# BUILDING A CELL-SPECIFIC CYTOSKELETAL FINITE ELEMENT MODEL OF SCLERAL FIBROBLASTS

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## Abstract

Introduction: The peripapillary sclera (PPS) has a large impact on the forces exerted on the optic nerve under fluctuating intraocular pressure (IOP) – implying a role in the mechanics of glaucoma. While the extracellular matrix component of the PPS has been previously studied with finite element modeling (FEM) this has not been performed for the cytoskeletal proteins in the context of cellular biomechanics [1]. Existing cell-specific FEM models do not take into account the organization and orientation of the cytoskeleton by simplifying and approximating it to a random fiber mesh [2,3]. As the cytoskeletal architecture has a key role in resisting mechanical deformation and in mechanotransduction there is a necessity for more physiologically accurate cell FEM. We present a new approach for creating cell-specific FEM cytoskeleton/fiber networks.

Methods: Primary bovine scleral fibroblasts, isolated from PPS explants, were seeded at $0.4x10^6$/well onto type I collagen coated BioFlex™ 6-well culture plates (Dunn Labortechnik, Germany). Equibiaxial cyclic tensile load (CTS) mimicking physiological IOP (0.26-1.8%, 1Hz), or unloaded state, were applied to the cells for 1h using an FX 3000 tensile system (Flexcell International, USA). Cells were fixed and fluorescently labelled for F-actin (microfilaments) and imaged on a Zeiss LSM 880 confocal microscope with Airyscan laser (Carl Zeiss, Germany). The collected stacks of images (0.14µm optical slice interval) were reconstructed to a 3D surface using Imaris 9.2 (Bitplane, UK) and meshed in the open source processing software MeshLab (ISTI-CNR, Italy). The mesh was subsequently imported to the commercial FEM software ABAQUS/CAE 6.14 (Dassault Systèmes, France).

Results: Application of CTS led to formation and realignment of actin stress fibers in comparison to the unloaded group. Images of the F-actin cytoskeleton were successfully imported as an accurate surface mesh into a finite element solver (Figure 1). The finite element mesh follows the contours and dimensions of the fiber network i.e. reconstruction precision is dependent on the fiber density.

Discussion: Alterations in the cytoskeletal organization of scleral fibroblasts is observed as an effect of mechanical loading. We present an approach to incorporate cytoskeletal protein architecture into FEM for greater physiological relevancy. A potential application for this method is for inverse FEM to determine material properties. Future work includes optimization of the surfacing and meshing procedures and application for other cellular components e.g. nucleus.

## Figures and Tables

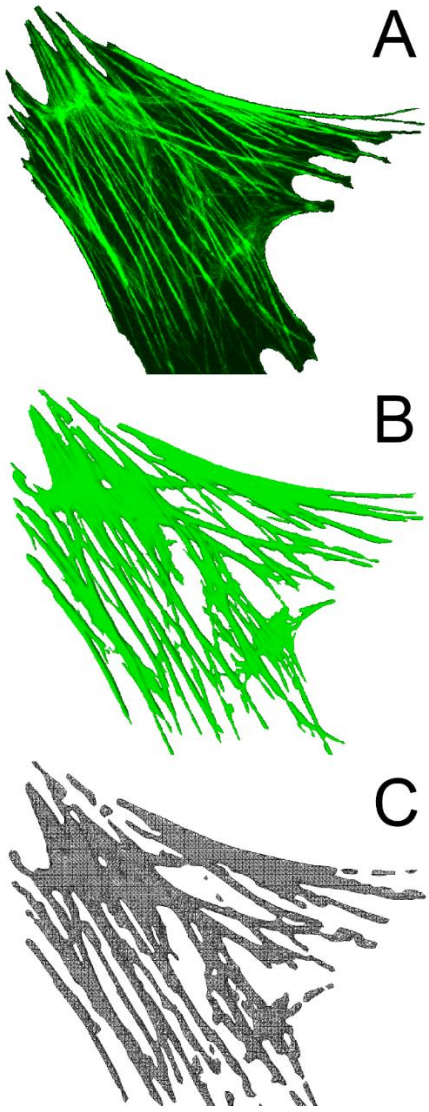


*Figure 1: Bovine scleral fibroblast actin stress fiber cytoskeleton 6h after mechanical loading. (A) Confocal laser microscope image; (B) Surface reconstruction in MeshLab; (C) FEM mesh in ABAQUS;*

## References

1. Grytz et al, Biomech Model Mechanobiol, 10:371-382, 2011.
2. Slomka and Gefen, J Biomech, 43:1806-1816, 2010.
3. Or-Tzadikario and Gefen, J Biomech, 44:567-573, 2011.