Prosthetic Hand

Design Team:
Emmalina Groves, Danielle Lefko, Stephanie Silin, Ren Scharlau

Advisor: Mitchell Tyler

Patient Information:

- Amputation of necrotic thumb, pointer finger, middle finger, and portion of the palm resulting from severe infection
  - Ring finger is non-functional
  - Pinky finger has 10 degrees of flexion at metacarpophalangeal joint
  - Sensitivity at location of finger amputation
- Patient has 20-30 degrees of flexion/extension at the wrist
- Skin graft from palm to ⅔ way up the forearm
  - Loss of superficial sensitivity in forearm

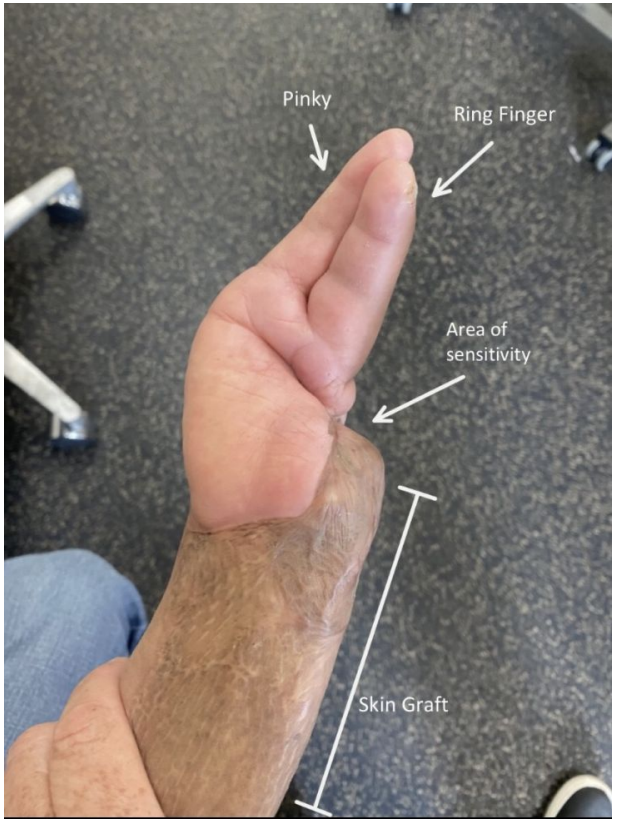


Figure 1: supine view of the affected right (dominant) hand

Background Information

- Amputations from infections account for 38 amputations in the US per day
    - Individually designed prosthetics are often necessary due to variability in injury extent and location

- Cost of singularly produced prosthetic device is **expensive**
    - A technologically advanced prosthetic can cost $70,000
    - “Budget” prosthetic fingers made from bike parts can cost $5,500-$9,500
    - Poor insured and non-insured patients lack cost effective solution.

Problem Statement

- What is the problem?
  - The patient is a low income individual who has suffered a severe infection resulting in the loss of his thumb, pointer finger, and middle finger as well as loss of function of his ring finger
- Why is it a problem?
  - The patient is now unable complete simple tasks with substantial weight or dexterity requirements, resulting in the inability to find a job
- What can be done to solve it?
  - Design and create a low cost prosthetic thumb to act in opposition to the currently existing pinky to increase hand function for our patient

Current Solutions

- Occupational Therapist created prosthetic with thermoplastic splinting material
  - Capable of holding objects up to 350 grams
  - Acts as opposition to the pinky
  - Limited applications: can not move to adjust to various activities or object sizes
- Splint to hold writing device
  - Lacks structural support due to flexibility
  - Lacks control due to attachment at wrist
    - Requires movement at the elbow

Figure 2: (Above) Current prosthetic designed by OT. The device provides a minimal opposing force for the patient to use when gripping things.

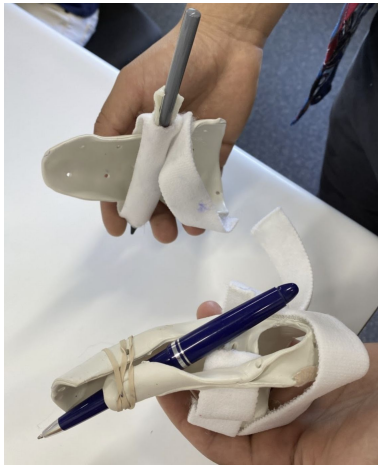


Figure 3: (Right) Prosthetic currently used for writing.

Product Design Specifications

- Prosthetic must:
  - Include a thumb that will work in opposition to the existing pinky
  - Be able to stabilize and hold objects that range in size from 1-10 cm
  - Lift and hold objects up to 2.5 kg
  - Provide stability to perform fine motor skills such as writing
  - Allow for comfortable, extended, daily wear
  - Perform skills needed for employment on an assembly line
    - Allow for future modifications based on specific work tasks desired
  - Have minimal cost, be accessible to low income/ uninsured amputees

Competing Designs

- e-NABLE
  - Manufactures kits with parts to assemble mechanical hands
  - Motion derived from wrist flexion
  - Incompatible: Designed for patients with 5 digit amputation
  - Patient has only 20-30° flexion in wrist, which would not provide much grip strength.
- 3D Printed purely cosmetic design
  - No mechanical function- patient emphasis on function

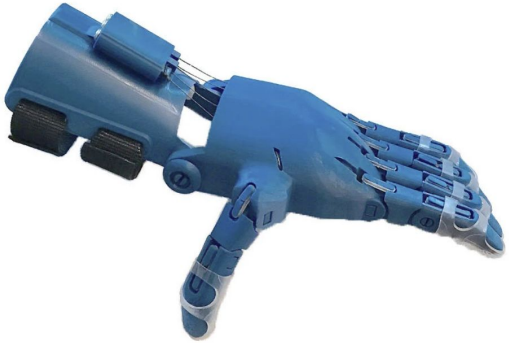


Figure 4: e-NABLE mechanical prosthetic

Figure 5: Cosmetic design

Design 1: Cosmetic

- Form over function
- Immobile
- Includes wrinkles, hair, nails, and fine detail to look as natural as possible
- Least functional

Figure 6 and 7: Cosmetic silicone hand mold option. https://www.medicalartresources.com/prosthetic-finger-hand-photos

Design 2: Mechanical

- String and pulley mechanism to flex the thumb with wrist flexion
- Requires a strong, flexible wrist
  - Patient's wrist could get tired
  - Patient lacks wrist strength and flexion, with would limit grip strength

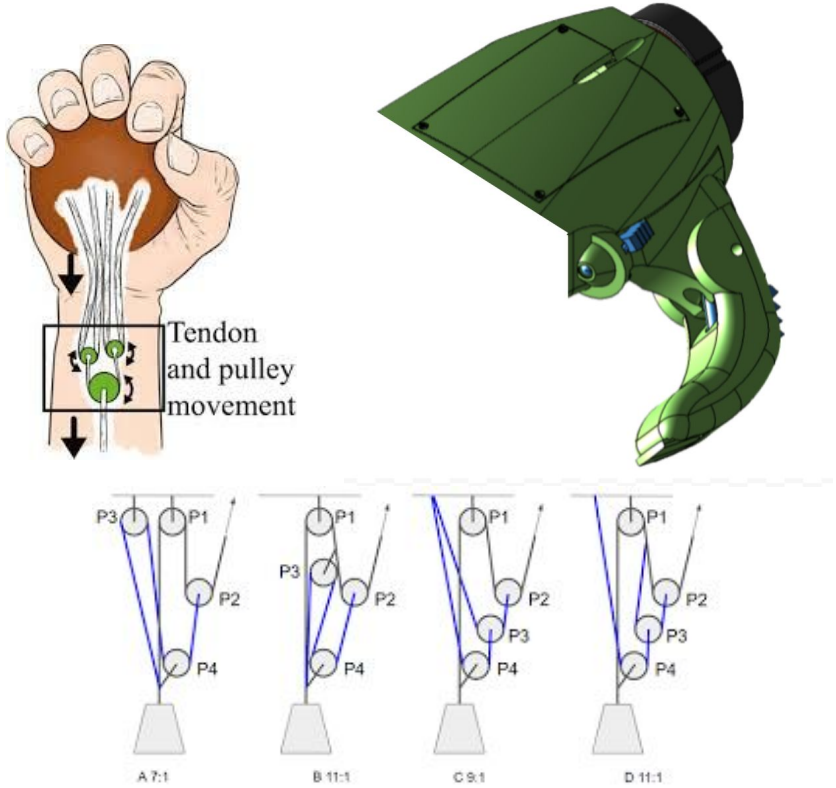


Figure 8, 9, and 10: Demonstration of how the pulley system in the hand would function in addition to a CAD model of the design.

Ren Scharlau

Design 3: Bionic

- Use electrical signals from forearm muscles to control flexion of thumb
    - EMG sensors sense electrical activity in muscles
- The thumb will support up to 5lbs and be a counter to the patients pinky finger
- Easy to learn because it is being controlled by muscle that is already there and being used

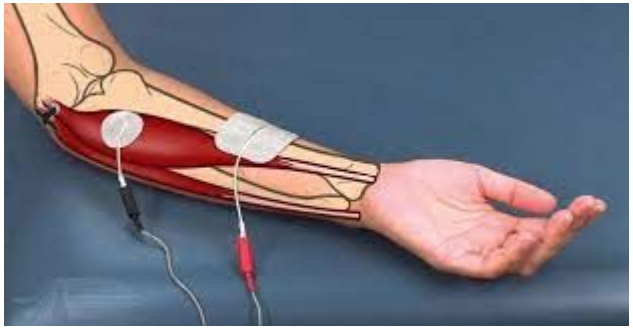
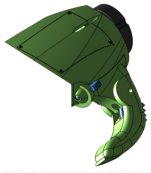


Figure 11 and 12: Bionic design demonstrating the use of signals obtained from preexisting forearm muscles to move.

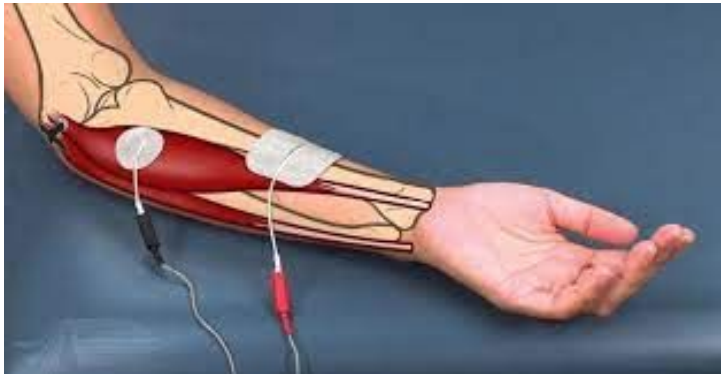
Design Matrix Criteria

Comfort	Ability to use the product for long periods of time with no physical harm or discomfort.
Ease of use	User will be able to assemble, wear, sanitize, and reuse device easily.
Strength	A measure of how much weight the prosthetic can hold.
Cosmesis	A measure of how close the appearance resembles the patients unaffected hand.
Functionality	Ability of the prosthetic to perform required tasks.
Ease of Fabrication	A measure of how difficult it is to make a design.
Cost	A measure of much the materials for the product and prototypes cost.
Response Time	The time it takes between the patient’s decision to perform an action and the actual action time.

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	(5/5)	15
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		67	

Winning Design: Bionic

- Best functionality
- Patient will control flexion of thumb with EMG sensors on flexor carpi muscles in forearm
- Most strength and flexion of prosthetic thumb compared with other designs
- Patient mainly concerned with strength and dexterity



Future Work

- Get feedback from the patient to improve the design.
- Make the hand easily customizable for other people in need of thumb prosthetics.
- Find ways to decrease the cost of the hand.

References and Acknowledgements

[1] “Amputation: Prosthetic hand and fingers,” *The Hand Society*. [Online]. Available: https://www.assh.org/handcare/condition/amputation-prosthetic-hand-and-fingers. [Accessed: 05-Oct-2021].

[2] A. Kargov, C. Pylatiuk, J. Martin, S. Schulz, and L. Döderlein, “A comparison of the grip force distribution in natural hands and in prosthetic hands,” *Disability and Rehabilitation*, vol. 26, no. 12, pp. 705–711, 2004.

[3] J. T. Belter and A. M. Dollar, “Performance characteristics of anthropomorphic prosthetic hands,” *2011 IEEE International Conference on Rehabilitation Robotics*, 2011.

[4] L. Roberts, G. Singhal and R. Kaliki, "Slip detection and grip adjustment using optical tracking in prosthetic hands," *2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2011, pp. 2929-2932, doi: 10.1109/IEMBS.2011.6090806.

[5] “Enabling the future,” *Enabling The Future*. [Online]. Available: https://enablingthefuture.org/. [Accessed: 14-Oct-2021].

[6] “Amputations,” *Sepsis Alliance*, 09-Aug-2020. [Online]. Available: https://www.sepsis.org/sepsisand/amputations/#:~:text=There%20are%2C%20on%20average%2C%20about,multiple%20fingers%2Ftoes%20and%20limbs. [Accessed: 14-Oct-2021].