A DIRECT ULTRASOUND PHANTOM FABRICATION FOR CATHETER INTERVENTION SIMULATION

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Abstract

Developing tissue mimicking phantoms for clinical use has been of interest for a long time; the appearance of 3D printing technology makes it possible to fabricate hollow cardiac models with complicated structures.

Two new materials—Layfomm 40 & Tango Plus—are used to fabricate phantoms for a general catheter intervention simulation. With these special materials, the phantoms can be printed directly instead of constructing and perfusing a mould.

The echocardiography results demonstrate that both materials are ultrasound compatible, and the softness comparison shows that they can be appropriate substitutes for soft tissue.

Introduction

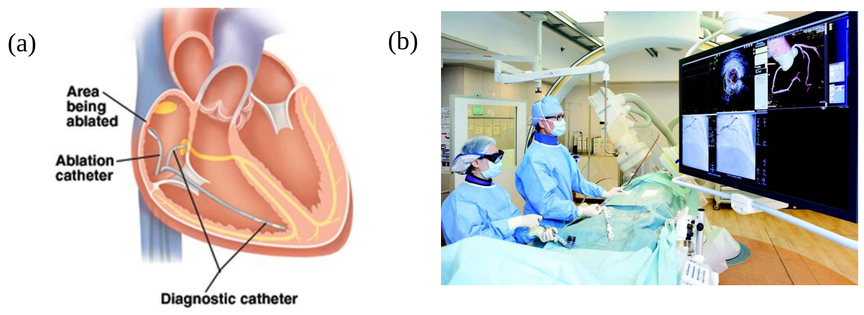

Figure 1: (a) Catheter intervention overview [1], (b) real image guided catheterization procedure [2]

Catheter intervention/catheterization (Fig. 1) is a typical strategy to treat various cardiovascular diseases. To simulate such a procedure, we need to develop cardiac phantoms into which catheters can be inserted, and then image the phantoms and catheters via echocardiography. The traditional approach (Fig. 2(a)) is to create a mould and perfuse it with gel. Here, we investigate direct 3D heart phantom printing (Fig. 2(b)).

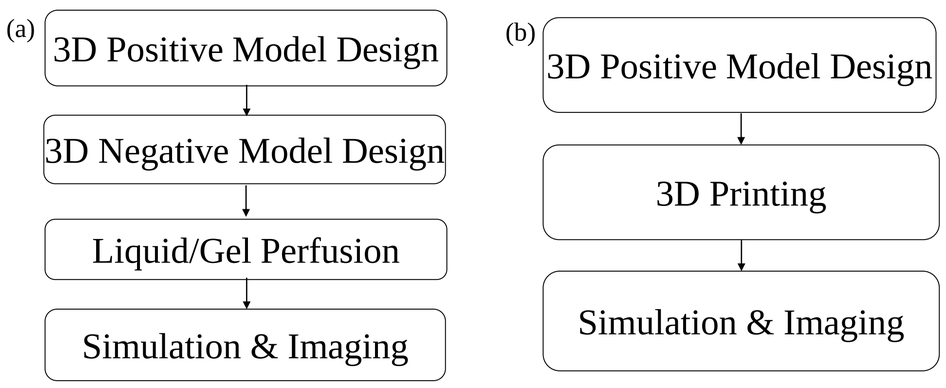

Figure 2: (a) Traditional mould based manufacturing method, (b) direct 3D printing method.

Materials & Methods

3D heart models were generated by segmenting the heart muscle from two CT scans of healthy male volunteers. These were printed in two materials:

- Layfomm 40 (Fig. 3(a)) printed on a Delta WASP 2040 printer (Fig. 3(b)).
- Tango Plus (Fig. 3(c)) printed on an Objet500 printer (Fig. 3(d)).

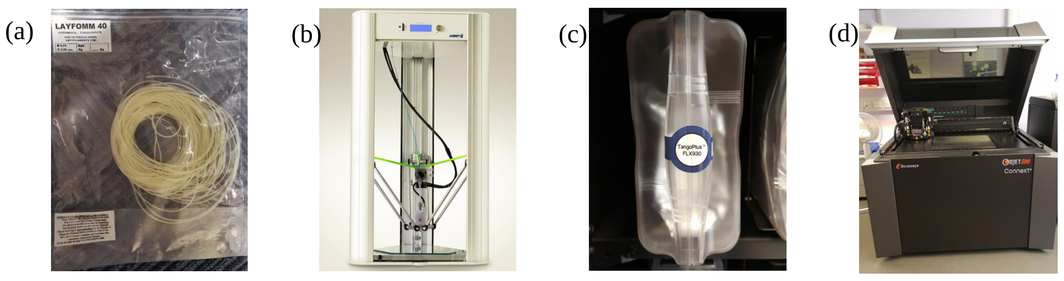

Figure 3: (a) Layform 40 material, used by (b) a Delta WASP 2040 printer, (c) Tango Plus material printed on (d) an Object500 printer.

After phantom fabrication, the materials' stiffness and elastic properties were compared using an Instron 3343 tension testing machine (Fig. 4(a), www.instron.co.uk) and a Shore A durometer hardness tester (Fig. 4(b), www.pce-instruments.com). Ultrasound images (Fig. 4(c)) were acquired using a Philips IE33 ultrasound scanner.

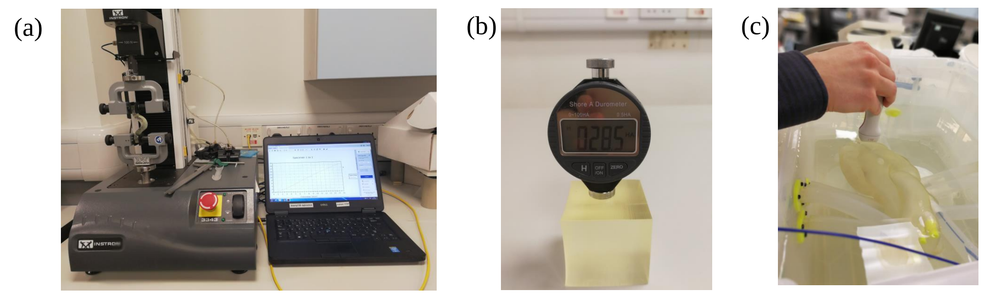

Figure 4: (a) Young's modulus testing, (b) Shore A durometer testing, (c) ultrasound imaging procedure of the Tango Plus phantom

Results

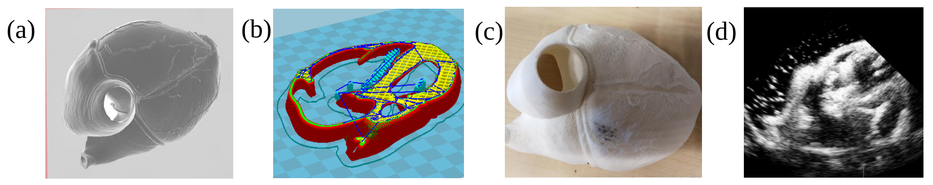

Figure 5: Layfomm 40 phantom (a) 3D model, (b) internal slide view, (c) printed result, (d) echocardiography

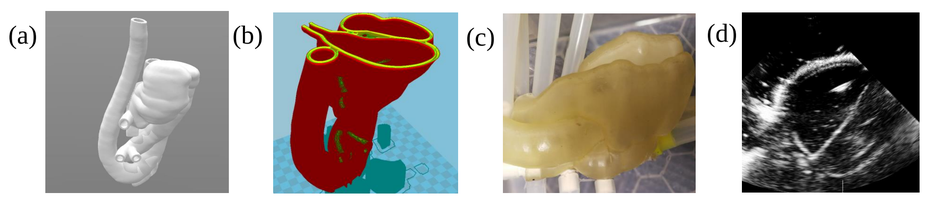

Figure 6: Tango Plus phantom (a) 3D model, (b) internal slide view, (c) printed result, (d) echocardiography

Figures 5(a)-(d) show the Layfomm40 cardiac phantom's 3D model, an internal slide view, the printed result and an echocardiography image; Figures 6(a)-(d) show the same for the Tango plus phantom. Both phantoms were successfully printed and can be imaged with ultrasound in water.

Table 1 compares material properties for the two materials tested, as well as real myocardium and two types of silicone.

Table 1. Tissue Mimicking Materials Softness Comparison

Material	Durometer /Stiffness (HA)	Young's Modulus/Elastic Modulus (kPa)	Source
Myocardium	-	170-280	[3]
Jehbco Silicone	39	2599.59	Self-testing
Silicone 0050	5	94.07	Self-testing
Tango Plus	29	500.07	Self-testing
Layfomm 40	4	207.13	Self-testing

Both the durometer and young's modulus comparison show that the softness of Layfomm 40 at its max flexibility can be tissue mimicking after rinsing.

Besides, Layfomm 40 performs better in ultrasound than Tango Plus even it is only £0.08/g while Tango Plus is £0.61/g. But in terms of printing difficulty and stability, Tango Plus is better than Layfomm 40.

Conclusions & Future Work

Layfomm 40 and tango plus are both shown to be good tissue mimicking materials for easy and direct phantom fabrication. These phantoms help us better understand and simulate the catheter intervention procedure for real clinical use.

Future work will focus on testing more ultrasound properties on both materials, as well as using them to build up the echocardiography dataset.

Reference: [1] http://www.heartrhythmsfla1.com/english/ablation_EN.html
[2] www.hksh-hospital.com
[3] A Review of Tissue Substitute for Ultrasound Imaging, Martin O. Culjat, Ultrasound in Med & Biol. Vol.36.No.6, pp. 861-873,2010