) (ICL by Staar Surgical, now Visian ICL), which is made of Collamer, a hydrophilic porcine collagen–hydroxyethyl methacrylate copolymer containing an ultraviolet chromophore.[3,4] Because refractive phakic lens surgery is minimally invasive, predictable, and stable, good results have been obtained with ICL implantation in hyperopic and myopic patients.[5]

However, because it is intraocular surgery, phakic IOL implantation can cause complications. Although IOLs in the anterior chamber can cause corneal decompensation, glaucoma, and ovaling of the pupil because of their location,[6] the major concern with posterior chamber IOLs includes anterior subcapsular cataract formation.[7–9] Although the reason for cataract formation is still unclear, the proximity of the implanted IOL to the crystalline lens

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is assumed to play an important role via direct mechanical contact or by interference with aqueous humor circulation over the crystalline lens.[10–12] Also, presbyopic age is thought to be a risk factor for cataract formation.[13] Therefore, the knowledge of ocular dynamics in vivo (eg, during accommodation) could shed light on possible mechanical contact or interaction.

Recently, partial coherence interferometry (PCI) has become commercially available for anterior segment measurements in form of the ACMaster (Carl Zeiss Meditec AG). The principle of this new optical method consists of PCI and was first reported by Fercher and Roth[14] in 1986 as an in vivo application. This technique enables precise measurement of ocular distances in a noncontact, noninvasive way.

Former studies of anterior segment PCI involved a device developed at the Institute of Medical Physics in Vienna, which allowed precise measurement of the anterior segment,[15,16] also during accommodation.[17] Petternel et al.[18] have shown shifts in ocular distances between the ICL and the crystalline lens during accommodation in 13 eyes with a nonsignificant reduction of the ICL–crystalline lens distance but did not correlate age with their findings.

The current study was performed to investigate the movement of the ICL in relation to the behavior of the crystalline lens during accommodation and patient age.

PATIENTS AND METHODS

Fifty-three eyes of 29 consecutive patients (20 women, 9 men) who had implantation of a posterior chamber IOL in the phakic eye for the correction of myopia were investigated. The Collamer implantable ICL was implanted by a single surgeon as a spherical (n = 30) or toric (n = 24) model V4 in the ALZ Augenklinik, Munich, Germany. The ICL material is a copolymer of collagen and polyHEMA.

The size of the ICL was chosen based on the gauge measurement of white-to-white by the surgeon. It was rounded up to the next higher 0.5 mm in all patients, neglecting age or lens thickness. The length of the implanted ICL was then chosen 0.5 mm larger than the rounded-up value. Mean size was 12.5 mm (range 12.0 to 13.0 mm).

Mean patient age 33 years ± 9 (SD) (range 21 to 59 years); median was 30 years (upper quartile 39.5 years, lower quartile 27 years). The preoperative mean sphere was −7.6 ± 1.9 diopters (D) (range −5.0 D to −11.5 D) and the cylinder was −1.4 ± 1.1 D (range 0 D to −4.25 D). Mean best corrected visual acuity was 20/20 (range 20/32 to 20/12.5).

Patients were measured with a new, commercially available anterior segment partial coherence interferometer, (the ACMaster) a mean of 7 months postoperatively (range 1 week to 32 months); median was 3 months (upper quartile 12 months, lower quartile 3 months). In contrast to the older PCI system by Zeiss, the IOLMaster, this system measures the whole anterior segment by PCI, including pachymetry, anterior chamber, phakic IOLs, and lens thickness. Different refractive indices are implemented in the system: $n_{\text{cornea}} = 1.3851$, $n_{\text{aqueous humor}} = 1.3454$, $n_{\text{crystalline lens}} = 1.4065$. Refractive indices for IOL material, which are currently already integrated, are $n_{\text{acryl}} = 1.5581$, $n_{\text{PMMA}} = 1.4941$ and $n_{\text{silicone}} = 1.4641$. Because the refractive index for Collamer, which is given as $n = 1.453$ by the manufacturer, was not integrated in the ACMaster yet, the ICL "thickness" was measured or converted with the phakic IOL silicone index. The calculated resulting difference of 0.76% is negligible, respectively, within measurement error.

The first series of measurements were conducted with distance correction. For a valid signal, all Purkinje images of the surfaces have to be aligned in a perpendicular manner. Therefore, sometimes only segmental distances could be measured with a single reading. A minimum of 15 measurements was taken to have multiple values from each wanted structure (Figure 1). Then, a second series of at least 15 measurements with a 3.00 D accommodation stimulus integrated into the system was performed. This means that a −3.00 D lens was put in front of the measured eye within the ACMaster, and the patient was asked to actively focus on the fixation target. When the patient then agreed to see the fixation target clearly, the measurement was taken. However, an actual measurement of the refractive change within the patient's eye was not determined and, therefore, accommodation was subjective.

In 9 randomly chosen eyes, an additional stimulus of 5.00 D was presented. Fourteen eyes were measured repetitively at different visits to show reliability.

For statistics, a linear regression analysis or the Student *t* test for related samples was conducted, after verifying normal distribution, defining $P \leq .05$ as statistically significant.

For comparing 2 or more sets of measurements, the intraclass correlation coefficient of reliability was calculated. Calculations for reliability (r) including the lower limit of a 1-sided 95% confidence interval (rlow) were performed using the method described by Fleiss.[19] Values above 0.75 are usually interpreted to represent excellent reliability with the optimum being 1. All calculations were performed using the SAS software, version 9.1.

RESULTS

Postoperative mean sphere was 0.07 ± 0.38 D (range −0.75 to 1.25 D), and the cylinder, −0.51 ± 0.35 D (range 0 to −1.5 D). Mean best corrected visual acuity was 20/16 in mean (range 20/25 to 20/12.5).

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