Design and fabrication of an intestinal phantom

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Modelling gut complexity is of particular interest for the study of intestinal dysfunctions, which are known to affect nutrient absorption. However, current systems are not able to provide a human-relevant model at the macroscale. Here, a method to create an intestinal phantom that can replicate the human gut will be presented. The aim is to engineer a physical twin replicating gut architecture, mechanical features, as well as the rheological properties of the luminal content and the inner mucus layer.

Firstly, porcine small intestine samples were tested for tensile properties (resulting in elastic modulus of 0.97±0.26 MPa). To match this, Polydimethylsiloxane (PDMS) at a 3:1 ratio was thus selected, functionalizing it with 3% v/v 3-AminoPropyl TriEthoxySilane (APTES) to enhance its hydrophilicity and mucus affinity (1.298±0.09 MPa). The mucus layer was obtained with 2% w/v type 2 mucins. After 24 h incubation with PDMS, the uniformity of the mucus layer was quantified using image analysis.

Different molds, replicating different small intestine tracts, were designed (using Fusion 360) and fabricated by fused deposition modelling (using Stratasys, Eden Prairie, USA). Finally, the intestinal fluid mimic was obtained by dissolving pectin in buffer solutions with pH values of 6,7 and 8 mimicking the intestinal pH range. Rheological measurements performed with a Brookfield viscosimeter demonstrated its suitability to replicate the physiological viscosity range of 0.1-10 Pa*s.

In conclusion, a phantom model replicating small intestine mechanics and anatomy, as well as the presence of an inner mucus layer and the luminal content, was designed, characterized, and fabricated. The development of human-relevant phantoms contributes to reducing the need for animal experimentation, in line with the 3Rs principles.

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