A combined approach of numerical simulation and additive manifacturing technique for in-silico and in-vitro testing of a 3D printing-based aortic polymeric heart valve

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ABSTRACT

Heart valve diseases are among the leading causes of cardiac failure around the globe. Currently, available options for heart valve replacement include bioprosthetic and mechanical valves, both of which have severe limitations [1]. Current advances in imaging technology, in numerical simulation and in additive manufacturing are opening new frontiers in the field of development of new personalized prosthetic devices. The 3D printing technique could allow the realization of personalized models for each patient undergoing valve replacement surgery. In the present work, a tri-leaflet aortic valve (AV) structure is developed starting from a patient specific CT dataset by using customized segmentation algorithms. The resulting CAD model was used both to perform numerical in-silico simualtion and to design a modular mould for AV fabrication. Simulations were performed through a novel hybrid approach based on RBF mesh morphing technique and CFD simulations. A polymeric AV stent was 3D printed according to [2]. The stent was positioned onto a tubular mould and dipped in CarboSil. The solution was then sprayed onto the mould by a spray-machine apparatus allowing a microfibrillar structure formation and a final dipping step was done. Finally, the tubular valve was housed and pressed in a modular 3D printed valve mould to obtain the final AV shape. To assess the in-vitro valve properties, the prototype was inserted in a custom mock circulatory loop to reproduce the aortic flow conditions. The manufacturing process of both the mould and the valve was successful and the in-vitro testing showed an effective orifice area (2.5 mm^2) and regurgitation fraction (5%) in accordance with the ISO-5840-2. The novel simulation strategies has revealed to be a promising approach to test both structural and functional device performances.

REFERENCES

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