Actuated medical validation organs with FDM 3D printing

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Validation organs are necessary to test and validate the rapidly advancing magnetic resonance imaging (MRI) technology. 3D printing such as material deposition printing are promising techniques to build such phantoms that must be flexible and actuated to simulate natural organ movements. In this study, flexible materials for material deposition printing, internal structures, actuation techniques and their possible combination were researched and tested to mimic natural organs

Motivation

The rapid developments of MRI technology requires validation to evaluate the accuracy and resolution of the imaging system. For these purposes, phantom organs must be improved to better simulate organs in a living patient, i.e. not only be visible but also mimic the natural internal movements like contraction (heartbeat, breathing) or peristalsis (digestive track). Even when the patient is immobile in the MRI, the internal organs are still moving. An MRI device must be able to capture these movements live during imaging.

Technical Aspects

MRI technology

MRI is an imaging technique used in medical diagnostics to visualize the structure and function of tissues and organs in the body. It is based on the principles of nuclear magnetic resonance. During the procedure, the patient is not exposed to any ionizing radiation.

Intestine section with different versions of infill structures.

Material deposition Printing

Material Deposition Modeling in the field of rapid prototyping has evolved considerably in recent years. It is now possible to print not only filaments but also viscous materials such as silicones, inks and hydrogels in a layer deposition process. In this process, a material is applied layer by layer in the desired form.

Material sciences

For the validation organs, different materials with various properties are to be processed with a printing system. The requirements on the different materials are very diverse (Shore hardness lower than 40A / Electrical conductivity/ MRI visibility and compatibility). Not every material has to fulfil every requirement, but their combination should allow printing a soft MRI visible tissue with elements for electrical conductivity and actuation.

Actuated force transmission

The MRI must detect natural organ movements of in the body. The new generation of phantom organs should not only be visible, but also perform natural movements that can be followed in MRI. To carry out realistic movements, the actuating force must be controlled and guided so that the movements occur where they are supposed to. This can be done by adapting the strength of the outer organ walls or the design of the infill structure.

Results

The materials found were listed and their adequacy assessed regarding the requirements. The most promising ones (Recreus FilaFlex, NinjaTek EEL) were tested on the laboratory 3D printers (Ultimaker 2 Extended+ & 3 Extended). These materials were combined with actuation concepts and different internal structures (Gyroid). In addition, an open lattice structure was developed for selective force distribution inside the validation organ. Materials will be prepared for MRI testing to assess their visibility and compatibility.

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