CHARACTERISATION OF THE PHANTOM TISSUE MODELS FOR MEDICAL DEVICE TESTING AND SURGICAL TRAINING

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Introduction

This research paper focuses on characterizing the mechanical properties of silicone rubbers used for the development of medical devices, medical training models and surgical procedural practice. High-fidelity phantoms provide test beds to improve all elements of healthcare. Silicones are a commonly used material in tissue phantoms and are assessed here for use in skin and cardiovascular applications. Silicone rubber is a highly desirable tissue mimicking material for medical training equipment due to its longevity and hyper-elastic behavior. Experimental and analytical studies of commercially available, maxillofacial prosthetic silicone materials have focused on material tensile strength, tear strength, percentage elongation, material hardness and bond strength [1, 2]. This study investigates the mechanical behavior of silicone blends suited for a range of phantoms.

Methods

Hybrid silicone blends of theoretical Shore 00-40, 00-50 and 00-60 silicone rubber specimens were created using the method outlined in Figure 1. The tensile, compressive and tear behavior was characterized. The tensile load tolerated by a suture through the silicone rubber specimens was also measured, following an experimental method from ref. [3]. Experimental results may be used to determine optimal silicone materials for suture practice models used by medical professionals.

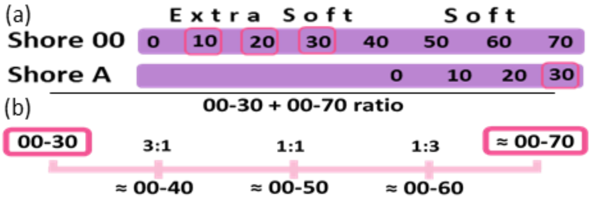

Figure 1: Durometer hardness scales. (a) Highlights the unmixed materials; and (b) illustrates the mixing ratios.

Digital Image Correlation (DIC) was used as a non-contact optical method for tracking and imaging the suture hold and tear through each sample. Platforms exploiting controlled silicone properties were then made to study applications where regional and individual soft tissue variations are important, such as the face.

Results

Figure 2 graphically displays the stress-strain results obtained from performing tensile tests on all the silicone specimens. Figure 2 also displays the DIC results obtained from the suture extrusion experiments as the sample began to tear.

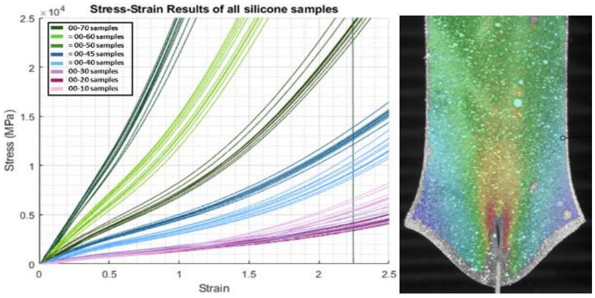

Figure 2: Sample stress-strain results and DIC image of the full-field strain observed during suture extrusion.

Discussion

The silicone specimens exhibit typical, hyper-elastic stress-strain behaviour with a relatively steady increase in compliance as the samples range from Shore 00-70 to 00-10. Furthermore, the suture imaging results illustrate high strain concentrations around the suture, which may further influence the design of suture training equipment and protocols. This study demonstrated the ability to tune mechanical properties of silicones for any application across phantom types. Surgical training or medical device testing have different properties of interest from their phantoms and this paper provides a mechanical reference database to enable tailored solutions. The silicone materials characterised in this study were used in testing oxygen face mask fit on pressure-sensitive head models, testing mechanics of heart valves and development of a skin phantoms for suture training devices (displayed in Figure 3).

Figure 3: Medical applications of silicone rubber including for use in a high-fidelity head rig for assessing mask fit quality.

References

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