

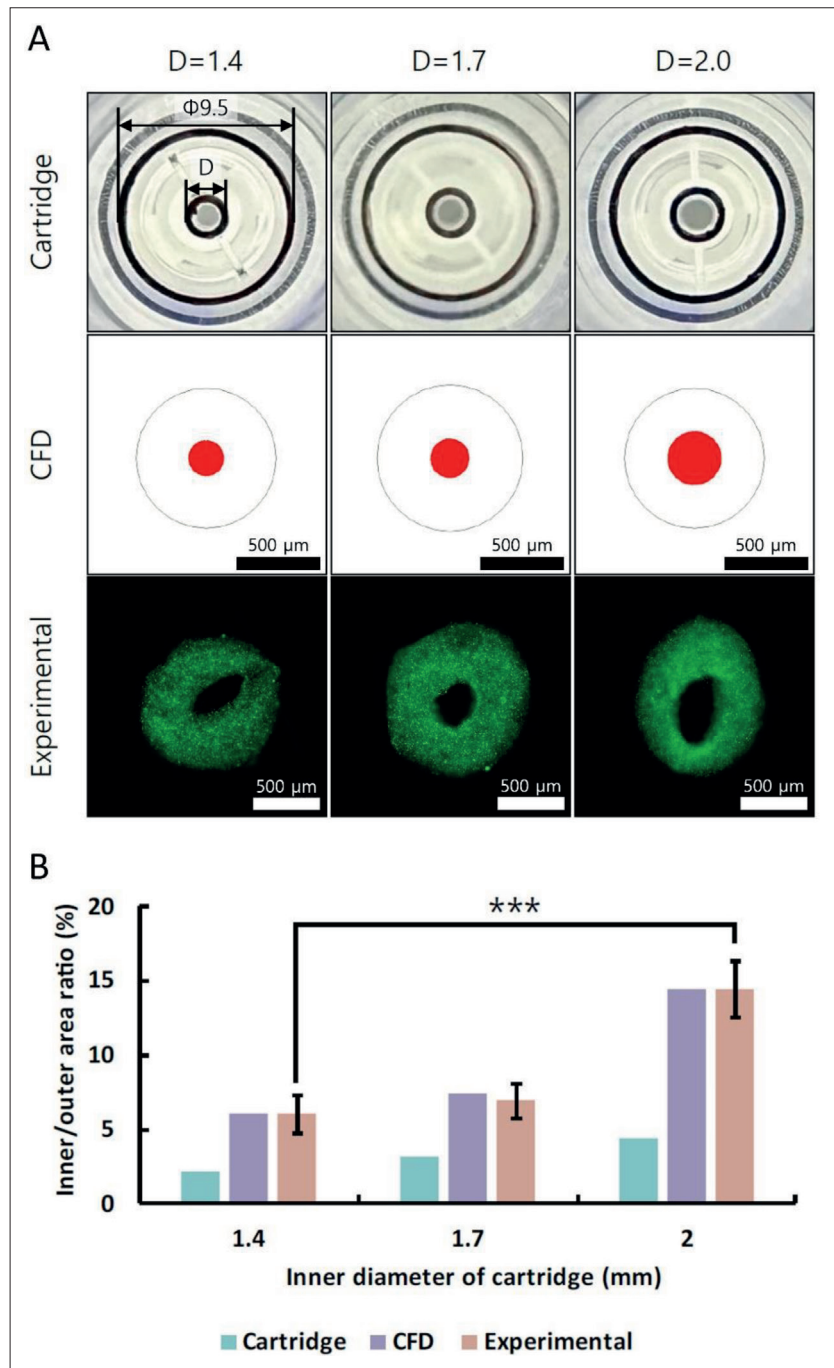
## RESEARCH ARTICLE

## 3D bioprinting of in vitro full-thickness skin model with a rete ridge structure

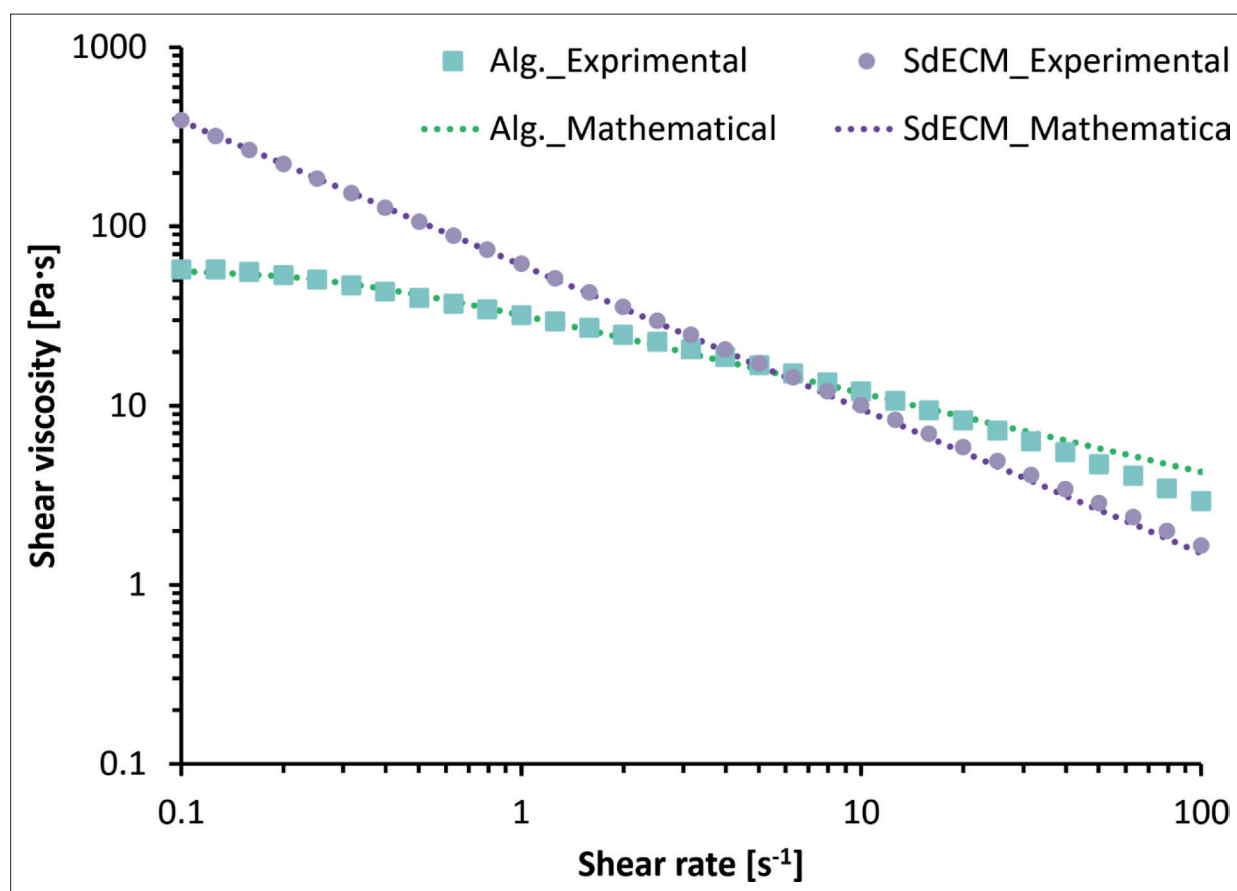
**Supplementary File****(A) Validation of computational fluid dynamics method**

To ensure the reliability of the computational fluid dynamics (CFD) method used in this study for designing a precursor cartridge for fissure structure printing, experimental results were compared with CFD simulations for precursor cartridges with core-shell structure (**Figure S1, Supporting Information**). The cartridges were fabricated to fit into 3 mL syringes, with cores designed to have diameters of 1.4, 1.7, and 2.0 mm, respectively. The alginate solution was filled into the core compartment, while the skin-derived decellularized extracellular matrix (SdECM) was filled into the shell compartment, and strands were extruded using an 18G nozzle. Simultaneously, CFD simulations were conducted for the same model. As alginate does not crosslink within the strand, observation of the cross-section revealed lumens formed within the strands composed of SdECM. Comparison of the lumen area ratio in the entire strand with the ratio of alginate solution within the simulation revealed highly similar results, suggesting that the CFD method utilized in this study can effectively predict the outcomes of the preset extrusion bioprinting process.

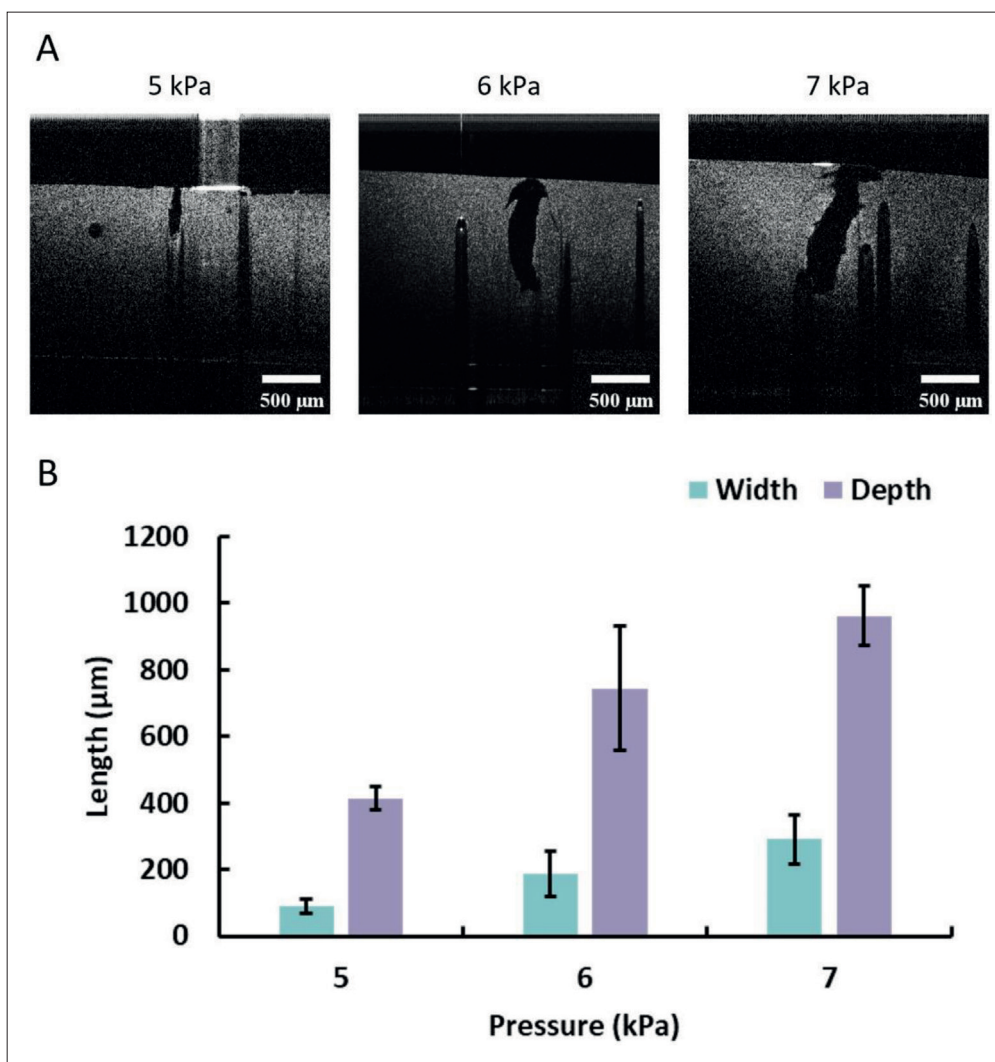
## (B) Supplementary figures



**Figure S1.** Comparison of computational fluid dynamic (CFD) simulation and experimental results to ensure the reliability of the CFD method with core-shell architecture. (A) Images of the precursor cartridge architecture, CFD simulation, and experimental cartridge at different diameters (D). (B) The proportion of alginate solution within the overall area encompassing the skin-derived decellularized extracellular matrix (SdECM) in the precursor cartridge, CFD simulation, and experimental cartridge. Scale bars: XXX. \*\*\*  $p < 0.001$ .



**Figure S2.** Shear viscosity profile of the 2.75% alginate solution (Alg) and 3.25% skin-derived decellularized extracellular matrix (SdECM) bioink. The markers denote the measured value by rheometer (experimental); the dashed line represents the trend line (mathematical).



**Figure S3.** Changes in fissure structure as pressure changes. (A) Cross-sectional image of the printed structure using optical coherence tomography (OCT). (B) Measured width and depth of the printed structure. Scale bars: 500 μm.

**(C) Supplementary table**

**Table S1.** Mathematical models of viscosity for the alginate solution and skin-derived decellularized extracellular matrix (SdECM) bioink.

Parameter	Alginate solution	SdECM bioink
Mathematical model	Carreau model: $\mu = 57.78 \times \left[ 1 + 0.369 \times \dot{\gamma}^2 \right]^{-0.221}$	Power model: $\mu = 61.08 \times \dot{\gamma}^{-0.804}$
R <sup>2</sup>	0.9966	0.9997