Sensor Technology for Enhanced Prosthesis Production (STEPP)

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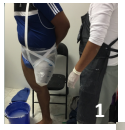
Abstract

- Inspired by Range of Motion Project in Quito, Ecuador
- Students worked directly with amputees and prosthetists
- Patients travel for hours, or even days, to receive prosthetic care
- Prosthetics now - artisanal process, highly specialized

1. Molding
2. Casting
3. Manufacturing
4. Final Socket



- This artisanal method quickly becomes **tedious** and **time-consuming**
- Can be difficult to achieve a socket that fits the patient perfectly
- STEPP is saving prosthetists time and money by allowing them to see more patients

Problem

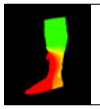
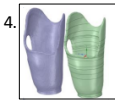
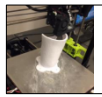
- Amputations occur **every 30 seconds** worldwide[1]
- 80% of amputees live in developing countries – only **2% have access to proper prosthetic care**[2]
- There is an increasing need for prosthetic care in developing countries.
- STEPP is addressing this need with an intuitive device that will quantitatively produce prosthetic sockets

Objectives

1. Reduce the number of fittings needed
2. Reduce manufacturing costs
3. Improve fit of socket for patients
4. Reduce time needed to make prosthetics

Methods

The STEPP team began solving the problem by focusing on designing a device to test for the tissue stiffness of residual limbs. This gives quantitative data that can be integrated with a topographical image of the residual limb.

1.  3D scanner gives topographical image of residual limb
2.  Force probe used to measure tissue stiffness (first prototype)
3.  Scanned image mesh is translated into heat intensity map for tissue differentiation
4.  Computer Aided Design (CAD) is made from scanned image
5.  Additive manufacturing is used for prosthetic socket

Step 2 was decided to be **the most important** part for STEPP this year. The measurement of tissue stiffness needs to be as accurate as possible.

Second prototype made to take out human error and focus on the accuracy of the measurements.

Third prototype made from scrapped 3D printer.

Cyclical tests were done on rubber, foam and plastic materials.

This design tested for accuracy and consistency of stiffness data from each of the samples.

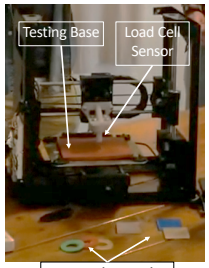
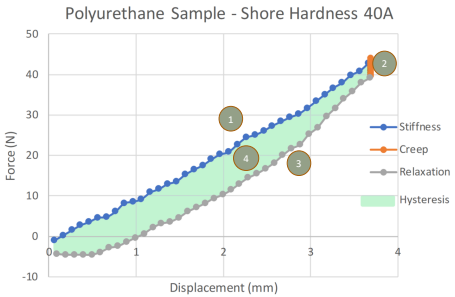
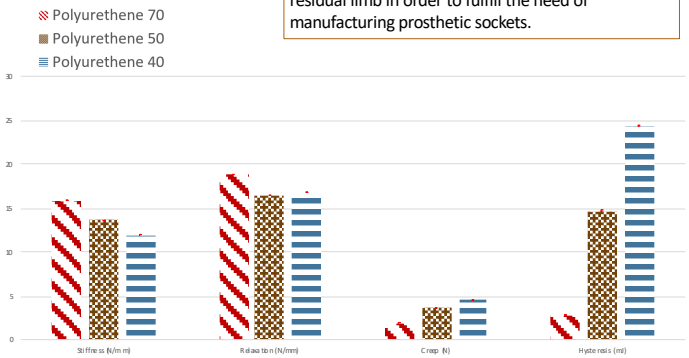


Chart 1. Force vs Displacement Data Collected During Test Procedure



1. **Stiffness**: Average slope of force as a function of displacement while pressing into material.
2. **Creep:** Decrease in recorded force while holding displacement constant.
3. **Relaxation**: Average slope of force as a function of displacement when removing sensor from material.
4. **Hysteresis:** Energy lost during testing. Recorded by difference in the area under the two curves.



Results

Four Material Properties: Stiffness, Relaxation, Creep, Hysteresis

- Total of 8 materials tested and 28 combinations when comparing to every other material
- An unpaired t-tests with 99.9% confidence compared all 28 combinations
- All 28 combinations of materials, were compared against each other and demonstrated that the material properties were **successfully differentiated**

Budget

Prosthetics Now
Labor cost = 30-40% of total cost[3]
Each socket built to last about 3 – 5 years
Average cost for one patient in 6 years = **$35,000** [3].

STEPP
Testing device = **$150**
Printed socket= **$550**
Other costs = maintenance and printing filament
Significant Cost Reduction Per Patient

Conclusions

STEPP's testing device successfully differentiated material properties from 8 different samples. This demonstrates that our device is on the right path to be able to differentiate biological tissues in the residual limb in order to fulfill the need of manufacturing prosthetic sockets.

Contact Information

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References

[1] Ziegler-Graham K, et. al. Estimating the Prevalence of Limb Loss in the United States: 2005 to 2050. Archives of Physical Medicine and Rehabilitation, 2008;89(3):422-9.
[2] "The Range of Motion Project." *The Range of Motion Project*. Retrieved from http://www.rompglobal.org/resource-center
[3] Frossard, L., Berg, D., Merlo, G., Quincey, T., & Burkett, B. (2017). Cost Comparison of Socket-Suspended and Bone-Anchored Transfemoral Prostheses. Journal of Prosthetics and Orthotics, 29(4), 150–160.

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