Modified eNABLE Prosthetic Hand with Continuous Hold Mechanism

Ryan Opansky, Bella Reichardt, Chiara Sanders, Ethan York

Client: Mr. Ken Bice • Advisor: Dr. Justin Williams

Abstract

e-NABLE is a 3D printing open source volunteer community that provides low cost easily sourced prosthetics to individuals with an afflicted hand. The hand designs provided by e-NABLE all have the same closing mechanism; the wrist is flexed causing wires to clench the fist. This flexion of the wrist leads to muscle fatigue especially while holding objects for an extended period of time. The goal of this project is to create a mechanism for locking the fingers in a closed position, while relieving muscle strain and wrist flexion during prolonged use of the device. To relieve this forearm fatigue the team will develop a clamping mechanism to lock the prosthetic hand fingers in place.

Problem Statement

The current eNABLE hand prosthetic causes forearm fatigue when holding objects for a long time. The goal of this project is to create a locking mechanism so objects can be held continuously with ease.

Background

- e-NABLE is a community of 10,000+ volunteers.
- 2500-3000 prosthetics delivered worldwide [1].
- Target Population: people from war-torn countries.
- Number of amputees since 2011: [2]
  - Syria= 25,000+
  - Sierra Leone = 27,000
  - Afghanistan = 100,000
- Lifetime of a prosthetic [3]
  - 6- 12 months for children
  - 3-5 years for adults

Figure 1: Picture of an e-NABLE user wearing her prosthetic [1].

Current Model

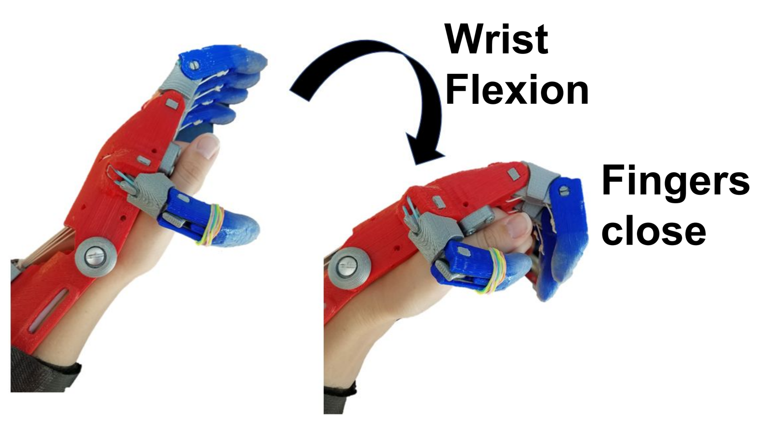


Figure 2: Current Raptor Reloaded e-NABLE prosthetic. Wrist flexion tightens the flexor cables, causing the fingers to close into a fist.

Competing Devices

- Prosthetics in the US can range from $5,000 - $100,000 [3]

Figure 3: Commercially available prosthetic hands. Left: Bebionic Myoelectric Hand [5]. Right: Generic Split-Hook Prosthetic [6].

Design Specifications

- The device should
  - Be able to close and stay closed without continuous wrist flexion
  - Be made of materials easily sourced in developing nations
  - Be relatively simple to assemble
  - Minimize metal and rubber bands
  - Cost $12-$20
  - Be able to hold 1 12 oz can of soda (<1lb)
- Total budget: $200

Final Design Concept - Clamp

- A clamp holds flexor cables in place.
- User may then relax wrist, thus reducing fatigue from wrist flexion

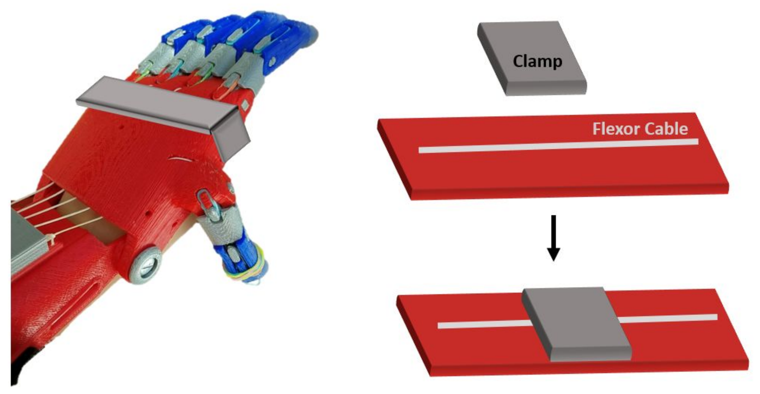
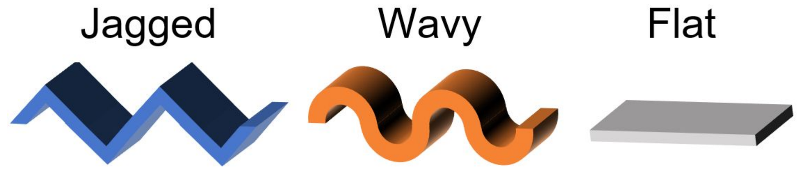


Figure 4: General depiction of clamp design concept. Clamp uses frictional forces to hold flexor cables in place, allowing wrist to move.

Clamp Material Tests

- Multiple geometries and materials of clamp were printed at the Makerspace:



- A C-clamp was used to apply a uniform clamping force between trials. A spring-loaded dynamometer was used to determine the force of failure (Figure 6).

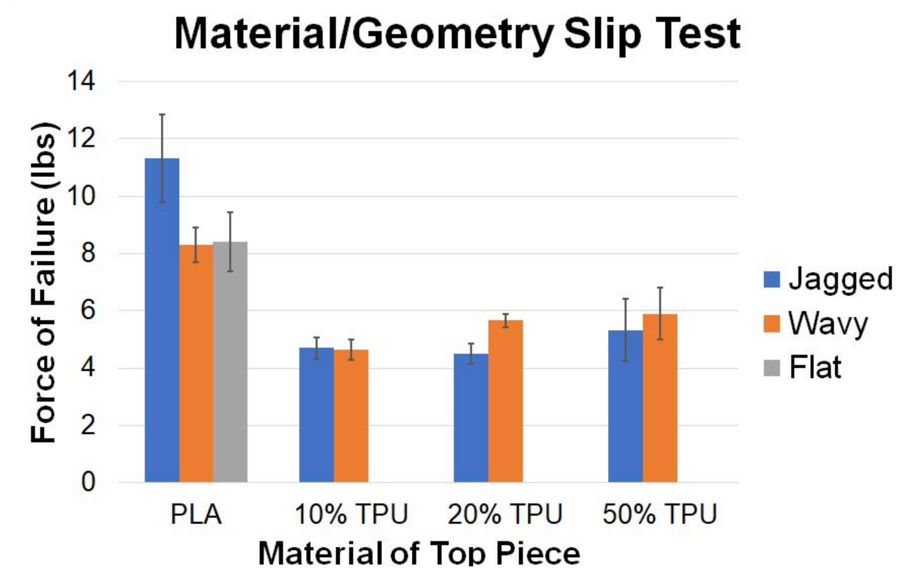


Figure 6: Measure of force required for strings to slip compared to various material compositions (n=3). Overall, the PLA/PLA wavy condition was able to provide the most force while mitigating damage to the fishing line and PLA.

Clamp Distributed Force Testing

- We hypothesized this type of clamp may have a force distribution. The purpose of this experiment was to determine if the amount of clamping force would be different for each finger.
- A dynamometer was used to measure the force of failure.

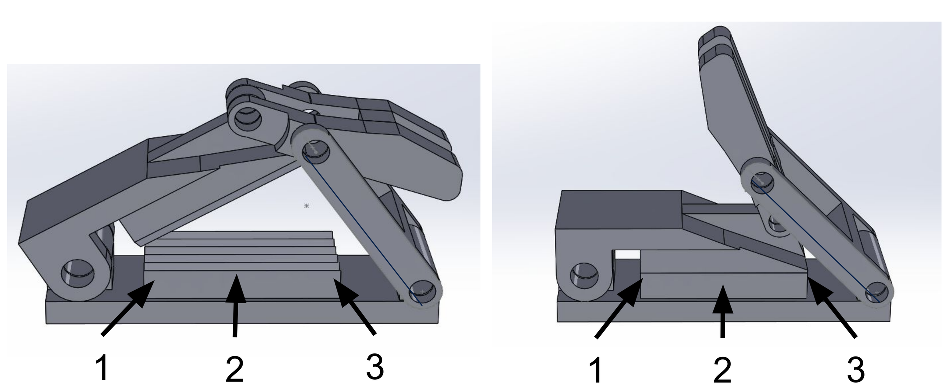


Figure 7: Clamp design in open (left) and closed (right) positions. Labels 1, 2 and 3 denote string positions during testing of the clamping force distribution.

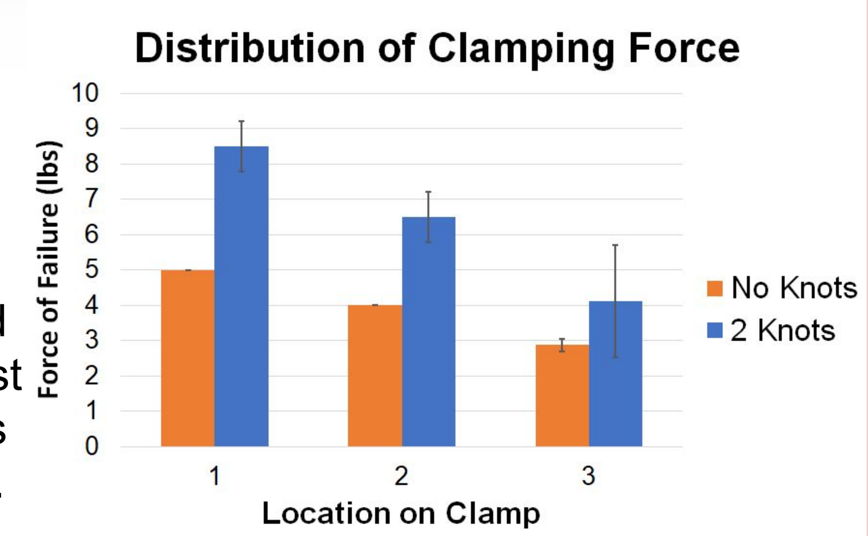


Figure 8: Measure of force required for strings to slip at different locations on the clamp (see figure 7) using strings with and without knots. Clamping force was greatest at location 1 and lowest at 3. Adding knots increased clamping force at each position.

Final Prototype

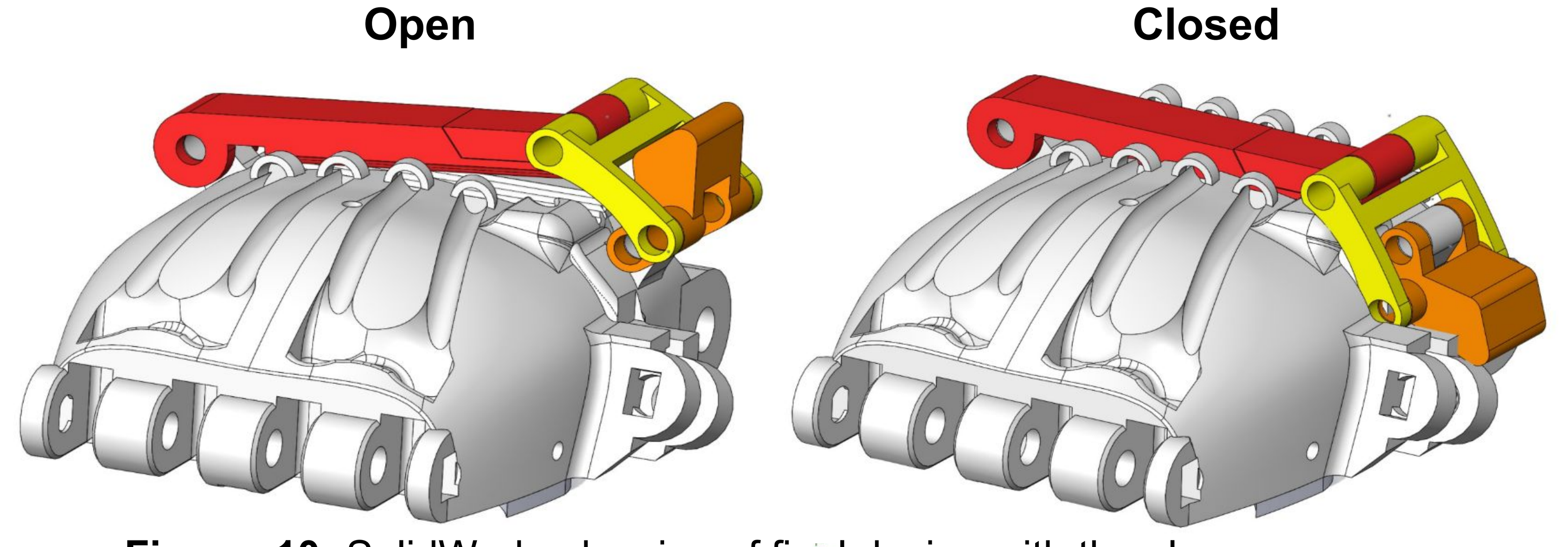


Figure 10: SolidWorks drawing of final design with the clamp open (left) and closed (right).

- Changes to Original Raptor Reloaded:
  - Added clamp attachment pieces and surface grooves.
  - Moved extensor cable attachments distally (in front of clamp).
  - Rerouted thumb so its flexor cable is clamped as well.
- Issues with design
  - 3d printing consistency.
  - Small components of clamp are too thin.

Full Hand Testing

- EMG measurements were taken in forearm extensor and flexor muscles.
- 20 fl oz bottle of soda was held in various positions.
- Test conditions:
  - Flexed vs unflexed wrist position vs no prosthetic
  - Arm parallel and perpendicular with floor

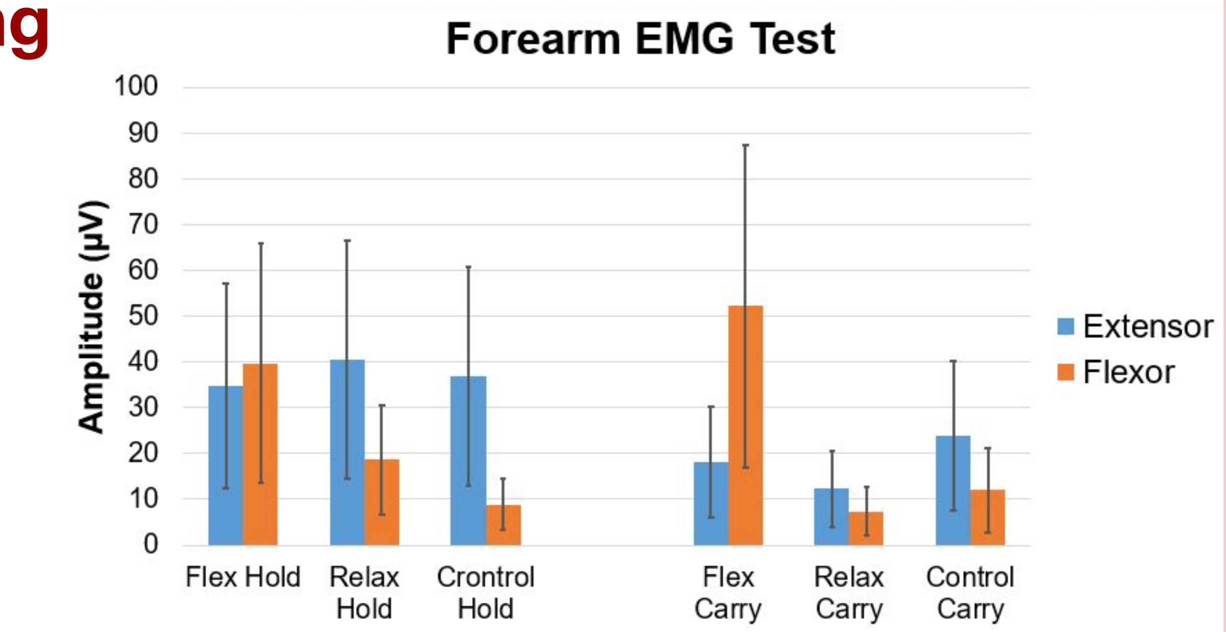


Figure 10: Results of EMG testing. In both holds, the flexor muscle was more engaged with wrist flexion than when the wrist was relaxed or when the bottle was held with a real hand. In general, extensor muscle activation was the same in each hold.

Conclusions and Future Work

- Results of testing indicate:
  - Clamp design successfully holds strings in place with weights <8lb
    - Clamp allows wrist to leave flexed position.
  - Forearm fatigue is reduced when wrist is unflexed.
- Next Steps
  - Assemble final prototype with clamp incorporated.
  - Re-print thicker clamp components.
  - Determine a way to hold soda bottles with hand.
  - Test fully assembled prototype.

References

[1] Enable, "ABOUT", Enabling The Future, 2018. [Online]. Available: http://enablingthefuture.org/about/. [Accessed: 02- Oct- 2018].
[2] “The Prosthetics Society,” Fine Acts. [Online]. Available: https://fineacts.co/the-prosthetics-society/. [Accessed: 02-Oct-2018].
[3] E. Strait, Prosthetics in Developing Countries. 2006.
[4] “How Much Does a Prosthetic Arm Cost? - CostHelper.com,” CostHelper. [Online]. Available: https://health.costhelper.com/prosthetic-arms.html. [Accessed: 02-Oct-2018].
[5] "The world's most advanced Prosthetic Hand - bebionic", Bebionic.com, 2018. [Online]. Available: http://bebionic.com/. [Accessed: 17- Sep- 2018].
[6] G. McGimpsey and T. Bradford, Limb Prosthetics Services and Devices. Worcester, Massachusetts: Worcester Polytechnic Institution, 2018.

Acknowledgements

Ken Bice
Dr. Justin Williams
Joseph Ulbrich
Dr. Robert Radwin
e-NABLE community
BME Design