GLOBAL PERSPECTIVE:

Do prosthetic limbs really have to cost an arm and a leg?

ARTIST: JEFF ZHANG

Exploring the development of an open-source, low-cost operational transradial prosthesis prototype

NOTE FROM THE EDITORS: Those of the disabled community identify themselves in different ways. Some prefer identity-first language as a "disabled person," while some prefer person-first language as a "person with disability." To respect the two groups, we have chosen to use both terms in this piece.

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INTRODUCTION

With the average cost of commercially available prosthetics ranging from $4,000 to $75,000 CAD, these essential devices are inaccessible to physically disabled people.[1] Production expenses of the various prosthesis types required for each individual's functional needs will continue increasing in coming years. This is one of the many factors that contributes to health inequities affecting those with physical disabilities in the Canadian healthcare system. Prosthesis coverage across the country is highly variable; many individuals are forced to rely on personal resources, fundraising, or contributions from non-governmental organizations (NGOs) to meet this basic healthcare need. The Institute for Research on Public Policy and Statistics Canada reports that disabled individuals are more likely to be unemployed, have lower median incomes, and be less likely to graduate with a university degree than those without a disability, further contributing to this disparity.[2,3] As a team, we address the cost barrier of prostheses by establishing Brachïum: a humanitarian initiative focused on creating an affordable, 3D printed, open-source transradial prosthesis prototype that could eventually be distributed to marginalized communities to improve their quality of life.

PERSONAL EXPERIENCES AND HEALTH TOPICS: STARTING BRACHÏUM

The idea was sparked when several members of our initiative volunteered with SMILE Canada to support Muslim youth with disabilities and their families. During this time, we had several first-hand experiences working with children requiring prostheses. SMILE Canada strives to ensure that all children are provided with the resources and support network for a happy, healthy lifestyle. While volunteering with this organization, we were involved with the mentorship program, where we developed meaningful relationships with our SMILE mentees and learned about their personal stories and experiences.

As we heard the stories of our SMILE mentees, we noticed how many families supported by the organization had a hard time affording high-quality assistive devices. With some prostheses costing as much as $75,000 CAD, many families are unable to afford the immense price tag.[1] We saw how this financial barrier prevents many children from receiving these devices, which inspired our group of engineering and health sciences students to start Brachïum.

MANUFACTURING THE PROSTHESES

Through research, we discovered that using manufacturing techniques, such as 3D printing and open-source electronics, could significantly reduce the cost of prosthetics.[4,5] Our goal was to create custom Computer-Aided Design (CAD) models that would make both assembly and repairs straightforward. To calibrate the function of the arm to each user, we utilized open-source microcontrollers that convert analog electromyography (EMG) signals into digital pulse-width modulation signals used to control arm movement.

Our CAD models were made and assembled in an online cloud platform known as Onshape. Onshape has 2D sketching and 3D modelling tools that allow users to create complex parts that can be arranged and exported using the online service. Our models were designed to be assembled using parts that are commonly available in hardware stores for ease of access. Through countless test prints and multiple revisions of the CAD models, we came up with an efficient and functioning design. After we finished developing our models, they were exported as high-quality STL files (3D models) and imported into the 3D Slicer program, Ultimaker Cura. Cura is a software that allows users to configure CAD models for 3D printing and customize infill and layer settings for their 3D printing environment. Additionally, Cura converts STL files to G-Code, a language used to control many automated machines, in preparation for the print. The G-Code file is then processed by the 3D printer, which converts it to x, y, and z coordinates and prints out the models layer by layer.

These models were designed to work simultaneously with the aforementioned open-source electronics. Specifically, our prosthetic arm uses an Arduino UNO microcontroller in combination with a Myoware EMG sensor, PCA9685 servo driver board and five SG90 servo motors. Using C++, we coded a program that runs on the Arduino UNO and is constantly checking the sensor for EMG voltage signals coming from a muscle. The EMG sensor is placed on the user's bicep at the middle of the muscle body and aligned with the orientation of the muscle fibers to increase the accuracy of its readings.[6] The program averages out the last 20 values it receives and based on that, sends commands to another function in the code that angles the servos to control which fingers move. Once the code is sent to the servos, a high tensile strength wire previously in tension is put on an increased strain. This strain value is attained using a predetermined scale that analyses tension compared to resulting flexion.

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Our completed prototype is capable of flexion, extension, abduction, adduction, and circumduction in multiple planes of movement at the metacarpophalangeal, interphalangeal, and radiocarpal joints. Additionally, our prosthesis benefits from low latency and a lightweight design, at a combined weight of under two lbs. The total production cost of the prosthesis device was approximately $83 CAD, including all costs associated with the 3D prototyping and manufacturing of the device. With this in mind, in comparison to the high costs of other prosthesis devices, Brachïum introduces an economical and open-source alternative to modern-day assistive devices.

CONCLUSION AND FUTURE STEPS

With the rate of amputees projected to double by 2050, our open-source prostheses aim to address a crucial gap in the local and global healthcare industry.[7] In the first phase of Brachïum's future plan, the prototype will be piloted with design and assembly instructions uploaded to an open-source website to provide access to users worldwide. Additionally, Brachïum plans on medically licensing our prosthesis as a type two medical device through Health Canada to commence the distribution of the arm. Eventually, we intend to reduce the cost of production and delivery of our prostheses via fundraising campaigns in an effort to improve the quality of life for those in need. Our end goal is to turn Brachïum into a licensed international NGO focused on lowering the disparity in the healthcare system through custom engineered, low-cost medical devices.

This plan was created with careful consideration of the manufacturing process. When planning out future steps, it is critical for us to ensure functionality of the product while limiting size, weight, material cost, and production time. With these constraints, it is crucial to continuously research and develop creative modifications in future iterations of the prosthesis, especially as the global healthcare industry continues to evolve.

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REVIEWED BY: DR. SHARON GRAD

Dr. Sharon Grad is an associate clinical professor in the Faculty of Health Sciences at McMaster University. Dr. Grad is also a medical specialist in the field of physical medicine and rehabilitation. Dr. Grad has published several papers pertaining to amputation research.

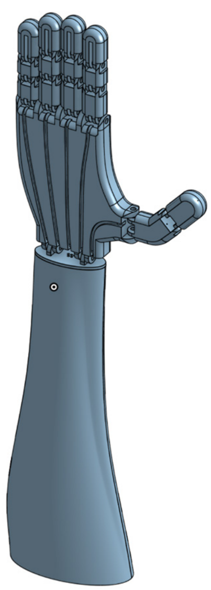

FIGURE 1. Isometric view of transradial prosthesis prototype (full forearm and hand)

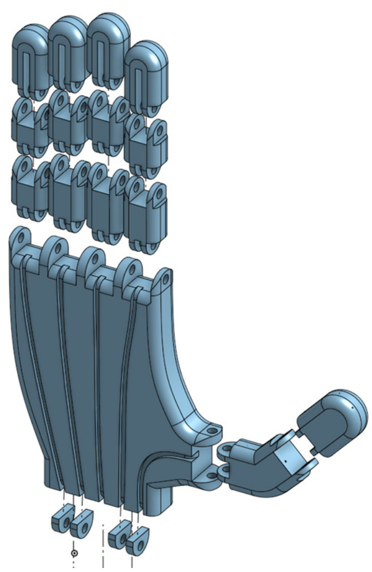

FIGURE 2. Exploded, dorsal view of transradial prosthesis prototype (hand)

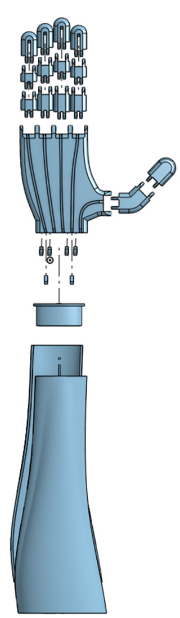

FIGURE 3. Exploded, palmar view of transradial prosthesis prototype (full forearm and hand)