Experimental Investigation on Mechanism of Hydrophilic Acrylic Intraocular Lens Calcification

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Introduction - Purpose

Over the past 20 years small incision cataract surgery with implantation of foldable lens is the most common procedure for removing cataracts. Foldable IOLs biomaterials include silicone, hydrophobic acrylic and recently hydrophilic acrylic.

Despite their remarkable advantages, such as, better tolerance within the eye, high uveal biocompatibility, durability, increased UV blocking, one major disadvantage of hydrophilic IOLs has been the repeated reports of late postoperative lens opacification, associated with calcium depositions (Fig. 1).

Our purpose was to experimentally investigate the mechanism of IOLs calcification attributable to the formation of calcium phosphate deposits.

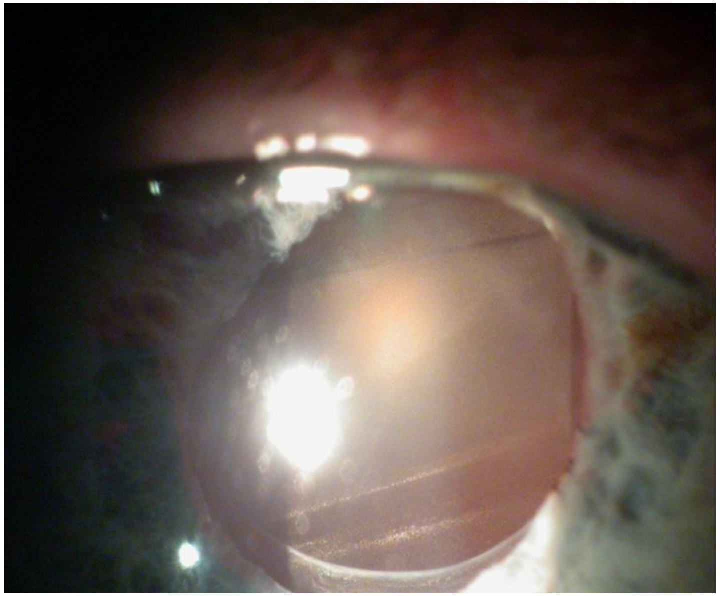

Figure 1. Slit-lamp appearance of an opacified IOL. A dusty haze covers its anterior surface.

Materials & Methods

An experimental model (Fig. 2) simulating the environment of IOLs into the eye was constructed in order to investigate the characterization and the kinetics of development of calcified deposits on IOLs, built of different materials.

A 10 ml double walled thermostated reactor (Fig. 3), manufactured of polyamide with glass windows, was used to simulate the anterior chamber. Simulated aqueous humor (SAH) was prepared using only inorganic components. SAH composition, typical for healthy subjects, was supersaturated with respect to calcium phosphate phases.

Inside the model reactor, three IOLs were placed in a special holder in order to maximize the available total surface area exposed to the SAH.

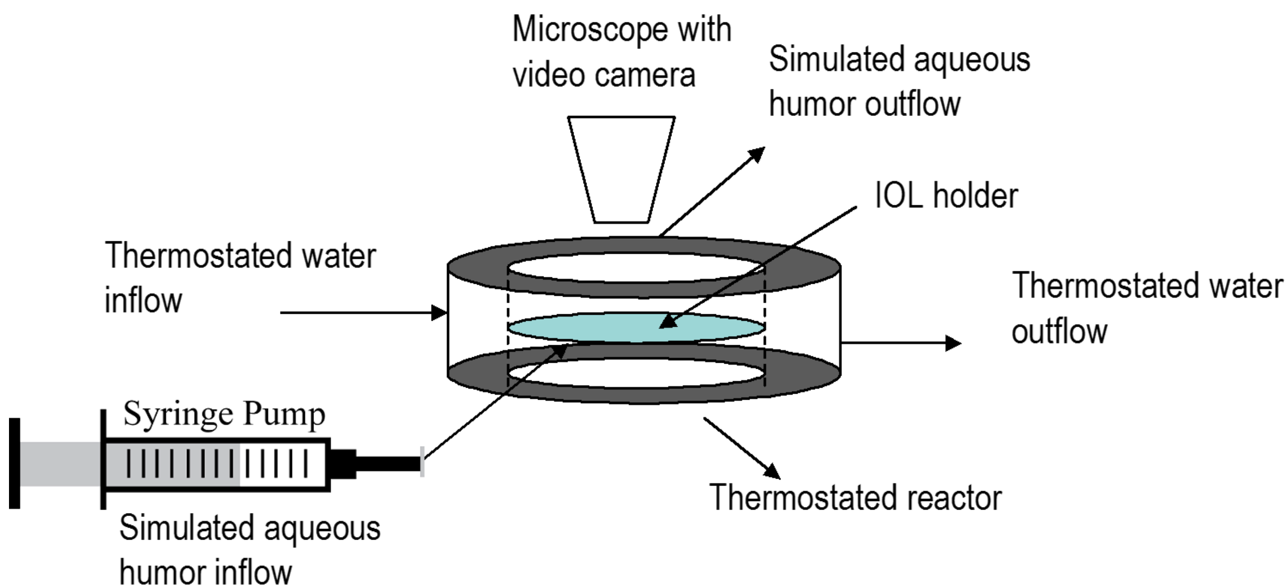

Figure 2. Experimental model simulating the environment of IOLs into the eye

Materials & Methods

SAH was continuously injected into the reactor using a variable speed pump (Fig. 4). At flow rate 0.2ml/h, three hydrophilic acrylic IOLs (26% water content) were tested simultaneously. The experiments were done at 37.0±0.2˚C, pH 7.40 at sustained supersaturation. The observation of IOLs was done *in situ* daily by optical microscopy, for the assessment of the opacification progress.

Four months after the initiation of the experiment, one of the lenses was removed and inspected. The morphology of the deposits was examined using Scanning Electron Microscopy (SEM). The composition of the deposits was identified by microanalysis with Energy Dispersive x-ray Spectroscopy (EDS).

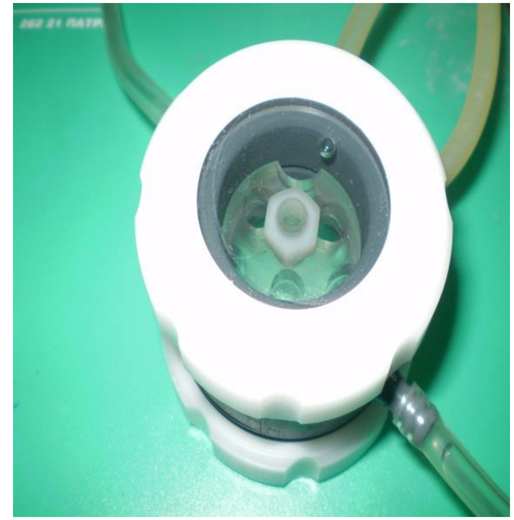

Figure 3. The thermostated reactor simulating the anterior chamber's conditions.

Figure 4. The pump used for the injection of SAH

Results

SEM investigation showed the development prismatic nanoparticle deposits of calcium phosphate crystallites typical of hydroxyapatite (HAP) **in the interior** of the IOL (Fig. 5), approximately 10 μm from the surface (Fig. 6).

EDS confirmed the chemical composition of the deposits (Fig. 7).

These prismatic HAP nanocrystals, however, were not observed on the IOL's surface.

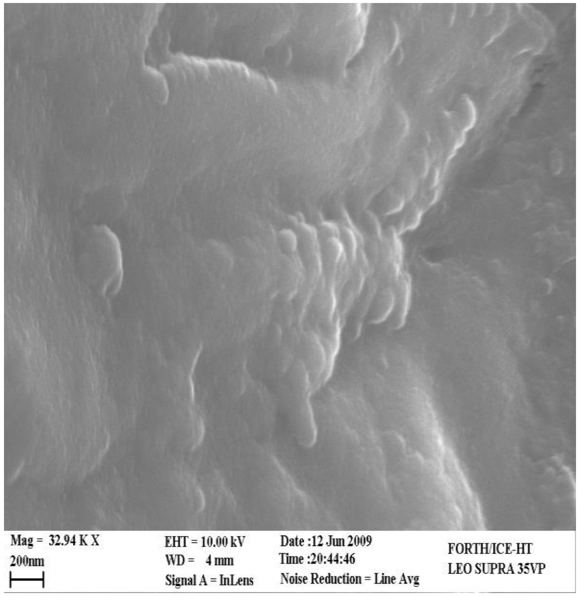

Figure 5. SEM image showed HAP prismatic nanoparticle deposits in the IOL interior

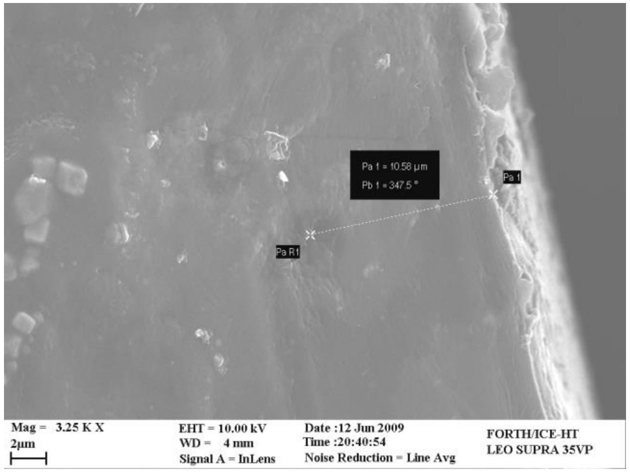

Figure 6. HAP was deposited at about 10 μm from the IOL surface

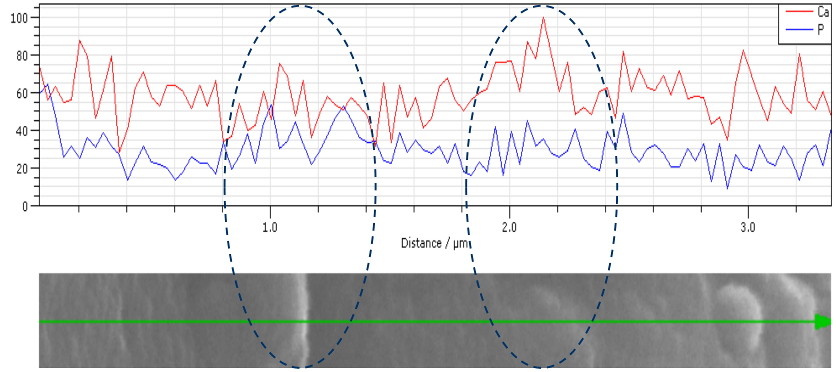

Figure 7. EDS analysis showed peaks corresponding to calcium and phosphorus

Conclusions

In agreement with earlier reports by our group and in the literature, IOLs' opacification is due to calcification.

The formation of calcific deposits may be explained by the fact that the aqueous humor is supersaturated with respect to different phases of calcium phosphate salts. HAP, the thermodynamically most stable calcium phosphate, is the predominant phase.

Surface hydroxyl groups of the polyacrylic materials facilitate nucleation and growth of crystals. Higher extent of hydration leads to higher ionization of the surface functional groups, promoting calcification.

IOL's calcification is a dynamic process which seems to be initiated from the interior of the IOL.

At least two years of follow-up is needed for all patients with implanted hydrophilic intraocular lenses.