# Development and Validation of A detailed Finite Element Model of Human Eye for Predicting Ocular Trauma


Kunal Dave[1], Sumit Sharma[2], Sayak Mukharjee[2], Liying Zhang[3]

[1]Advance Human Modelling Laboratory, Wayne State University
[2]IICAE indore, India
[3]Department of Biomedical Engineering, Wayne State University


*Objective:*
Approximately 2.5 million traumatic eye injuries occur each year in the United States. Eye injuries can be caused by blunt, penetrating and blast trauma to the eyeball, orbit or through the face. Eye injuries often involve orbital, facial bone fracture and brain damage. A handful of finite element (FE) models of human eye have been developed to study biomechanical response of the traumatic globe rupture. These models incorporated intraocular anatomy but lacked detailed extraocular tissues and orbital structure. None of the model has been integrated with a detailed validated head model. The current communication reports the development and validation of a detailed FE eye model integrated with a high-resolution human head model that can be used to improve our understanding of the mechanism of ocular, orbital, maxilla-facial and traumatic brain injuries resulted from trauma to the face.

*Problem to be solved:*
The measurement of biomechanical parameters at tissue level during ocular and facial impact test is technically challenging using the sensor and the human cadaver. An anatomically detailed computational model of the eye once has been validated it can provide important biomechanical responses variables such as pressure, stress and strain to understand ocular injury biomechanics.

*Methodology:*
The detailed FE model of human eye consists of all essential components of the eye: the cornea, sclera, aqueous humor, iris, lens, zonules, ciliary body, retina, and vitreous humor. The six extraocular muscles, optic nerve and extraocular fat model were also developed and directly connected to the globe. To incorporate the eye model to the orbit of the WSU human head model developed previously, the mesh at the orbital roof, wall and floor was improved first in order to accurately represent the geometry and anatomy of the orbit. The eye model was made up of over 28,000 elements. The mechanical responses predicted by the eye model were validated against experimental measurements from cadaveric eye impact tests from different projectile types and impact velocities. Various biomechanical response parameters including ocular pressure, localized stress and strain within the eye were calculated.

*Results and discussion:*
The current study utilized FE model simulation to provide ocular pressure, stress and strain information which are relevant mechanical measures for tissue level injury. During experiments, the globe rupture was not found for the 56 m/s case with BB, although the induced peak coronal displacement in BB case was much higher than baseball cases. Our simulations revealed that the pressure in the aqueous humor and lens were constantly higher in the case with globe rupture than that without globe rupture. The model results suggested that the localized ocular pressure might be a relevant injury predictor for ocular trauma induced globe rupture.

*Conclusion*
An anatomically detailed FE eye model with essential extraocular tissues was developed. The model has been integrated with a human head model, making it the first sophisticated human head model with

detailed eye, face, brain and skull anatomy. This complete head model can be used to study ocular, facial-maxilla and brain trauma in blunt and blast head injury.