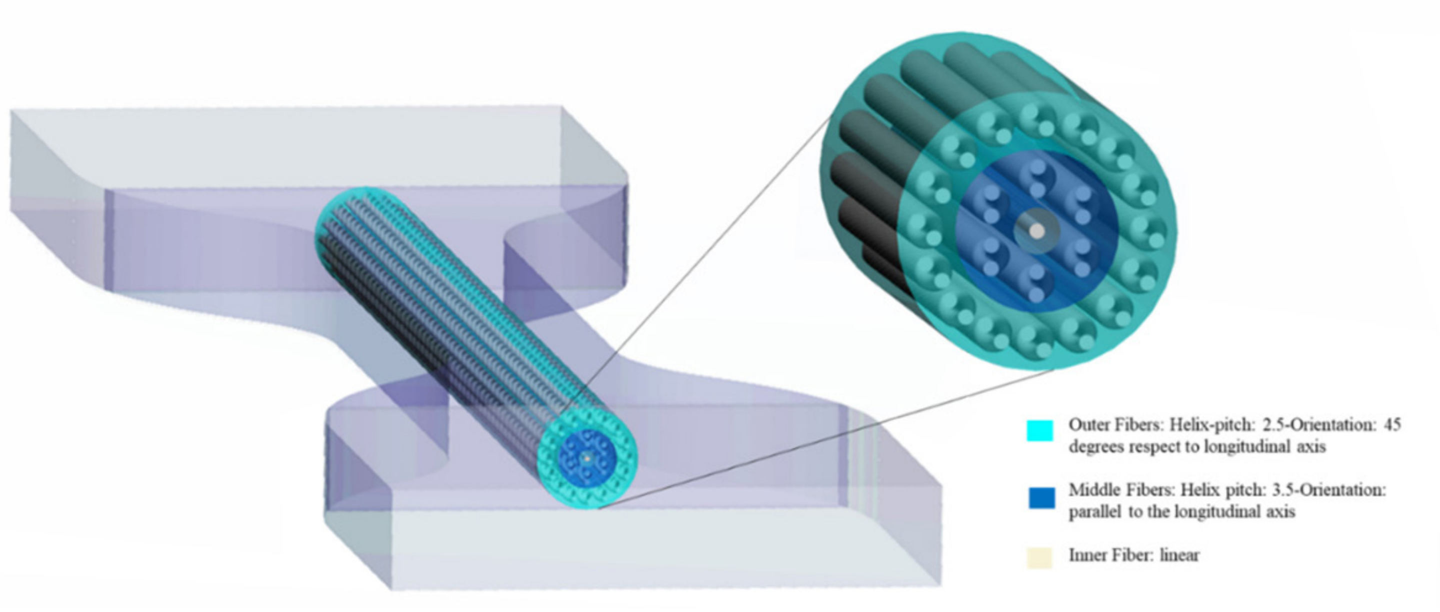


White Paper

Creating realistic tendon and ligament models using the Digital Anatomy Printer

Alongside the shift in healthcare toward personalized medicine, 3D print technology has emerged as an invaluable tool for academic medical centers, hospitals, and medical device manufacturers to create patient-specific anatomical models.

These models have fueled unprecedented research, training and education, pre-surgical planning, manufacturing custom-made medical devices, and testing novel devices before in-vivo trials.

But to date, traditional modeling methods and legacy print technologies have limited the degree to which models can accurately replicate the biomechanical properties of organic tissue.

Using PolyJet™ to accurately mimic human bio-structures

PolyJet print technology allows manufacturers to create models using high-performance composites of materials—with variations in rigidity and elasticity, blended transitions, and multiple colors, textures, and transparencies.

By using these different stiffness values and textures, biomedical models can mimic the mechanical properties of their pathologies—without compromising the complexity of the geometric design.

The Study

In 2022, a team of researchers at the Bio-Inspired Nanomechanics Laboratory of the Politecnico di Torino sought to create a multi-material model that mimics the mechanical behavior of specialized soft tissues such as tendons and ligaments—with the help of the Digital Anatomy™ Printer, powered by PolyJet technology.

To date, it has been difficult to emulate the bio-structures of these specialized soft tissues because of the complex transmission of the mechanical load that accomplishes joint stability and range of motion.

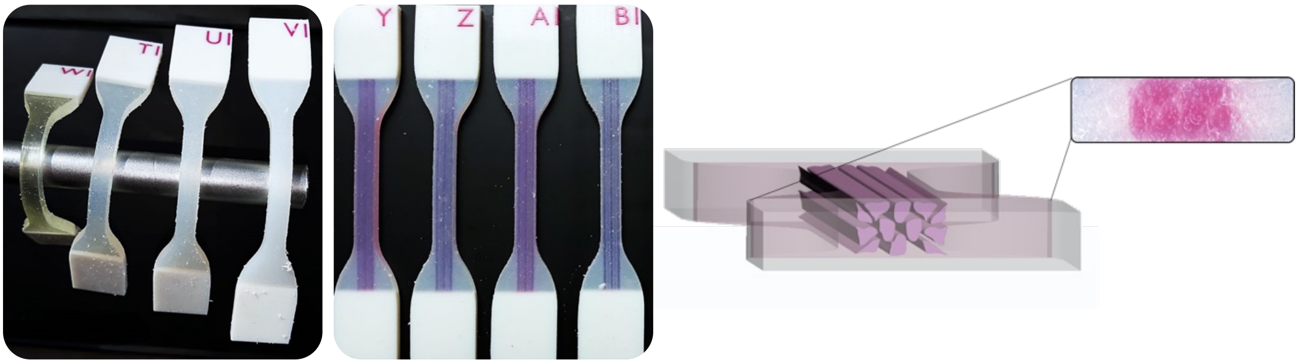


Figure 1: Three-dimensional printed dog-bone specimens of the different base PolyJet™ materials and the proposed biomimetic patterns. A) Comparison of the different durometers' levels of the Agilus30™ and TissueMatrix™ materials. B) The specimens with the different embedded patterns are shown. The test piece combines the rigid (VeroWhite™) and flexible (Agilus30™) materials. C) A cross-section of the Tendon-Mimic (TM) specimen is shown in a microscope view at 100X magnification.

Method

To evaluate material patterns that mimic the mechanical properties of tendon and ligament tissues, four structure patterns with varying Shore A hardness levels were chosen, designed, embedded within a matrix, and printed using the Digital Anatomy Printer.

The team performed a finite element analysis and evaluated the pattern position inside the models to assess their tensile strength. Using Digital Image Correlation, the team evaluated differences in mechanical properties according to pattern type, hardness combinations, and matrix-to fiber ratio and compared them to the mechanical characteristics of base PolyJet composite materials with fixed hardness values.

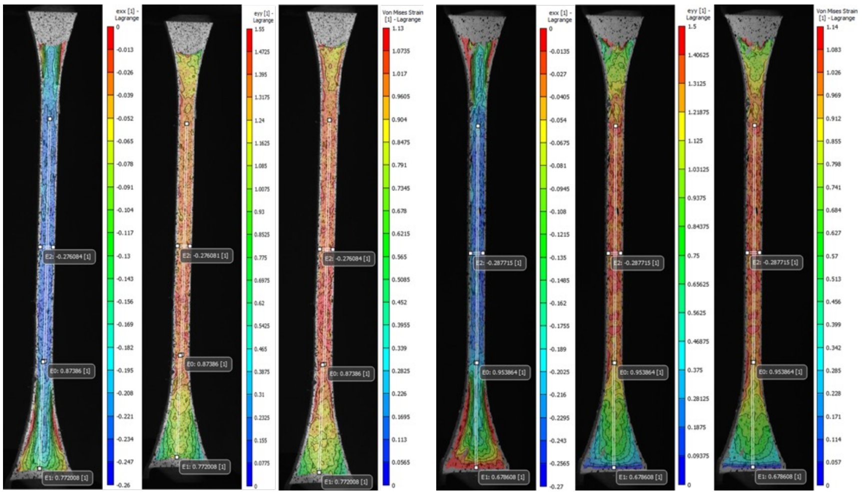


Figure 2: Digital image correlation (DIC) strain fields of the most significant specimens: V Tendon-Mimic (TM) - J1 Helix-Bamboo (HB) patterns. Longitudinal strain (eyy), local transverse strain (exx), and Von Mises equivalent strain (eeq). The virtual longitudinal extensometers E0 and E1 are positioned at L_0=33 mm (narrow section) and L= 16 mm (distal). Transverse extensometer E2 is positioned at L=6 mm (central).

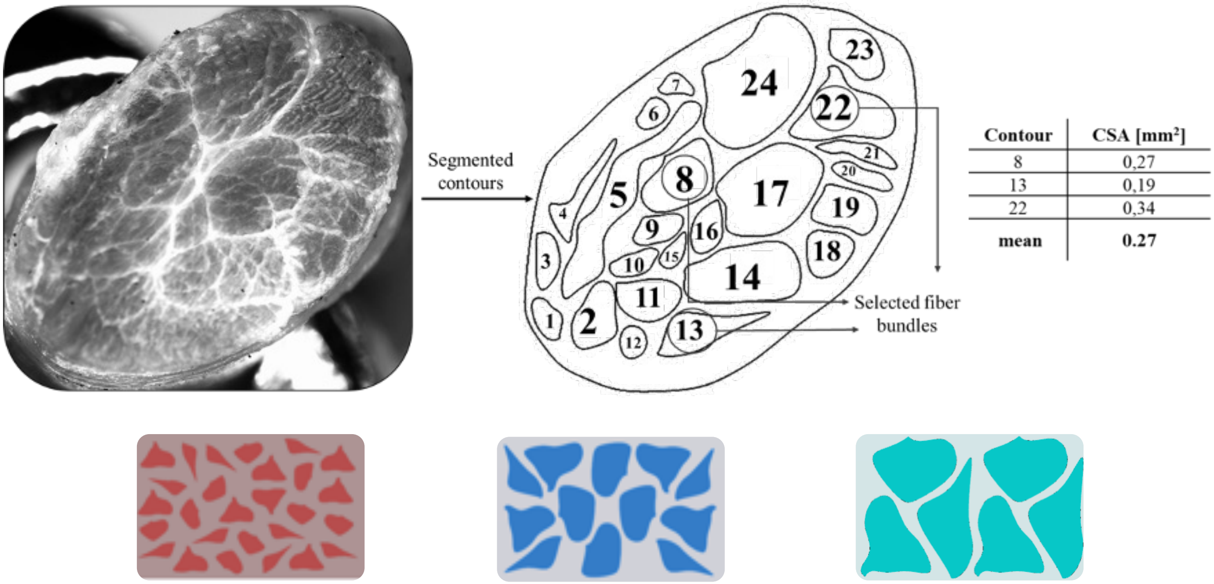
The Results

The Digital Anatomy Printer technology allowed the researchers to set different Shore A hardness values to the various components of the pattern within its geometric design, which demonstrated superior mechanical performance compared to the base PolyJet print materials.

The high resolution and micrometric layer thickness available through the Digital Anatomy Printer technology mimicked the mechanical response of tendon and ligament structures with precise repeatability in the mechanical tensile test.

The Conclusion

PolyJet technology allows academic medical centers, hospitals, and medical device manufacturers to create highly accurate anatomy and pathology models. With sophisticated presets configured using material combinations and transitions that vary in density and flexibility, **the Digital Anatomy Printer offers the versatility to tailor to specific clinical needs.**



Contour	CSA [mm²]
8	0,27
13	0,19
22	0,34
mean	**0.27**

Variation A
F33-M66

Variation B
F60-M40

Variation C
F50-M50

Figure 3: Tendon-Mimic (TM) pattern arrangement. The segmented contours of the equine tendon and cross-sectional areas are reported, as well as the percentage of area occupied by the fibers on the narrow cross-section of the specimen.

Reference

Grimaldo Ruiz, Oliver et al. “Design and Mechanical Characterization Using Digital Image Correlation of Soft Tissue-Mimicking Polymers,” Polymers Special Issue: Structure and Properties of Polymeric Materials in Additive Manufacturing (2022).

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