Biomechanical Evaluation of Printed Liver and Myocardium Samples

J5 Digital Anatomy™ Printer

Introduction

The immense value of realistic surgical planning, training and education, medical device development, and patient communication has long inspired researchers and engineers to search for a synthetic, 3D printable alternative to animal and cadaver models that accurately mimics human tissue. Biomechanically accurate soft tissue models, such as liver or myocardium, can aid point of care and accelerate medical innovation.

Now, with its multi-material capabilities and facility-friendly size, the J5 Digital Anatomy printer is making precision anatomy modeling possible like never before.

To validate the functional performance of the J5 Digital Anatomy printer, researchers replicated tests that were originally performed in 2021 to compare live porcine samples to myocardium and liver samples created using the J750 Digital Anatomy printer. In 2024, the same tests were replicated using J5 Digital Anatomy samples.

Objective

Scientists and engineers from Medtronic, a global leader in medical device manufacturing, conducted independent third-party research to compare the mechanical properties of J5 Digital Anatomy samples with the results from previous J750 Digital Anatomy and porcine tissue tests.

Methods

The research team tested mixed-material 3D printed samples using the J5 Digital Anatomy printer that were designed to mimic myocardium and liver tissues. Mechanical tests were performed to compare biomechanical properties to samples created using the J750 Digital Anatomy Printer and to porcine tissue.

The stiffness of the samples was evaluated by compressing liver samples with small and large pins. Compliance testing was used to measure the stiffness of printed myocardium samples. Lubricity testing recorded the coefficient of friction between printed cardiac samples, with different lubricants.

The values were evaluated against those of live porcine tissue, which was used as the baseline for comparison because of its similarity to human tissue, availability, and the precedent for its use in pre-clinical testing. Figures 1-3 demonstrate the test setups.

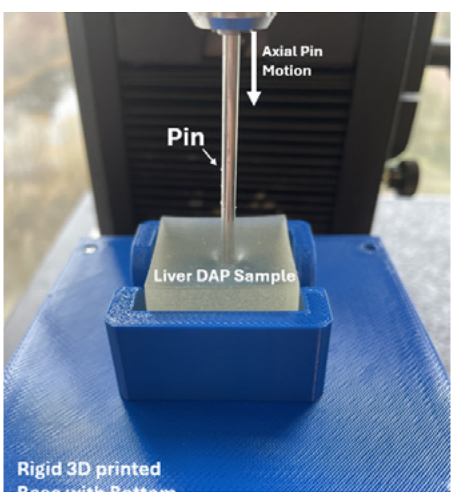

Figure 1- Printed liver sample showing tenting from a 9Fr rod during the compression test

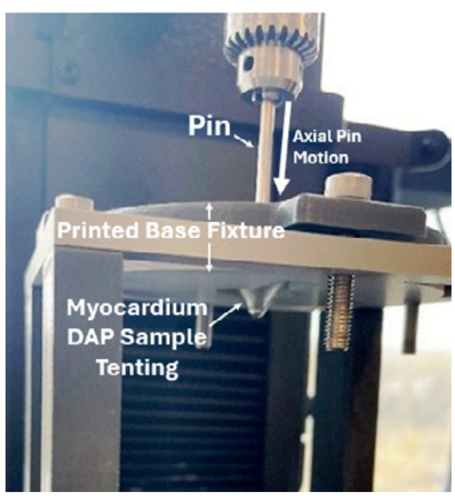

Figure 2- Printed myocardium sample (2.5mm) showing tenting from a 9Fr rod penetration

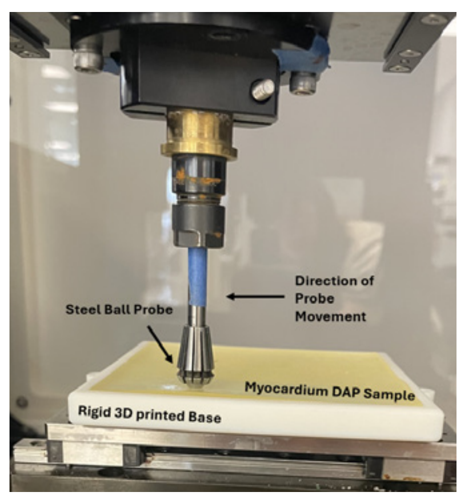

Figure 3- Lubricity test fixturing showing the printed myocardium sample loaded into the rigid 3D printed test fixture. The rod travels from the middle of the sample to the left for each iteration.

Key Findings

Stiffness Testing

All printed liver samples had stiffness values within the range of porcine liver stiffness values (Fig 4).

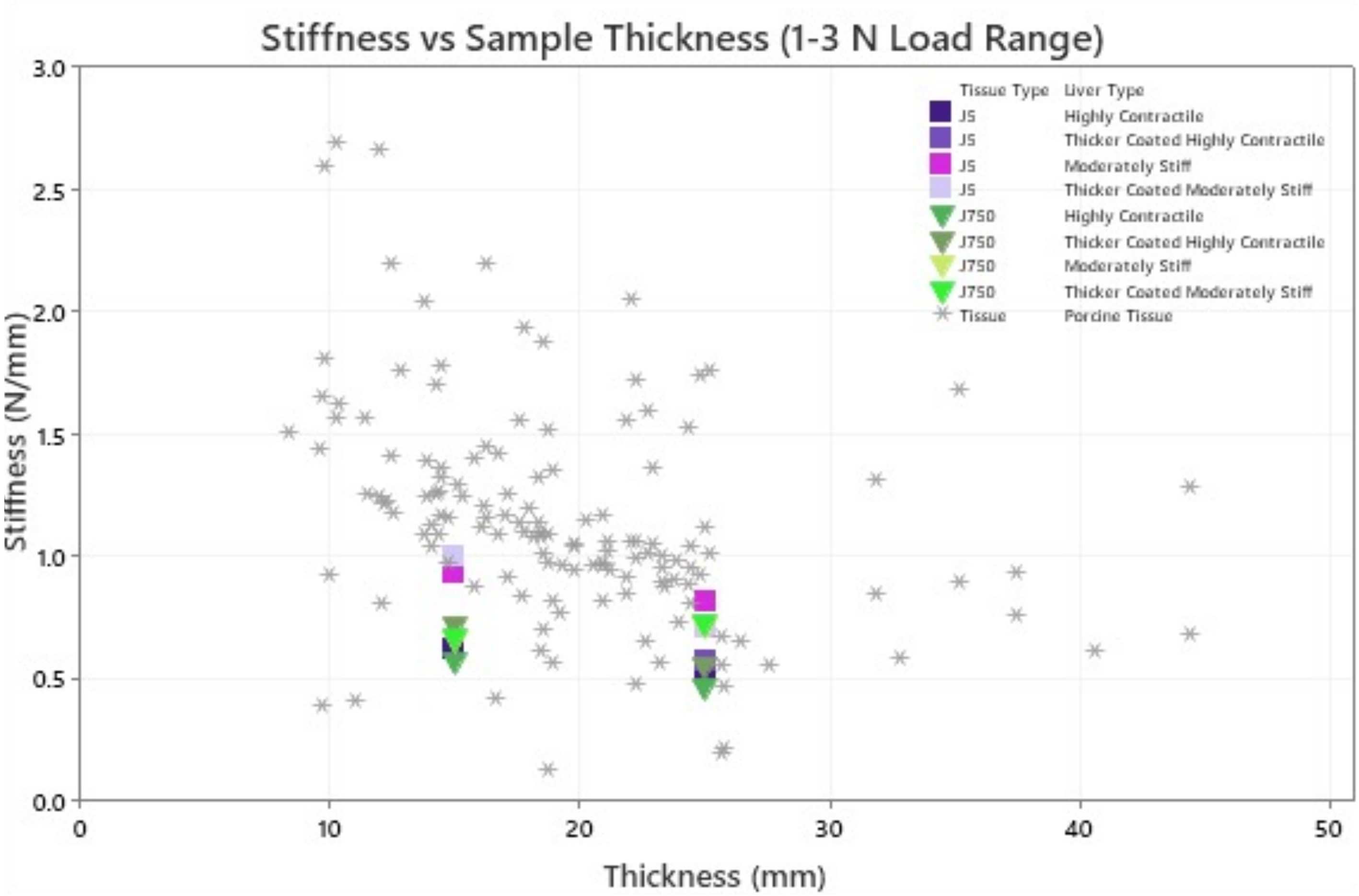

Figure 4- J5 and J750 Digital Anatomy liver samples at two thicknesses compared to porcine liver samples of variable thicknesses from multiple liver lobes

Compliance Testing

Printed samples of J5 Digital Anatomy myocardium tissues were compressed using small and large pins. Results of 5 mm displacement of both pins is shown in Figures 5 and 6.

J5 Digital Anatomy printer samples were within the stiffness range observed from various porcine cardiac locations.

Compliance testing of myocardium tissue demonstrated comparable stiffness values between thickness and printer types. Thicker, more compliant J5 Digital Anatomy samples showed more variability between stiffness values compared to J750 Digital Anatomy samples, but these ranges still fell within porcine tissue stiffness. Both printer types had higher stiffness values compared to stiffness values that would correspond to those thicknesses within the heart.

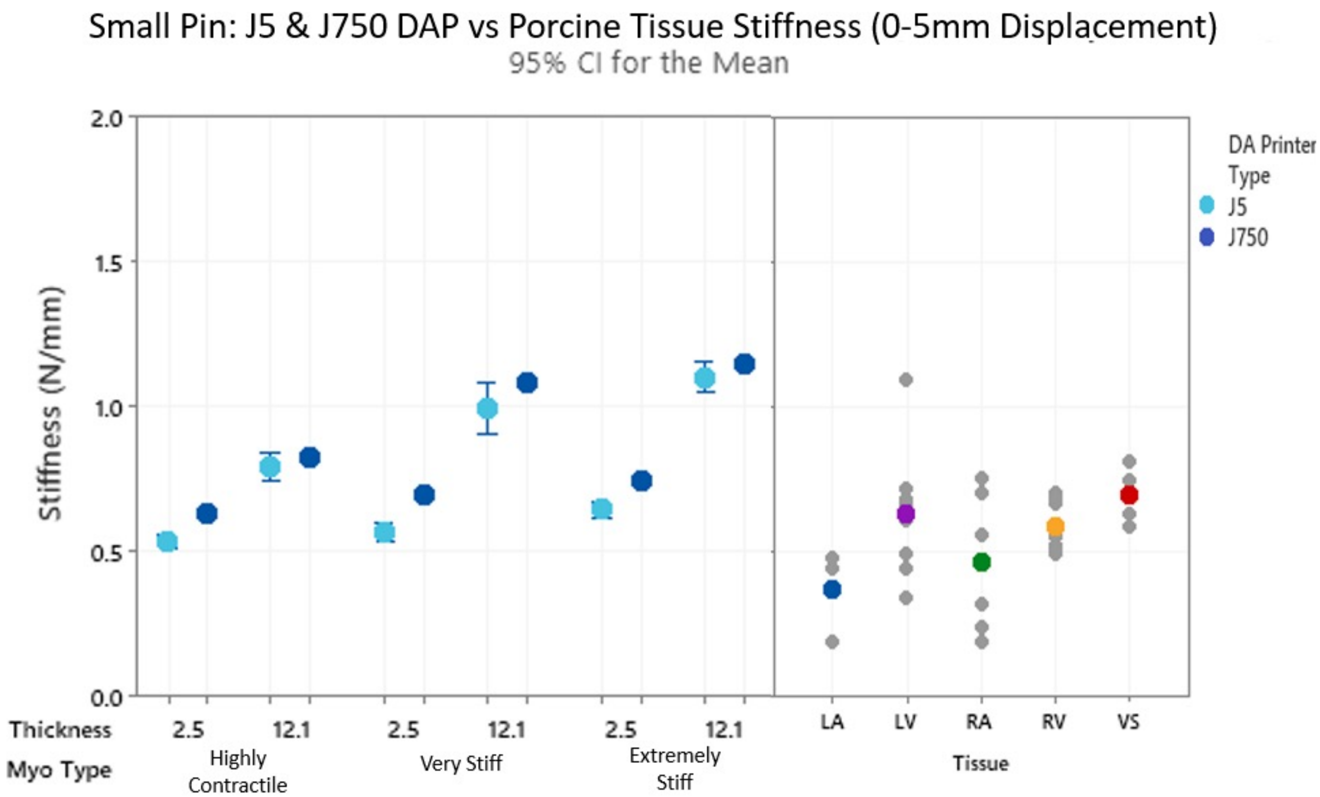

Figure 5- Stiffness comparison of the J5 Printer and J8 Printer myocardium samples compared to porcine tissue using a 9Fr pin displaced within the first 5mm.

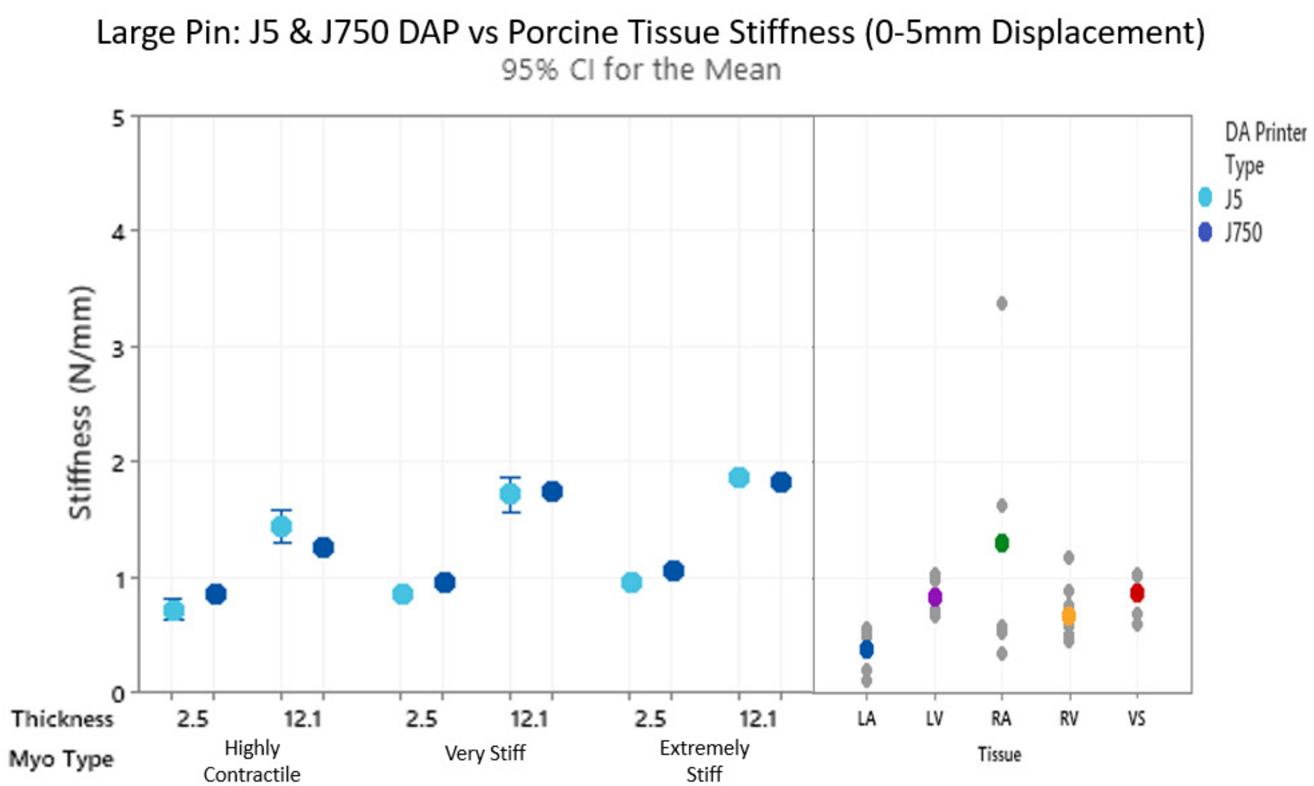

Figure 6- Stiffness comparison of the J5 Printer and J8 Printer myocardium samples compared to porcine tissue using a 22Fr pin displaced within the first 5mm.

Lubricity Test

In general, all J5 Digital Anatomy printer samples that were lubricated fell within the coefficient of friction ranges observed from porcine samples. The coefficient of friction of all myocardium types between both printers produced higher values when compared to the porcine tissue samples. Results are presented in figures 7 A-D.

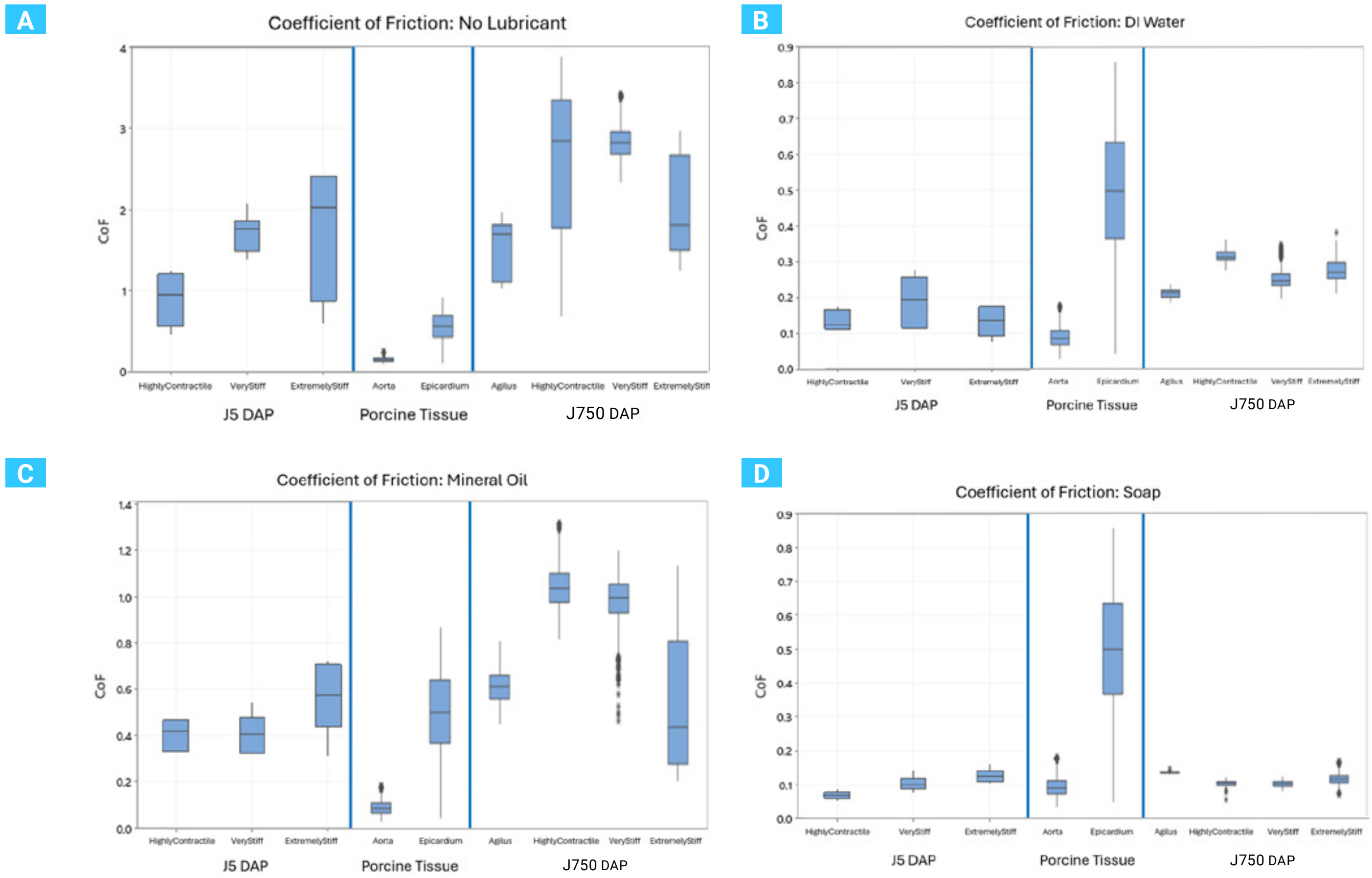

Figure 7- The coefficient of friction with different lubricants. comparison between J5 Digital Anatomy printed cardiac tissue sample types (left), to porcine tissue (middle) and J750 Digital Anatomy printed cardiac tissue samples (right).

Conclusions

Based on the three mechanical tests conducted, researchers concluded that J5 Digital Anatomy printer samples are very similar to J750 Digital Anatomy printer samples and fall within the range of porcine tissue. They did note that there may be slight differences in stiffness, depending on the application.

Both printers create accurate Digital Anatomy samples and offer different compliance of the simulated tissue, which may be useful to not only simulate tissue from multiple areas of anatomy, but also to potentially simulate disease state tissues.

For the full report, please read- https://doi.org/10.1101/2024.06.18.599608

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