The development of direct 3D print of patient-specific mitral valve for a high-fidelity minimally invasive mitral valve surgery simulator: a step forward to personalized surgery

ABSTRACT

Objectives: Preoperative physical simulation of patient-specific mitral valve repair could be beneficial in simulation-based training and procedural planning. Replication of 3D-prints of patient-specific mitral valve has been through a cumbersome and time-consuming process of negative mould fabrication and silicone-casting. The aim of this study was to develop a method for a direct 3D printing of patient-specific mitral valve in soft material for simulation-based training and procedural planning.

Methods: We developed a process composed of three steps: Data acquisition, processing and 3D printing using 3D transoesophageal echocardiography Cartesian DICOM format, image processing softwares (Vesalius3D, Blender, Meshlab, Atum3D Operation Station) and digital light processing (DLP), an additive manufacturing process based on photopolymer resins. To develop a direct 3D printing process in suitable soft material we experimented by adjusting three variables: curing times, thinner models and building lattice structuring. The prints and ability for physical simulation were tested by an experienced mitral valve surgeon.

Results: By reducing or increasing the curing times we could influence the stiffness of the 3D prints. Making the 3D prints thinner created more flexibility and a more compliant feeling of the print could be achieved by placement of lattice structures. Direct 3D print of patient’s mitral valve in soft material was completed between 3.5 and 6.5 hours. Prints with post curing times of 5, 7, 10 and 15 minutes increased the stiffness. The mitral valves with 2.0- and 2.4 mm thinner leaflets felt more flexible. Sutures did not tear through the material. Lattice structures made the prints more compliant and supported suturing. Lattice structure with a wall thickness of 1.0 mm, element dimension of 0.5 mm and element space of 1.5 mm was more realistic compliant mitral valves.

Conclusion: Direct 3D printing of a realistic and flexible patient-specific mitral valve was created within a few hours for the high-fidelity minimally invasive mitral valve surgery (MIMVS) simulator. Combination of thinner leaflets, reduction in curing time and lattice structures created a realistic patient-specific mitral valve in soft material for physical simulation.

Keywords: 3D print; Simulation; Minimally invasive mitral valve surgery; Mitral valve repair