XXXIV Convegno Nazionale di Idraulica e Costruzioni Idrauliche
BARI - 8-10 Settembre 2014

Fluid dynamics of the anterior chamber in the presence of intraocular lenses

R. Repetto[1], J. O. Pralits[1] and J. H. Siggers[2]

[1]Dipartimento di Ingegneria Civile, Chimica e Ambientale, Università di Genova
rodolfo.repetto@unige.it, jan.pralits@unige.it
[2]Department of Bioengineering, Imperial College London (UK), j.siggers@imperial.ac.uk

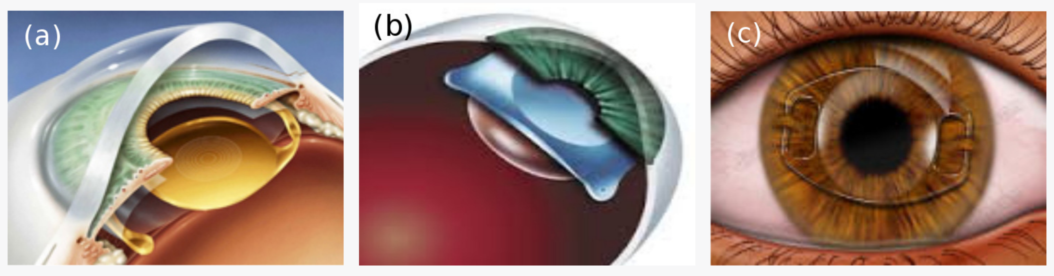
Abstract

Purpose: To investigate the effects of implantation of a phakic iris-fixated intraocular lens (IOL) on aqueous flow in the anterior chamber.
Methods: We use a mathematical model to study fluid flow in the anterior chamber in the presence of a IOL. The governing equations are solved numerically using the free software OpenFoam.
Results: IOL implantation has very little influence on the pressure in the anterior chamber, unless the IOL is placed very close to the iris. The presence of the IOL significantly modifies the thermal flow induced by temperature differences between the cornea and the posterior region of the chamber. The maximum corneal WSS does not increase for normal IOL placement. Relatively large values of the WSS can be attained on the iris.
Conclusions: The numerical simulations suggest that cell detachment from the iris and cornea, which is a known possible complication of IOL implantation, is not induced by large values of the WSS. In the case of correct IOL placement the intraocular pressure (IOP) is almost unaffected.

Intraocular lenses (IOL)

- **Cataract.** Artificial intraocular lenses (IOLs) replace the eye's natural lens that is removed during cataract surgery.
- **Refractive correction.** IOLs are increasingly adopted to correct refractive errors and provide spectacle independence.

Types of intraocular lenses



- **(a) pseudophakic IOL.** This is the most common type of IOL. It is implanted during cataract surgery, after the crystalline lens has been removed.
- **(b) Implantable contact IOL.** The lens is inserted behind the iris and in front of the natural lens where it cannot be seen or felt.
- **(c) Iris-fixated IOL.** The lens is implanted in the anterior chamber, in front of the iris.

Possible complications with iris-fixated IOLs

- **Loss on corneal endothelial cells,**
- loss of pigment cells from the iris,
- increase of IOP,
- cataract.

Mechanisms inducing flow

- **Flow induced by aqueous production/drainage**
  Aqueous is produced at the ciliary processes and drained at the trabecular meshwork.
- **Pupil contraction-expansion**
  During pupil contraction/dilation aqueous flows from the posterior to the anterior chamber at a relatively high rate.
- **Buoyancy driven flow due to a temperature difference between the cornea and the iris**
  Buoyant flow is generated owing to temperature differences between the inner surface of the cornea and the back part of the anterior chamber.
- **Eye rotations** (not considered here)

Numerical tools

- We performed numerical simulations using the open source software OpenFoam (Open Source CFD Toolbox by OpenCFD Ltd, http://www.openfoam.com/), which uses the finite volume method to solve the governing equations.
- Three-dimensional meshes are generated using the OpenFoam tool snappyHexMesh.

Equations of motion

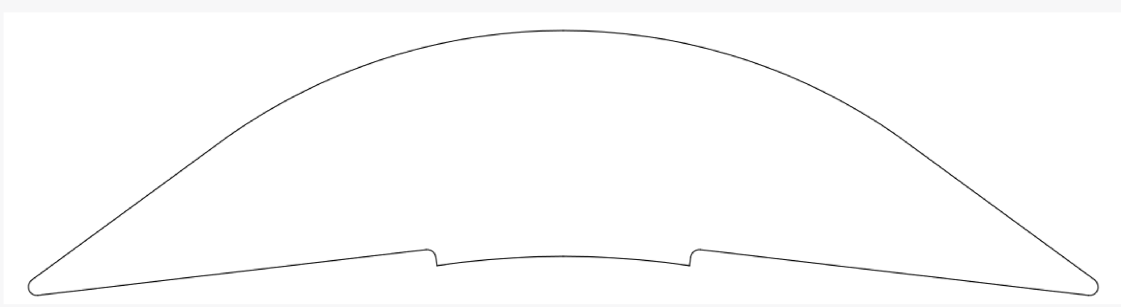
- We solved the Navier-Stokes equations for a Newtonian incompressible fluid.
- In the case of buoyancy driven flow we adopt the Boussinesq approximation, according to which changes in fluid density are only accounted for in the gravitational term in the Navier-Stokes equations.

Analytical results based on the lubrication theory

Geometry

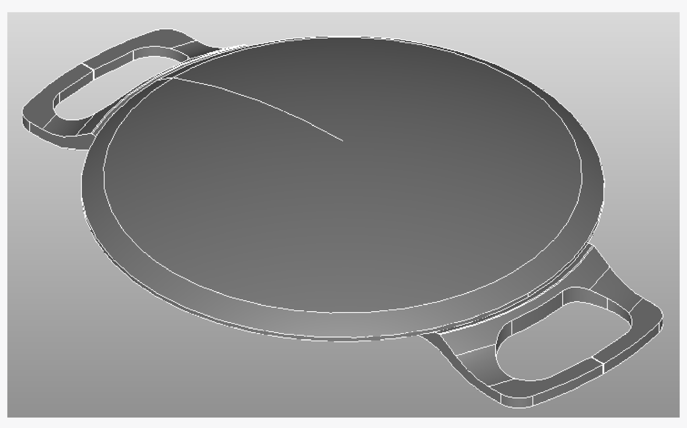
Shape of the anterior chamber

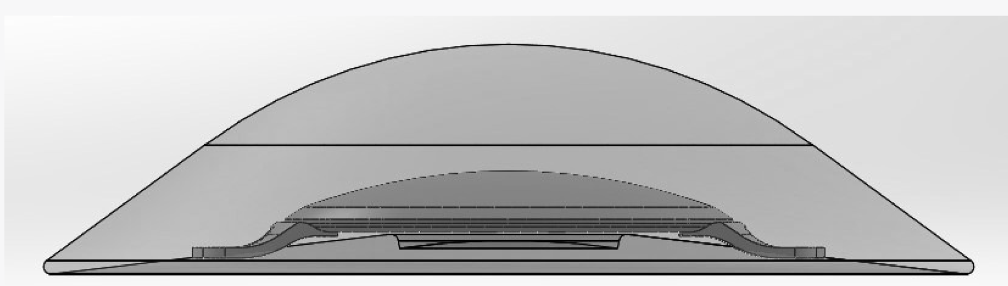
We employ an idealised axisymmetric shape of the anterior chamber.



Geometry of the iris-fixated IOL

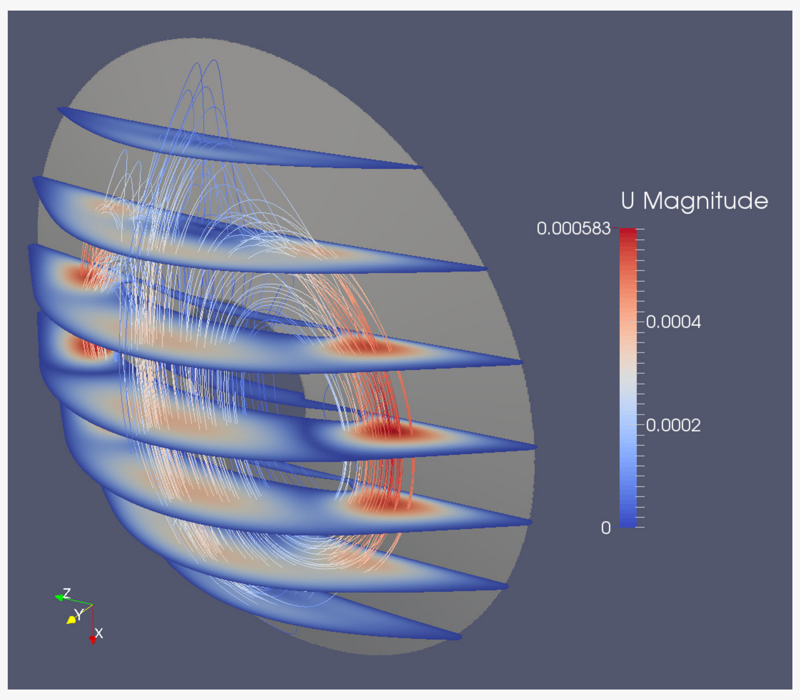
The IOL consists of a **body** and **haptics**. Most of the simulations are run neglecting the presence of haptics.





Examples of the results

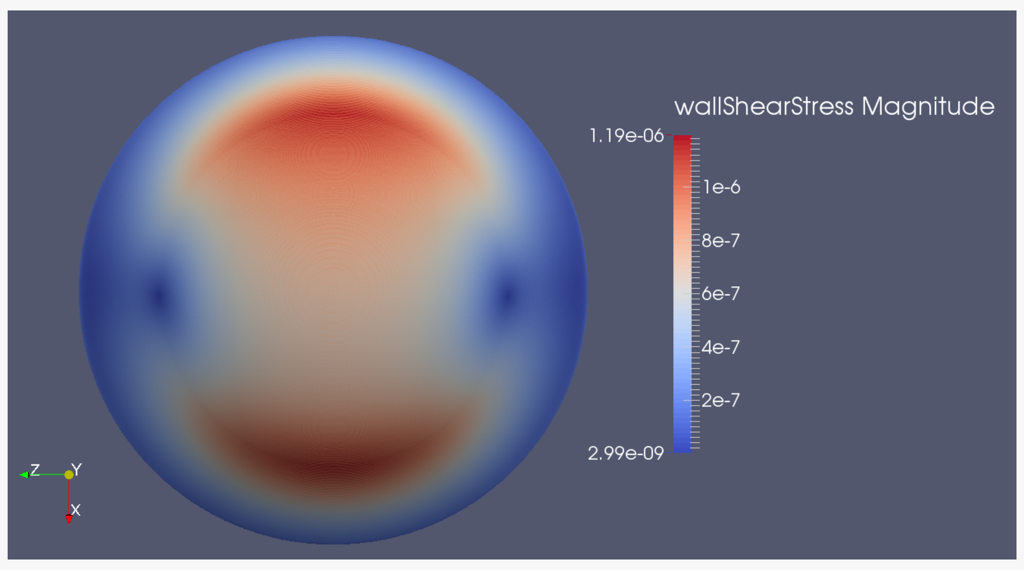
Numerical results for the buoyancy driven flow



Streamlines of the flow. Colours represent the velocity magnitude.

- The flow is highly three-dimensional.
- Fluid particles move around the IOL.

Wall shear stress on the cornea



Distribution of the (kinematic) WSS on the cornea.

- The (kinematic) WSS distribution on the cornea is significantly modified with respect to the case in which there is no IOL.

Conclusions

- Implantation on IOLs in the anterior chamber has very little influence on the IOP.
- The maximum values of the WSS do not change significantly.
- The WSS on the iris increases. The maximum values predicted by the model are, however, still relatively small.
- The fluid dynamics in the anterior chamber is significantly modified. However, the computed values of pressure and WSS are within a physiologically acceptable range (if the lens is properly positioned!).