Uveal and capsular biocompatibility of an intraocular lens with a hydrophilic anterior surface and a hydrophobic posterior surface

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PURPOSE: To evaluate the uveal and capsular biocompatibility of intraocular lenses (IOLs) with a hydrophilic anterior surface and a hydrophobic posterior surface in a rabbit model.

SETTING: Eye Center, Affiliated Second Hospital, College of Medicine, Zhejiang University, Hangzhou, China.

METHODS: Modified silicone IOLs were produced by grafting 2-methacryloyloxyethyl phosphorylcholine (MPC) onto the anterior IOL surface using a plasma technique. A contact-angle test characterized the hydrophilicity of the IOL surface; physical and optical properties were determined by State Food and Drug Administration (SFDA) standards. Rabbits had phacomulsification and implantation a modified silicone IOL, a control silicone IOL, or a hydrogel IOL. Postoperative inflammation was assessed by aqueous flare measurement, and PCO was evaluated by software analysis. Three months after surgery, attached cells on extracted IOLs were evaluated by light microscopy; PCO was evaluated by Miyake-Apple technique. Histologic sections of globes were used to assess lens epithelial cells (LECs) and extracellular matrix in the capsular bag.

RESULTS: Contact angle data showed the MPC-modified IOL had a hydrophilic anterior surface and hydrophobic posterior surface. The properties of the modified IOLs met SFDA standards. There was no statistical difference in aqueous flare between the IOL groups at any time. The modified and control IOLs had less PCO than the hydrogel IOLs ($P<.05$). There were fewer cells on modified IOLs than on silicone IOLs ($P<.05$). The LECs and cortical remnants on modified IOLs had a rapid, fibroblastic appearance at the optic periphery; the center was clear.

CONCLUSIONS: Results suggest that the MPC-modified IOL has excellent uveal and capsule biocompatibility from hydrophilic anterior surface and hydrophobic posterior surface properties, respectively.

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With the development of phacoemulsification and foldable intraocular lens (IOL) implantation, the material and design of IOLs have continually changed. One important parameter in successful IOL application, and hence a target for improvement, is the biocompatibility of IOL materials.[1]

Intraocular lenses are primarily located in the immediate vicinity of uveal tissue and are in direct contact with lens capsule tissue; this can cause a pathophysiologic reaction comprising inflammatory cells and lens epithelial cells (LECs). The reactive patterns of both types of tissue are generally considered indicators of IOL biocompatibility. Amon[2] proposed dividing IOL compatibility into uveal and capsular. Inflammatory cell reaction, especially foreign-body cells, is the most important parameter of uveal biocompatibility. The main parameters of capsular biocompatibility include anterior chamber opacification, posterior chamber opacification (PCO), and capsule contraction.[2,3] A particular IOL might have excellent uveal biocompatibility, characterized by few foreign-body giant cells on the IOL surface and low postoperative aqueous flare, and yet have poor capsular biocompatibility, characterized by lens epithelial overgrowth or capsule contraction.[4] Therefore, it would be beneficial to design an IOL that provides maximum uveal and capsular biocompatibility.

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The material of an IOL may affect the severity of the postoperative reaction. This is especially true of the IOL surface, which comes in direct contact with the ocular tissues, cells, proteins, and mediators of inflammation.[4] The surface characteristics, especially hydrophilicity and hydrophobicity, influence biocompatibility in different ways. Clinical observations indicate that uveal tissue reactions, such as macrophage and foreign-body giant-cell adhesion, aqueous flare, and synechias of the iris, are more commonly seen with hydrophobic IOLs than with hydrophilic IOLs. However, LEC proliferation and migration are seen more frequently with hydrophilic IOLs, resulting in a higher incidence of PCO than with hydrophobic IOLs.[5–7]

A 2003 American Society of Cataract and Refractive Surgery survey reported that silicone IOLs are second in popularity to hydrophobic acrylic IOLs.[8] Silicone IOLs have certain favorable properties. They are inert, flexible, and chemically stable; have a suitable refractive index; and have a relatively low PCO incidence.[9] However, bacteria and inflammatory cells adhere easily to the surfaces of silicone IOLs, which can lead to a high incidence of endophthalmitis, posterior synechias, and giant-cell adhesion.[10,11] Therefore, surface modification of the anterior surface of silicone IOLs may improve their biocompatibility and reduce complications without changing the bulk of the IOL.

With these factors in mind, we designed and prepared an IOL with a hydrophilic anterior surface and a hydrophobic posterior surface with the goal of reducing postoperative complications and achieving maximum uveal and capsular biocompatibility. The IOL design is patented in China.[12] The anterior surface of silicone IOLs was modified with a phospholipid-containing monomer (2-methacryloyloxyethyl phosphorylcholine [MPC]) using a plasma technique. The excellent biocompatibility of MPC-containing polymers is the result of their characteristics; they are inert in biological systems, reduce protein absorption, inhibit bacterial adhesion, and suppress cell attachment.[13,14] Therefore, biomaterials modified with phospholipid analogues have potential for use in a wide range of medical applications, including soft contact lenses, membranes for artificial kidneys, vascular prostheses, artificial joints, and urological devices with low biofouling.[13,15,16] Previous studies[17,18] found that after modification with MPC, the hydrophilicity of silicone IOLs improved permanently, with platelet, cell, and bacterial adhesion to the IOL surface suppressed in vitro. To evaluate the uveal and capsule biocompatibility of the new silicone IOL design, we implanted it and 2 other IOL types (hydrophobic silicone, hydrophilic hydrogel) in rabbit eyes after phacoemulsification. The inflammatory reaction and PCO development were then assessed by clinical and histopathological observation.

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MATERIALS AND METHODS

The hydrophobic silicone IOLs (both model KS-1, CanonStaar) were 3 piece with a biconvex 6.0 mm optic, 12.5 mm overall length, and modified C polyimide haptics. The hydrophilic hydrogel IOLs were model H60 M (Bausch & Lomb).

Modification of Anterior Surface

First, the posterior surface of silicone IOLs was embedded with paraffin to prevent it from being modified. Then, the IOLs were pretreated with air plasma (air pressure 0.4 Torr) for 5 minutes. The applied power was maintained at 60 W at a radio frequency of 13.5 kHz. After plasma treatment, a drop of 5 μL MPC aqueous solution (20 wt %) was placed on the anterior surface of the IOLs. The IOLs were then put in the discharge chamber for an additional 6 minutes of air plasma treatment. Finally, the MPC-modified anterior surface was washed with ultrafiltrated water for 24 hours to remove the nonbinding MPC monomers and paraffin wax.

Hydrophilicity Measurement

The hydrophilicity of the IOL surface was characterized with a contact-angle goniometer (OCA20, Dataphysics). Two microliters of distilled water was dropped on surfaces of the unmodified silicone IOL and the MPC-modified silicone IOL at room temperature with a relative humidity of 50% to 60% and a temperature of 25°C. The static water contact angle was determined from the image using imaging software. The value reported here is the mean of at least 8 experiments.

Optical and Physical Properties

The diopter and resolution of MPC-modified IOLs were measured with an IOL resolution tester (SFDA). Transmission was measured with a spectrophotometer. Antifatigue resistance was tested by bending and stretching the haptics 1 time per second for 2.5 million times.

Animals

Pigmented Dutch rabbits of the same age and sex weighing between 3 pounds and 4 pounds were used in the study. The animals were maintained in a controlled environment with a specified range of 65°F ± 5°F and a relative humidity of 30% or more. They were housed at the Zhejiang University Animal Maintenance Facility according to the Association for Research and Vision in Ophthalmology Statement for the Use of Animals in Ophthalmic and Vision Research. The rabbits were randomly assigned to 1 of 3 IOL groups: hydrophobic silicone (control group), MPC-modified silicone, and hydrophilic hydrogel. The IOLs were implanted in the right eye of the rabbits.

Surgical Technique

The same ophthalmic surgeon (K.Y.) performed all cataract surgery using a standard technique. Anesthesia of 2 g/kg ethylurethanm was administered intravenously. Pupils were dilated with 4 drops of tropicamide. Two drops of oxybuprocaine were applied topically for analgesia. The eye was draped, and a lid speculum placed.

A corneal paracentesis incision was made with a microsurgical steel knife. Sodium hyaluronate 1% was injected to deepen the anterior chamber. A 3.0 mm superior clear corneal incision was made. A continuous curvilinear capsulorhexis was created with a capsulorhexis forceps. Phacoemulsification of the lens was performed using irrigation with a balanced salt solution containing heparin (heparin sodium injection, USP; 1 mL of 1000 U/mL) and epinephrine (0.5 mL of 1:1000).[19] The remaining cortical material was then aspirated. The IOL was implanted in the capsular bag using the manufacturer's recommended foldable IOL injector system. Wound closure was achieved with a 10-0 monofilament nylon suture. At the end of surgery, a subconjunctival injection of dexamethasone 0.25 mg and tobramycin 20.00 mg was given.

The postoperative regimen was atropine sulfate 1% ophthalmic solution 2 times daily and tobramycin sulfate–dexamethasone ophthalmic solution 4 times daily for 4 weeks.

Aqueous Flare

To evaluate inflammation, aqueous flare (photons/millisecond) was measured preoperatively and 1, 3, 7, 30, 60, and 90 days postoperatively using a laser flare–cell meter (FC-1000, Kowa). Measurements were taken approximately 30 minutes after pupil dilation. Seven consecutive laser flare readings with background scatter of less than 10% were taken. The highest and lowest readings were discarded; the remaining 5 were averaged to obtain the flare measurement.

Posterior Capsule Opacification Analysis

Digital retroillumination photographs were taken with a fully dilated pupil 1, 3, 7, 30, 60, and 90 days postoperatively. The digital retroillumination photographs were imported into the Evaluation of Posterior Capsule Opacification 2000 software program for analysis. The boundaries of the posterior capsule and each opaque area of the posterior capsule were drawn on the stored images using the computer mouse so that the fraction of the opaque area could be calculated using the software. The density of the PCO was clinically graded as 0 (none), 1 (minimal), 2 (mild), 3 (moderate), or 4 (severe). The individual PCO score for each image was calculated by multiplying the density of the opacification by the fraction of the capsule area.

Cytology

Three months after surgery, the rabbits were killed humanely by an intravenous overdose of phenobarbital. The removed IOLs were fixed in methanol for 10 minutes and then stained with Giemsa. The IOLs were examined for the presence of cells on the anterior surface and photographed using phase-contrast microscopy (Leica, original magnification ×200). The number of cells on the IOLs was counted and scored as 0 (no cells), 1 (1 to 10 cells), 2 (11 to 50 cells), or 3 (more than 50 cells). The individual IOL cell score was calculated by 4 peripheral visual field cells and 1 central visual field cells for each IOL.

Gross Examination and Posterior Capsule Opacification Scoring

The enucleated globes were fixed in neutral buffered formalin 10% solution for 24 hours. They were then bisected coronally just anterior to the equator. Gross examination from the posterior aspect (Miyake-Apple view) was performed to assess PCO development. The severity of PCO was evaluated by estimating the cleanliness of each of 4 quadrants of the entire posterior capsule area within the IOL optic as follows: 0 (none), 1 (slight; iris pattern still detectable), 2 (obvious; iris pattern barely detectable), or 3 (distinct; iris pattern not detectable). All globes were analyzed for the following: central PCO (graded from 0 to 3), which corresponded to the area including the IOL optic within the pupillary area; peripheral PCO (graded from 0 to 3), which corresponded to the area including the IOL optic outside the pupillary area; and Soemmerring ring (graded from 0 to 3 in intensity and area), which corresponded to the area outside the IOL optic and inside the capsular bag. All capsular bags were divided into 4 areas. The intensity of each area was graded and the mean of all 4 areas calculated.

Histopathology

After gross examination, all globes were sectioned in the pupil–optic nerve plane, with the cuts oriented parallel to the IOL haptics. This secured the entire IOL in the capsular bag. After the globe was dehydrated and embedded in paraffin, 4.0 μm thick sections were taken from each eye. The sections were stained with hematoxylin–eosin, periodic acid-Schiff (PAS), and Masson trichrome for normal histologic evaluation. The sections were examined under light microscopy (Olympus Optical Co. Ltd.), and photomicrographs were taken for documentation.

Transmission Electron Microscopy

Posterior capsule specimens were fixed with 2.5% glutaraldehyde and then postfixed in 1.0% osmium tetroxide in 0.1 M phosphate buffer, dehydrated through a graded series of ethanol, and embedded in Epon 812 mixture. Ultrathin sections were electron stained with uranyl acetate and lead citrate and observed by transmission electron microscopy (TEM) (JEM-1230, JEOL, Ltd.).

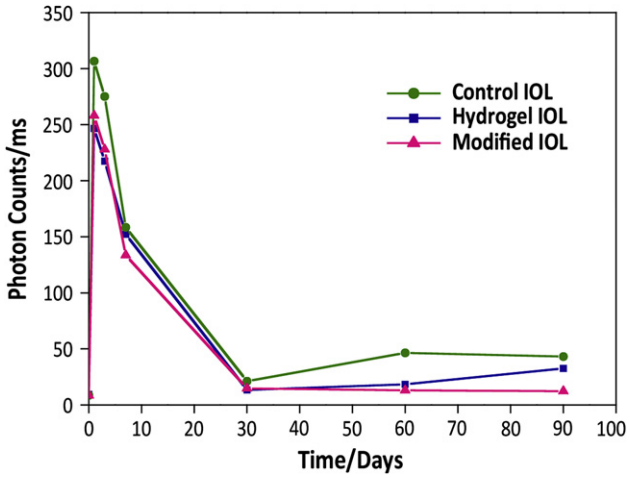

Figure 1. Fluctuation in aqueous flare by IOL groups 3 months postoperatively (IOL = intraocular lens).

Statistical Analysis

The nonparametric Kruskal-Wallis test was used to evaluate the differences in the degree of flare and PCO between the 3 IOL groups. The nonparametric Mann-Whitney test was used to determine differences between each set of 2 groups. A *P* value less than 0.05 was considered statistically significant.

RESULTS

Phacoemulsification with IOL implantation in the capsular bag was performed in the right eyes of 36 pigmented Dutch rabbits. There were 12 rabbits in the each IOL groups. There were no cases of postoperative infection.

Measurements showed that MPC modification of the anterior surface IOL surface decreased the water contact angle. The control IOLs had a water contact angle of 110 degrees. The anterior surface of the MPC-modified IOL had a water contact angle of 36 degrees; the posterior surface had the same water contact angle as the control silicone IOLs (ie, 110 degrees).

There were no statistically significant differences in the diopters or resolution results between the modified IOLs and the control IOLs ($P > .05$, Kruskal-Wallis test). The transmission test showed no absorption peak in the visible spectrum and no ultraviolet absorber degeneration or separation in the ultraviolet spectrum. The antifatigue test showed that all haptics endured stretching and bending, thus meeting SFDA standards.

Flare measurements in all 3 IOL groups reached an initial peak on the first day after surgery (Figure 1). Subsequently, there was a general tendency toward a decrease in flare in all 3 groups, with values dropping to nearly preoperative levels within 1 month. There was a second peak at 2 months in the control IOL group and at 3 months in the hydrogel IOL group. The flare level in the modified IOL group was low and stable from 1 to 3 months. There was no statistically significant difference between the 3 groups at any time point ($P > .05$, Kruskal-Wallis test).

The retroillumination photographs showed obvious PCO development 90 days after surgery. The computer analysis showed mean PCO scores of 0.72 $\pm$ 0.57 (SD) in the control IOL group, 0.57 $\pm$ 0.31 in the modified IOL group, and 1.63 $\pm$ 0.64 in the hydrogel IOL group; the PCO scores in the modified IOL group and control IOL group were statistically significantly lower than in the hydrogel IOL group ($P = .001$, Mann-Whitney test). There were no statistically significant differences between the control IOL and the modified IOL ($P = .755$, Mann-Whitney test). Figure 2 shows a retroillumination photograph of a rabbit eye in each IOL group. The eye with the modified IOL had an almost clear optic region and little peripheral fibrotic PCO. The eye with the control IOL had peripheral fibrotic PCO and capsule contraction, with a clear optic center. The eye with the hydrogel IOL had an obvious Elschnig body formation and fibrotic PCO in the peripheral and central posterior capsule.

Cytologic examination showed that the cellular components on the surface of control IOLs comprised small round cells, macrophages, fibroblast-like cells, and giant cells. There was less adhesion of small round cells, fibroblast-like cells, and epithelial cells on the surfaces of modified IOLs and hydrogel IOLs. Lens epithelial cells were seen on the surfaces of modified IOL and hydrogel IOL, especially near the IOL edge; they

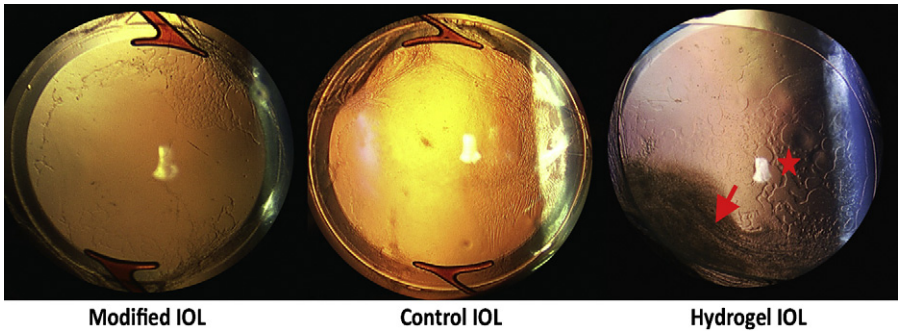

Figure 2. The retroillumination photographs of rabbit eyes 90 days after surgery. In the photograph of the eye with a hydrogel IOL, the star indicates an Elschnig body and the arrow indicates fibrotic PCO (IOL = intraocular lens).

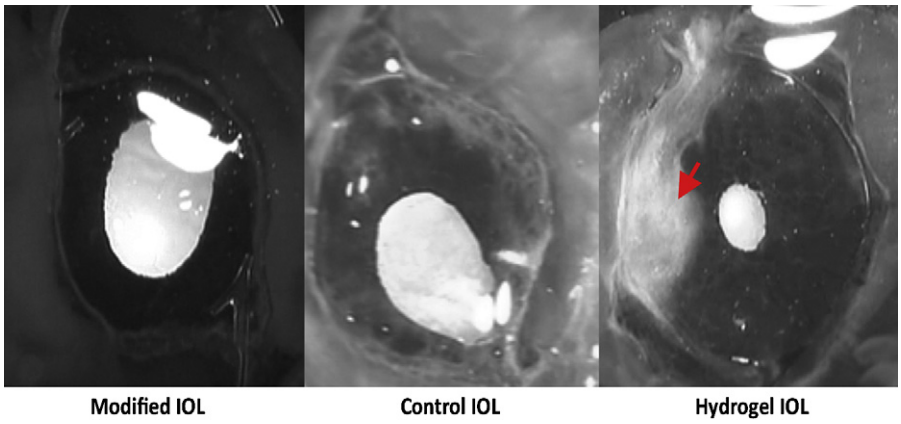

Figure 3. Gross photographs (Miyake-Apple view) of rabbit eyes. In the photograph of the eye with a hydrogel IOL, the arrow indicates abundant LEC migration onto the posterior capsule (IOL = intraocular lens).

became elongated and spread, forming an LEC monolayer in some ares. The mean cell grade was 2.24 ± 0.46 in the control IOL group, 1.54 ± 0.5 in the modified IOL group, and 1.72 ± 0.4 in the hydrogel IOL group; the differences between the 3 groups were statistically significant (P = .011, Kruskal-Wallis test). The modified IOL group had a statistically significantly lower cell count than the control IOL group (P = .007, Mann-Whitney test).

Figure 3 shows gross photographs of a rabbit eye in each IOL group from a posterior Miyake-Apple view. A posterior surface barrier effect of the hydrophobic biomaterial was seen with the modified IOL and control IOL. There was obvious opacity on the peripheral optic of the modified IOL and silicone IOL, although the optic center maintained clarity. In the eye with a hydrogel IOL, the edge barrier was destroyed by the formation of a vast Soemmerring ring; abundant LECs had migrated onto the posterior capsule, and the central posterior capsule was opaque.

Figure 4 shows the PCO and Soemmerring ring scores. The central PCO score was low in all groups; it was lowest in the modified IOL group and highest in the hydrogel IOL group. The difference between the hydrogel IOL group and the other IOL 2 groups was statistically significant (P = .023, Kruskal-Wallis test); the difference between the control IOL group and modified IOL group was not statistically significant (P = .630, Mann-Whitney test). The peripheral PCO scores were similar to the central PCO scores but had higher values. Most eyes developed a high degree of Soemmerring ring, with no statistically significant difference between the 3 IOL groups.

Histopathologic analysis of the rabbit eyes complemented the results observed macroscopically from the posterior view of the anterior eye segments. Figure 5 shows growth of LECs and cortex remnants starting from the haptics toward the visual axis and stopping at the optic periphery of the control IOL

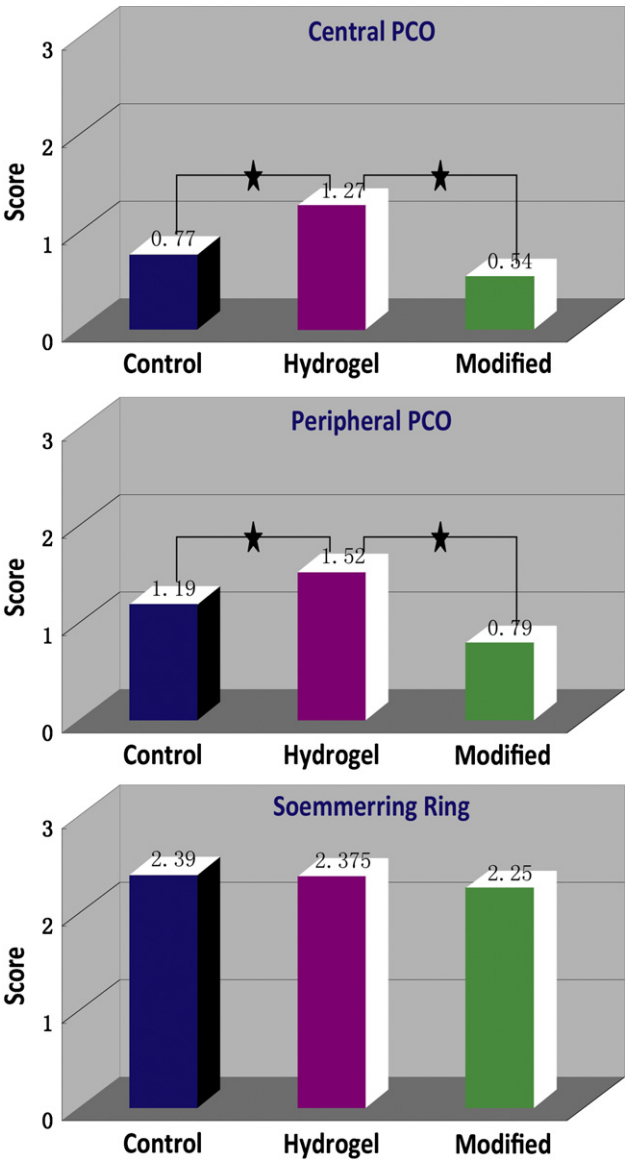

Figure 4. Posterior capsule opacification (PCO) and Soemmerring ring scores.

and modified IOL. The central posterior capsule was clear in both cases. In contrast, in the capsular bag containing the hydrogel IOL, the LECs and extracellular matrix (ECM) continued to grow toward the center of the optic area, leading to opacification of the central posterior capsule.

Figure 6 shows the TEM of PCO tissue. The PCO tissue in modified IOL specimens had LECs with an elongated fibroblastic appearance amid an accumulation of collagenous ECM substance. The PCO tissue in control IOL specimens had massive fibrotic LECs and accumulated ECM. The PCO tissue in hydrogel IOL specimens had relatively ovoid, less fibroblastic LECs with an amorphous ECM. The LEC density was higher in hydrogel IOL specimens than in the specimens of the other 2 IOLs.

DISCUSSION

As several studies[20–22] show, surface modification is a promising way to alter the character of the surface of an IOL without changing the bulk. In the present study, contact angle results showed that a new IOL with a hydrophilic anterior surface and a hydrophobic posterior surface was successfully prepared through plasma treatment. Physical and optical properties tests showed no obvious damage after MPC modification.

Our in vivo experimental study was designed to evaluate the uveal and capsular biocompatibility of the MPC-modified IOL. It has been suggested that blood–aqueous barrier (BAB) breakdown and inflammation after IOL implantation are indicators of uveal biocompatibility, both of which are related to the surface properties of the IOL biomaterial.[2,19] The fluctuation in aqueous flare values in the 3 IOL groups in our study give a general idea of the level of anterior chamber inflammation and BAB breakdown. The aqueous flare increase at 2 months in eyes with the control (unmodified) silicone IOL could be related to the iris posterior synechias and subsequent uveitis in 2 eyes with the IOL. There are other reports of higher relative flare values in eyes with uveitis and a silicone IOL.[23] The flare increase at 3 months in the hydrogel IOL group could be related to the obvious LEC proliferation on the IOL surface. Nishi et al.[24] and Nishi and Nishi[25] concluded that mediators are released during fibrous proliferation of LECs, causing renewed BAB breakdown. The curve of the flare level in the MPC-modified IOL group was long and flat, and there was no obvious rebound of flare over the follow-up. This may be associated with the comparatively mild foreign-body and LEC reaction resulting from the IOL's hydrophilic anterior surface and hydrophobic posterior surface.

Inflammatory cell adhesion and cell proliferation on the IOL surface are influenced by the contact angle of the IOL biomaterials.[20] The more hydrophilic the IOL surface, the less adhesive and proliferative the cells.[26,27] Hydrophilic heparin-surface-modified IOLs are one successful example of surface modification in which hydrophilic moieties are used to reduce protein and cell adhesion; these IOLs yield a significantly lower inflammatory response after cataract extraction than unmodified poly(methyl methacrylate) IOLs.[28] In our study, the MPC-modified hydrophilic IOL had less cell adhesion than an untreated silicone IOL in rabbit eyes. This agrees with findings in our previous studies[17,18] that showed that an MPC-modified hydrophilic surface can suppress platelet, cells, and bacteria adhesion in vitro. The hydrated phospholipid moieties on the surface likely exert hydrodynamic and steric hindrance effects when the IOL surface comes in contact with proteins and cells.[13]

Posterior capsule opacification can be categorized as regeneratory or fibrotic. Both types are initiated by the migration and proliferation of residual LECs from the lens equator in the space between the posterior capsule and IOL. The 3 main factors contributing to the incidence and degree of PCO are the IOL design, IOL material, and surgical technique.[29] Recent studies[3,30] suggest that a sharp-edged optic design might inhibit PCO to a greater degree but that IOL materials also play an important role in PCO development.[3,30] In the present study, we mainly assessed the capsular biocompatibility of the IOL material. To eliminate design-related factors, we implanted IOLs with the same round-edged optic design and 6.0 mm optic diameter. In addition, the same surgeon performed standard surgery, including 360-degree overlap of the anterior capsule by a 5.0 mm capsulorhexis to eliminate any surgical factors. Therefore, the degree of PCO in the 3 IOL groups was mainly related to the different IOL materials.

Software analysis and gross examination (Miyake-Apple view) showed that the MPC-modified silicone IOLs and unmodified silicone IOLs had lower PCO values than the hydrogel IOLs. Several studies have found that hydrophobic biomaterials, such as silicone and hydrophobic acrylic, are better at preventing PCO. Li et al.[31] compared a round-edged optic silicone IOL with a sharp-edged optic acrylic IOL and a sharp-edged optic silicone IOL in patients with senile cataract and found that the sharp-edged acrylic and sharp-edged silicone IOLs were similarly effective in inhibiting PCO after cataract surgery. A study by Vock et al.[32] with a 10-year follow-up concluded that silicone IOLs had lower PCO scores than hydrophobic acrylic IOLs. The effect of the IOL on PCO has been explained by various concepts, such as capsule

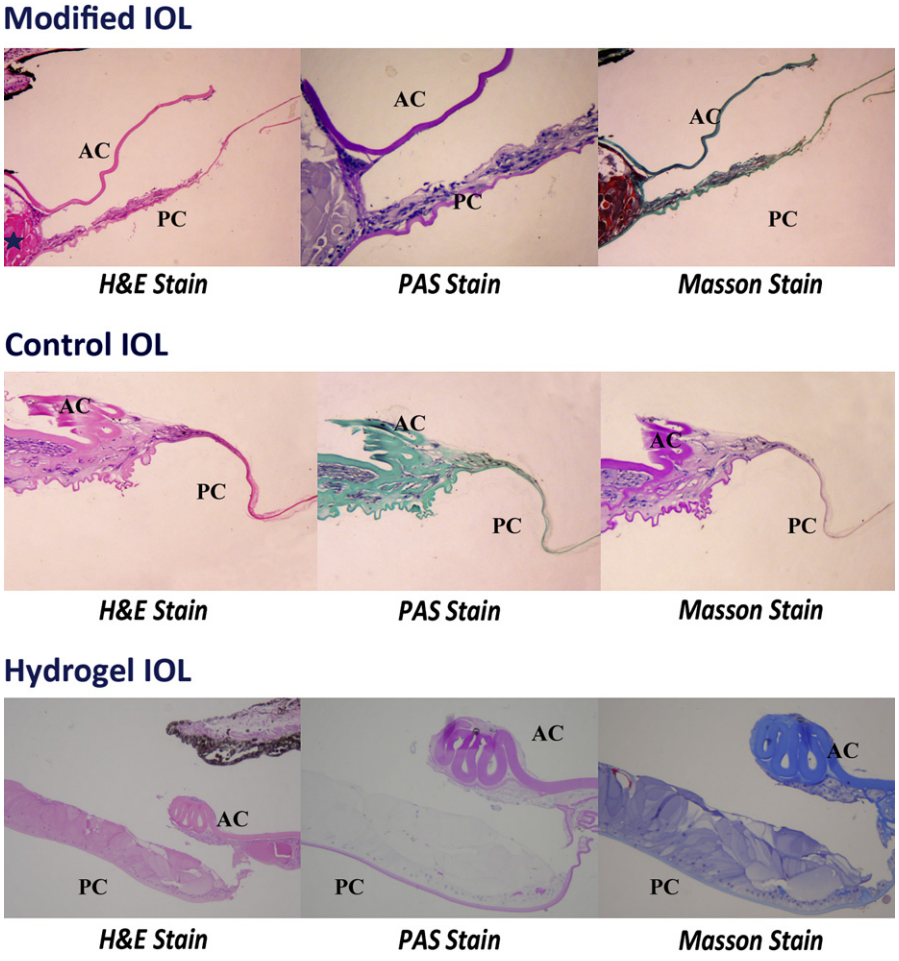

Figure 5. Light microscopic histology of the anterior fragment eye tissue and capsule (AC = anterior capsule; H&E = hematoxylin–eosin; IOL = intraocular lens; PAS = periodic acid-Schiff; PC = posterior capsule; *star* = LEC and cortex remnants).

stretching, compression, the barrier effect, and the no-space–no-cells theory. The exact cause of the low incidence of PCO with silicone IOLs remains to be determined. Some studies suggest it is likely caused by the high potential of silicone material to induce myofibroblastic contraction and collagenous sealing of the capsulorhexis rim, resulting in tighter wrapping of the capsular bag around the IOL. This wrapping may result in a better seal between the IOL optic and posterior capsule that prevents LEC migration, resulting in less PCO.[33,34] Our clinical, histopathological, and TEM observations showed that the LECs on the hydrophobic silicone posterior surface of modified IOLs had a rapid fibroblastic appearance, leading to capsule fibrosis at the edge of the IOL optic and myofibroblastic contraction of the capsule that inhibited LEC proliferation and immigration onto the center of the optic, leaving the central posterior capsule clear.

Several studies[6,9,10] report that hydrophilic acrylic IOLs have a higher PCO incidence and degree than silicone and hydrophobic acrylic IOLs. A possible explanation for the high incidence of PCO is that there is less

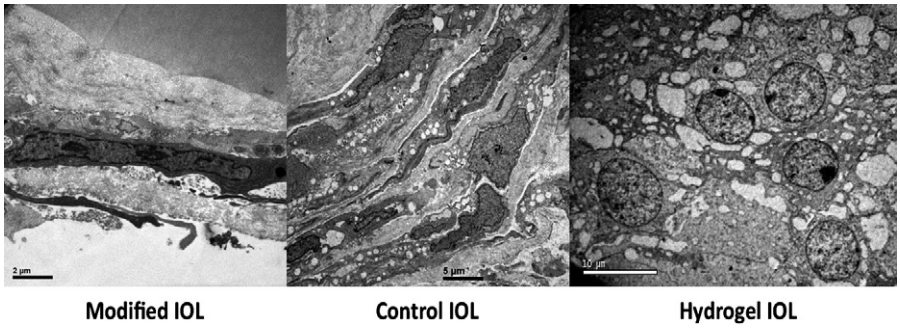

Figure 6. Transmission electron microscopy of the PCO specimens (IOL = intraocular lens).

epithelial–mesenchymal transition in LECs with this more biocompatible material. As a result, there may be less contraction-induced reduction in the size of the residual capsular bag, which would leave space and allow cells to migrate onto the inner surface of the posterior capsule before the posterior capsule adheres to the posterior surface of the IOL.[35] Our histopathologic and TEM evaluations of hydrogel IOLs showed the hydrophilic surface properties provide an optimum matrix for LECs and cortical proliferation and migration from the equatorial region toward the center of the visual axis, leading to the higher degree of PCO.

It has been proposed that inflammatory cells (eg, macrophages, giant cells) secrete cytokines, which may in turn affect the behavior of LECs, resulting in severe PCO.[35,36] In our study, the MPC-modified IOLs had lower flare values and a lower degree of PCO than the unmodified silicone IOLs but with no significant difference in PCO incidence between the 2 IOLs. A limitation of this study is the relatively small number of cases; further study using a larger sample number should be performed to confirm our findings.

In conclusion, a silicone IOL with an MPC-modified anterior surface was successfully produced. The IOL has a hydrophilic anterior surface while retaining the hydrophobic posterior surface. Our clinical and histopathologic results in rabbit eyes indicate that the modified IOLs induce a milder inflammatory reaction and lower incidence of PCO. These results indicate that the MPC-modified IOL can reduce postoperative complications and has good uveal and capsular biocompatibility as a result of the properties of its 2 different surfaces.

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