case reports

Contact between 3 phakic intraocular lens models and the crystalline lens: An anterior chamber optical coherence tomography study

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Three phakic intraocular lens (IOL) models were implanted in 3 different patients. With the usual slitlamp examination, it was not possible to determine whether there was contact between the IOLs and the natural crystalline lens. Using the anterior chamber optical coherence tomography (AC OCT) scanner, direct contact between the natural crystalline lens and the 3 phakic IOLs was revealed. A dynamic study of the contact was performed during accommodation. These observations show that examination of the anterior segment with the AC OCT scanner provides new data about the status of the anterior segment after implantation of phakic IOLs.

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Refractive phakic intraocular lenses (IOLs) are being used more frequently to correct high ametropia and/or associated astigmatism. Three models are available: angle-supported anterior chamber (AC) IOLs (ZB, ZB5M, NuVita [Bausch & Lomb]; GBR [Ioltech]; Vivarte [Ciba Vision]); iris-fixated AC IOLs (iris claw, Artisan®/Verisyse [Ophtec]); and posterior chamber (PC) IOLs (ICL® [Staar Surgical], PRL [Medennium]). Refractive IOLs were introduced because of the limitations of laser in situ keratomileusis (LASIK) and better understanding of how the cornea reacts to surgery (eg, post-radial keratotomy hyperopia, post-LASIK keratectasia, haze, regression, dry eyes, and optical aberrations).

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Knowledge of anterior segment physiology (endothelium, biomaterial tolerance) has improved IOL tolerance. Today, AC IOLs induce few or no cataracts and do not endanger the natural crystalline lens. The most important development in the design of these IOLs is related to the endothelial safety factor. Reports of extensive corneal edema secondary to phakic IOL surgery have almost disappeared from recent literature. However, even if PC IOLs do not appear to damage the corneal endothelium, numerous questions about the state of the crystalline lens at midterm and long term remain unanswered.

We studied the way 3 phakic IOL models came in contact with the natural crystalline lens. With 2 models, we were unable to produce evidence of contact using standard examination methods. However, contact was visible using a new device, the AC optical coherence tomography device (OCT) scanner.

The AC OCT scanner is described in a related article in this issue.[1] Interest in the device lies in its micron-scale resolution (10 μm) and its ability to capture the entire anterior segment in 1 step. The operator can choose to scan the horizontal, vertical, or oblique diameter of the anterior segment. This device is different

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from other OCT devices that have been described.[2–4] Once the image is taken, the device's software restores the image to its real dimensions, avoiding the errors induced by differences in ray transmission through the cornea. Specific software can measure the distance between 2 points—the curvature radius and the angles.

Case Reports

Case 1

In March 2003, a 25-year-old woman presented with hyperopia of +5.00 diopters (D) in the right eye. A +7.00 D Artisan IOL was implanted in the right eye, with the IOL fixated in the horizontal axis of the iris. The patient had an uncorrected visual acuity (UCVA) of 0.9 postoperatively, with a residual refraction of −0.75 D. The intraocular pressure (IOP) and cell count were normal. The preoperative anterior chamber depth (ACD) was 3.31 mm (IOLMaster, Carl Zeiss Meditec). At the last examination, the endothelial cell count was 3000 cells/mm^2 (the same as preoperatively).

During a recent postoperative examination, a complete anterior segment examination was performed with and without dilation. After pupil dilation, biomicroscopy seemed to indicate a tilt of the Artisan IOL, which appeared to pivot around the horizontal axis under the influence of gravity. The lower edge of the IOL appeared extremely close to and possibly in contact with the crystalline lens. The anterior segment was then photographed in the vertical plane in mydriatic conditions with the AC OCT scanner. This showed the lower part of the IOL was slightly oblique posteriorly and was in contact with the crystalline lens (Figure 1). This can be explained by the tilting of the Artisan IOL around the horizontal axis, which was the fixation axis. When the pupil is not dilated, the crystalline lens is protected by the iris tissue, which comes between the IOL and the anterior surface of the crystalline lens.

The patient was reevaluated a few days later with a dynamic examination of the anterior segment. Pictures of the unaccommodated (Figure 2) and accommodated (Figure 3) eye were taken. The natural movement of the crystalline lens was observed, with a forward bulge of the anterior pole of approximately 268 μm for 7.00 D of accommodation. During accommodation, the crystalline lens came extremely close to the posterior face of the IOL. During this natural accommodation, unexpected pupil movement that showed no accommodative miosis was noted (Figures 2 and 3). Under examination conditions, the space between the anterior surface of the IOL and the natural crystalline lens was considerably reduced and it was easy to see the inclination of the IOL relative to the anterior curvature of the crystalline lens. The crystalline lens is currently clear.

Case 2

Within 1 week, a +10.00 D PRL was implanted in both eyes of a 24-year-old patient to correct high hyperopia. The preoperative visual acuity was 0.8 with +11.0 D; the ACD was 3.40 mm (IOLMaster). The IOP was 14 mm Hg and the endothelial cell count, 3000 cells/mm^2. Two weeks after surgery, the UCVA was 0.5, the residual spherical equivalent (SE) refraction was +1.00 D, and the IOP was 14 mm Hg. The position of the PRL was studied clinically with a slitlamp and the AC OCT tomographer. With the slitlamp and an undilated pupil, it was impossible to see whether there was contact between the PRL and the natural crystalline lens. After dilation, it appeared there might be contact between the PRL edges and the crystalline lens near the pupil margin. In images taken with the AC OCT scanner, the edges of the PRL optic were seen to touch the crystalline lens (Figure 4).

As in the first case, the patient was reexamined and a dynamic study of the relationship between the PRL and the crystalline lens during accommodation was performed. Pupil contraction was observed concurrent with accommodation and forward steepening and bulging of the crystalline lens' anterior pole (Figures 5 and 6). In the unaccommodated state, there was a space between the posterior surface of the IOL and the anterior pole of the crystalline lens; this space was largest at the center of the PRL. It seemed to decrease toward the periphery, which is hidden by the iris. In the accommodated state, the entire posterior surface of the PRL was visible in the pupil area and was in direct contact with the crystalline lens. This indicated that during efforts to accommodate, as a result of zonular slackening and steepening of the crystalline lens' anterior curvature, the forward movement of the anterior pole caused contact. To date, the crystalline lens remains clear.

Case 3

In 1993, a ZB5M refractive AC IOL was implanted in a 30-year-old woman to treat unilateral high myopia. The preoperative best corrected visual acuity in the left eye was 0.7 with a refraction of −12.0 D. The patient was seen every year to monitor the corneal endothelium. Ten years after implantation, the UCVA was 0.4, the residual SE refraction was −2.00 D, and the IOP was 14 mm Hg. The angle was normal with no synechias, the pupil was round, and the mean endothelial cell density was 2000 cells/mm^2. For the first time, the slitlamp examination showed possible contact between the crystalline lens and the posterior surface of the IOL optic in the pupil area. Examination with the AC OCT scanner was performed without dilation. Since this patient was 40 years old, the dynamics of accommodation were not studied as the images from the unaccommodated eye were sufficiently conclusive. Contact between the posterior surface of the IOL optic and the central part of the natural lens was confirmed (Figure 7). There is no cataract to date.

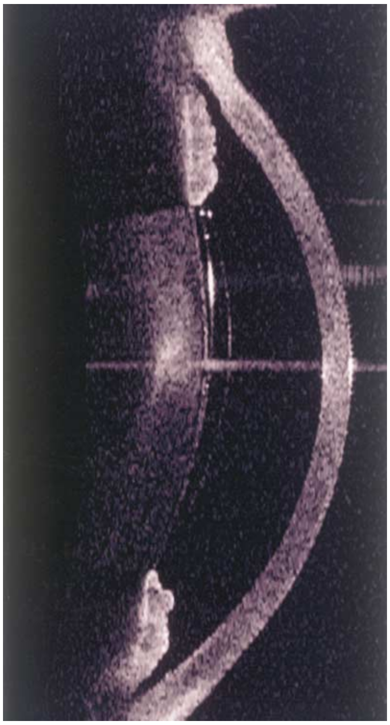

Figure 1. (Baikoff) Vertical profile of an Artisan IOL after mydriatic contact on the 6 o'clock meridian between the crystalline lens and the posterior IOL surface.

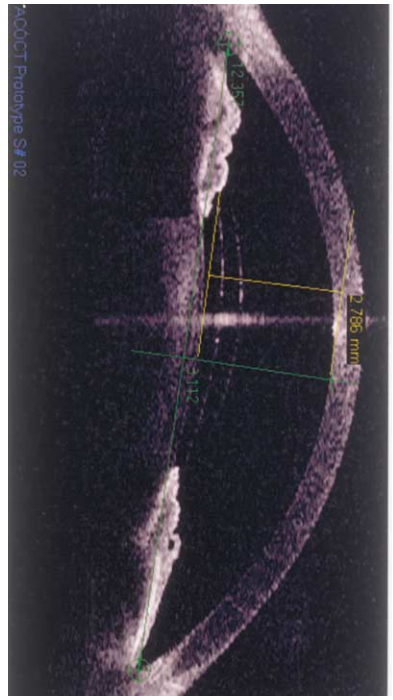

Figure 2. (Baikoff) The ACD (posterior face of the cornea to anterior face of crystalline lens) in the eye in Figure 1 (unaccommodated) with an Artisan IOL was 2.786 mm.

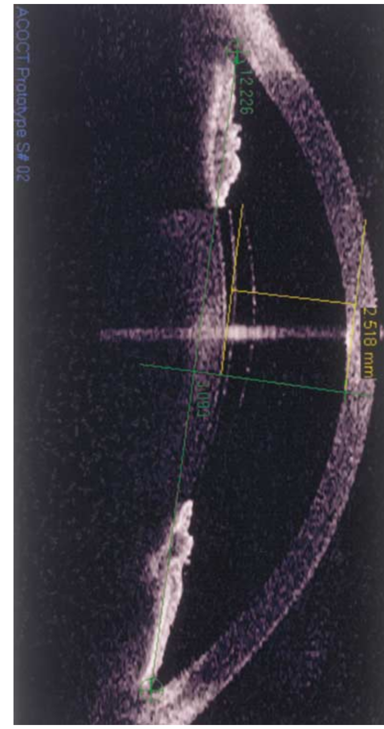

Figure 3. (Baikoff) The ACD of the eye in Figure 1 (accommodated) was 2.518 mm.

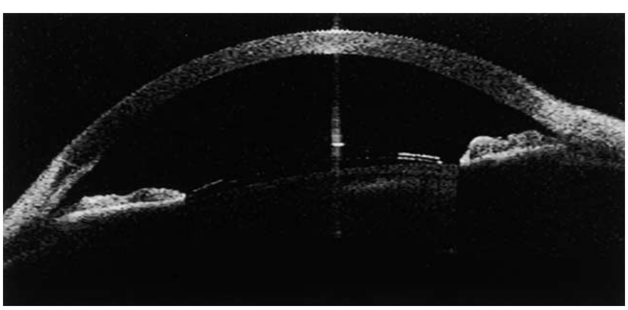

Figure 4. (Baikoff) After dilation, the edges of the PRL are in contact with the crystalline lens.

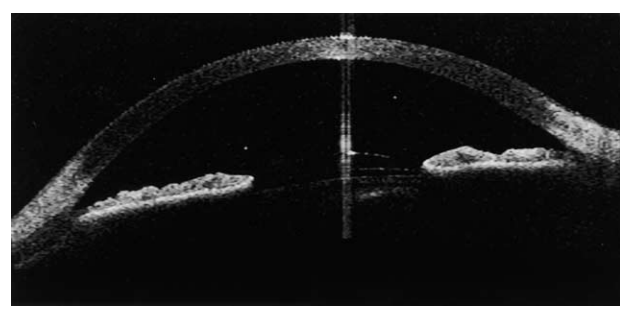

Figure 5. (Baikoff) The PRL in the eye in Figure 4 (unaccommodated).

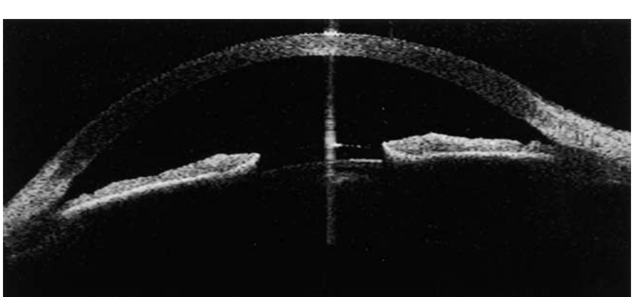

Figure 6. (Baikoff) The PRL in the eye in Figure 4 with 12.0 D of accommodation; the anterior surface of the crystalline lens touches the IOL.

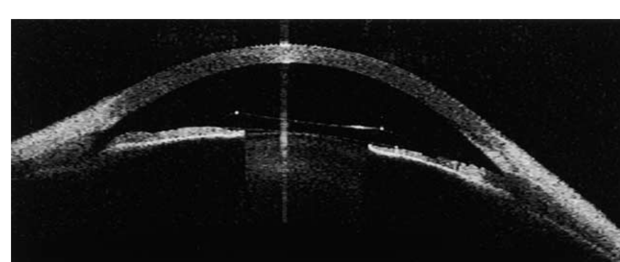

Figure 7. (Baikoff) The ZB5M IOL 10 years after implantation. There is contact between the anterior face of the crystalline lens and the posterior face of the phakic IOL.

Discussion

These 3 cases raise the following issues: the risk for induced cataract after refractive lens surgery in a phakic eye, the importance of developing new technologies to explore the anterior segment, and the need for new inclusion criteria for refractive phakic IOLs.

Risk for Induced Cataract After Refractive Phakic IOL Implantation

The ZB, ZB5M, and NuVita IOLs are not known to induce cataracts. During a multicenter study performed by Baikoff et al.,[5] the cataract rate was extremely low. Alió and coauthors[6] report 9 cases of cataract that occurred in extremely myopic eyes with axial lengths greater than 30.0 mm. It is well known that highly myopic patients have a greater risk for spontaneous cataract development than the normal population. Introducing a foreign body into the AC may modify the metabolism of the crystalline lens. Nevertheless, AC IOLs are not considered an important contributing factor to cataracts in a population already at risk (highly myopic patients). An increase in crystalline lens thickness from aging should be considered and the patient informed of this possibility.

Iris-claw IOLs[7–9] are not considered more cataract inducing than angle-supported IOLs.

However, it is different with PC IOLs, especially the ICL. Zaldivar and coauthors[10] demonstrate that during successive modifications of the lens, the V3 model induced a number of cataracts that increased with time. Gonvers and coauthors[11] report that with the ICL, the increase in cataracts seems proportionate to age. A 20-year-old patient has a low risk for developing cataract; a 40 year old runs a higher risk. The ICL generally rests in the iridociliary sulcus, and the vault was modified in later generations of the lens. Today, a higher vault is recommended to maintain sufficient space between the posterior surface of the ICL and the crystalline lens to reduce the risk for cataract.

The PRL is also placed in the PC. It is made of silicone and "floats" in the PC without touching the ciliary sulcus. Some images of myopic PRLs show significant space between the posterior surface and the crystalline lens.[12] The cataract rate after PRL IOL implantation appears to be less than 2%.[13] However, in 1 hyperopic case, observation showed that if the eye is undilated when the examination is done, there is a space between the IOL and the anterior capsule of the crystalline lens. When the subject accommodates, which happens constantly in everyday life, the anterior pole of the crystalline lens is pushed forward under recurrent modifications of the anterior segment and comes in contact with the posterior surface of the PRL. The question is whether, in the long term, this intermittent but repetitive contact is dangerous to the natural crystalline lens of a young subject.

Anterior Segment Examination of Refractive Phakic IOL Candidates

Today, anatomical inclusion criteria for a refractive phakic IOL rest essentially on the quality of the endothelium, the ACD, an open angle, and the white-to-white diameter. The endothelium is easily evaluated with the specular microscope; the angle opening can be analyzed clinically by gonioscopy; and the ACD (generally considered the distance between the corneal epithelium and the anterior surface of the crystalline lens) is measured without difficulty by A-scan, B-scan, or ultrasound biomicroscopy (UBM). Optical systems such as the IOLMaster are also routinely used. However, these measures are static and are performed in an unaccommodated eye; the ACD and its variations during accommodation cannot be evaluated.

The AC OCT scanner offers something new: First, because it is a noncontact examination, it is simple and rapid. Second, by focusing or defocusing with positive or negative lenses, it is possible to relax or stimulate the subject's accommodation in a natural way. Considering our observations in Cases 1 and 2, this dynamic study will become essential because no one imagined the crystalline lens could come in contact with the posterior surface of a phakic AC IOL during accommodation. We had doubts concerning PC IOLs, but we now have proof that a genuine risk exists. The technique used with the 1310 nm OCT prototype gives a much better image than the 820 nm OCT used for the posterior segment.[14]

Various white-to-white methods are used to evaluate the internal diameter of the AC. Ultra-high-frequency UBM devices[12] offer excellent images. The progress made in lower-frequency UBM scans is equally significant, but in our experience, no equipment other than the AC OCT tomographer allows visualization of the diameter of the AC simply and with such precision.

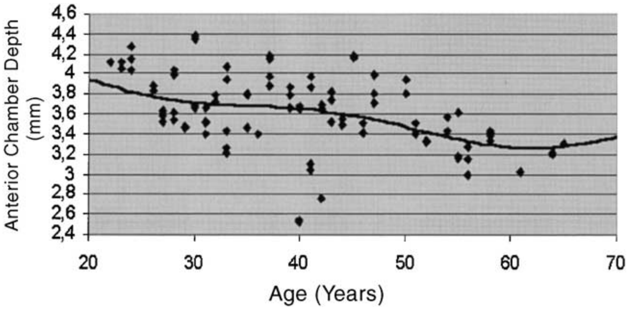

Figure 8. (Baikoff) Evolution of the ACD relative to age.

The relationship between the internal diameter and the AC IOL must be studied separately.

New Inclusion Criteria for Refractive IOLs

The 3 observations reported here are crucial. The ACD, open angle, endothelial cell density, and white-to-white diameter are considered essential implantation criteria today, but in the light of our observations, they appear insufficient. It is urgent and advisable that surgeons have more advanced technologies such as the AC OCT tomographer, which seems to be a significant advancement because of its simplicity.

We suggest that the software of anterior segment examination systems include the dimensions and profiles of different refractive IOL models, with visualization of the different powers. This allows us to preoperatively superimpose the selected IOL on the image of the patient's anterior segment. If safety criteria are not met (eg, a safe distance between the endothelium and the IOL, the posterior surface of the IOL and the iris, and the posterior surface of the IOL and the crystalline lens), the model will have to be changed or implantation not performed. Moreover, it will be possible to simulate the position of an IOL in the eye and know in advance its position during accommodation. Statistical studies of AC OCT observations of the anatomical modifications of the anterior segment during accommodation and aging are described in a related article in this issue.[1] The statistical studies of the forward movement of the crystalline lens' anterior pole relative to accommodation (see Figure 11[1]), the maximum forward movement of the crystalline lens' anterior pole relative to age (see Figure 12[1]), and the ACD relative to age (Figure 8) should be integrated into the software to carry out static and dynamic simulations of the IOL position in a young subject and then simulate the relationship between the position of the IOL and the crystalline lens relative to theoretical aging and modifications of the AC with age.

Conclusions

These 3 cases establish the possibility that contact between a refractive phakic IOL and the crystalline lens is not always well detected with the slitlamp (or biomicroscopy). The AC OCT is a better tool to ascertain whether such contact exists. This means we can evoke accommodative trauma as a cause of cataract in subjects with phakic IOLs; in particular, subjects with PC phakic IOLs, in whom contact between the posterior surface of the IOL and the crystalline lens is more frequent than we imagined from the recurrent accommodative movements of a young subject in everyday life.

This study recommends extending the safety criteria for implanting refractive phakic IOLs in young subjects. As soon as new examination procedures such as the AC OCT tomographer are available, it will be vital to carry out a dynamic examination and simulate aging in an eye with a refractive IOL. A simple way of describing the problem is that the phakic IOL is going to hang out in the anterior segment and it is essential to know whether this "hanging out" will be safe and for how long.

Our observations have to be confirmed by other refractive surgery centers, but reporting these analyses provides new perspectives on refractive phakic IOLs. In our opinion, the AC OCT tomographer or similar equipment should become as necessary for phakic IOL implantation as topography is for corneal refractive surgery.

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