Study Confirms 3D Printed Tissue Can Mimic the Properties of Porcine Liver, Epicardium and Aorta Tissue

White Paper

stratasys

Introduction

Anatomical 3D printing has mainly been used for training, education and surgical planning purposes because previous materials have been unable to mimic the mechanical and material properties of tissue.

However, there are new Digital Anatomy (DA) materials on the market that mimic the material configurations of soft organ, subcutaneous tissue and myocardium. These new DA materials, developed by Stratasys, promise to mimic the mechanical performance of biological tissue and allow for lower cost and quicker development of models.

The use of 3D anatomical models promise to be beneficial because it doesn't require regulatory ethical requirements (or a facility to handle the biohazards and sterilization) and offers longevity and reduced cost compared to ex-vivo and in-vivo cadaveric animal testing. In addition, 3D technologies also address constraints of conventional manufacturing that require fabrication processes like molding and casting, which is not ideal for the creation of patient-specific models because of high tooling costs and process time.

Study Confirms 3D Printed Tissue Can Mimic the Properties of Porcine Liver, Epicardium and Aorta Tissue

Objective

The study focused on comparing porcine tissue with the mechanical properties of DA Soft Organ (SO), the lubricity of DA myocardium (very stiff, extremely stiff and highly contractile) and the tactile capabilities of DA Subcutaneous Tissue (ST).

Scientists and engineers from Medtronic, a global leader in medical device manufacturing, conducted an independent third-party comparison of the DA materials to porcine tissue. The following summarizes the findings and presents implications for future work in material development.

Methods

The stiffness and lubricity of 3D models was compared to those of porcine tissue. To mimic the conditions during in-vivo procedures, tests were developed to evaluate lubricity/friction, qualitative cutting, stiffness and puncture testing and tunneling (subcutaneous tissue) for comparison between porcine tissue and DA materials.

The mechanical properties of porcine tissue (liver, aorta and epicardium) were compared to those from a wide spectrum of 3D DA material blends. Porcine tissue was chosen as the baseline for comparison because of its similarity to human tissue, availability, and the precedent for its use in pre-clinical testing. All samples were printed on the Stratasys J750 Digital Anatomy™ 3D printer.

Key **findings**

Stiffness Testing

Porcine livers were dissected and assessed for stiffness from 1 to 3 N. From those samples, two representative values for thickness were used as the size for the DA liver cube samples. Two iterations of the porcine and DA liver configurations were tested.

The statistics for Iteration 1 – Liver 2 are displayed in Table 1, which shows the lower standard deviation, which equates to higher repeatability of DA SO liver in comparison to the porcine liver tissue.

Success:

- The experimental DA SO liver configurations have the capability to match the stiffness of liver tissue.
- The stiffness of 3D printed parts is more consistent than porcine tissue, which can be highly variable between samples.

Sample Type	Mean [N/mm]	Standard Deviation	Standard Error of the Mean (SEM)
Iteration 1 – Liver 2 Shell: 0.4 mm | Thickness: 15 mm	0.695	0.025	0.010
Iteration 1 – Liver 2 Shell: 0.4 mm | Thickness: 25 mm	0.570	0.033	0.014
Iteration 1 – Liver 2 Shell: 1.0 mm | Thickness: 15 mm	0.914	0.020	0.008
Iteration 1 – Liver 2 Shell: 1.0 mm | Thickness: 25 mm	0.743	0.033	0.003
Porcine Liver Tissue	1.144	0.455	0.038

Table 1

Key findings

Lubricity (epicardium and aorta)

Porcine heart tissue samples were attached to a tribometer and tested with a 0.25 in diameter steel ball with an applied axial force along the tissue surface of 0.75 N at a velocity of 0.5 mm/s for a distance of 30 mm. The output was a coefficient of friction vs. time curve which was analyzed for a stabilized window of time. DA myocardium was also attached to the base of the tribometer and tested with a 0.25 in diameter steel ball probe with the following lubricant conditions: none (dry), DI water, mineral oil, and dish soap.

All of the DA printed materials were close in value to the porcine aorta when tested with a lubricant layer of soap, with Agilus being slightly higher in value than the DA materials. DA myocardium had values which encompassed the lower to upper quartile of the porcine epicardium and Agilus was very close to porcine epicardium under these conditions.

Figures 1-5 shows how the various printed configurations compare with the porcine tissue values.

Success:

- By combining the ability to modify the coefficient friction with tissue realistic values, DA materials can allow for more appropriate bench testing boundary conditions prior to utilizing animal or cadaver models.

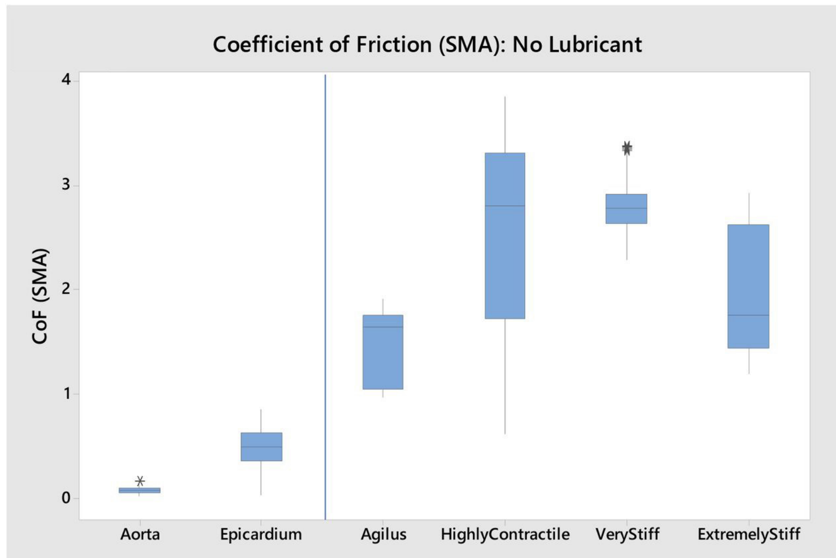

Figure 1

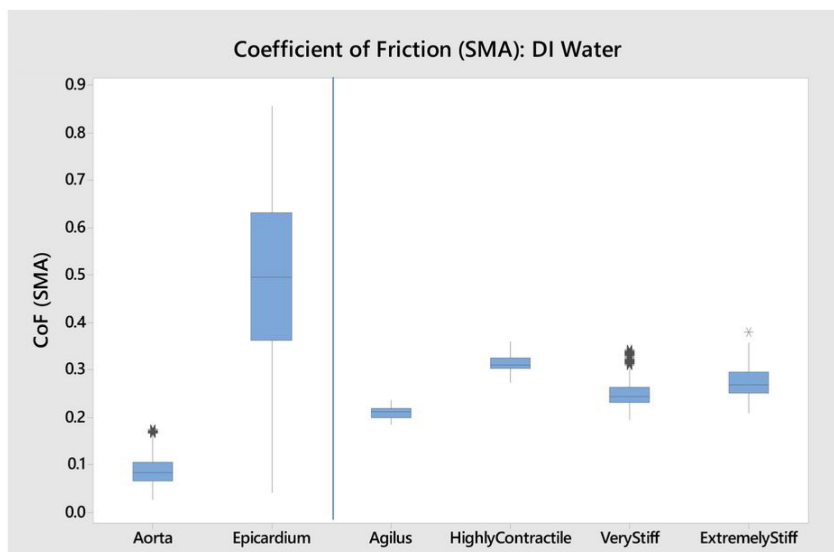

Figure 2

Tunneling and Puncture (Subcutaneous)

Cutting, puncture and tunneling of DA ST (fat and muscle) were evaluated qualitatively by pre-clinical implant specialists. They found the puncture and tunneling to be close to real tissue behavior for many of the DA ST configurations, however, cutting was not. According to the specialists, too much force was needed to create an initial incision and there was also too much drag in the cutting motion.

Success:

- DA materials can be used to design anatomical models for qualitative benchtop testing, implant procedure testing and planning because of its ability to mimic mechanical properties and the qualitative hepatics of tissue.

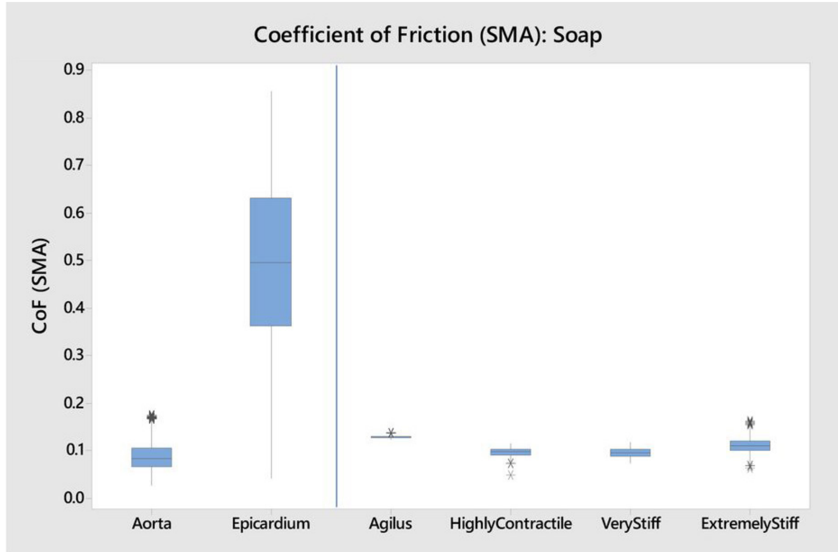

Figure 3

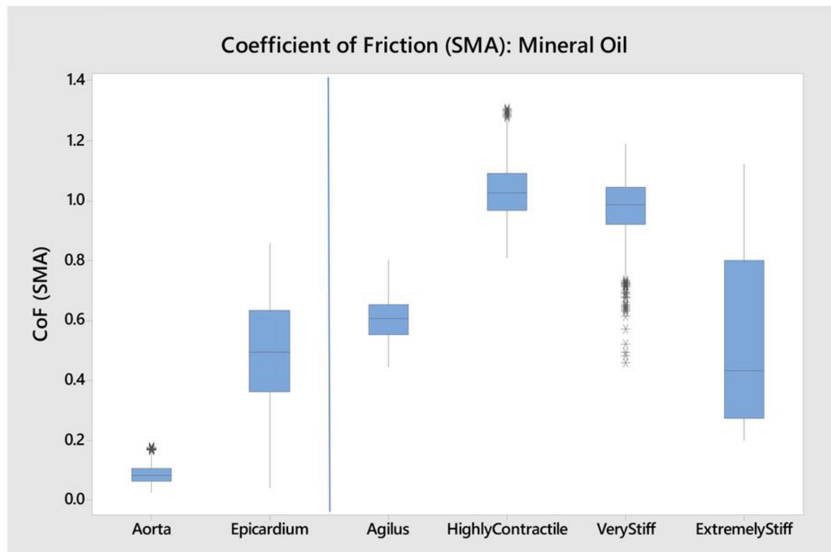

Figure 4

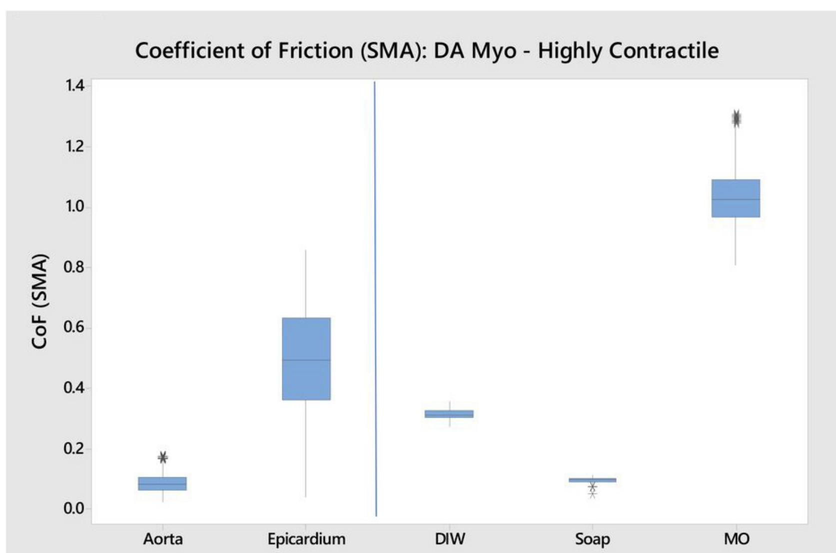

Figure 5

Summary

In summary, the new DA materials developed by Stratasys mimic the mechanical performance of biological tissue including soft organs, subcutaneous tissue and myocardium. Results from this study showed:

- DA SO liver configurations displayed the capability to match the stiffness of liver tissue and were more consistent between samples.
- The lubricity of DA materials with surface treatments were similar to porcine epicardium and aorta.
- Puncture and tunneling of DA materials also behaved comparable to real tissue, however, qualitative cutting had limited performance.

Despite a few shortcomings, the DA materials from Stratasys perform more like real tissue than any other commercial 3D printed materials on the market today. These promising results suggest that in addition to being a tool for surgery, training and education, anatomical models made with DA materials can add new value as a research tool and could reduce preliminary animal testing and usage of cadaver models.

Read the full study results here: PolyJet 3D Printing of Tissue Mimicking Materials: An Investigation of Characteristic Properties of 3D Printed Synthetic Tissue

Learn more about Digital Anatomy™ Material

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