XII JORNADA DE JÓVENES INVESTIGADORES DEL I3A

A new procedure to estimate patient-specific intraocular pressure

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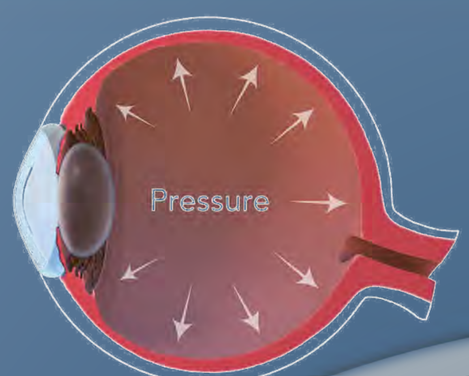
Intraocular Pressure

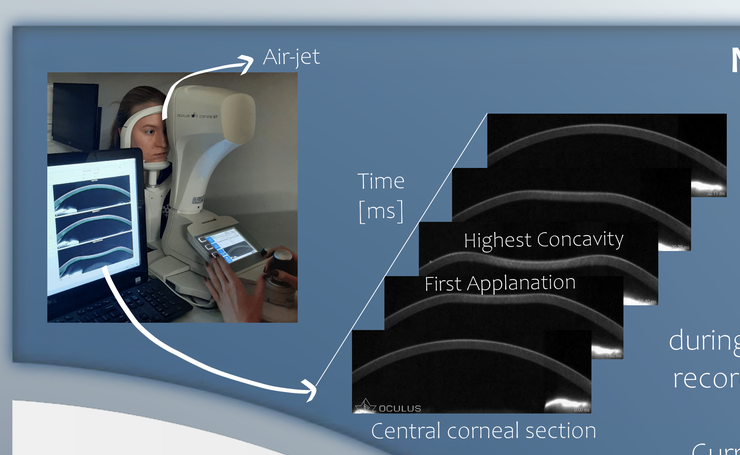
The intraocular pressure (**IOP**) is defined as the pressure inside the eye that is maintained by the balance of aqueous humor production and drainage.

Elevated IOP is a significant risk factor for **glaucoma**, which is a leading cause of blindness worldwide.

Accurate and repeatable IOP **measurements** are the key to **diagnose** the pathology in time and to provide for effective **treatment strategies**.



Non Contact Tonometry



Corvis ST is a commercially available Non-Contact Tonometer.

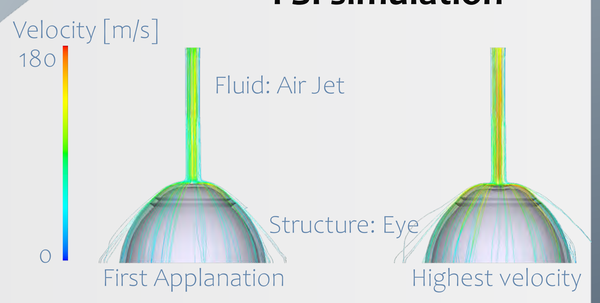
An **air jet** deforms the cornea during 30 ms and the deformation is recorded by a **Scheimpflug camera**.

Currently, the IOP measurement is based on the **first applanation time**.

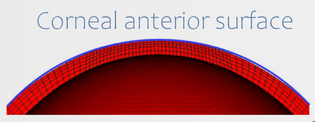
However, the applanation time also depends on the **thickness** of the cornea and on the **mechanical properties** of the corneal tissue.

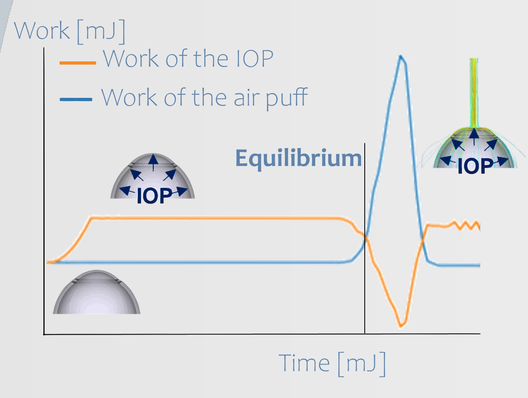
NUMERICAL ANALYSIS

FSI simulation



The **equilibrium** occurs when the work of the air puff and the work of the IOP on the corneal anterior surface are equal.

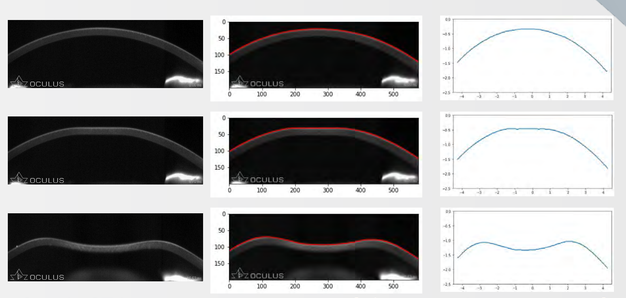




Changing both the **mechanical properties** of the corneal tissue and the **thickness** of the eye, the equilibrium point does not change, it only depends on the IOP.

CLINICAL ANALYSIS

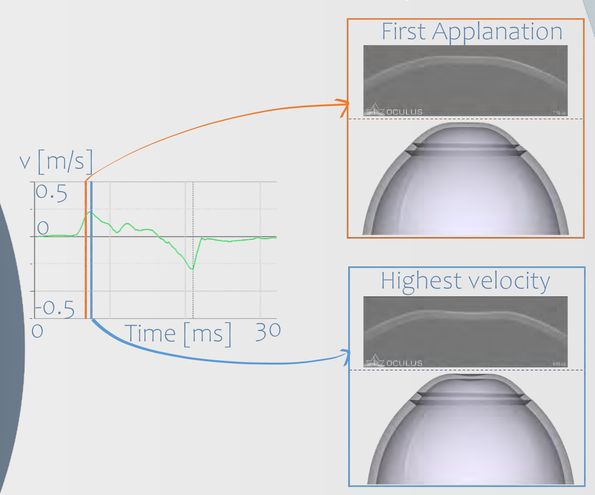
Clinical images segmentation



Working Hypothesis

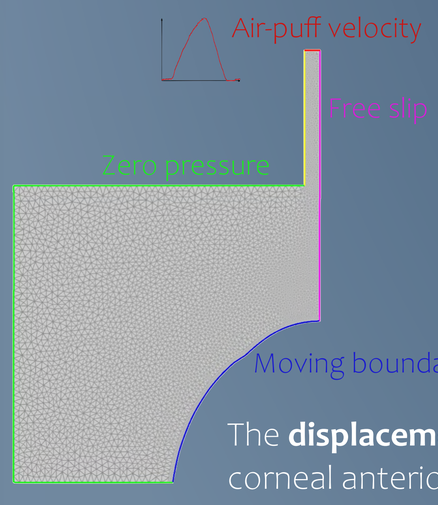
	Pressurization	Equilibrium	Highest concavity
Work	$Work_{IOP} > Work_{AIR}$	$Work_{IOP} = Work_{AIR}$	$Work_{IOP} < Work_{AIR}$
Potential Energy	Maximum	Zero	Minimum
Kinetic Energy	Zero	Maximum	Zero

Corneal Velocity



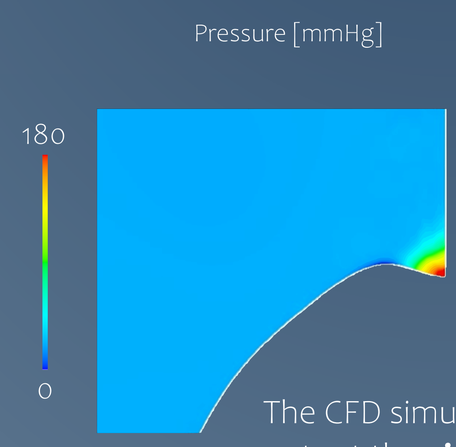
The **first applanation** time does not correspond to the instant of **highest velocity** of the cornea. At highest velocity, the cornea is at **equilibrium**, the net force is zero.

CFD simulation



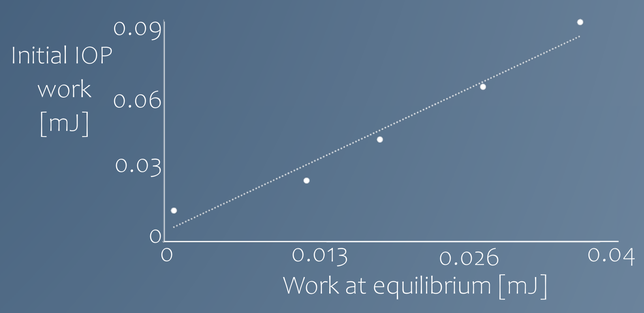
The **displacement** of the corneal anterior surface deriving from the **segmented images** is used to impose a **movement** to the **boundary** of the CFD simulation.

IOP estimation

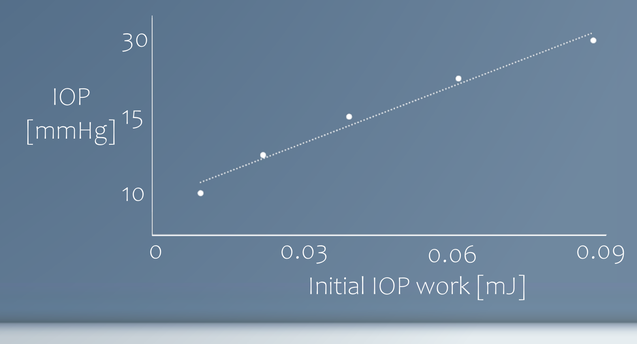


The CFD simulation gives as output the **air pressure** over the corneal anterior surface. The pressure depends on the **movement of the eye** of the patient during the air puff.

Initial IOP work [mJ] = 2.1719 · Work at equilibrium [mJ] + 0.0009



IOP [mmHg] = 262.56 · Initial IOP work [mJ] + 8.6761



Conclusions

- The equilibrium of the anterior corneal surface is considered. The mechanical properties and the thickness of the cornea does not influence the methodology.
- The FSI simulation and the subsequent CFD permit to study the air pressure over the corneal surface, that is different from the air pressure at the Corvis ST nozzle.
- Combining numerical simulations and the segmentation of clinical images it is possible to estimate the patient-specific IOP.

References

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[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.
[3] P. Brusini et al., "How to measure intraocular pressure: an updated review of various tonometers." Journal of clinical medicine, vol. 10, no 17, p. 3860, 2021.

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