Design and Prototyping of Dynamic Midurethral Sling for The Treatment of Stress Urinary Incontinence

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Statement of Purpose: Stress Urinary Incontinence (SUI) is a condition that affects 1 in 2 women during their lifetime. This condition is characterized by involuntary leakage of urine during increased intra-abdominal pressure such as when coughing, laughing, or exercising. SUI is commonly treated with the surgical implantation of a sling underneath the urethra. The sling supports the urethra and can improve continence. However, these slings are static, which leads to a tradeoff. If the sling compresses the urethra too much, urine is retained. If the sling is too loose, incontinence persists. Here, we evaluate the use of light-activated Liquid Crystal Elastomer (LCE) for the fabrication of a dynamic sling. This sling is designed to enable continence normally, but then to reduce support of the urethra by shape change of the sling triggered by IR light.

Methods: 3D printing of LCEs enables the programming of the reversible shape change in these materials. Our prior work has shown that LCEs change shape in response to temperatures in the range of 37°C – 45°C, which is considered safe for tissue hyperthermia [1,2]. Here, we incorporate IR-absorbing particles, carbon black (CB), to enable the shape change of LCE to be triggered by IR light. To simulate the mechanical environment of scar tissue, 3D printed LCE-CB composites were embedded in agar gels with varying moduli. Shape change of the LCE-CB sling with CB concentration between 0 and 0.4 wt% is studied in response to varying IR intensities and illumination times. Change in temperature at the sling surface and surrounding agar is evaluated.

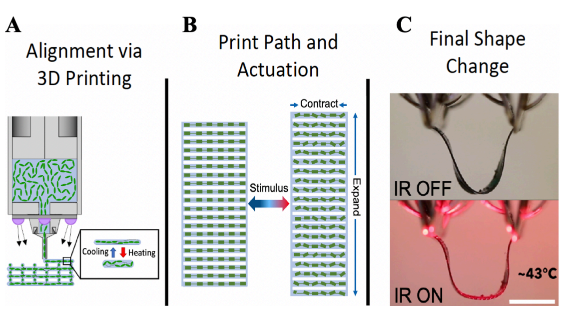

Figure 1. *Schematic of 3D printing of LCEs (A). Schematic of shape morphing stimulus response of 3D printed LCE (B). Photothermal actuation of LCE-CB sling with IR light, scale bar: 5mm (C).*

Results: 3D printing slings with a rectilinear print path (filaments aligned along the short axis) allows for sling elongation on heating ***(Fig. 1A, B)***. We expect that as the LCE-CB sling elongates, some urethral pressure is released to allow voiding ***(Fig. 1C)***. This shape change must occur even after the scar formation around the device. An LCE-CB sling with 0.2wt% CB, embedded in 1% agar (100kPa modulus [3]) demonstrates a $3.9 \pm 0.6\%$ width contraction within 90 seconds when illuminated with IR light (400 mW/cm^2) ***(Fig. 2A)***. Continuous illumination of IR light for three minutes leads to a 10°C increase in sling temperature and a 6°C increase in the temperature of the surrounding agar, which is below the threshold for thermal damage ***(Fig. 2B)***. The LCE-CB sling embedded in agar returns back to its original shape after 30-45 seconds. Increased CB content increases the photothermal heating efficiency.

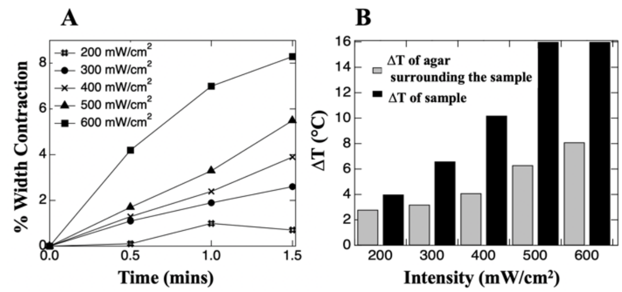

Figure 2. *Actuation of LCE-CB sample tested in 1% agar with multiple light intensities over 90 seconds (A), temperature increase of the sample and surrounding agar at varying intensities, tested over three minutes (B).*

Conclusions:
LCE-CB slings embedded in agar-based model mimicking scar were heated using IR light and programmable shape change occurs. 3D printing of LCE-CB slings will allow patient specific device fabrication. Future work will involve testing LCE-CB slings implanted in multiparous animal model of incontinence.

References:
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