Mechanical Investigation of a Novel Alveoli-on-Chip Model

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Introduction

The Alveoli-on-Chip is an advanced *in-vitro* model that mimics the microenvironment of the human distal lung. The chip, made of Polydimethylsiloxan (PDMS), consists of an array of alveoli formed by a pillar structure with a membrane situated on top (Fig. 1). A vacuum can be applied by a pneumatic setup to deflect the membrane into different positions. In this work, a mechanical investigation of the novel Alveoli-on-Chip was performed and improvements were made to the chips design and the production process.

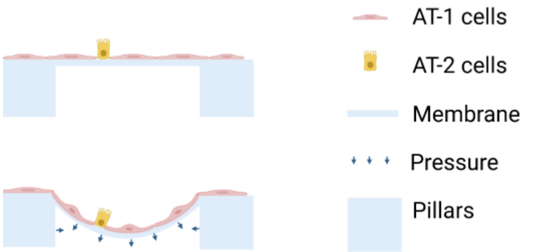

Fig. 1: Basic working principle of the novel Alveoli-on-Chip model, The pillars and the membrane made of PDMS form an array of alveoli on which cells can be grown (e.g., Alveolar type one or two cells, AT1 and AT2). When a vacuum is applied in the chamber below the membrane, this membrane deflects downward and the cells experience strain. The dust around the cells symbolises their reaction to the strain.

Materials and Methods

The mechanical investigation consisted of a standardisation of the pneumatic setup, improvement of the chip design and production procedure, a long-term breathing experiment, and a Finite Element Analysis (FEA) to study the strain pattern on the top of the membrane during deflection.

Results

The improvements of the chip design consisted of implementing columns in the 3D-printed mold to reduce the bending of the mold during the production procedure. Further, the balance was replaced with a more precise one to reduce the uncertainty in the mixing ratio of the base polymer and curing agent of the PDMS. These changes increased the deflection accuracy of the membrane at a pressure of -400 mbar from a standard deviation of 17.72 µm to 7.82 µm. The long-term breathing experiment of the chip inside an incubator for 10 days showed showed stiffening of the chips, likely caused by post curing of PDMS. A diverse strain distribution pattern on top of the deflected membrane was shown by the FEA model (Fig. 2). The highest strain occurs above the pillars with a maximal principal in-plane strain of 28.2 % at a pressure of -400 mbar.

Max. principal in-plane strain [arb. unit]

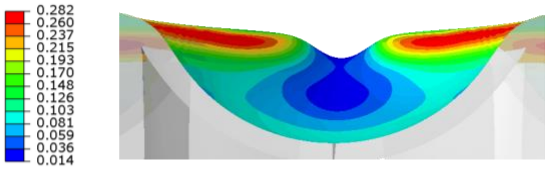

Fig. 2: FEA model of a part of the novel Alveoli-on-Chip design. The maximal colorcode is the maximal principal in-plane strain on the surface of the membrane.

Discussion

A change of mold material to potentially increase the deflection accuracy is recommended. Since the diverse strain distribution could be undiserd for some experimental applications, a upward deflection could be beneficial.

Additionally, the membrane could be deflected upwards with positive pressure instead of downwards with a vacuum, to reduce the strain variability on top of the membrane. Taken together, these findings present a number of improvements to the novel alveoli-on-chip, further enhancing its capacity to mimick the human distal lung.

References

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