

CLINICAL SCIENCE-EXTENDED REPORT

Effect of the hydrophilicity of acrylic intraocular lens material and haptic angulation on anterior capsule opacification

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Br J Ophthalmol 2007;91:476–480. doi: 10.1136/bjo.2006.103390

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Accepted 7 November 2006
Published Online First:
15 November 2006

Aim: To evaluate the influence of hydrophilic and hydrophobic acrylic material and haptic angulation on anterior capsule opacification (ACO).

Methods: Prospective study on 53 patients with bilateral age-related cataract. Patients underwent standard cataract surgery by the same surgeon and randomly received a hydrophilic acrylic intraocular lens (IOL) in one eye and a hydrophobic acrylic IOL in the other eye. Forty five of these patients completed the one-year follow-up. The following parameters were assessed: decentration, buttonholing, anterolenticular gap (ALG), ACO, outgrowth and refractive outcome.

Results: At the one-year follow-up, ACO was seen in 80% of the hydrophilic and 100% of the hydrophobic IOLs. ACO was more intense in the hydrophobic IOLs ($p < 0.001$). Outgrowth was seen in 42% of the hydrophilic and 2% of the hydrophobic IOLs ($p = 0.0003$). No case of persisting ALG was seen in the hydrophobic IOLs, but in 42% of the hydrophilic IOLs. The refractive outcome was -0.29 (SD 0.56) dioptres for the hydrophilic and 0.003 (SD 0.44) dioptres for the hydrophobic IOLs ($p < 0.001$).

Conclusion: These results suggest that there is less ACO in hydrophilic acrylic than in hydrophobic acrylic IOLs. Although material properties might play a role, the angulated haptics of the hydrophilic IOLs exert an additional effect by the persisting ALG and a lack of contact between the IOL and the anterior capsule.

Anterior capsule opacification (ACO) generally occurs early after surgery, sometimes within the first month.^{1,2} Excessive ACO can be accompanied by contraction of the capsulorhexis or even capsular phimosis^{3–6} and can lead to decentration of the intraocular lens (IOL), partial or total buttonholing of the rhexis, and IOL optic and axial shift of the IOL leading to ametropia.

Additionally, the whitening of the anterior capsule covering the IOL optic can hinder the visualisation and treatment of the peripheral retina. Extended capsular contraction has been reported in eyes with high myopia, pseudo-exfoliation, uveitis, pars planitis, diabetes mellitus and retinitis pigmentosa.^{7–9} However, it also occurs to a certain extent in normal eyes after standard cataract surgery. The major factors that have been discussed as contributing to ACO and contraction of the capsulorhexis are: IOL material and surface properties,¹⁰ and size and overlap of the continuous curvilinear capsulorhexis.^{11,12}

The purpose of this study is to evaluate the influence of IOL material and haptic design on ACO with hydrophilic and hydrophobic acrylic IOLs.

MATERIALS AND METHODS

The ACR6D SE (Laboratoires Cornéal®, Paris, France) is a single-piece IOL made from a hydrophilic acrylic copolymer of hydroxyl-ethyl methacrylate (HEMA) and ethyl methacrylate (EMA) with a water content of 26%. It has an optic with a diameter of 6.0 mm and an overall length of 12.0 mm. The optic has a sharp posterior edge. The ACR6D SE has 10° angulated haptics.

The AcrySof® SA60AT (Alcon® Fort Worth Tx, USA) is a single-piece non-angulated IOL made of hydrophobic acrylic material, comprising a biconvex optic with a diameter of 6.0 mm and an overall length of 13.0 mm. The optic has a sharp anterior and posterior edge.

Fifty three consecutive patients with age-related cataract were included in this prospective study at the Department of Ophthalmology, Medical University of Vienna. Inclusion

criteria were bilateral age-related cataract. Exclusion criteria were a history of other ocular diseases or prior intraocular surgery, laser treatment, diabetes requiring medical control, glaucoma and retinal pathology that would make a post-operative visual acuity (VA) of 20/40 (decimal equivalent: 0.5) or better unlikely. All the research and measurements followed the tenets of the Helsinki Declaration. The approval of the ethics committee of the Medical University of Vienna and Vienna General Hospital was secured.

All patients underwent a preoperative examination and standard cataract surgery comprising peribulbar local anesthesia and a 3.2 mm limbo-corneal tunnel incision. After filling the anterior chamber with a viscoelastic material, a continuous curvilinear capsulorhexis (CCC) was performed, followed by hydro-dissection and phacoemulsification of the lens. All patients randomly received a hydrophilic acrylic IOL in one eye and a hydrophobic acrylic IOL in the other eye with an injector system.

The postoperative treatment consisted of prednisolone-acetate (Ultracortenol® Novartis, Berne, Switzerland) and diclofenac-sodium (Voltaren®, Novartis, Berne, Switzerland) eye-drops four times a day for 4 weeks. At the time of surgery, the patients had a mean (SD) age of 76.9 (6.4) years with 39 (74%) female and 14 (26%) male patients. Patients were examined at baseline and 14 (4) months (one-year follow-up) after surgery. Of 53 patients at baseline, 45 were available for the one-year follow-up.

At the one-year follow-up, ACO intensity was subjectively assessed at the slit lamp (fig 1) using four categories:

- none: clear (transparent) anterior capsule;
- mild: mild whitening without capsular folding;
- moderate: moderate whitening, sometimes with areas of capsular folding;

Abbreviations: ACO, anterior capsule opacification; ALG, anterolenticular gap; CCC, continuous curvilinear capsulorhexis; IOL, intraocular lens; LEC, lens epithelial cell.

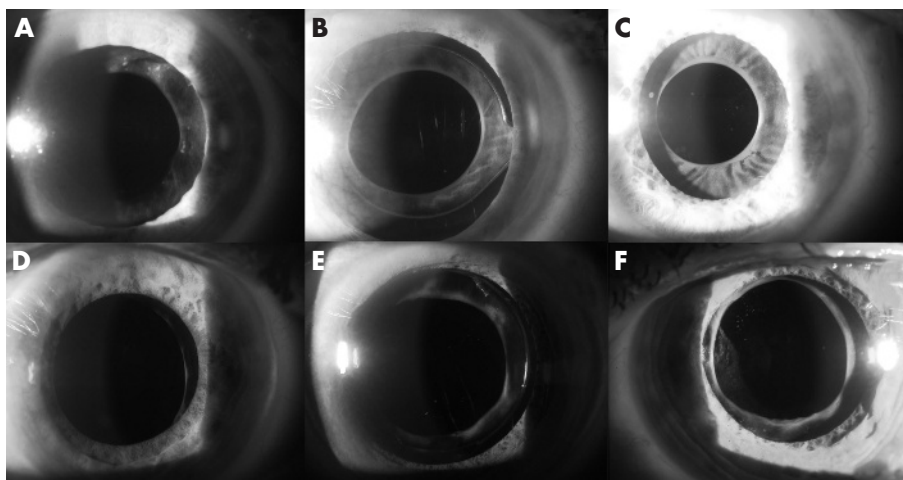


Figure 1 Anterior capsule opacification (ACO) intensity and pattern: **a** diffuse mild; **b** diffuse moderate; **c** diffuse severe; **d** rhexis edge mild; **e** rhexis edge moderate; **f** rhexis edge severe.

severe: intense whitening, with areas of capsular folding.

ACO was also divided into two morphological types: opacification of the “rhexis edge” and opacification of the entire capsule being in contact with the optic, i.e. “diffuse”. Gaps between the IOL-optic and the capsular bag (anterolenticular gap, ALG) were subjectively categorised into (none, small, moderate, large) at the slit-lamp (fig 2). Cases of outgrowth of lens epithelial cells (LECs) onto the IOL optic, decentration or buttonholing were documented. The IOL power and the targeted postoperative refractive error (spherical equivalent) were calculated using the SRK-T formula with biometric data obtained with the IOL-Master® (Carl Zeiss Meditec AG Jena, Germany). The postoperative refractive error was assessed at the follow-up. The refractive outcome was calculated as the difference between measured refractive error and targeted refractive error.

All statistical analysis was performed using NCSS® software. Analytical statistics were performed with paired tests as fellow eyes of each patient were compared (inpatient design) using McNemar’s test for categorical data and paired *t*-tests for ordinal and scaled data. *p* values are results of two-sided tests if not explicitly stated otherwise. Results were deemed to be statistically significant at $p < 0.05$. Spearman rank correlation coefficients were calculated with one-sided *p* values.

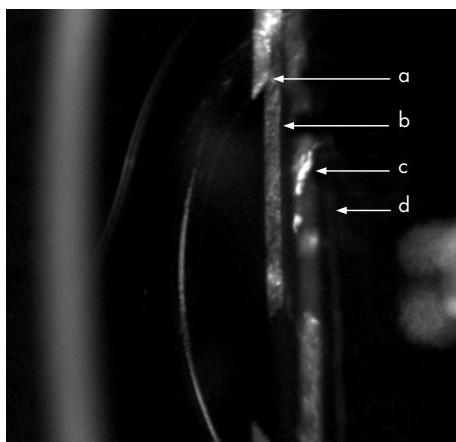


Figure 2 Hydrophilic intraocular lens (IOL) after one year: anterolenticular gap (ALG) small, ACO mild at rhexis edge. **a** rhexis edge ACO; **b** IOL anterior surface; **c** IOL posterior surface; **d** vitreous anterior limiting membrane.

RESULTS

In general, we found ACO in 67% of the hydrophilic and 100% of the hydrophobic acrylic IOLs (table 1). Hydrophilic IOLs had less intense ACO than hydrophobic IOLs ($p < 0.05$).

Diffuse ACO (fig 1a–c) was seen in 33% of the hydrophilic acrylic IOLs and 87% of the hydrophobic acrylic IOLs ($p < 0.05$). Rhexis edge ACO (fig 1d–f) was found in 33% of the hydrophilic acrylic IOLs and 13% of the hydrophobic acrylic IOLs but the difference of this distribution was not significant ($p = 0.088$). Outgrowth was seen in 40% of the hydrophilic acrylic IOLs and 2% of the hydrophobic acrylic IOLs.

In the hydrophilic acrylic IOLs (table 2), the intensity as well as the ACO type and outgrowth inversely correlated with the persistence of an ALG. The correlation was weak but significant for ACO intensity (fig 3; $c = -0.31$, $p = 0.018$), diffuse ACO ($c = -0.27$, $p = 0.035$) and outgrowth ($c = -0.33$, $p = 0.013$). In hydrophilic IOLs, there was no significant correlation found for rhexis edge type ACO (fig 4; $c = 0.022$, $p = 0.44$) and ALG. As there were no persisting ALGs in hydrophobic acrylic IOLs, no correlation could be computed.

During examination, we also found fibrosis in four hydrophilic IOLs at the IOL edge, which, to our knowledge, has not been described in the literature (fig 5). We could not reliably assess the true number of hydrophilic IOLs affected by this type of fibrosis as the necessary strong mydriasis could not be achieved in many eyes.

The refractive outcome for the hydrophilic acrylic IOLs was -0.29 (SD 0.56) dioptres (median: -0.16) and for the hydrophobic acrylic IOLs 0.026 (SD 0.44) dioptres (median: 0). The difference was significant ($p = 0.0001$).

DISCUSSION

In this study, hydrophobic and hydrophilic acrylic IOLs were found to have a different induction of ACO one year postoperatively. In general, hydrophilic IOLs induced less intense ACO. The proportion of ACO of the rhexis edge was higher in the hydrophilic than in the hydrophobic IOLs as well as the proportion of outgrowth. The hydrophilic IOLs more often had persisting ALG, which inversely correlated with ACO intensity, diffuse ACO and outgrowth but not with ACO of the rhexis edge.

ACO and IOL material

ACO is understood to be the result of a fibrous dysplasia of residual anterior lens epithelial cells (LECs) coming into contact with the anterior surface of the IOL.^{13 14} Hydrophilic acrylic material is said to be a better matrix for migration of

Table 1 Anterior capsule opacification (ACO) in hydrophilic and hydrophobic acrylic intraocular lenses (IOLs): detailed results after one year

	Hydrophilic	Hydrophobic	p
ACO intensity	67% (30)	100% (45)	0.0000016
None	33% (15)	0% (0)	
Mild	51% (23)	33% (15)	
Moderate	16% (7)	56% (25)	
Severe	0% (0)	11% (5)	
ACO rhexis edge	33% (15)	13% (6)	0.088
ACO diffuse	33% (15)	87% (39)	0.000016
Outgrowth	40% (18)	2% (1)	0.00034
Refractive outcome (SD)	-0.29 (0.56)	0.03 (0.44)	0.0001
Decentration	2%(1)	0% (0)	—
ALG			0.00013
None	58 (26)	100% (45)	
Small	27 (12)	0% (0)	
Moderate	9 (4)	0% (0)	
Large	7 (3)	0% (0)	
Buttonholing	2%(1)	0% (0)	—

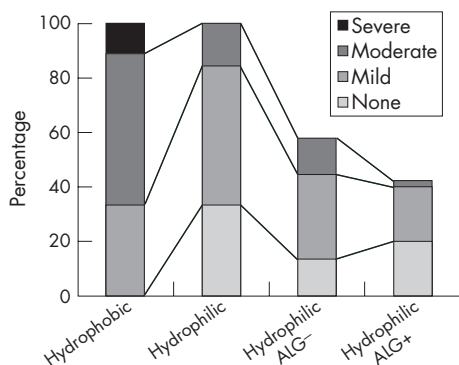
cells,¹⁵⁻¹⁷ i.e. has worse capsular biocompatibility, but adheres less to inflammatory cells,^{10,18} that is has better uveal biocompatibility than hydrophobic acrylic material or silicone.¹⁹⁻²¹

Saika *et al*²² suggest that the biocompatible hydrophilic acrylic material allows more postoperative LEC proliferation, maintaining an active wound-healing reaction with continuous cell proliferation and an epithelial-cell phenotype. On the contrary, in hydrophobic IOLs, cells would switch to a fibroblast-like phenotype.

Whereas the ACO of hydrophobic acrylic single-piece IOLs is already well described in the literature, no studies for hydrophilic acrylic IOLs with angulated haptics are available. The hydrophilic acrylic material (HEMA/EMA) used in the ACR6D and ACR6D SE is different from other hydrophilic IOL materials described so far and has a water content of 26%. For the ACR6D, the predecessor of the ACR6D SE, a hydrophilic acrylic IOL made of the same material but without angulated haptics, Tognetto *et al*²³ found ACO in 100% after 2 years. The ACR6D had higher ACO rates than AcrySof® and Hydroview® IOLs. High ACO rates for the ACR6D were also found by Park *et al*.²⁴

ACO and haptic angulation

Compared with Tognetto's and Park's findings, less ACO was found in the hydrophilic IOLs in our study. As the inverse correlation of ACO intensity and ALG suggests, this could be explained by the haptic angulation, a new feature of the ACR6D SE.

**Figure 3** ACO intensity in hydrophilic and hydrophobic IOLs and ALG after one year.

The haptic angulation could have prevented permanent contact of the anterior capsule and the IOL. This would lead to less intense ACO than one could have expected from the ACR6D SE's material and the broad fenestrated haptics, which per se would have offered more contact area with the anterior capsule leading to more intense ACO.²⁵ Therefore, haptic angulation and its influence on the contact between the anterior capsule and the IOL seem to be an important determinant for ACO.

ACO of the rhexis edge and IOL edge

Only a few studies have discerned diffuse ACO and ACO of the rhexis edge.²¹ Although Werner *et al*²⁵ defined rhexis-edge-related ACO as a more minor degree of ACO than diffuse ACO, we chose to define the rhexis edge ACO as a category of its own. In this study, in the hydrophilic acrylic IOLs, the incidence of ACO of the rhexis edge did not correlate with a persisting ALG. Several reasons might explain this.

As Saika *et al*²² indicated in a histopathologic study, LEC proliferation was more marked at the edge of the anterior capsulotomy with a hydrogel IOL than with IOLs of other materials. Although the phenotype of LECs in hydrophilic acrylic IOLs seems to be less fibroblastic, there is expression of α -smooth-muscle actin, a contractile protein expressed in myofibroblasts, collagen I and III, both usually expressed in fibroblastic cell types but not in epithelial cells.²² Perhaps marked proliferation of LECs at the rhexis edge in hydrophilic establishes contact of the rhexis edge and the IOL. It also seems possible that the trauma of the capsulorhexis can, per se,

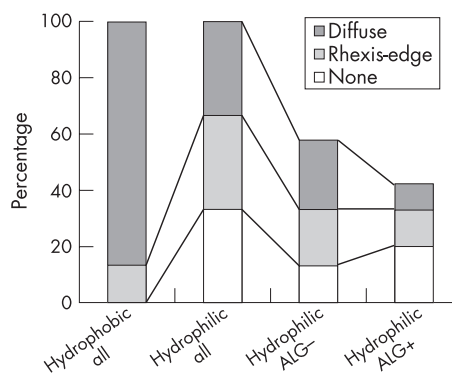
**Figure 4** ACO types in hydrophilic and hydrophobic IOLs and ALG after one year.

Table 2 ACO intensity and types in hydrophilic IOLs with and without anterolenticular gap (ALG)

	ALG –	ALG +	Correlation coefficient	p (one-sided)
Intensity			–0.31	0.018
No	13% (6)	20% (9)		
Mild	31% (14)	20% (9)		
Moderate	13% (6)	2% (1)		
Severe	0% (0)	0% (0)		
Rhexis edge	20% (9)	13% (6)	–0.022	0.44
Diffuse	24% (11)	9% (4)	–0.27	0.035
Outgrowth			–0.33	0.013
No	27% (12)	33% (15)		
Yes	31% (14)	9% (4)		

induce fibrosis of the rhexis edge or that the haptic angulation prevents permanent and/or entire contact of the anterior capsule and the IOL.

Fibrosis of the IOL edge in the hydrophilic IOLs in this study might be induced by the angulated haptics. These angulated haptics seem to exert a tangential stress onto the whole capsule. The originally round capsular bag could be deformed and pressed against the IOL in a 90° angle to the haptic insertion zones.

Currently, we have no data about how IOL-edge fibrosis affects the barrier effect of the sharp optic edge. Further studies are needed to clarify this form of fibrosis.

Capsular contraction

In our study, the CCC sizes were not significantly different between hydrophilic and hydrophobic IOLs one year post-operatively. In vitro studies indicate that α -smooth-muscle actin can be detected in LECs regardless of the hydrophilicity of the acrylic material²² these LECs are in contact with.

Clinically, Hayashi *et al*²⁶ found a more pronounced contraction of the anterior capsule in hydrophilic (Hydroview® H60M) IOLs than in hydrophobic acrylic IOLs (MA60BM) of the same material as used for the hydrophobic IOLs in our study. The hydrophobic acrylic IOL in their study, however, had 10° angulated haptics. Park *et al*²⁴ found no significant reduction of the area of the CCC in the ACR6D and the MA60BM.

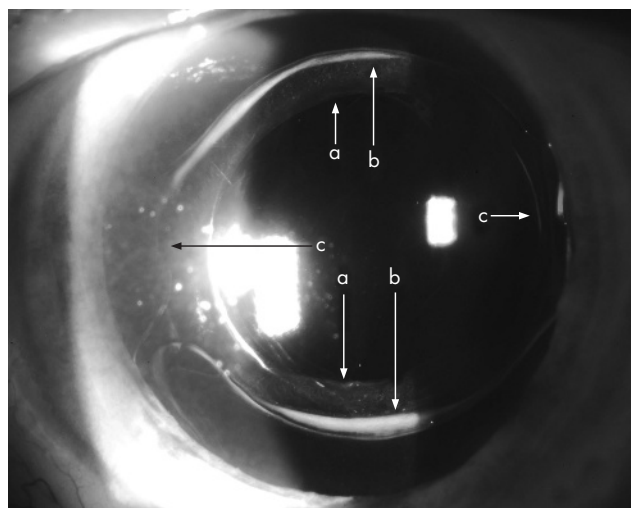


Figure 5 Fibrosis of the IOL edge in a hydrophilic IOL: a rhexis edge; b IOL-edge fibrosis; c haptic insertion.

Outgrowth

There was practically no outgrowth in the hydrophobic acrylic IOLs at the one-year follow-up but outgrowth was found in 40% of the hydrophilic IOLs in this study.

Outgrowth is frequent in all types of IOLs immediately after surgery. It is known to degenerate over time.²¹ The degeneration of outgrowth is more pronounced in hydrophobic acrylic materials, whereas hydrophilic acrylic IOLs are frequently found to have persisting outgrowth. It is generally believed that this is an effect of the hydrophilicity of the material which is promoting and prolonging an active wound-healing process.^{17–21} Therefore, LEC proliferation is more increased at the edge of the CCC with a hydrophilic acrylic IOL.²¹

Koch *et al*¹⁶ found outgrowth in 33% of hydrophilic acrylic IOLs (Hydroview®). Georgopoulos *et al*²⁷ found outgrowth in 62% one year after surgery and in 90% 2 years after surgery in the same IOL (Hydroview®).²⁸ For the ACR6D, outgrowth was found to be even higher than in other hydrophilic IOLs (Stabibag® and Hydroview®).^{18–23} In one of our previous studies²⁹ we only found 15% outgrowth in the same hydrophilic IOLs (ACR6D SE) as used for this study. One can expect lower outgrowth rates for (hydrophilic acrylic) IOLs when the anterior capsule is not in contact with the IOL optic.

Refractive error

For the hydrophobic IOLs in this study, the targeted spherical equivalent was not significantly different from the postoperatively measured spherical equivalent one year after surgery. However, the postoperatively measured spherical equivalent of the hydrophilic acrylic IOLs was lower than targeted. The difference was small (0.29 (SD 0.56) dioptres) but significant.

In part, an A-constant of 120.0 was used for the power calculation with the IOL-Master® whereas the recommended A-constant is 119.8. Further, in angulated IOLs a postoperative forward shift was detected,^{30–31} which was attributed to a decay of memory of the haptics. The weak intensity of ACO in the hydrophilic IOLs could add to a postulated anterior shift, as the anterior capsule could be a weak bearing for the haptics resulting in a weaker pressure towards the posterior.

We do not believe that ACO-induced capsular contraction³ or sharp-optic edges of IOLs resulting in less posterior fibrosis³¹ have significantly influenced the IOL position of the IOLs, as this would have led to a posterior shift and relative hyperopia.

CONCLUSION

In this study, we found less intense ACO in hydrophilic acrylic IOLs with haptic angulation than in hydrophobic acrylic IOLs without haptic angulation. Our results indicate that intense and diffuse ACO also occurs in hydrophilic acrylic IOLs when contact of the anterior capsule and the IOL is given. At least

some of the ACO differences between the IOLs seem to be due to haptic angulation. Hence, haptic angulation and anterior capsule contact seem to be an important determinant of ACO. Future studies should examine this variable, rather than purely at optic material.

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Competing interests: None.

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