ME Seminar

Implications of corneal biomechanics on patient-specific surgical planning and corneal tissue engineering

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ABSTRACT

Over the last few decades, engineering solutions have significantly shaped medical decision-making, particularly in improving surgical outcomes and enhancing patient experiences. This influence is particularly pronounced in ophthalmology, where understanding the biomechanics of the cornea is crucial for tailoring surgical approaches to individual patient needs. Notably, advancements in techniques for measuring corneal biomechanics and developing bioengineered corneal substitutes for transplantation have garnered considerable attention. In the following study, the authors have developed a first-of-its-kind experimental setup based on digital photoelasticity to map the collagen fiber structure of the Human and Rabbit cornea [1,2]. The method is then used to understand the effect of graft-host misalignment on the topographical features of the cornea undergoing corneal transplantation [3]. The authors observed that structural mismatch between the graft and the host cornea may induce unforced surgeon error to put the sutures with improper tension, leading to irregular topography of the cornea. Further analysis focused on the mechanical and structural properties of the graft-host junction (GHJ) in a case study involving a 46-year-old patient whose graft remained viable for 13 years post-transplantation [4]. The strength of the GHJ was quantified using the suture retention strength test. The findings indicated that the strength of the GHJ was significantly lower—approximately ten times weaker—compared to the native cornea, highlighting a potential area of concern regarding the durability of such surgical interventions. Overall, these findings underscore the critical role of engineering innovations in advancing our understanding of corneal biomechanics and optimizing surgical techniques to achieve better outcomes in ophthalmic care.

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2. Gururani H, Richhariya A, M. R, Chinthapenta V. Implications of the structure-property relationship on the optomechanical characterization of the cornea: A review. Optik (Stuttg) 2021; 232:166529. https://doi.org/10.1016/j.ijleo.2021.166529.
3. Gururani H, Chittajallu SNSH, Doulatramani M, Manoharan R, Basu S, Chinthapenta V. Intraoperative collagen imaging of sutured cornea: A way towards managing post-penetrating keratoplasty astigmatism. Med Eng Phys 2023:104076. https://doi.org/10.1016/j.medengphy.2023.104076.
4. Chittajallu SNSH, Gururani H, Jakati S, Basu S, Vaddavalli PK, Tse KM, et al. Investigation of mechanical strength and structure of corneal graft-host junction. Heliyon 2024; 10. https://doi.org/10.1016/j.heliyon.2024.e30871.

ABOUT THE SPEAKER

Viswanath Chinthapenta is an Associate Professor in Department of Mechanical and Aerospace Engineering in IIT Hyderabad. He did his Bachelor's in Civil Engg. from Osmania University, Master's in Aerospace Engg. from IISc Bangalore, and PhD in Solid Mechanics from Brown University. He briefly worked in GE, Bangalore and ABAQUS (3DS) Rhode Island, USA before joining IITH. His research interests are in Computational Solid Mechanics with focus on Fracture Mechanics, process modelling of Additive Manufacturing and Biomechanics (Ophthalmology).

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