G-Force Guided Self-Assembly of Collagen Hydrogels for Transparent Cornea Equivalents

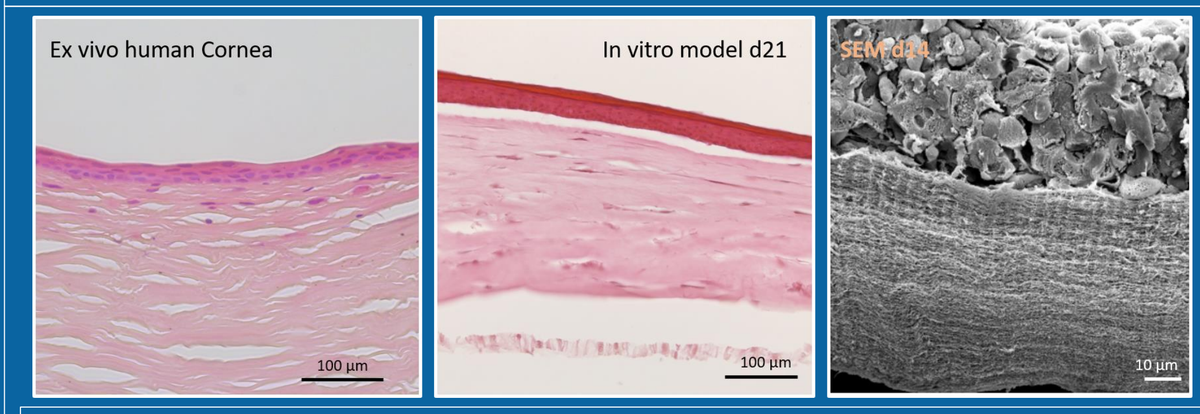
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Introduction

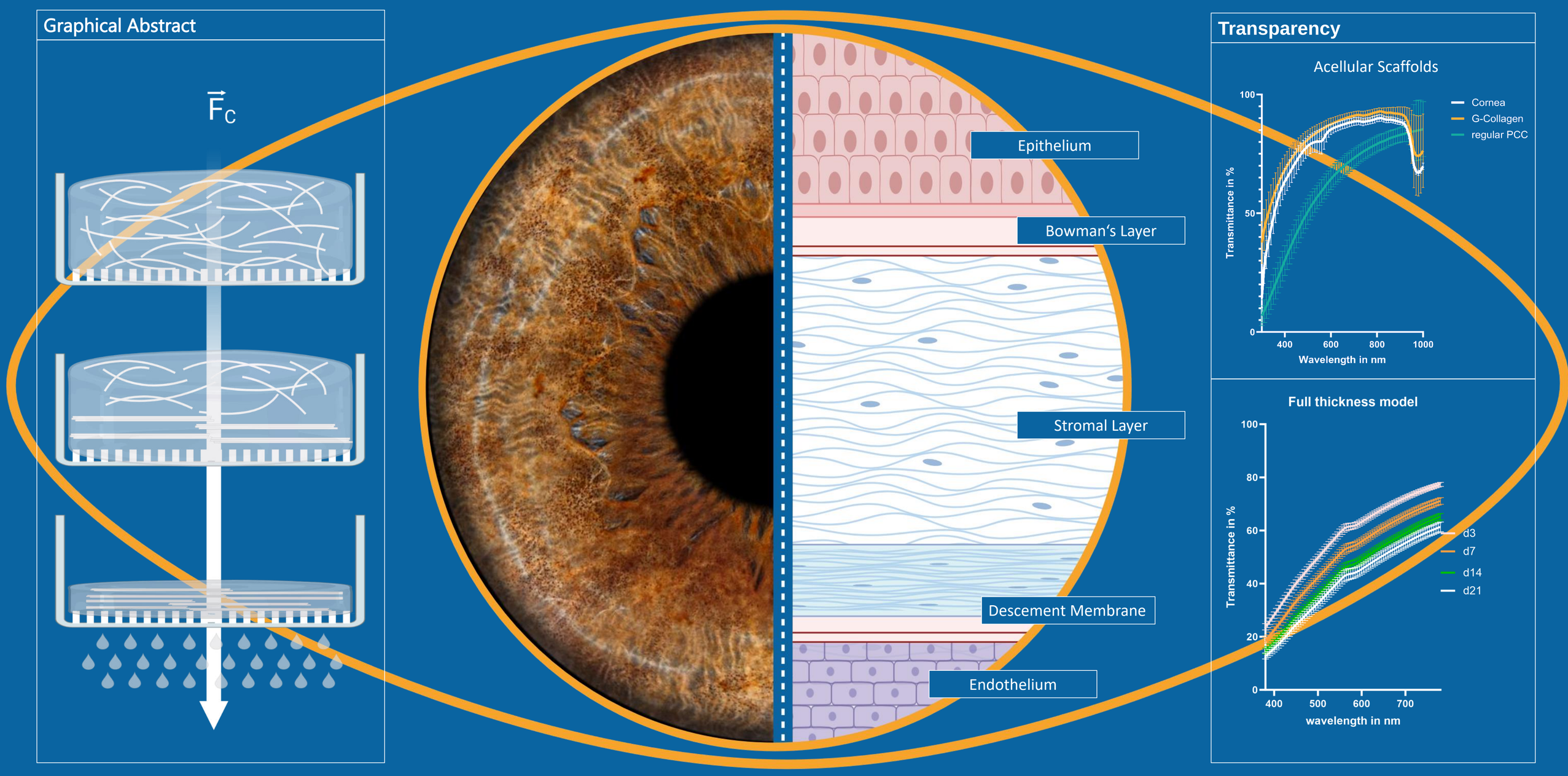
The optical clarity and refractive index of the human cornea result from the highly organized architecture of its collagen type I fibrils. Collagen hydrogels have been extensively investigated for corneal tissue engineering; however, conventional fabrication methods often produce scaffolds with limited optical performance or inadequate mechanical strength. In this study, we present a scalable fabrication method for producing highly transparent, refractive collagen scaffolds with improved mechanical and biological properties. By precisely controlling the magnitude of G-force during gelation, collagen type I fibrils can be directed to self-assemble into planar ordered structures. The resulting scaffolds exhibit optical transparency comparable to that of the native cornea across the visible spectrum. The compact fibrillar organization enhances mechanical strength without compromising light transmission, closely mimicking the structure and function of the corneal stroma. The process is inherently cytocompatible and allows uniform stromal cell integration within the hydrogel matrix. In vitro culture studies further confirmed the retention of collagen's native cyto- and biocompatibility. Overall, G-force–guided fibrillogenesis offers a robust and reproducible platform for fabricating advanced corneal equivalents, where optical transparency serves as a practical and quantifiable indicator of model health, supporting future applications in corneal tissue engineering and translational research.

Epithelium



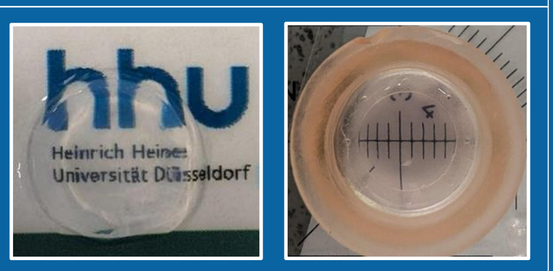
Left: H&E staining of a human donor cornea
Mid: H&E staining of a G-Collagen based in vitro model seeded with human keratocytes endothelial and epithelial cells
Right: Scanning electron microscopy image of an in vitro cornea model (d14), sliced previously with a vibratome

Graphical Abstract



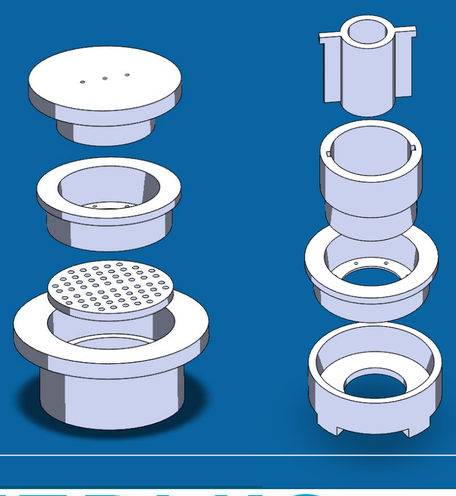
Transparency

Custom Inserts

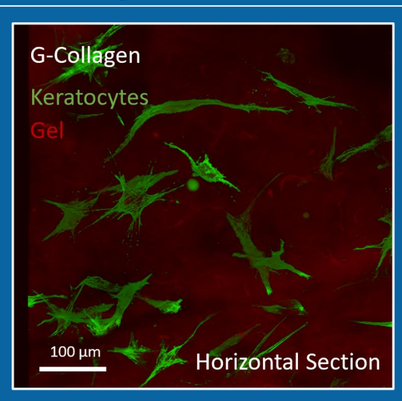


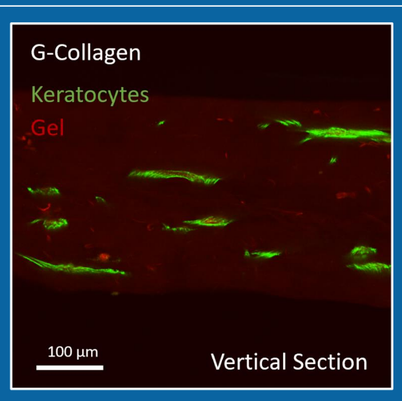
Centrifugation

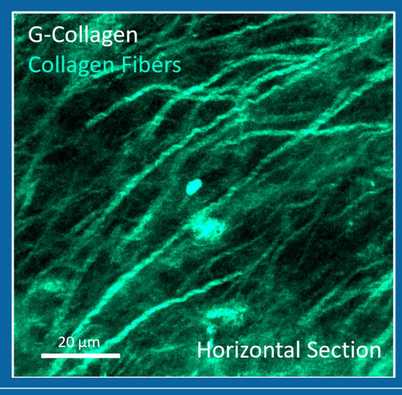
Cultivation

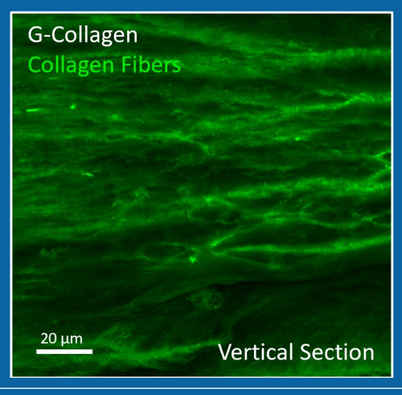


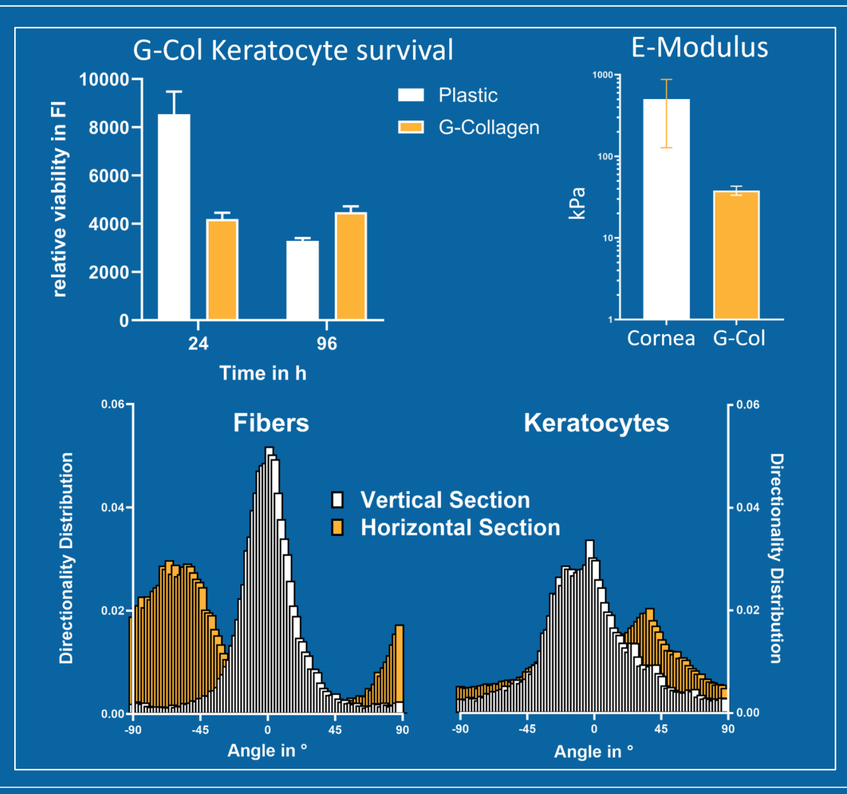
Stromal Layer











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