Sweat-Wicking Prosthetic Liner for Lower Limb Amputees

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Problem Statement

- Over 185,000 lower limb amputations are performed in US each year [1]
- Prosthetic users need liner to interface with prosthetic device [2]
- Current liners accumulate sweat, leading to skin irritation, discomfort, and reduced mobility [3]

Needs Statement

The development of a novel solution for prosthetic device liners to reduce moisture build up due to perspiration in lower limb amputees.

Proposed Solution

A silicone prosthetic liner with:

1. Channels: silicone molded with channels to wick sweat via capillary action
2. Absorbent fabric: sweat travels to absorbent insert at base of liner which can be removed and washed daily

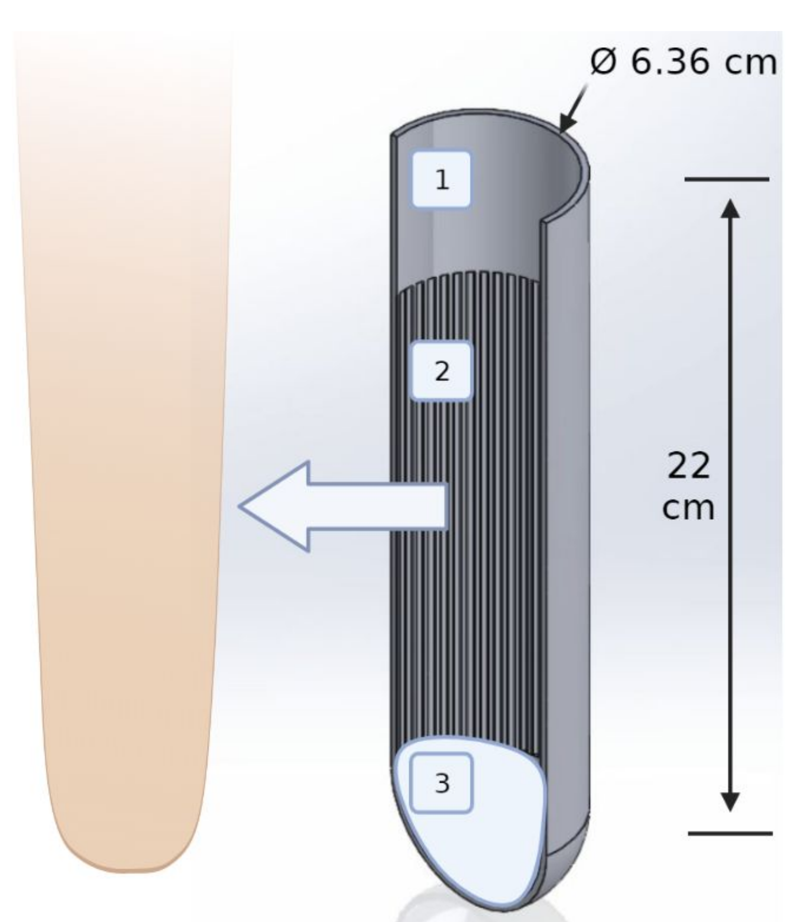

Fig. 1: CAD cross-section representation of a silicone lower limb prosthetic liner with interior channels to wick sweat downwards towards a removable absorbent pad.

1. Smooth region to maintain seal of liner to limb
2. Channeled region to allow for sweat-wicking capillary action
3. Absorbent fabric insert

Final Prototype

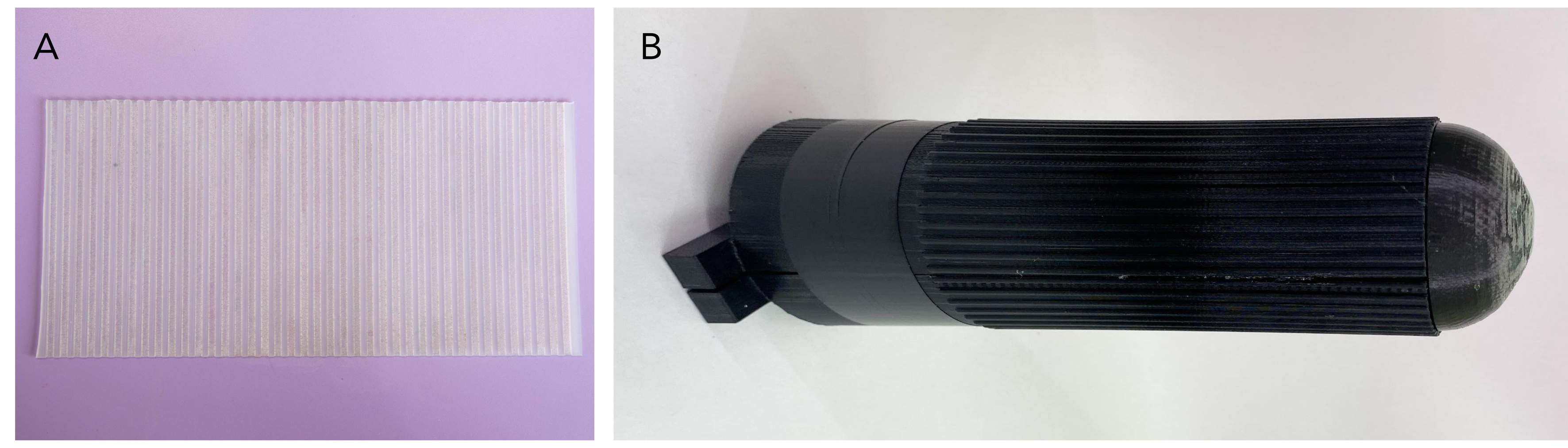

Fig. 2: A. Flat silicone sheet fabricated in a 3D printed mold with channels.
B. Final 3D printed mold for liquid silicone. This inner mold rests in an outer cylindrical shell to create a single silicone piece with both channeled and non-channeled regions.

Capillary Flow Testing

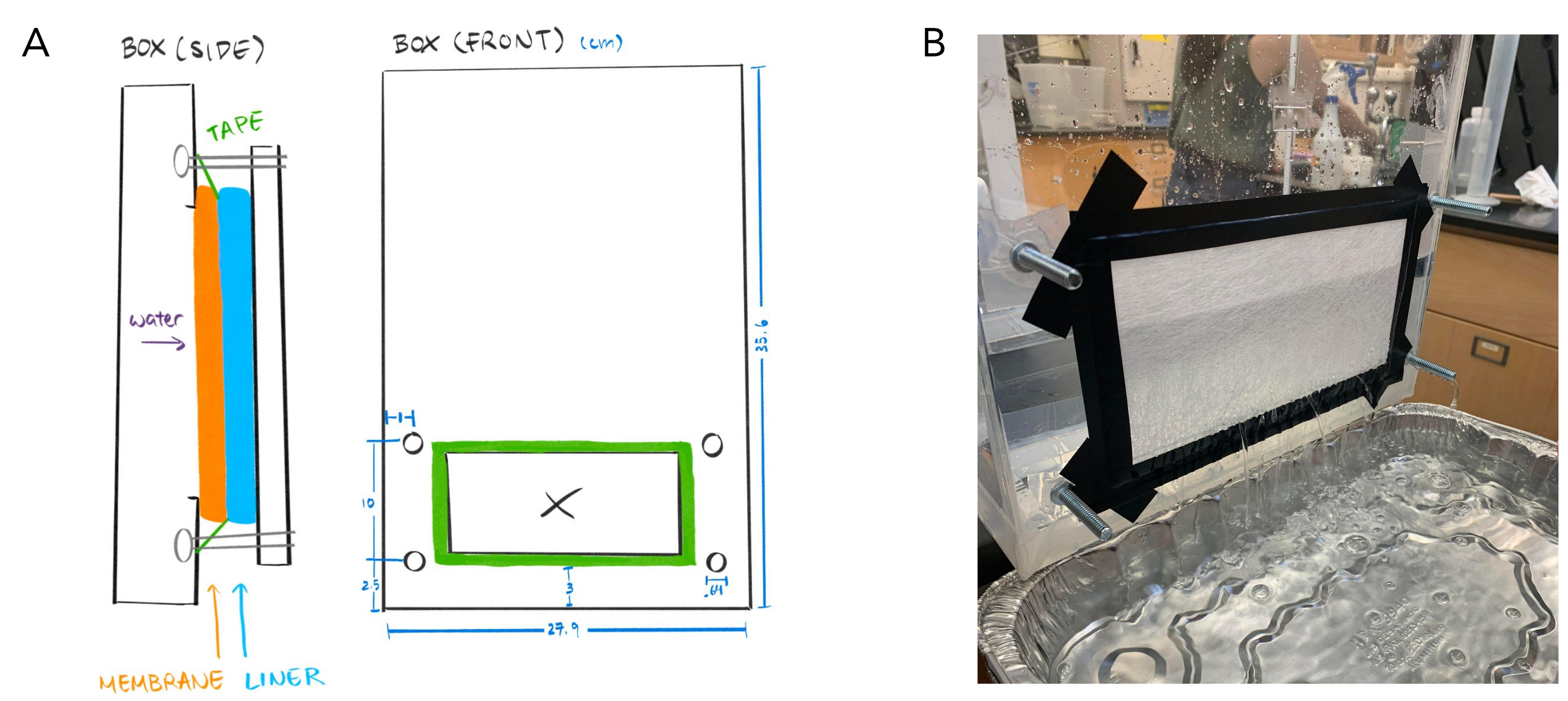

Fig. 3: A. Side and front view schematic of the membrane based reservoir flow panel.
B. water flowing through a double layered 10 micron membrane

Iteration of capillary flow experiments

1. Pipetting water into liner: Proof of concept, water travels preferentially through channels.
2. Pore reservoir: Reservoir box with laser cut holes in one side to mimic sweat pores. Saline flows through pores as a result of hydrostatic pressure.
3. Membrane reservoir: Reservoir box with double-layered 10 micron membrane panel to control flow rate. Secondary acrylic plate is screwed on to press the test liner tightly to membrane with even pressure.

Fig. 4 Front view of experimental setup with liner pressed against membrane-based reservoir flow panel

Quantitative Testing Results

Channel Size	Average amount of fluid collected after 15 seconds (mL)
Control: No channels	980 ± 75.8 (N = 5)
Small Channels: 2mm width, 4mm spacing	1250 ± 81.2 (N = 5)
Large Channels: 3.5 mm width, 2.5 mm spacing	1660 ± 192 (N = 5)

Table 1: Amount of water flowing through the membrane due to hydrostatic pressure while pressed against a flat silicone sheet in a 15 second increment.

A one-way ANOVA test produced a p-value of 8.73×10^{-6}, showing a statistically significant difference between the mean fluid fluid flow with and without channels.

Reimbursement and Patents [4,5]

- Reimbursable by Medicare /Medicaid under Durable Medical Equipment coverage
- Similar patent search:
  - US20170079811A1: System and method for polymeric prosthetic liner perspiration removal
  - US8308815B2: Vacuum-assisted liner system
  - US9155636B1: Prosthetic socket liner

Conclusions

- Presence of channels increase rate of sweat transport
- Larger channels quantitatively wick more water at high flow conditions
- Smaller channels qualitatively wick more water at physiologically appropriate flow

Future Work

- Channel pattern design: exploring nonlinear channel patterns, such as fractals
- Reduce flow rate of membrane box to better mimic physiological conditions
- Optimize 3D printed mold and 3D liner

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