3D Printed Limb Prosthesis

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Background

Mechanical body-powered prostheses for upper-arm amputations can cost between $5,000 - $10,000. Myoelectrically actuated prostheses can cost between $20,000 - $100,000. Even at the entry level, the high cost makes prosthetic limbs inaccessible to disadvantaged amputees who lack adequate funds or insurance.

Even with professionally made prostheses, user comfort still remains a poignant issue today. The user's comfort comes in two forms; **physical and psychological**.

The socket portion of a prosthesis which attaches to the user's residual limb often lacks breathability and builds up heat and sweat over time, causing physical discomfort. [1]
A poor-fitting socket can also cause major discomfort.

The appearance of a prosthesis can also cause psychological discomfort for the user. If the user feels unsatisfied or self-concious wearing their prosthesis due to how it looks, it can cause lowered self-esteem. [2]

These two factors are the leading causes for patients to abandon usage of their prosthetic devices in the long term. [1]

Design Development

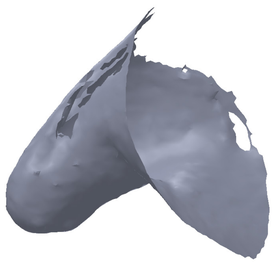
During inception of the initial design, great emphasis was placed on breathability and fit of the socket, which influenced the prosthetic arm's form.

With the patient being a male who performs physical labor as his occupation, the design of the arm moved towards the direction of a more masculine, aggressive aesthetic to better suit his persona.

First design iteration, with ample ventilation cutouts in the socket area

Breathable neoprene liner installed in socket

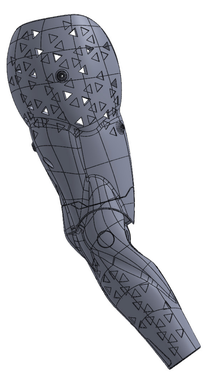
First harness iteration "sling-style"



3D scan of the patient's residual limb to serve as a design aid when modeling the socket for proper fit

Second design iteration; ensured proper fitment of the socket via use of the 3D scan

Second and final harness iteration "figure-eight style"



Third and final design iteration of the prosthetic arm

Testing

Round 1

- arm was proportionally correct
- initial test for fit and comfort, possible actuation points
- socket did not fit patient's residual limb, required modification on-site
- residual limb was 3D scanned to resolve this issue in the next design iteration

Round 2

- socket fit correctly, form-fitting the patient's residual limb due to the 3D scan and redesign
- initial test of cable-actuated elbow joint
- harness and cable routing was clunky and uncomfortable, required revision

Round 3

- based off the previous design's socket, the socket fit comfortably
- new harness and cable routing improved comfort and usability
- patient and occupational therapists were impressed by the aesthetic refinement of the design, blending anthropomorphism with technical elements

Conclusions and Future Work

The 3D printed prosthetic arm proved to be functional for use after repeated testing and feedback from the patient after at-home testing of the prosthesis. Comfort and fit of the prosthesis socket was ensured through repeated trials and feedback with the patient. The patient, as well as the occupational therapists involved, expressed a positive reception to the visual design of the prosthesis. All in all, development costs of the entire prosthesis did not exceed $400 during the term of the study.

Our efforts in this study of designing a 3D printed prosthesis for a patient was able to address the three issues of cost, physical comfort, and psychological comfort. The prosthesis I have designed serves as an example of what can be achieved through this method and a possible direction of prosthetic development in the future.

Further optimizations to the design of the mechanical cable-actuated elbow joint and the harness to require less effort and apply less pressure to the user would ultimately allow for enhanced comfort and usability.

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References

[1] Rezvanifar, S. C., Conklin, S., & Davis, B. L. (2020). Experimental thermal analysis of a novel prosthetic socket along with silicone and PCM liners. Journal of biomechanics, 104, 109788. https://doi.org/10.1016/j.jbiomech.2020.10978

[2] Vujaklija, I., Farina, D., & Aszmann, O. C. (2016). New developments in prosthetic arm systems. Orthopedic research and reviews, 8, 31–39. https://doi.org/10.2147/ORR.S71468