XI JORNADA DE JÓVENES INVESTIGADORES DEL I3A

CORVIS ST BIOMARKERS IN HEALTHY AND KERATOCONIC EYES: CLINICAL AND NUMERICAL EVALUATION

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INTRODUCTION

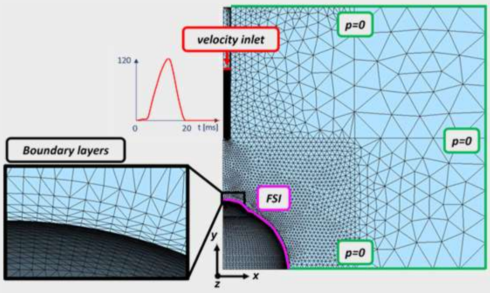
KERATOCONUS (KC) is a corneal disease characterized by a region of high curvature and reduced thickness [1].
Understanding the mechanical properties of the cornea is crucial to diagnose the pathology in time.
Non-contact tonometry (NCT) (***Corvis ST***®) is a diagnostic tool which applies a defined air pulse to the eye. The cornea deforms depending on the interaction between the **AIR PRESSURE**, the intraocular pressure (**IOP**), the **GEOMETRY** of the eye, and the **BIOMECHANICAL PROPERTIES** of the tissues involved.
To detect the mechanical properties, a **Fluid-Structure Interaction (FSI) simulation** of the procedure is necessary [2].
Patient-specific simulations of healthy and keratoconus corneas subjected to Corvis ST are presented.

METHODS

STRUCTURAL MODEL

CORNEA and LIMBUS:
Anisotropic hyperelastic tissues.
Holzapfel-Gasser-Ogden formulation.
SCLERA:
Isotropic hyperelastic tissue.
Neo-Hookean formulation.
HUMORS:
Incompressible fluids pressurized at the physiological IOP.

FLUID MODEL



AIR: *Incompressible* fluid.
Turbulence model based on a variational multiscale approach.

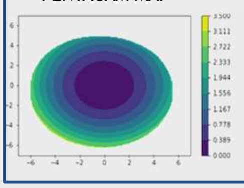
STRONGLY COUPLED, 2-WAY AND BOUNDARY FITTED FSI

RESULTS

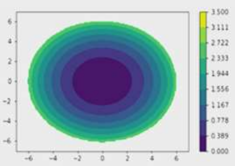
1. CORNEAL GEOMETRY

HEALTHY

PENTACAM MAP



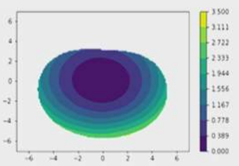
FEM MODEL



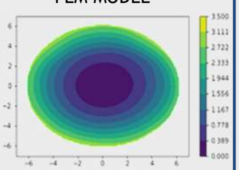
The corneal models are constructed based on elevation data retrieved by ***Pentacam®***.
A surface fitting is performed to adjust the point cloud and to construct a cornea of 6mm radius.

KERATOCONIC

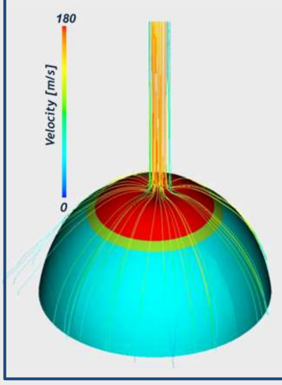
PENTACAM MAP



FEM MODEL

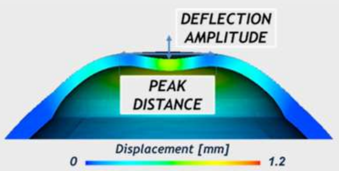


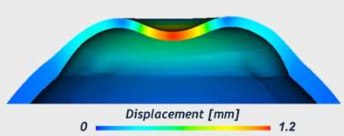
2. FLUID STRUCTURE INTERACTION SIMULATION

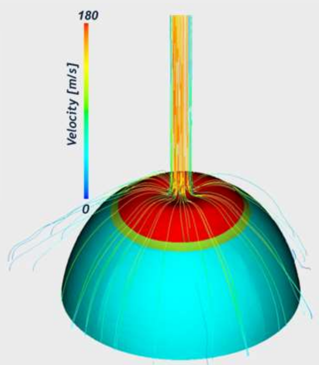


The use of **FSI simulation** is key to capture the correct air pressure distribution over the cornea during the NCT caused by the interaction of the air-puff with the deformable anisotropic cornea.

The nasal-temporal plane of the eye is analyzed to compare the result of the simulation to the clinical biomarkers.



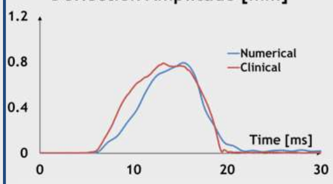




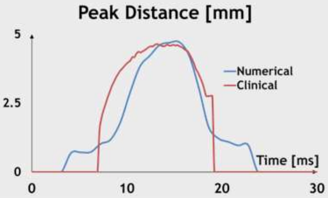
3. BIOMARKERS EVALUATION

HEALTHY

Deflection Amplitude [mm]

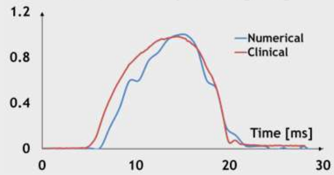


Peak Distance [mm]

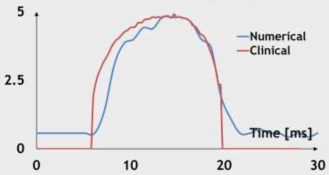


KERATOCONIC

Deflection Amplitude [mm]



Peak Distance [mm]



The biomarkers inferred from the numerical simulations reproduce correctly the clinical biomarkers. The values of deflection amplitude and peak distance in keratoconic eyes are higher than in healthy eyes due to the more compliant mechanical properties of keratoconic corneas.

CONCLUSIONS

The validation of patient-specific FSI simulations to model the NCT has shown very promising results and constitutes a fundamental step to find accurately the corneal tissue properties of both healthy and pathological eyes.

REFERENCES:

[1] J. Santodomingo-Rubido et al., "Keratoconus: An updated review," Contact Lens Anterior Eye, vol. 45, no. 3, p. 101559, 2022.
[2] M. Á. Ariza-Gracia et al., "Fluid–structure simulation of a general non-contact tonometry. A required complexity?" Comput. Methods Appl. Mech. Eng., vol. 340, pp. 202–215, 2018.

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