Akreos® Acrylic IOLs:

Clinical Evidence Continues to Support Biocompatibility and Design Features

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Overview

Akreos® Adapt, Fit and Disc are hydrophilic acrylic intraocular lenses that ophthalmic surgeons throughout Europe have implanted in patients more than 500,000 times over the last five years. This publication summarizes the available information on the key characteristics of Akreos IOLs that have made them so popular, including: biocompatibility, optical clarity, stability and low incidence of posterior capsular opacification and anterior cell growth. It is intended to help ophthalmic surgeons better evaluate the role that the Akreos Adapt, Fit and Disc hydrophilic IOLs can play in today's cataract surgery practice.

Background

The rapid evolution of intraocular lenses in recent years has increased the chances for confusion about the designs and materials with which IOLs are made. The earliest intraocular lenses were made of polymethylmethacrylate (PMMA), the plastic that IOL inventor Harold Ridley, MD, had noticed was inert in the eyes of World War II aviators struck by flying plastic during battle. For the next 30 years removal of the crystalline lens required large incisions, and the hard, rigid PMMA became the material of choice for IOL optics. [1]

It wasn't until phacoemulsification made it possible to remove the cataract through a smaller incision that ophthalmic companies began looking for foldable and compressible materials, to allow an IOL to be inserted through an unenlarged phacoemulsification incision. [2] This search for a pliable material led to the exploration for intraocular use of poly-HEMA - the hydrogel material Bausch & Lomb had used to create the first soft contact lenses during the 1960s. A watershed in the history of hydrophilic IOLs came in 1986 and 1987, when Barrett et al. reported on the first large clinical studies of poly-HEMA lenses. [3,4] Later, publication of a prospective study with 5 then 12 years of follow-up demonstrated the longterm compatibility of IOLs made from poly-HEMA. [5,6]

However, the quest for smaller, clear-corneal incisions without sutures spawned further experimentation on ways to make foldable and injectable IOL optics thinner yet robust. It was in this context that materials for the first hydrophilic acrylic IOLs were created by modifying poly-HEMA. [2] There have been a variety of formulations developed, but most of them share a common structure: a copolymer of the hydrophilic hydroxylethyl methacrylate (HEMA) and the hydrophobic methylmethacrylate (MMA). These copolymers have water contents around 25%, are mechanically robust and foldable and have a higher refractive index than the pure poly-HEMA materials. This allows for thinner lens designs that fold and compress easily without the damage and fold marks that have been reported in silicone and hydrophobic acrylic IOLs. [7,8,9,10]

The Akreos® IOLs

Over the past five years, the continuous research and development at the Chauvin division of Bausch & Lomb has led to three different models of Akreos IOLs. Their physical designs vary, but all are one-piece equiconvex IOLs made from a single poly-HEMA/MMA copolymer. Akreos IOLs have a moderate refractive index of 1.46. All also have double square edges to inhibit posterior capsular opacification. The three Akreos models are:

- Adapt - This one-piece IOL features four haptics for stable fixation within the capsular bag. The optic body measures 6.0 mm in diameter. Because the diameter of the capsular bag increases with the axial length of the eye, [11-12] the Adapt's total diameter ranges from 10.5-11.0 mm depending on its refractive power. This optimizes posterior and edge contact with even the largest capsular bags. The Adapt is inserted one-handed with the closed, single-use Hydroport injector system.

- Fit - This IOL has C-shaped haptics (0-degree angulation) and an optic diameter of 5.7 mm. The diameter with haptics is 11.5 mm. The Akreos Fold device is used to prepare this IOL for insertion, which is accomplished with forceps.

- Disc - This circular IOL has two fenestrated plate haptics. The optic measures 6.0 mm, and the total diameter is 10.7 mm. After folding, it is inserted with forceps.

Advantages of Hydrophilic Acrylic Materials

Hydrophilic acrylics offer physical, biological and optical qualities that make them attractive for use in foldable intraocular lenses. An IOL made from a hydrophilic acrylic:

Has few dysphotopsias: Because of their water content, hydrophilic acrylics have a lower refractive index than hydrophobic acrylics, which minimizes problems with glare, external and internal reflections and other unwanted visual phenomena seen in IOLs with a higher refractive index. [13,14,15,16,17,18,19,20,21,22] Glare accounted for about 3% of the hydrogel explantations reported in a large 2001 survey of ophthalmic surgeons, compared to 29% for three-piece hydrophobic acrylic IOLs. [7] A comparison between the Akreos Fit and hydrophobic Acrysof MA30 and MA60 IOLs (110 patients) found severe glare symptoms in 4.6% of the Akreos Fit eyes, compared to 13% for the Acrysof lenses. [22] Lack of glare was reported by 28% of the Akreos Fit patients, and 18% of the Acrysof recipients.

In a more recent study, Dr. Pascal Rozot of Marseilles, France, reported on the 1-month postoperative visual performance of 150 eyes implanted with either the Akreos Adapt or the Akreos Disc. [23]

The patients surveyed were part of a larger, eight-center study in which 62% of 340 patients received an Adapt IOL and 38% received the Disc. A total of 240 eyes had at least 1 month of follow-up at the time of the study and, of those, 150 had a BCVA >/= 0.8. This latter group was asked to complete the same patient-satisfaction survey used by Tester et al. in their 2000 study of IOL dysphotopsias. [21]

Overall, the Akreos recipients reported fewer dysphotopsias than were found in the Tester study (36% vs. 49%), as detailed in Table 1. The Akreos patients reported fewer problems with driving into sunset or sunrise(18.8% vs. 23%); haloes (5.6% vs. 11%); generalized light sensitivity (8% vs. 33%); and those who stopped driving at night due to light related sensitivity (8.8% vs. 40%). In addition, 95.3% (143) of the Akreos patients reported they were "very satisfied to satisfied" with their corrected distance vision after IOL surgery. That compared to 90% in the Tester study.

Table 1

Best cases: BCVA>=20/25, no pre-existing disease, no incidents	Tester study	Akreos study
Number of cases	352 *	150
Light eye related problem	49%	36%
- stop driving at night	40%	8.8%
- driving into the sunset or sunrise	23%	18.8%
- oncoming headlights at night	29%	22.3%
- brightly supermarket	6%	20.3%
- halos	11%	5.6%
- generalised light sensitivity	33%	8%
- unwanted images	20%	6%

* Includes 50 phakic eyes as controls. In general, controls reported more severe glare than the pseudophakes. (Akreos figures do not include any phakic eyes.)

Source: Dr. Pascal Rozot

Exhibits good biocompatibility: After prospectively following patients with hydrophilic IOLs for 12 years, Khan and Percival concluded that poly-HEMA "can be unreservedly recommended for incorporation into acrylic lenses to improve flexibility and hydrophilicity." [5,6] In addition to this indication of long term biocompatibility, researchers have shown that hydrophilic acrylics are very "quiet" in the eye. [24,25,26] This has led many ophthalmic surgeons to use them in cataract patients with inflammatory conditions or co-morbidities such as diabetes.

Has good optical clarity: The Khan and Percival study found that, among the 35 surviving recipients of poly-HEMA IOLs (Iogel PC12, 38% water content), the four cases of visual acuity worse than 20/40 could be attributed to age-related maculopathy or late endophthalmitis. [6] Because of their hydrophilic nature, poly-HEMA IOLs have a typical aspect under slit lamp examination that is different from hydrophobic IOLs and similar to that of the cornea or the young natural lens.

These researchers noticed this difference but found there was no discoloration, nor were there the microvacuoles or "glistenings" that have been observed in hydrophobic acrylic lenses. [27,28,29] The final visual acuities were slightly superior to those achieved with PMMA.

In a more recent study in uveitis patients, the hydrophobic Acrysof MA60BM was 38.5 times more likely than other foldable IOLs to accumulate unexplained brown deposits within the optic (95% CI 6.9-200, P<0.001). Eighteen of 22 Acrysof IOLs they examined showed the deposits. Two of the three IOLs showing no deposits were hydrophilic: the Akreos Fit and the Bausch & Lomb Hydroview. The third was a silicone lens, the Allergan AR-40. [30]

IOLs made from newer hydrophilic materials, such as the poly-HEMA/MMA copolymer in Akreos, may have a further advantage because of improvements in IOL designs and manufacturing methods, according to a report at the 2003 meeting of the European Society for Cataract and Refractive Surgery. Vryghem and Cools implanted 29 patients with the Akreos Adapt and Pfizer Tecnis Z9000 contralaterally, and found no significant difference in their optical performance. [31] Seventeen of the patients rated their vision as similar in both eyes, seven preferred the Akreos Adapt eye and five the Tecnis eye. Wavefront analysis in seven subjects found lower levels of higher-order aberrations in four Tecnis eyes and in one Adapt eye.

In the past, there have been reports of opacification due to calcification in some hydrophilic IOLs, [7, 32-39] but these lenses have a different copolymer composition from that of the Akreos models. The problems with these other IOLs generally occurred within two years of implantation. [36, 40] Nick Mamalis, MD, a University of Utah professor well respected for his IOL biocompatibility studies, has said that follow-up of two years is sufficient for him to conclude that a hydrophilic IOL has no calcification problems similar to those previously reported in other hydrophilics. [41] More than 110,000 Akreos IOLs have passed this two-year milestone without any reports of such complications. [42]

Resists damage during insertion: Hydrophilic acrylic resists the fold marks and forceps damage that have been reported in silicone and other foldable acrylic IOLs. [7-10] In the 2001 survey of IOL complications by the American Society for Cataract and Refractive Surgery, there wasn't a single report of explantation of a hydrophilic IOL because of damage during insertion. [7] (However, damage to a hydrophilic acrylic IOL is possible through incorrect loading or use of an injector, or through inappropriate use of forceps.)[43]

Stands up to Nd:YAG laser energy: As long ago as 1987, researchers reported that HEMA and HEMA/MMA copolymer were less susceptible to damage during Nd:YAG laser irradiation than PMMA. [44,45] More recently, a comparison among foldable IOL materials found that the three hydrophilic IOLs tested had higher thresholds for damage than did IOLs made of hydrophobic acrylic or silicone. [46]

Appears to be less susceptible to biocontamination: In February 2003, a paper by Schauersberger et al. proposed that the wider use of hydrophilic acrylic IOLs might reduce the incidence of endophthalmitis after cataract surgery. [47] The researchers exposed nine different types of IOLs to standardized suspensions of *Staphylococcus epidermidis* for five minutes, then rinsed them and tested for continued presence of bacteria. The IOLs made from PMMA or hydrophobic acrylic had bacterial densities two or more times as high as those seen on hydrophilic IOLs. "Our data suggest that the higher the hydrophilicity of the IOL material, the lower the early adhesion and bacterial density on the IOL surface," the authors wrote.

Advantages Specific to Akreos

Stability in the capsular bag

For an implant's power calculation to be accurate, the IOL must be firmly fixated to prevent anterior or posterior shifting. [48] Surveys of ophthalmic surgeons indicate that incorrect lens power and decentration/dislocation are two of the most common reasons for IOLs to be explanted. [7, 49] In clinical studies, the Akreos line of IOLs has demonstrated a reliable A-constant for power calculation, and excellent positional stability in the eye. [50-52]

At France's Ophthalmic Institute of Somain, Thierry Amzallag, MD, compared IOLs with different types of haptics *in vitro* and found that the plate haptics of the Akreos Disc had two to six times the contact length with a simulated capsular bag than did other IOLs. [50] In a clinical study of decentration, Laube and colleagues compared the Akreos Fit to the three-piece Alcon Acrysof in 62 patients. They found that, after 6 months, decentration had occurred in 39% of the Acrysof eyes, compared to 10% with Akreos Fit. [51]

In a German study of 27 patients with Akreos Fit and Disc IOLs, Spath et al. concluded that the lenses' biogeometry gave them good contact between optic and the capsular bag's equator, producing stable centration. [52]

In another study, at 1 year after surgery 24 Akreos Disc patients showed a difference between expected and observed refraction averaging −0.10 D. The mean refraction shifted to the hyperopic by a mean of 0.18 D between 10 days and 1 year after surgery, without refractive effect. The subjects' mean refraction at 1 year was +0.03 D (SD: 0.56) [53]

A British study of 30 Akreos Adapt patients confirmed the accuracy of the A-constant for this newest IOL in the Akreos line, finding that the difference between the mean expected and mean observed refractions at three weeks was +0.17 D. The patients' refraction through 1 year remained stable (mean difference: −0.66 D; SD 1.25). In addition, decentration of the Adapt was minimal, with a mean lateral movement of 0.048 mm (SD: 0.02). [54]

In-vitro studies of cell migration

With its four-haptic design, the Akreos Adapt maximizes the contact between the IOL surfaces and the capsular bag. In one study, six IOLs models were implanted in an artificial capsular bag and 3D ultrasound biomicroscopy was used to measure IOL-bag contact. The researchers found that all the IOLs were in contact with the central part of the bag, but the Akreos Adapt was one of two that had complete contact along the equatorial zone. [55] This correlated with reduced spreading of cultured human lens epithelial cells on the Adapt. The other IOL with complete equatorial contact and reduced LEC migration was the Acrysof MA60.

Low PCO

In addition to double square edges intended to minimize posterior capsular opacification via a sharp bend in the capsular bag, [56-67] Akreos IOLs are designed to minimize the chances of lens epithelial cell migration by producing a maximum of contact with the capsular bag ("no space, no cells").

In a clinical study on 68 eyes, Arné reported that the Akreos Disc's circular design produced an even distribution of tension on the capsular bag; he also noted the enhanced angle of contact that Amzallag had measured *in vitro*. [50, 68]

Clinical studies of the Akreos line's PCO performance also are positive. They include:

- A report by Dr. Giorgio Lofoco that, in 632 Akreos Adapt eyes with 1 year of follow-up, only one eye (0.15%) required Nd:YAG laser capsulotomy. [69] Dr. Lofoco, of Rome, Italy, also studied a subset of 390 eyes with the EPCO 2000 software for grading PCO, and compared the Adapt's scores to those of the H60m (Bausch & Lomb), a hydrophilic IOL with round edges. (On the EPCO scale, 0 equals no PCO, and >1 means Nd:YAG surgery performed.) The Akreos Adapt's mean score was 0.54, compared to 1.02 for the round-edged hydrophilic IOL. Furthermore, the transparency of the central (3.5 mm) posterior capsule measured 0.24 for the Adapt, and was 0.96 for the H60m.

- After a mean follow-up of 1 year in 101 Akreos Adapt recipients, Robin et al. reported a 3.9% Nd:YAG rate. The mean time to laser capsulotomy was 12.6 months. [70]

- A German study of Akreos Disc and Fit in 27 patients found PCO was low and progressed only slightly during the first postoperative year. [52]

These figures compare to a meta-analysis that estimated incidence of PCO across all IOL types at 11.8% at 1 year after surgery and 20.7% at 3 years. [71]

Less anterior cell growth

The incidence of either anterior capsule opacification (ACO) or cellular attachment to the IOL differs among all types of IOL materials, and within the hydrophilic acrylic materials category itself. [72,73] Akreos IOLs have shown very little propensity for either inflammatory cell attachment or the lens epithelial cell outgrowth that has been reported in some other hydrophilic acrylics. A recently reported in vivo study in 180 patients found the Akreos Fit had fewer small cells, giant cells or LECs at 6 months than either Alcon Acrysof or the hydrophilic Centerflex 570H (Rayner). [74]

Adapt: A solution to posterior capsular rupture

The four-point fixation design of the Akreos Adapt can secure the IOL firmly even when the complication of posterior capsular rupture has occurred, according to a paper delivered at the 2003 ASCRS meeting. [75] In that Belgian study, Smeets reported success with placing two of the Adapt's haptics behind the capsular bag and two in front. This creates crossed bag/sulcus fixation and good separation between the chambers without putting pressure on the ciliary body. Follow-up of 3 to 14 months showed good centration and stability of the IOLs, and stable UCVA in all patients. There was no inflammation, vitreous loss or refractive shift.

Planar, one-handed insertion of the Adapt

The surgeon places the Akreos Adapt in the eye using the Hydroport® one-handed inserter system. This single-use injector eliminates the risk of contamination and reduces preoperative preparation time. It allows flat loading of the lens, and planar delivery through an incision of under 3 mm. Ophthalmic surgeons who have used the Hydroport report that it accomplishes the Adapt insertion safely and easily. [50,70]

Future Development of Hydrophilic Acrylic Lenses

Hydrophilic acrylic lenses such as Akreos are manufactured in a single piece using a lathing process. Not only does this process create better optical performance than molding at the high powers required for IOLs, [76] it also permits the creation of aspheric and non-rotationally symmetrical surfaces. Therefore, in the future Bausch & Lomb anticipates creating lens designs that limit or eliminate the higher-order aberrations inherent in conventional IOL designs.

In addition, the compressibility of hydrophilic materials in the future will permit the creation of designs that can be injected through smaller incisions, improving the speed and quality of visual recovery after surgery.

Conclusion

Both in research studies and in clinical use, the Akreos® Adapt, Fit and Disc intraocular lenses have demonstrated advantages that include good biocompatibility, optical clarity, stability in the capsular bag, and inhibition of cell growth on the optic.

Akreos IOLs are made from a combination of two materials with the longest track record for ocular biocompatibility, poly-HEMA and MMA. The moderate refractive index gives Akreos lenses a significantly lower rate of dysphotopsias than is experienced with high-index hydrophobic IOLs (4.6% vs. 13% in one study). [22] Hydrophilic acrylic maintains its clarity over time, with none of the glistenings observed in hydrophobic acrylics. [27-29] Akreos also is very stable within the capsular bag; for example, the Akreos Fit undergoes nearly 4 times less decentration than the three-piece Acrysof (10% vs. 39%). [51] The Akreos Adapt exhibits the same amount of equatorial contact with the capsular bag as Acrysof, [50] and it also has double square edges that lead to clear central posterior capsules and a low rate of Nd:YAG laser capsulotomy (0.15%) at 1 year. [69]

With the wealth of experience that has been gained using them, hydrophilic acrylic lenses have been shown to be a significant addition to the surgeon's range of clinical options and have become the lens of first choice for many in Europe and Asia.

References

1. Lindstrom RL: The polymethylmethacrylate (PMMA) intraocular lenses. In Steinert RF, Fine IH, Gimbel HV, Lindstrom RL, Neuhann TF, Osher RH (eds): Cataract Surgery: Technique, Complications, & Management, pp 271-78.
2. Lindstrom RL: Foldable intraocular lenses. In Steinert RF, Fine IH, Gimbel HV, Lindstrom RL, Neuhann TF, Osher RH (eds): Cataract Surgery: Technique, Complications, & Management, p 279.
3. Barrett GD, Constable IJ, Stewart AD. Clinical results of hydro gel lens implantation. J Cataract Refract Surg. 1986 Nov; 12(6):623-31.
4. Barrett GD, Beasley H, Lorenzetti OJ, Rosenthal A. Multicenter trial of an intraocular hydrogel lens implant. J Cataract Refract Surg. 1987 Nov;13(6):621-6.
5. Percival SPB. Five-year follow-up of a prospective study comparing hydrogel with PMMA single piece lenses. Eur J Implant Refract Surg 1994; 6:10-13.
6. Khan AJ, Percival SP. 12 year results of a prospective trial comparing poly(methyl methacrylate) and poly(hydroxyethyl methacrylate) intraocular lenses. J Cataract Refract Surg. 1999 Oct; 25(10):1404-7.
7. Mamalis N. Complication of foldable intraocular lenses requiring explantation or secondary intervention - 2001 survey update. J Cataract Refract Surg 2002 Dec; 28:2193-2201.
8. Schmidbauer JM, Peng Q, Apple DJ, Pandey SK, Escobar-Gomez M, Auffarth GU, Werner L, Vargas LG. Rates and causes of intraoperative removal of foldable and rigid intraocular lenses: clinicopathological analysis of 100 cases. J Cataract Refract Surg. 2002 Jul;28(7):1223-8.
9. Kohnen T, Magdowski G, Koch DD. Scanning electron microscopic analysis of foldable acrylic and hydrogel intraocular lenses. J Cataract Refract Surg. 1996;22 Suppl 2:1342-50.
10. Brady DG, Giamporcaro JE, Steinert RF. Effect of folding instruments on silicone intraocular lenses. J Cataract Refract Surg. 1994 May;20(3):310-5.
11. Vass C, Menapace R, Schmetterer K, Findl O, Rainer G, Steineck I. Prediction of pseudophakic capsular bag diameter based on biometric variables. J Cataract Refract Surg. 1999 Oct;25(10):1376-81.
12. Lim SJ, Kang SJ, Kim HB, Kurata Y, Sakabe I, Apple DJ. Analysis of zonular-free zone and lens size in relation to axial length of eye with age. J Cataract Refract Surg. 1998 Mar;24(3):390-6.
13. Davison JA. Positive and negative dysphotopsia in patients with acrylic intraocular lenses. J Cataract Refract Surg. 2000 Sep;26(9):1346-55.
14. Erie JC, Bandhauer MH. Intraocular lens surfaces and their relationship to postoperative glare. J Cataract Refract Surg, 2003; 29(2):336-41.
15. Erie JC, Bandhauer MH, McLaren JW. Analysis of postoperative glare and intraocular lens design. J Cataract Refract Surg 2001 Apr; 27(4):614-621.
16. Ellis MF. Sharp-edged intraocular lens design as a cause of permanent glare. J Cataract Refract Surg 2001 Jul; 27(7): 1061-1064.
17. Farbowitz MA, Zabriskie NA, Crandall AS, Olson RJ, Miller KM. Visual complaints associated with the AcrySof acrylic intraocular lens. J Cataract Refract Surg 2000 Sept; 26(9): 1339-1345.
18. Franchini A, Gallarati BZ, Vaccari E. Computerized analysis of the effects of intraocular lens edge design on the quality of vision in pseudophakic patients. J Cataract Refract Surg 2003 Feb; 29(2):342-347.
19. Holladay JT, Lang A, Portney V. Analysis of edge glare phenomena in intraocular lens edge designs. J Cataract Refract Surg 1999 Jun; 25(6):748-752.
20. Hwang IP, Olson RJ. Patient satisfaction after uneventful cataract surgery with implantation of a silicone or acrylic foldable intraocular lens. Comparative study. J Cataract Refract Surg. 2001 Oct;27(10):1607-10.
21. Tester R, Pace NL, Samore M, Olson RJ. Dysphotopsia in phakic and pseudophakic patients: incidence and relation to intraocular lens type. J Cataract Refract Surg 2000; 26: 811-816.
22. Shambhu SS, V. Shanmuganathan V, Charles SJ. Acrysof vs Akreos IOLs - A comparison of dysphotopsia (poster). Royal College of Ophthalmologists meeting, May 2003.
23. Rozot P. Light-related eye problems with Akreos Adapt and Akreos Disc and their incidence on patient satisfaction. Presented at the San Diego meeting of ASCRS, May 2004.
24. Abela-Formanek C, Amon M, Schauersberger J, Kruger A, Nepp J, Schild G. Results of hydrophilic acrylic, hydrophobic acrylic, and silicone intraocular lenses in uveitic eyes with cataract: Comparison to a control group. J Cataract Refract Surg 2002 Jul; 28(7): 1141-1152.
25. Schauersberger J, Amon M, Kruger A, Abela C, Schild G, Kolodjaschna J. Comparison of the biocompatibility of 2 foldable intraocular lenses with sharp optic edges. J Cataract Refract Surg. 2001 Oct; 27(10):1579-85.
26. Schauersberger J, Amon M, Kruger A, Abela C, Schild G, Kolodjaschna J. Comparison of the biocompatibility of 2 foldable intraocular lenses with sharp optic edges. J Cataract Refract Surg. 2001 Oct; 27(10):1579-85.
27. Dhaliwal DK, Mamalis N, Olson RJ, Crandall AS, Zimmerman P, Alldredge OC, Durcan FJ, Omar O. Visual significance of glistenings seen in the AcrySof intraocular lens. J Cataract Refract Surg 1996 May; 22(4):452-457.
28. Christiansen G, Durcan FJ, Olson RJ, Christiansen K. Glistenings in the AcrySof intraocular lens: pilot study. J Cataract Refract Surg 2001May; 27(5):728-33.
29. Gregori NZ, Spencer TS, Mamalis N, Olson RJ. In vitro comparison of glistening formation among hydrophobic acrylic intraocular lenses. J Cataract Refract Surg 2002 Jul; 28(7): 1262-1268.

30. Manuchehri K, Mohamed S, Cheung D, Saeed T, Murray PI. Brown deposits in the optic of foldable intraocular lenses in patients with uveitis. Eye. 2004 Jan;18(1):54-8.
31. Vryghem JC, Cools D. Clinical results, contrast sensitivity and wavefront aberrations comparing the Pharmacia Tecnis Z 9000 and the Bausch & Lomb Akreos Adapt IOLs. Presented on 7/9/2003 in Munich at the XXIth Congress of the European Society of Cataract and Refractive Surgeons.
32. Apple DJ, Werner L. Complications of cataract and refractive surgery: a clinicopathological documentation. Trans Am Ophthalmol Soc 2001; 99:95-107.
33. Apple DJ, Werner L, Escobar-Gomez M, Pandey SK. Deposits on the optical surfaces of Hydroview intraocular lenses (Letter to the Editor). J Cataract Refract Surg 2000; 26:796-797.
34. Apple DJ, Werner L. Pandey SK. Newly recognized complications of posterior chamber intraocular lenses (Editorial). Arch Ophthalmol 2001: 119:581-582.
35. Fernando GT, Crayford BB. Visually significant calcification of hydrogel intraocular lenses necessitating explantation. Clinical Experiment Ophthalmol 2000 Aug; 28(4):280-86.
36. Frohm A, Dick B, Augustin AJ, Grus FH. A late opacification of the foldable hydrophilic acrylic lens SC60B-OUV. Ophthalmology 2001; 108:1999-2004.
37. Pandey SK, Werner L, Apple DJ, Gravel JP. Calcium precipitation on the optical surfaces of a foldable intraocular lens: a clinicopathological correlation. Arch Ophthalmol 2001; 120:391-393.
38. Werner L., Apple DJ, Kaskaloglu M, Pandey SK. Dense opacification of the optic component of a hydrophilic acrylic intraocular lens: a clinical pathological analysis of 9 explanted lenses. J Cataract Refract Surg 2001; 27:1485-1492.
39. Werner L, Apple DJ, Escobar-Gomez M, Ohrstrom A, Crayford BB, Bianchi R, Pandey SK. Postoperative deposition of calcium on the surfaces of a hydrogel intraocular lens. Ophthalmology 2000 Dec; 107(12):2179-2185.
40. Bausch & Lomb. Final report: Hydroview calcification, Aug. 23, 2001.
41. Mamalis N. Private communication, May 2003.
42. Internal Bausch & Lomb data, on file.
43. Baldeschi L, Rizzo S, Nardi M. Damage of foldable intraocular lenses by incorrect folder forceps. Am J Ophthalmol. 1997 Aug;124(2):245-7.
44. Keates RH, Sall KN, Kreter JK. Effect of the Nd:YAG laser on polymethylmethacrylate, HEMA copolymer, and silicone intraocular materials. J Cataract Refract Surg. 1987 Jul;13(4):401-9.
45. Newland TJ, McDermott ML, Eliott D, Hazlett LD, Apple DJ, Lambert RJ, Barrett RP. Experimental neodymium:YAG laser damage to acrylic, poly(methyl methacrylate), and silicone intraocular lens materials. J Cataract Refract Surg. 1999 Jan;25(1):72-6.
46. Trinavarat A, Atchaneeyasakul L, Udompunturak S. Neodymium:YAG laser damage threshold of foldable intraocular lenses. J Cataract Refract Surg. 2001 May;27(5): 775-80.
47. Schauersberger J, Amon M, Aichinger D, Georgopoulos A. Bacterial adhesion to rigid and foldable posterior chamber intraocular lenses: in vitro study. J Cataract Refract Surg. 2003 Feb;29(2):361-6.
48. Erickson P. Effects of intraocular lens position errors on postoperative refractive error. J Cataract Refract Surg 1990 May; 16(3):305-311.
49. Mamalis N, Spencer TS. Complications of foldable intraocular lenses requiring explantation or secondary intervention--2000 survey update. J Cataract Refract Surg. 2001 Aug; 27(8):1310-7.
50. Amzallag T. Morphological compatibility of intraocular lens: an objective approach. Presented at ASCRS 1999.
51. Laube T. Comparative investigation of two acrylic intraocular lenses: Acrysof and Akreos Fit. Presented at ESCRS 2003.
52. Spath U, Liekfeld A, Hartmann C, Pham DT. [Evaluation of posterior capsule opacification after implantation of the akreos disc and akreos fit acrylic intraocular lenses - pilot studies] [Article in German]. Klin Monatsbl Augenheilkd. 2003 Oct;220(10):695-8.
53. Santiago PV. Evaluation of posterior capsular opacification with the Akreos Disc IOL: 2 year results. Presented at ASCRS 2002.
54. Davies G. Reliability of the Akreos Adapt, an original hydrophilic acrylic IOL. Poster at ESCRS 2002, presentation at ASCRS 2003.
55. Stachs O. Influence of intraocular lens design on posterior capsular opacification-an in-vitro study. Presentations at 2003 meetings of ESCRS and ASCRS.
56. Apple DJ, Peng Q, Visessook N, Werner L, Pandey SK, Escobar-Gomez M, Ram J, Auffarth GU. Eradication of posterior capsule opacification: documentation of a marked decrease in Nd:YAG laser posterior capsulotomy rates noted in an analysis of 5416 pseudophakic human eyes obtained postmortem. Ophthal. 2001 Mar; 108(3):505-18.
57. Ayaki M, Ishida Y, Nishimura E, Yaguchi S. Lens epithelial cell migration between posterior capsule and intraocular lens with variously finished posterior optic edge and two haptic angulations. Ophthalmic Res. 2003 Sep-Oct; 35(5):261-7.
58. Bertelmann E, Kojetinsky C. Posterior capsule opacification and anterior capsule opacification. Curr Opin Ophthalmol. 2001 Feb; 12(1):35-40.
59. Kohnen T. The squared, sharp-edged optic intraocular lens design. J Cataract Refract Surg. 2001 Apr; 27(4):485-6.
60. Kruger AJ, Schauersberger J, Abela C, Schild G, Amon M. Two year results: sharp versus rounded optic edges on silicone lenses. J Cataract Refract Surg. 2000 Apr; 26(4):566-70.
61. Nishi O. Effect of a discontinuous capsule bend (letter). J Cataract Refract Surg. 2003 Jun; 29(6):1051-2, author reply 1052.
62. Nishi O, Nishi K, Akura J, Nagata T. Effect of round-edged acrylic intraocular lenses on preventing posterior capsule opacification. J Cataract Refract Surg. 2001 Apr; 27(4):608-13.
63. Nishi O, Nishi K, Sakanishi K. Inhibition of migrating lens epithelial cells at the capsular bend created by the rectangular optic edge of a posterior chamber intraocular lens. Ophthalmic Surg Lasers. 1998 Jul; 29(7):587-94.

64. Nishi O. Posterior capsule opacification. Part 1: Experimental investigations. J Cataract Refract Surg. 1999 Jan; 25(1):106-17.
65. Nishi O, Nishi K, Wickstrom K. Preventing lens epithelial cell migration using intraocular lenses with sharp rectangular edges. J Cataract Refract Surg. 2000 Oct; 26(10):1543-9.
66. Nishi O, Nishi K. Preventing posterior capsule opacification by creating a discontinuous sharp bend in the capsule. J Cataract Refract Surg. 1999 Apr; 25(4):521-6.
67. Peng Q, Visessook N, Apple DJ, Pandey SK, Werner L, Escobar-Gomez M, Schoderbek R, Solomon KD, Guindi A. Surgical prevention of posterior capsule opacification. Part 3: Intraocular lens optic barrier effect as a second line of defense. J Cataract Refract Surg. 2000 Feb; 26(2):198-213.
68. Arne JL, Lesueur LC, Glabeke C. Implantation of a double-square-edges disc IOL - a 3 years follow-up. Presented at ASCRS 2001.
69. Lofoco G. Akreos Adapt IOL Implantation in 632 patients. Presented at the San Diego meeting of ASCRS, May 2004.
70. Robin H, Lumbroso JP, Vermelle JP. One-year results using a single piece hydrophilic acrylic PC IOL. Presented at 2002 meetings of ESCRS and ASCRS.
71. Schaumberg DA, Dana MR, Christen WG, Glynn RJ. A systematic overview of the incidence of posterior capsule opacification. Ophthalmology. 1998 Jul; 105(7):1213-21.
72. Tognetto D, Toto L, Ballone E, Ravalico G. Biocompatibility of hydrophilic intraocular lenses. J Cataract Refract Surg. 2002 Apr;28(4):644-51.
73. Werner L, Pandey SK, Apple DJ, Escobar-Gomez M, McLendon L, Macky TA. Anterior capsule opacification: correlation of pathologic findings with clinical sequelae. Ophthal. 2001 Sep; 108(9):1675-81.
74. Ursell P. Prospective randomized trial of the surface cytology of three different single-piece acrylic intraocular lenses. Presented at ESCRS 2003.
75. Smeets B. Personal experience with crossed bag/sulcus fixation of a 4-haptic IOL in the management of posterior capsular rupture. Presented at ESCRS 2002 and ASCRS 2003.
76. Altmann G. Internal Bausch & Lomb data, on file.