Prosthetic Hand

Preliminary Report

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BME 400

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Abstract

Amputations are a common occurrence in the United States with between 500,000 and 100,000 limb amputations (including trans-carpal amputations) occurring per year [12]. As of 2008 approximately 1.7 million people in the United States are amputees and of those people an estimated 500,000 have minor upper limb amputation, defined as amputation at the fingers, the hand, or the forearm distal to the elbow [13].

The US census reports that in 2019 8.0% of people were uninsured for the entire year, however this does not give an accurate understanding of how many people are uninsured at any given point in time [14]. The CDC reported that at the time of an interview in 2019 14.7% of people aged 18-64 were uninsured [15]. The percentage of uninsured 18-64 age people has been increasing again since 2016, showing a peak in 2019 [16].

A body-powered hand prosthetic costs from $4,000 to $20,000, and a myoelectric prosthetic can cost between $25,000 and $75,000 which also does not account for the medical bills that come with some of the most common ways someone becomes an amputee: trauma, vascular disease, infection, etc. [17][18][12]. With the population of amputees in the United states rising, and the percentage of insured people declining, a more affordable prosthetic option is needed [13]. The team took on the challenge of creating a low-cost, functional prosthetic device. Various design approaches were considered and evaluated before choosing a myoelectric prosthetic thumb option. This option was best suited for the specifications the patient requested.

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Introduction

Motivation

The motivation behind this project is to help improve the life of an uninsured man who lost part of his dominant hand from an infection. Building a functional prosthetic for this man will allow him to return to work and regain hand functionality in his life. Additionally, there is a gap in the market for affordable and functional prosthetics, while they need to be customized, offering a non-invasive prosthetic that can easily adjust wrist flexion angle to a person's maximum and minimum EMG signals would fit that need. Once a prosthetic is made, if the calibration to the patient only needed a scan of the hand, an app could be made to adjust the readings. Since 3D scans can be obtained via a CT, which is likely done if the occurrence of the amputation required recent surgery, the customization could be automated.

To provide a prosthetic for a man who lost part of his dominant hand is enough motivation, however to create an inexpensive option for many people in this situation offers even more motivation.

Current Methods

Currently, the patient is using a simple thermoplastic piece attached with elastic around his hand. Its primary function is to oppose his functional pinky, giving him some rudimentary ability to pick up very light objects. This design is very limited by the ability of the elastic to grip the hand and the strength of the thermoplastic. It is not very robust or a viable long-term solution. A pen can be attached to it with rubber bands, but that doesn't allow for a lot of strength or control when writing.

Figure 1: Current prosthetic designed by OT. The device provides a minimal opposing force for the patient to use when gripping things.

Figure 2: Prosthetic currently used for writing.

Existing Devices

There are devices on the market that would work for the patient, but they are expensive or ineffective due to his remaining anatomy. In terms of finances, the patient is unable to afford more technologically advanced solutions from bigger companies. One cheaper solution for the patient would be a prosthetic from the company, e-NABLE, shown in Figure 3. This prosthetic is intended for users who have lost all digits on their hand. Due to the patient's remaining two fingers, it makes this solution much more complex. In addition, the patient has only 20 to 30 degrees of flexion at the wrist, making this design impractical because it utilizes flexion at the wrist to bend the fingers and grasp objects. The patient also has sensitivity at the area where the amputations occurred. This adds an additional layer of complexity when considering the generic cheaper options on the market currently. The only other options available to the patient are simple 3D printed cosmetic designs, shown in Figure 4. This design provides no functionality, making this an impractical solution for the patient.

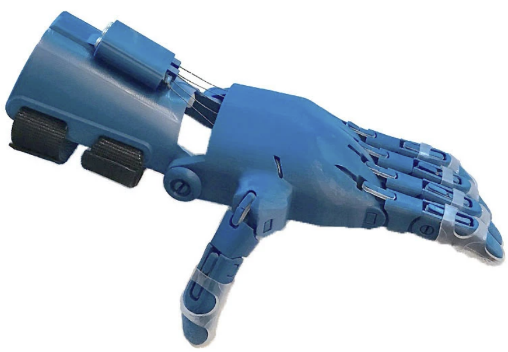

Figure 3: e-NABLE mechanical prosthetic.

Figure 4: Cosmetic design.

Problem Statement

The patient is a low-income individual who has suffered a severe infection, resulting in the loss of his thumb, pointer finger, middle finger, and part of his palm in his dominant hand. The ring finger is immobile, and the pinky can bend up to an angle of 10 degrees. His wrist can bend only 20 to 30 degrees. The skin from his palm to ⅔ way up his forearm received a skin graft, and as a result, he does not have superficial feeling there anymore. There is sensitivity and pain at the locations of the lost digits, so contact should be avoided at these points. The patient is unable to complete simple tasks with substantial weight or dexterity, resulting in an inability to perform required tasks at a job. To help the patient, the team will build a functional, long-term hand prosthetic, allowing him to lift up to 2.5 kg. It should also provide a way to hold smaller items, such as a writing utensil, among other fine motor functions.

Background

Biology and Physiology

The hand and wrist work in tandem to complete an astounding array of functions in daily life. They are a very complex system of bones, muscles, tendons, and skin. The bones are the underlying structure of the hand, wrist, and forearm. Through a series of insertion points, muscles and tendons attach to different bones to cause coordinated movements. The wrist generally rotates in an ellipse, but there are many small movements between the numerous wrist bones that also aid in movement [19]. The flexor carpi ulnaris inserts at the 5th metacarpal, and the flexor carpi radialis inserts at the base of the second and third metacarpals. Both originate from the humorous, and act to flex the wrist [20] The pads of the fingers are exceptional at gripping and holding onto objects. There is a layer of fat underneath the sensitive skin of the fingers. This provides padding and small deformations of the skin that aid in holding or gripping. The skin cannot be loose, or objects would slip out of a grasp. To counter this, there is connective tissue that keeps the skin in place [21].

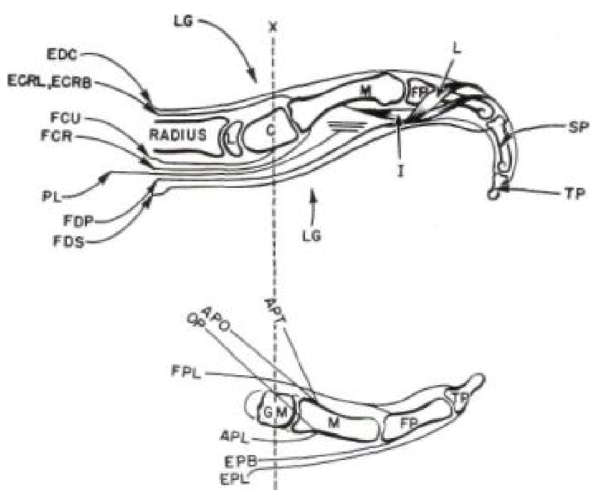

Figure 5: A cross section of the hand shows how various muscles are inserted and connected.
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The innervation of the integument allows fine touch reception, pain and temperature reception, as well as deep touch sensation. This allows humans to sense their surroundings and respond to them.For this humans have many kinds of reception including: tactile receptors (fine touch and low frequency vibrations), free nerve endings (pain and temperature), Bulbous corpuscles (continuous deep pressure), lamellated corpuscles (deep pressure and high frequency vibrations), and others. These are all located in different layers of the integument. The most superficial layer is the epidermis, which itself is subdivided into 4 layers on an area like the arm, but 5 for thick skin such as on the palms of the hands. The deepest layer of the epidermis, and the layer in which innervation begins is the stratum basale. After the epidermis is the dermis, containing the papillary layer (more superficial), and the reticular layer.
The last layer of the integument is the hypodermis or subcutaneous layer. Which mostly functions to connect the skin, bones, and muscles. This layer also functions to store fat and acts as cushioning.

Tactile cells are found in the stratum basale, tactile discs in the epidermal-dermal junction, and tactile corpuscles in the papillary dermis. Free nerve endings are scattered throughout the stratum basale and papillary dermis. Bulbous corpuscles are found throughout the dermis, and Ruffini corpuscles are in the reticular layer of the dermis and in the hypodermis. Keeping the light touch receptors and the free nerve endings more superficial is important because the body can respond more quickly to changes in temperature, and it allows better sensation of fine touch. However, the more superficial layers are less vascularized, thus if being in a superficial layer is less important to function, the receptors will be in deeper layers.

Client Information

The patient had an amputation of necrotic thumb, pointer finger, middle finger, and portion of the palm resulting from severe infection. Twelve surgeries were needed to preserve what is left at the hand. The ring finger is non-functional and acts only as an appendage. The pinky finger has ten degrees of flexion at the metacarpophalangeal joint and is able to hold 2 kg. At the location the pointer and middle fingers were removed, there is sensitivity. A skin graft extends from the palm to two-thirds of the way up the forearm. The patient has lost most superficial sensation on the areas covered by graft. The patient has a range of motion at the wrist limited to 10-15° of flexion and 10-15° of extension.

Design Specifications

According to the client and patient, the prosthetic must provide the patient with basic functionality to help him regain some independence in his daily life. This means the device must include a thumb that will work in opposition to the existing pinky finger. The device must be able to stabilize and hold objects that range in size from one to ten centimeters. The user must be able to lift and hold objects up to 2.5 kilograms. The prosthetic device needs to provide stability for the user to perform fine motor skills, such as writing and drawing. Due to the residual tissue damage at the patient's hand and lower forearm, the device must allow for comfortable extended daily wear. To ensure the patient is able to get back into the workforce, the device must allow him to perform skills necessary for employment on an assembly line. The team will have to allow for future modifications based on specific work tasks desired. Finally, due to the patient's low income and unemployed status, the device must have minimal cost in order to be accessible to him and other low income or uninsured amputees.

Figure 6: Supine view of 3D scan of the affected right (dominant) hand.

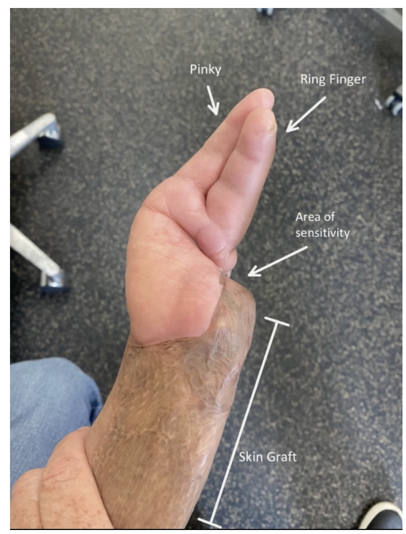


Figure 7: supine view of the affected right (dominant) hand

Preliminary Designs

Design 1 - Cosmetic

Figure 8: Example of a cosmetic silicone hand mold (on the left) intended to blend seamlessly with the natural hand (on the right).

The cosmetic design was created with cosmesis at the forefront of importance. This design would focus on materials and details that blended in seamlessly with the user's natural hand. The team would use silicone for the majority of the device and add details with paint or artificial hair. In addition to cosmetics, this design would be extremely comfortable for the user, as their natural hand is only in contact with the flexible material, silicone. With the team's specific patient in mind, the design would have to consist of the thumb, pointer finger, and middle finger. Considering the sensitivity the patient has where the original fingers were removed, the team would have to add additional comfort in this area. This would mean forcing the resting points to be elsewhere on the patient's hand and create a gap to avoid contact at this point.

Design 2 - Mechanical

Figure 9: CAD model of the mechanical design intended to provide more functionality.

The mechanical design takes a similar approach as the competing design from e-NABLE. However, this design is more effective for the team's patient because it allows for the user to have pre-existing digits. The competing design requires the user to have no fingers. This design functions when the user bends their wrist. This causes the finger(s) to close by pulling on a chord that is attached at the wrist on one end and the finger on the other. This design would be easily fabricated through 3D printing. The device would be attached at the wrist with a sturdy cuff to counteract the force when bending the wrist.

Design 3 - Bionic

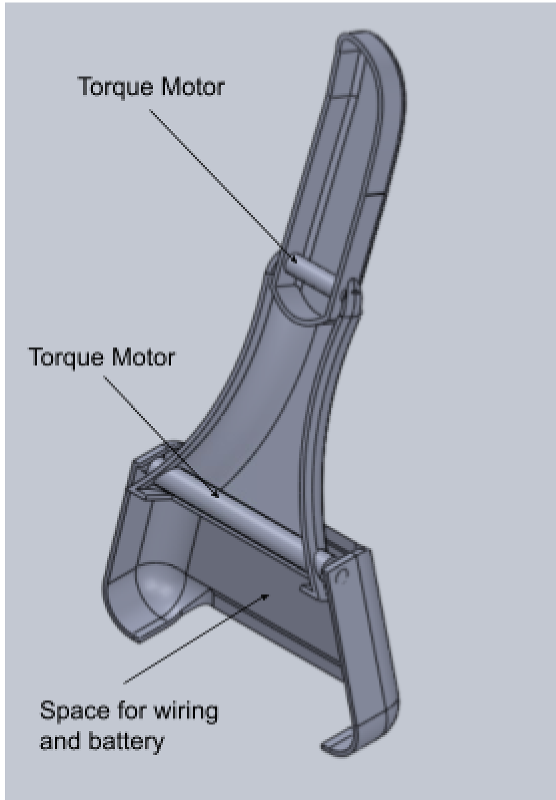


Figure 10: Example of a bionic addition to provide better functionality.

The bionic design utilizes EMG sensors attached on the skin of the forearm. These sensors read electrical signals emitted by the muscles in the user's forearm. These signals are then read by a microcontroller and translated into movement of the fingers. Because the team's patient experienced an infection that went up part of his forearm, the team will likely have to amplify the signal obtained from these sensors in order to create a strong enough grip. Three EMG sensors will be used to sense the muscle activity in the patient's arm. One will be negative, one will be positive, and one will be grounded. The positive and negative electrodes will be placed in the middle and at the end of the flexor carpi ulnaris. The ground electrode will be placed near a bone to ground the signal. The signal will then be passed through a differential amplifier. This is what will allow the signal to be amplified. Then the signal will pass through a high pass filter and a low pass filter. These are simple filters that use resistors in order to only use signals within a specified range. This will lessen the noise of the signal. The team expects to receive signals from the muscles between 50 and 150 hertz. Anything out of this range will be filtered out [22]. The team intends to use a deconstructed robotic claw design. The thumb will act as one half of a claw for the user to push against with their pre-existing pinky finger. This provides much more strength for the user to be able to grasp and hold different items because it is not dependent on the amount of wrist flexion they have.

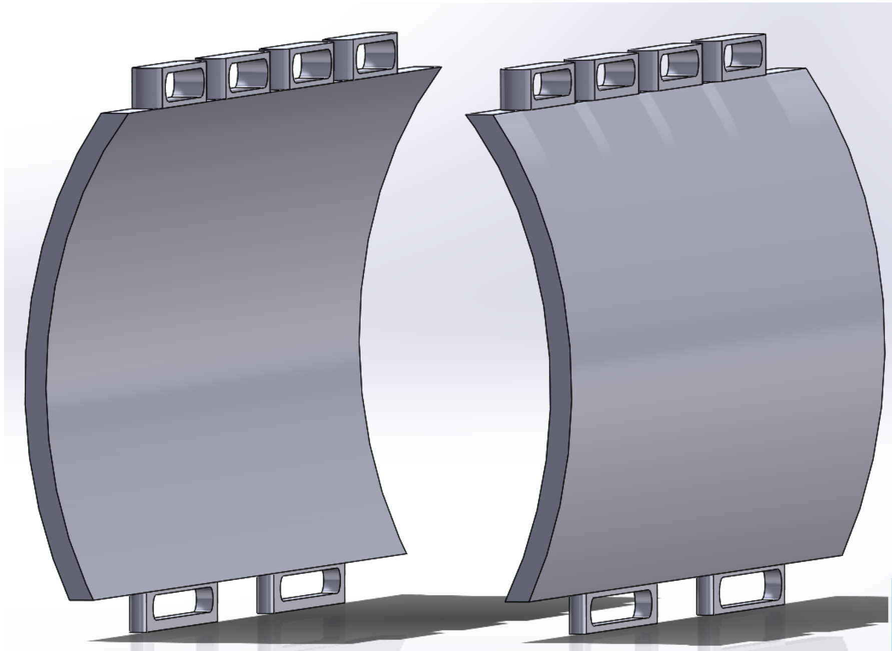


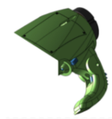
Figure 11: The patient has sensitivity on the hand at the amputation points, so the thumb will be anchored to this cuff that will fit on the forearm. Foam will be attached to the inside and velcro straps will join the halves.

The prosthetic thumb must be anchored securely in order to support any weight being lifted. It cannot slip, so it needs to have a tight, secure fit without being too tight. One major challenge is that the patient’s hand has sensitivity at the points of amputation. It was suggested by the client to stay away from those areas. For this reason, the team decided to anchor the thumb onto a cuff that is supported by the forearm. This way, the patient’s hand will not be bothered. In this design, velcro straps will connect each pair of slots. The side with 4 slots will be adjusted to the patient, then can stay at this adjustment. The side with two slots will be the side the patient uses to put on and take off the prosthetic. The client will need to put the prosthetic on with one hand, so the simple velcro straps will allow him to do so. To maximize the comfort and safety of the patient, a silicone sock will be fitted to the patient's arm, and rest in between the prosthetic and the skin. To provide additional padding, closed-cell foam will be attached to the inside of the cuff [23]. Finally, any sharp edges or corners on the cuff will be sanded down to ensure it does not catch on anything or cause discomfort.

Preliminary Design Evaluation

Design Matrix

Table 1: Design matrix demonstrating how the bionic design is chosen.

Name		Cosmetic 		Mechanical 		Bionic 	
Criteria	Weight						
Comfort	20%	5/5	20	(1/5)	4	(3/5)	12
Ease of use	15%	1/5	3	(3/5)	9	(3/5)	9
Cost	15%	4/5	12	(4/5)	12	(1/5)	3
Strength	15%	1/5	3	(2/5)	6	(5/5)	15
Functionality	15%	1/5	3	(2/5)	6	(5/5)	15
Ease of Fabrication	10%	4/5	8	(5/5)	10	(1/5)	2
Cosmesis	5%	5/5	5	(1/5)	1	(2/5)	2
Response Time	5%	1/5	1	(5/5)	5	(3/5)	3
Total	100%	55		53		61	

Design Matrix Summary

Design 1: Cosmetic:

This purely cosmetic design would be made with materials that best resemble the touch and feel of skin, however would not provide much additional functionality past a backbone for the patient to pinch against with his pinky finger. This design would be easier to fabricate as it would have less moving pieces, but creating a realistic looking finger could be challenging. Additionally without any moving pieces this design would have less potential pinch points, or electrical issues making it comfortable and more easily worn in the rain/water. However, this design does provide much functionality or strength to the patient as some of the other designs and therefore it was not selected.

Design 2: Mechanical:

The fully mechanical design is the most simple design. The string is shortened by flexion of the wrist, allowing the user to grasp items. The major shortcoming in this design with regards to the patient, is that they are unable to move their wrist more than 20-30 degrees. This would severely limit the grip and grip strength of the prosthetic. It is a straight forward design, so it scored well in the ease of use, cost, and ease of fabrication. One of the major benefits of this design is the low cost. However, since the client did not provide a budget, it is crucial to keep the cost relatively low so that it can be funded from outside sources. The response time in the mechanical design would also be the best because there will be no lag time that some of the electronic components in other designs may have.

Design 3: Bionic:

The bionic design meets some of the client's most important requirements, which are strength and functionality. These criteria would allow the patient to go back to work. The design would be more expensive than the other designs, but based on the criteria, this is a trade-off for making a prosthetic that works for the user. There would also be a larger learning curve for the user, resulting in a lower score in the ease of use category. Finally, when taking the team's combined skills into consideration, we decided that the bionic design would be difficult to fabricate in the given amount of time, resulting in a low ease of fabrication score. However, as the team discovered they are limited to making only a prosthetic thumb due to pain in other parts of the patient's hand, this was the chosen design.

Proposed Final Design

The overall winner of the design matrix was the bionic design. This design won because it scored the highest in the categories the team valued most. The bionic design provides the user with the greatest amount of force and strength when grasping and holding objects. This was the most important quality to consider for the patient because he is looking for a solution to help him get back into the workforce. In addition to strength, the bionic design is also easier to use for the patient because of the limited flexion in his wrist. The use of a microcontroller allows for the patient to be able to grasp many objects of different sizes and weights. The microcontroller is able to amplify any signal read from the forearm into any movement response necessary. This is valuable to the patient because he will be able to hold larger and heavier objects as well as utilize smaller movements for tasks such as writing. This solution will take some adjustment initially, but it will ultimately be a better solution for the patient.

Fabrication/Development

Materials

There will be various materials used in the fabrication of the prosthetic. The skeleton of the prosthetic will be 3D printed out of polylactic acid (PLA), a thermoplastic polyester. PLA is skin safe, so it should not pose any safety concerns to the patient. The brace that the 3D printed skeleton will be attached to will be made out of carbon fiber. There will be a silicone sleeve that will ensure protection of the patient's skin. Additionally, silicone will be adhered to the fingertips and other points that will come into contact with the prosthetic to increase friction between objects and the prosthetic. In these contacts, the silicone attachments are considered a grip.

Methods

The thumb mechanism will be 3D printed and attached to the motor mechanism. The motor will also attach to the prosthetic skeleton and brace. This brace will be made of a hard carbon fiber sheet that will be molded into a shape that matches the form of the hand and forearm where it is located. This carbon fiber shell will act as the attachment point for all extensions of the design such as the arduino, motor, and thumb mechanism. To provide comfort and stability at the prosthetic-body interface a layer of silicone will be used. These silicon gel pads will be purchased and modified to fit the attachment points for our prosthetic. A silicone skin mimic will also be purchased to apply to the thumb tip in order to provide a grippable surface. In terms of the electronic aspect of the project, an arduino will respond to myoelectric signals. These signals will trigger a motor movement that flexes the thumb joints. Muscle movement strength will correlate to grip strength.

Testing

In order to test the functionality and reliability of the hand, it will need to undergo rigorous testing. Testing will be performed by attaching the prosthetic to one of the team member's own hands. Then, the hand will be subjected to picking up various objects of different sizes and weights. Some of the objects will be a glass of water, keys, a pencil, a phone, and a five pound weight. The difficulty, successes, or failures will be recorded. The subject will have multiple attempts at first in order to learn to use the device. While the device is in use, any large delays or other problems will be recorded and investigated. To ensure the device can be used consistently for a long period of time, a synthetic electrical signal will be input into the electrodes, and the thumb will be observed over multiple hours. If there are any unforeseen problems encountered during the testing process, the team will assess solutions and implement the best one.

Discussion

Future Work

The next steps in the project include securing funding for the project, creating a prototype, and testing whether the sEMG sensors will work well on the grafted skin of the patient's forearm. The team will use the chosen design to gather expected costs to submit in a funding proposal. With funding in place, the team will then be able to order the required materials for fabrication. While the materials are being ordered, the team will send sEMG sensors to the client in order to test whether a signal can be obtained from the grafted skin of the patient's forearm. Beyond the scope of the fall semester, the team looks forward to getting feedback on the prosthetic from the patient. This will be used to create an even better version of the hand. It is also in the team's interest to make the hand easily customizable so that other people who may need prosthetic thumbs can also use the design. Finally, the team will evaluate all methods and materials in order to reduce cost as much as possible.

Ethical and Safety Concerns

The largest safety concern in this project is that the prosthetic does not cause damage, harm, or discomfort to the patient in any way. To minimize all risks, the team will cover any sharp points or pinch points in the design. Additionally, the team will ensure that there is appropriate cushioning throughout the design so that extended wear will not cause any rubbing or discomfort. This is especially important for this specific patient, because he does not have a lot of superficial feeling in his forearm and hand. If the prosthetic is rubbing somewhere or is uncomfortable, it may not be noticed right away, depending on the specific location. Another consideration is the reliability of the design. It could be dangerous if the patient is relying on the prosthetic and the prosthetic suddenly stops working. For this reason, the team will put the prosthetic through rigorous testing to ensure its reliability. Another safety concern is the materials used in the fabrication of the prosthetic must be safe for extended contact with the skin. In regard to ethics, the team will respect any wishes of the patient. If he prefers that the team does not have direct contact with him, the team will communicate through the occupational therapist and client, Shirley Katz. Additionally, his identity will be kept confidential throughout the whole project.

Other Concerns

Since the patient has grafted skin on a large portion of the forearm and some muscle degeneration, functionality of sEMG sensors needs to be tested before there is further progress with the design. The team will test the strength of the signal from the sensors and make a determination on whether the signal is strong enough and variable enough to perform variable flexion strength motions. If the signal strength is good, the team will move forward with the chosen design. If the sEMG sensors are not compatible with the grafted skin, the team will evaluate the design and either find a new attachment point location or change directions.

Conclusion

Losing function in the hand dramatically impacts all aspects of life and prosthetic devices are needed. Unfortunately prosthetics are either very expensive or do not offer much functionality. Which is why accessible and customizable prosthetic devices are a major unmet need.

The winning design, the bionic thumb, is the design the team will move forward with fabricating. This design best aligns with the patient's needs of strength and dexterity. The next steps in making the bionic design include determining a motor that can output enough force while maintaining a small enough size to fit in a thumb. From here a model of the thumb will be customized to the motor and 3D printed. After that, different electrodes will be tested with the patient; and a circuit will be set up to produce flexion/extension when the wrist muscles fire and relax. Additionally code will need to be written in conjunction with the microcontroller, EMG sensors, and the data acquired from the patient to determine the relative amount of signal for a certain amount of flexion.

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Appendix

Appendix A: PDS

Prosthetic Hand

PDS | Sept. 24, 2021

Client: Ms. Shirley Katz

Advisor: Mitchell Tyler

Team: Emmalina Groves - Team Leader

Karen Scharlau - BWIG

Danielle Lefko - BSAC

Stephanie Silin - Communicator and BPAG

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Reference 8

Function

Losing part of a hand is an incredibly difficult obstacle to overcome considering how much a person uses their hands throughout any given day. Not only does it affect many physical aspects in a person's life, but it can cause mental hardships as well. Unfortunately, state of the art prosthetics can cost a fortune, which is not an option for many people. In this case, the patient has lost their thumb, pointer, middle finger, and much of their palm to a serious infection. They retain their ring finger and pinky finger, however movement is severely restricted. The ring finger is immobile, and the pinky finger can bend at the metacarpophalangeal joint a maximum of 10 degrees. Our team will work to help this patient restore functionality to his hand while making it look as real as possible. The goal is to create an affordable solution so that more people like our patient can regain use of their hands.

Client requirements:

- Prosthetic must be able to stabilize and hold objects.
- Cosmetic appearance of prosthetic is more important than the function.
- Prosthetic needs to be comfortable for extended, daily wear.
- Prosthetic should include at least a thumb, preferably 2-3 additional digits.
- Prosthetic needs to be water-resistant or water-proof.

Design requirements:

1. **Physical and Operational Characteristics**

a. *Performance requirements*:

The prosthetic must provide the user with the ability to stabilize and hold objects that are light to moderate in weight. The prosthetic hand should give a gripping force of between 4 $kg*m/s^2$ and 17N $kg*m/s^2$ before significant slipping occurs [2][4]. A gripping force 17 $kg*m/s^2$ should be achieved, as this was shown to be effective [2]. It should be able to manipulate any utensils, i.e. pencil, fork, etc. Additionally, the attachment to the body should not put the user in danger, or be too costly as this is intended to be a cost-efficient device.

b. *Safety*:

The prosthetic must be safe for continuous wear for 3 to 5 years[1]. All materials used must be safe for extended contact with skin, and sharp edges or pinch points must be covered.

c. *Accuracy and Reliability*:

The prosthetic hand must move in a controlled manner so the patient is able to benefit from understanding the consistent movements. Hand must be able to continuously function for 8 hours of use so the user is able to work without changes in function.

d. *Life in Service*:

The prosthetic must be functional for constant wear by the user for 3 to 5 years, and be durable enough to withstand common daily tasks [1].

e. *Shelf Life*:

The prosthetic should not have any problems being stored for several years.

f. *Operating Environment*:

The prosthetic must be functional in all environments the user encounters in daily life. This includes rain and very cold weather. It would be ideal for it to function fully submerged in water, but not necessary. The device should be able to be cleaned with soap and water.

g. *Ergonomics*:

The prosthetic should be comfortable for writing, picking items up, and holding items. It should act as an extension of the body, and prolonged use should not cause any discomfort.

h. *Size*:

The prosthetic must blend in with the size of the user's natural hand. The team received a 3D scan of the user's affected hand and can use this to reference specific measurements.

i. *Weight*:

According to the prosthetic development community, there is no specific maximum weight of prosthetic hands. However, the general consensus is that the prosthetic hand should remain below 400 grams, which is the average weight of an adult human hand. Many current users indicated that when wearing a prosthetic hand that weighed the same as a natural hand, it felt too heavy. This is a direct result of the attachment. [2] A smaller weight would be ideal as it would be easier to stabilize and reduce wrist torque. The goal is to produce a device that is around 300 grams.

j. *Materials*:

The materials used should not cause any adverse effects to the user after prolonged use. They should provide both structural support and grip in order to pick up and hold various objects. A 3D printing material such as PLA or ABS, a prosthetic structural material, cushioning, and electronic components will make up the bulk of the design.

k. *Aesthetics*, *Appearance, and Finish*:

The user desires a more cosmetic approach to this device. This means that the prosthetic hand must maintain cosmesis and blend appropriately with the rest of the body. The device should achieve the closest to a natural look as possible, and if possible include natural features such as fingernails.

2. Production Characteristics

a. Quantity:

The device is being made for a specific patient, so only one device is necessary to manufacture. However, the prosthetic device will be made so that others who have lost some or all digits can use the same design principles with aspects of the design tailored to the limb of the patient.

b. Target Product Cost:

The prosthetic device must be as economical as possible because the client did not provide a budget. All funding will be coming from an outside source.

3. Miscellaneous

a. *Standards and Specifications*:

1. Grip light-medium objects with 17 N of force [2]. This max force should be for steady grip of smaller rectangular objects such as a phone.
2. Remain around 300 grams [3]
3. Match size of the client's hand provided by .stl file
4. Must be reproducible in multiple skin tones.
5. Velcro adjustable brace will attach to lower forearm above the wrist. This will be accompanied by a ‘sweatband’/sock type material to go underneath and prevent frictional irritation and distribute uneven stresses on the wrist.
6. Strings pulled by motors will close the fingers into a grip. The motors will engage when an electrode, attached to the skin of the forearm, registers muscular movement.

7. The user should be able to pick up a cup and small items off of a flat surface.

b. *Customer*:

The customer for this project is the client's patient. However, this project will be applicable for other users down the line. These users will be individuals who have had one or more compromised digits on their hand that has limited functionality.

c. *Competition*:

The client has reached out to other organizations for additional assistance. One company includes Enabling the Future. E-nable is a company that produces 3D printed mechanical prosthetic hands for individuals who have at least some movement of the wrist.

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