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NON CONTACT TONOMETRY: A FLUID STRUCTURE INTERACTION STUDY

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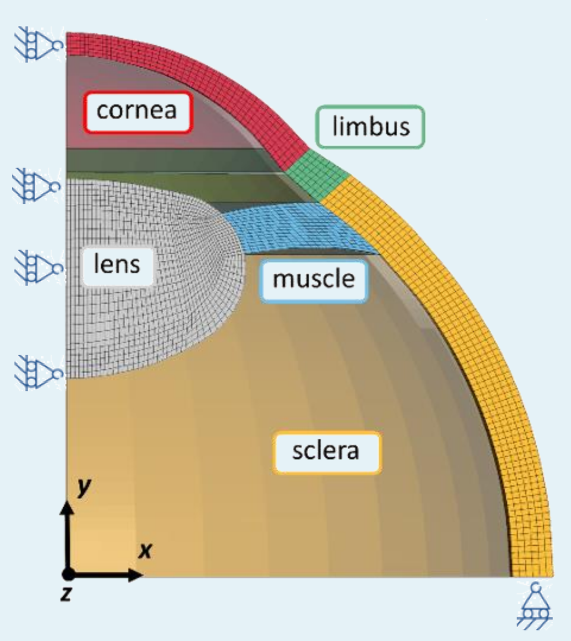
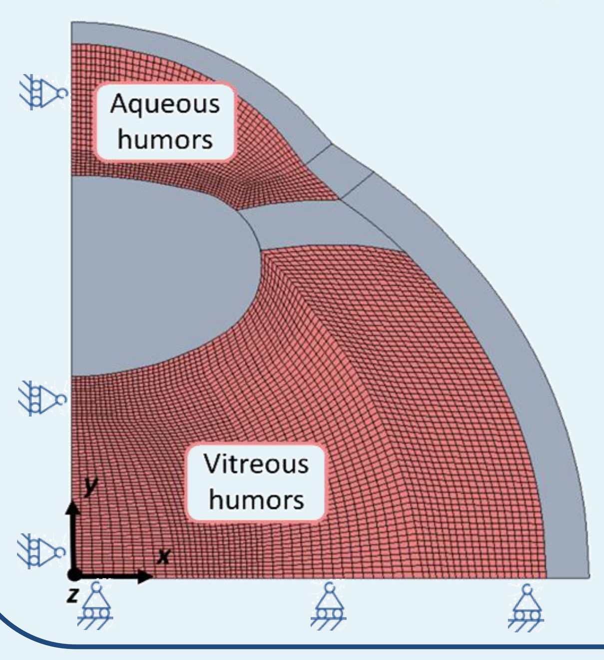
INTRODUCTION

The cornea is the primary refractive surface of the eye, responsible for approximately ⅔ of its optical power [1]. The corneal shape is the result of the equilibrium between its ***mechanical stiffness***, ***intraocular pressure*** (IOP), and the ***external forces*** acting upon it. An imbalance between these parameters can produce ocular pathologies which seriously affect patient sight. The Non Contact Tonometry (*Corvis-ST*) is a diagnostic tool that aims at determining the IOP and characterizing the mechanical properties of the corneal tissue by applying a **short high velocity air-jet** to the tissue. A deeper understanding of the process is required to **translate the results of the test into clinical data**. From a modelling perspective, the best numerical approach to reproduce the procedure is the Fluid Structure Interaction (**FSI**) modelling [3]. This work presents a FSI analysis to virtually apply an air-jet to a 3D idealized eye model.

METHODS

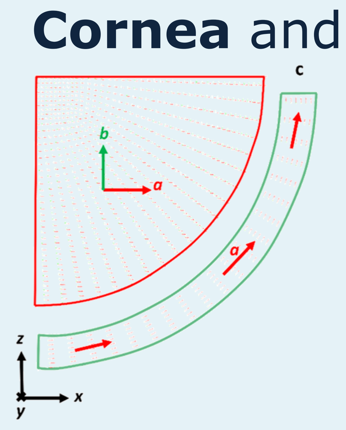
Eye model





Material Model

Cornea and **Limbus**: anisotropic hyperelastic material.



Cornea: two families of fibers perpendicular to each other.
Limbo: one circumferential family of fibers.
Isotropic Demirey formulation.
Anisotropic Holzapfel-Gasser-Ogden formulation.

$$\Psi = D_1[exp\{D_2(\bar{I}_1 - 3)\} - 1] + \frac{k_1}{2k_2}[exp\{k_2(\bar{I}_4 - 1)^2\} - 1] + \frac{k_3}{2k_4}[exp\{k_4(\bar{I}_6 - 1)^2\} - 1] + \frac{\kappa}{2}(J-1)^2$$

$D_1 = 2.77 * 10^{-4} MPa$ $k_1 = 0.0208\ MPa$ $k_3 = 0.0208\ MPa$

$D_2 = 120.6\ [-]$ $k_2 = 516.9\ [-]$ $k_4 = 516.9\ [-]$

$\kappa = 334.04\ MPa$

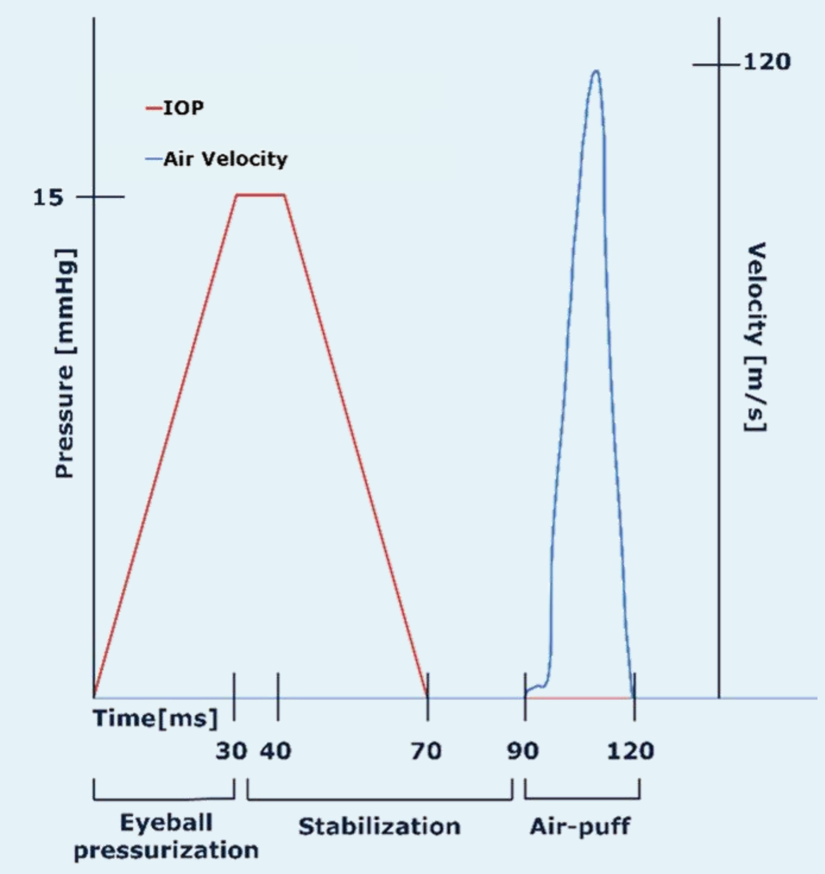
Sclera: Hyperelastic material: Yeoh model.

$$\Psi = C_{10}(\bar{I}_1 - 3) + C_{20}(\bar{I}_1 - 3)^2 + C_{30}(\bar{I}_1 - 3)^3 + \frac{\kappa}{2}(J-1)^2$$

$C_{10} = 0.81\ MPa$
$C_{20} = 54.05\ MPa$
$C_{30} = 2332.26 MPa$

Lens and **Muscle**: linear elastic material.
Humors: Newtonian fluids.
Air: incompressible fluid.

Boundary conditions

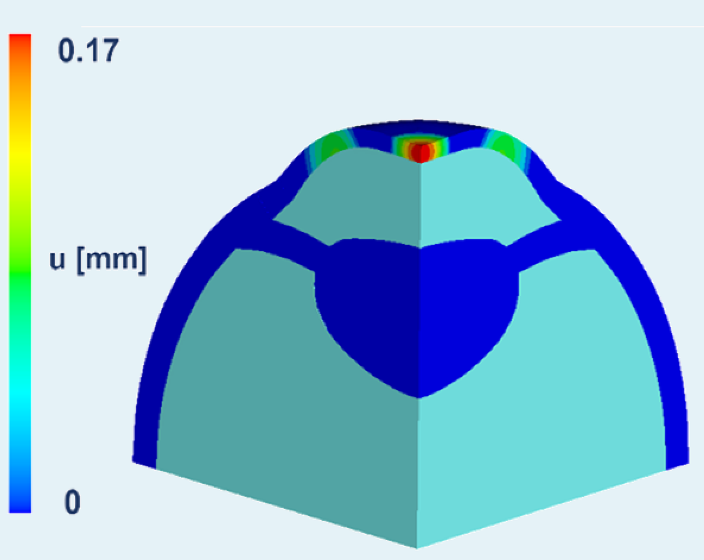


- Zero pressure is imposed as the outflow condition.

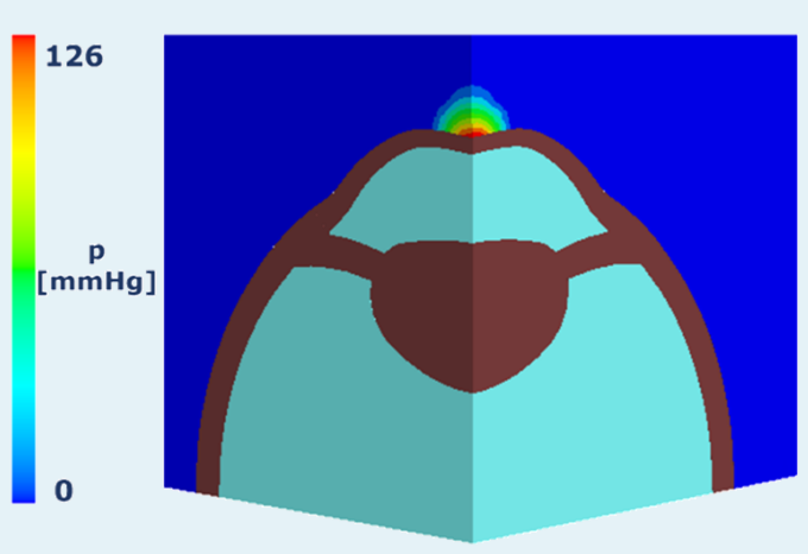
RESULTS

The Non Contact Tonometry monitors the bidirectional deformation of the cornea through two applanation points during loading (the cornea deforms inwardly) and unloading[1].

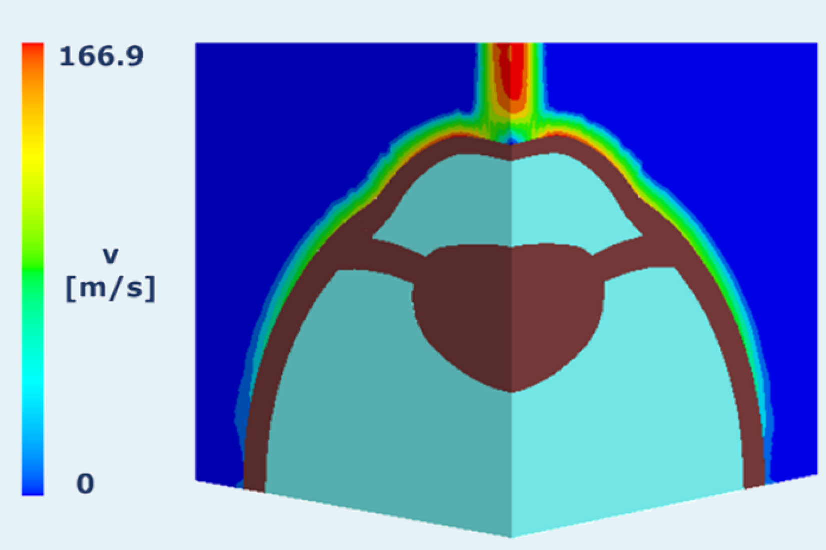
Corneal deformation
@maximum deformation point



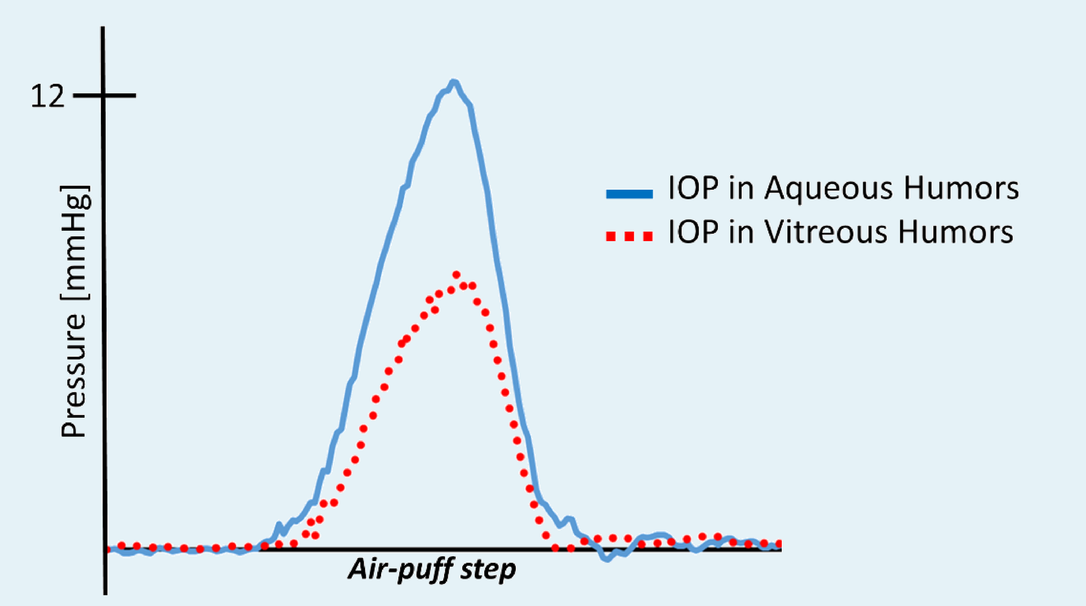
Pressure
@maximum deformation point



Velocity
@maximum deformation point



Intraocular pressure during the test



CONCLUSIONS

The development of a strong FSI tool amenable to model coupled structures and fluid can be useful to **correlate the results of the Non Contact Tonometry test to the biomechanical properties of the cornea**. With the proposed simulation, it is possible to **vary the mechanical stiffness of each tissue** of the eye studying the influence that each parameter has on the results of the test. Moreover, the eye can be modelled with **different intraocular pressures** in order to study the effect of the IOP on the Non Contact Tonometry. In a second step, the properties of the corneal tissue can be determined through an **optimisation process** by numerically reproducing the deformation of the cornea.

REFERENCES

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