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Design and Computational Validation of a Shear Stress Bioreactor for Conditioning Vascular Tissue to Time-Varying Multidirectional Fluid Shear Stress

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Altered biological environments and conditions, such as microgravity and pregnancy, can impact vascular blood flow and, in turn, generate fluid wall shear stress (WSS; frictional force generated on the tissue surface due to blood flow) abnormalities. These abnormalities are known to affect cardiovascular tissue biology and can be replicated experimentally using a cone-and-plate shear stress bioreactor. This device exposes tissue samples mounted on a stationary place to native WSS signals via angular rotation of a cone submerged in culture medium. However, bubble formation on the tissue surface due to the moving fluid is a serious issue which may impede WSS exposure. A larger fluid volume may mitigate these issues while still transmitting the desired signal to the samples. The current study aimed to computationally characterize the impact of increasing the fluid volume within the bioreactor to mitigate bubble formation. The fluid domain was constructed based on a cone radius and angle of 40 mm and 0.5°, respectively, a plate radius of 41 mm, and an initial gap of 0.2 mm between the cone apex and plate. Based on motor requirements from theoretical torque calculations, three additional geometries were constructed by increasing the gap height to 1, 3, and 5 mm to test the ability of the device to replicate the desired WSS waveforms. Computational fluid dynamic simulations were performed using ANSYS Fluent to validate the operating conditions and design. We anticipate that this design will allow for exposure of native WSS on the tissue samples while alleviating bubble formation.