

## *Evaluation of surrogate soft tissue candidates for biofidelity and durability*

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**Introduction:** Biofidelic human surrogates are used to estimate human responses in injurious scenarios, where impacts to the body are transmitted to internal sensors in the ‘skeleton’ via soft tissue analogue materials. Current anthropomorphic test devices (ATDs) use materials that have high repeatability but low biofidelity [1]. As they are used for regulatory testing, repeatability and durability have been prioritized; as such, soft tissue analogues have higher innate stiffnesses [1] and do not capture the viscoelasticity of flesh properly [2]. A more biofidelic soft tissue material would provide better translation of injury limits defined using cadaveric tissue to these standardized tools but must preserve durability.

**Objective:** To investigate how synthetic materials respond to repeated dynamic loading and compare to previous tissue characterization.

**Methodology:** Three elastomers (silicone 10A, silicone 20A, and urethane 25A), were selected for evaluation (three samples of each material, n=15). The materials were cast or cut into 10mm thick samples (113 x 50mm cross-section). A current ATD soft tissue surrogate material (foam, Humanetics Innovative Solutions, Inc., Plymouth, Michigan, USA, n=2) was similarly prepared for comparison. Samples were subjected to quasi-static compression testing using a materials testing machine, dynamically impacted nine times with a pneumatic impacting apparatus, and then re-characterized under quasi-static compression. During dynamic testing, each sample was impacted at 40J while mounted over a force sensor, to quantify the load transmitted by each material. Compression testing was performed at 12 mm/min to 25% strain, and unloaded at the same rate. The material modulus was calculated for each quasi-static test, and a paired t-test ( $\alpha=0.05$ ) used to identify changes between pre- and post-dynamic testing as a proxy for durability. Values were also compared to those from previous quasi-static human tissue characterization to evaluate biofidelity.

**Results:** No visible damage was noted on samples. Significant differences were found in mean peak force transmitted between silicone 10A:  $8,530 \pm 184$  N and urethane 25A:  $7,308 \pm 29$  N ( $p=0.0003$ ) and silicone 20A:  $8,160.5 \pm 232$  N and urethane 25A ( $p=0.0022$ ). The Humanetics foam transmitted significantly higher forces than all elastomer materials, mean peak force:  $9,266 \pm 196$  N ( $p<0.012$ ). Under quasi-static compression, no significant changes were found in elastic moduli between pre and post impact analysis ( $p>0.35$ , Figure 1). The materials elastic moduli's post-impact: silicone 10A was  $651 \pm 379$  kPa, silicone 20A was  $1,065 \pm 318$  kPa, urethane 25A was  $729 \pm 608$  kPa, and Humanetics foam was 33 kPa. Silicone 10A and urethane 25A fell within the previously reported range of human tissue (118.6 – 867.2 kPa) [3] under unconfined compression.

**Conclusions:** Under repeated dynamic loading, each elastomer and foam sample had consistent impact responses over the series of high-force impacts. Silicone 10A and urethane 25A demonstrated an elastic modulus within the range of human soft tissue, suggesting they may be biofidelic options for a future soft tissue analogue. This research can inform and guide the selection of future materials to preserve durability while enhancing biofidelity for more accurate injury evaluation.

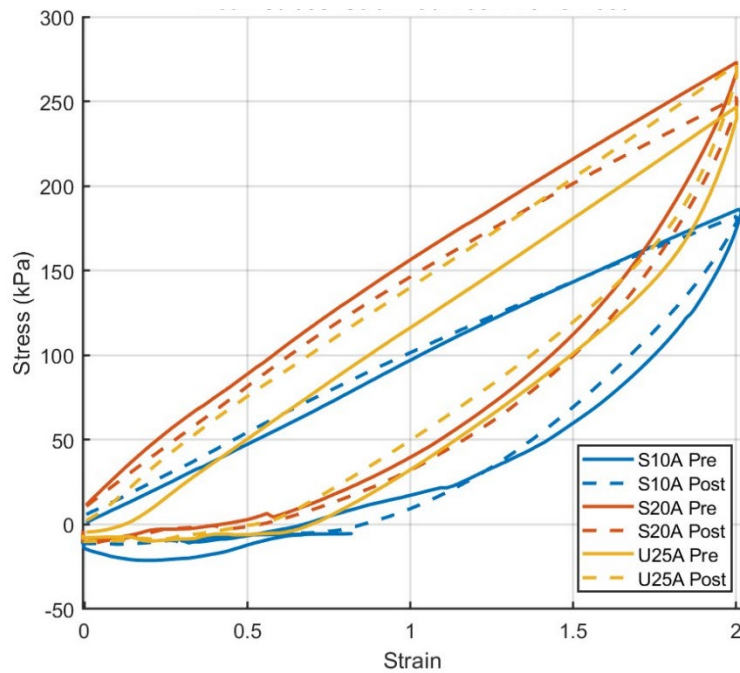


Figure 1. Mean stress-strain curves for silicone and urethane materials, comparing pre- and post-impact, showing material-dependent changes in stiffness and hysteresis

## References

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