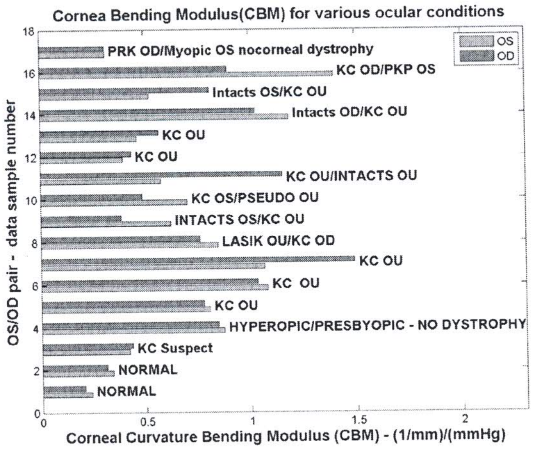

Figure 2 - Summary of CBM trial results**Commercial Relationships: David Luce**

Program Number: 2398 **Poster Board Number:** A0127
Presentation Time: 3:45 PM–5:30 PM
Biomechanical properties and IOP reconstruction from air-puff corneal deformation imaging: validations in model and porcine eyes
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Purpose: Keratoconus is a disease that alters the mechanical behavior of the cornea. Air-puff corneal dynamic deformation depends on the corneal biomechanical properties, corneal thickness and Intraocular Pressure (IOP). The aim of the study is to estimate both mechanical properties and IOP by means of inverse Finite Element modeling.
Methods: Corneal deformation of artificial hydrogel corneal models and enucleated porcine eyes (n = 8) to an air puff were measured by high speed Scheimpflug imaging (Corvis ST) at different IOPs (15 to 45 mmHg). A computational optimization incorporating inverse modeling was utilized in order to obtain mechanical properties from Corvis deformation images. Corneal Finite Element Models were programmed in ANSYS software, using Scheimpflug-based corneal geometry measurements, and literature values for the sclera. Air-puff pressure dynamics was measured in a previous study (Kling et al PLOS One 2014). The parameters of the hyperelastic material model and the IOP were changed in an iterative simulation to fit the simulated deformed shape and the deformation history of the corneas with the measured ones.
Results: The maximum deformation amplitudes (DA) of the artificial corneal model were 0.69, 0.52 and 0.47 mm at IOP of 15, 30 and 45 mmHg, respectively. Simulations resulted in Young's moduli of 0.475, 0.465 and 0.478 MPa for the three IOP levels respectively. DA of porcine corneas were 1.25, 0.869 and 0.624 mm at IOP of 15, 30 and 45 mmHg, respectively. Resulting Young's moduli of the cornea were 0.462, 0.436 and 0.454 MPa. The simulated IOP values matched the nominal IOP values within the step size (1 mmHg) of the optimization.
Conclusions: High speed imaging together with numerical optimization allows simultaneous accurate reconstruction of both corneal mechanical properties and IOP, as validated with models ex vivo. This study extends previous work where the reconstructed mechanical parameters were obtained ex vivo with fixed, known IOP. The proposed method can be useful to monitor corneal mechanical parameters in patients (i.e. keratoconus and cross-linking treatment). Also, it allows absolute estimates of IOP, independent of mechanical parameters, of high relevance to monitoring of glaucoma.
Commercial Relationships: Nandor Bekesi; **Carlos Dorronsoro**; **Susana Marcos**, None
Support: Comunidad de Madrid & EU Marie Curie (FP7/2007-2013/ REA 291820), ERC Advanced Grant 294099, Spanish Government Grant FIS2014-56643-R

Program Number: 2399 **Poster Board Number:** A0128
Presentation Time: 3:45 PM–5:30 PM
Finite Element Analysis of Penetrating Injury to the Human Eye
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Purpose: Penetrating injuries to the eye are among the most frequent causes of permanent visual impairment. The purpose of this study was to determine the strain at which rupture occurs in the cornea due to a penetrating object.
Methods: For the experiment, probes of varying diameters (1.0, 1.5, and 2.0 mm) were pressed into the apex of the cornea in 36 human cadaveric globes until perforation of the specimen. To match the experiment, an axisymmetric finite element model of the idealized human globe was created in Abaqus 6.14 (Figure 1). The cornea and sclera were modeled as isotropic nonlinear hyperelastic materials. To evaluate model sensitivity, three separate models for the sclera were constructed (minimum, medium, and maximum stiffness) within the range of experimentally-observed material behavior. In addition, two separate internal pressure conditions were implemented: 1) a sealed fluid cavity with an initial pressure, and 2) a constant pressure applied directly to the cavity surfaces. The model was used to map the force-displacement response of the experiments and quantitatively determine a peak strain at which the eye ruptures.
Results: For the experiments, the average force at failure increased from 30.5±5.5 N (1.0 mm probe) to 40.5±8.3 N (1.5 mm probe) to 58.2±14.5 N (2.0 mm probe) as the probe size increased ($p<0.002$). The force-displacement responses of the finite element models of all three probe sizes bounded and tracked the experimental data. The peak strain at failure in the cornea was located on its posterior surface. This strain was in the range of 29% to 33% for all models analyzed. Figure 2 shows strain contours for the 1 mm probe.
Conclusions: The current study has developed a validated finite element model of the human eye for analysis of penetrating injury to the cornea. The results have determined an objective failure strain of corneal tissue, which is consistent between sensitivity studies of varying material models, pressure conditions, and penetrating objects sizes. These results provide critical, quantitative information for understanding the risk of penetrating eye injuries.