Modified eNABLE Prosthetic Hand with Continuous Hold Mechanism

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Abstract

e-NABLE is a 3D printing, open-source, volunteer community that provides low cost, easily sourced prosthetics to individuals. The hand designs provided by e-NABLE all have the same closing mechanism: the wrist is flexed, tensing the flexor cables, causing the fingers to close. 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 during prolonged use of the device. To relieve this forearm fatigue the team added a clamping mechanism to the existing Raptor Reloaded design. This piece locks fingers in a closed position, allowing free movement of the wrist.

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

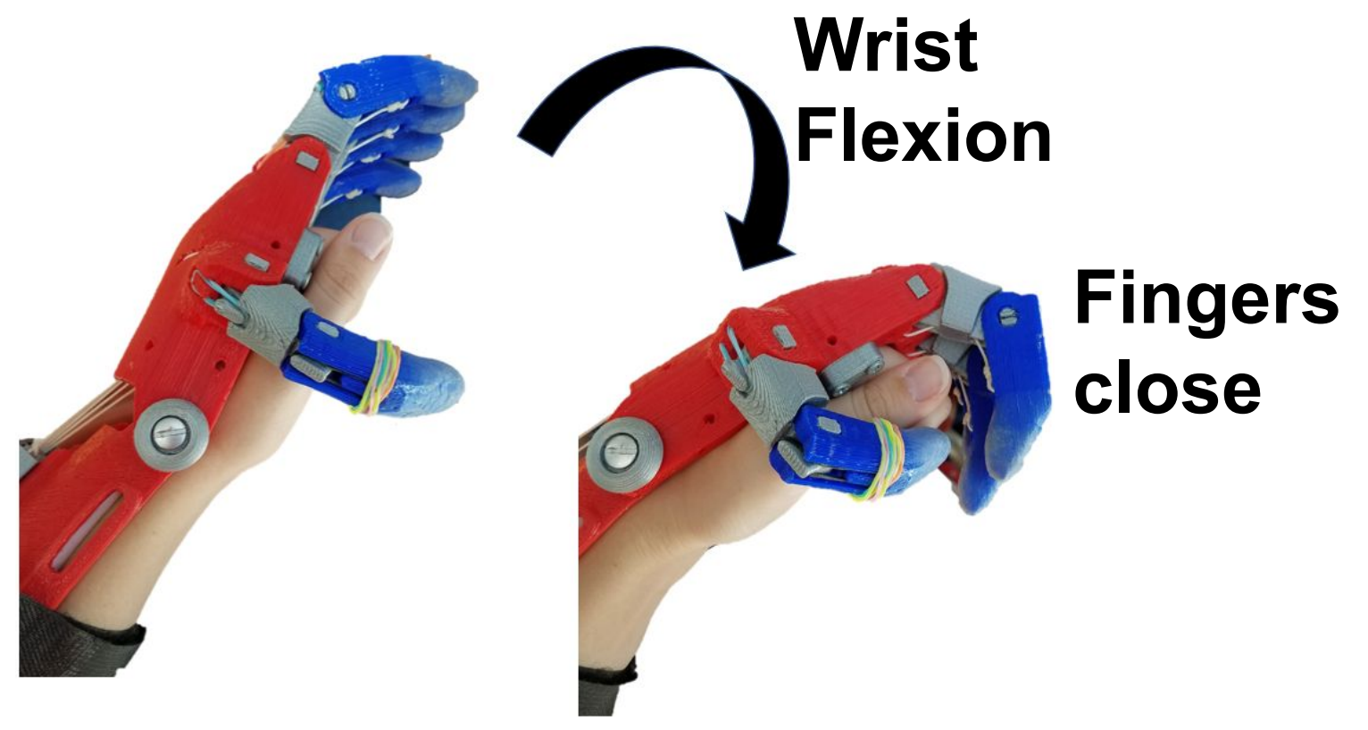

Figure 2: Current Raptor Reloaded e-NABLE prosthetic. Wrist flexion tightens the flexor cables, causing the fingers to close into a fist.

Competing Devices

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

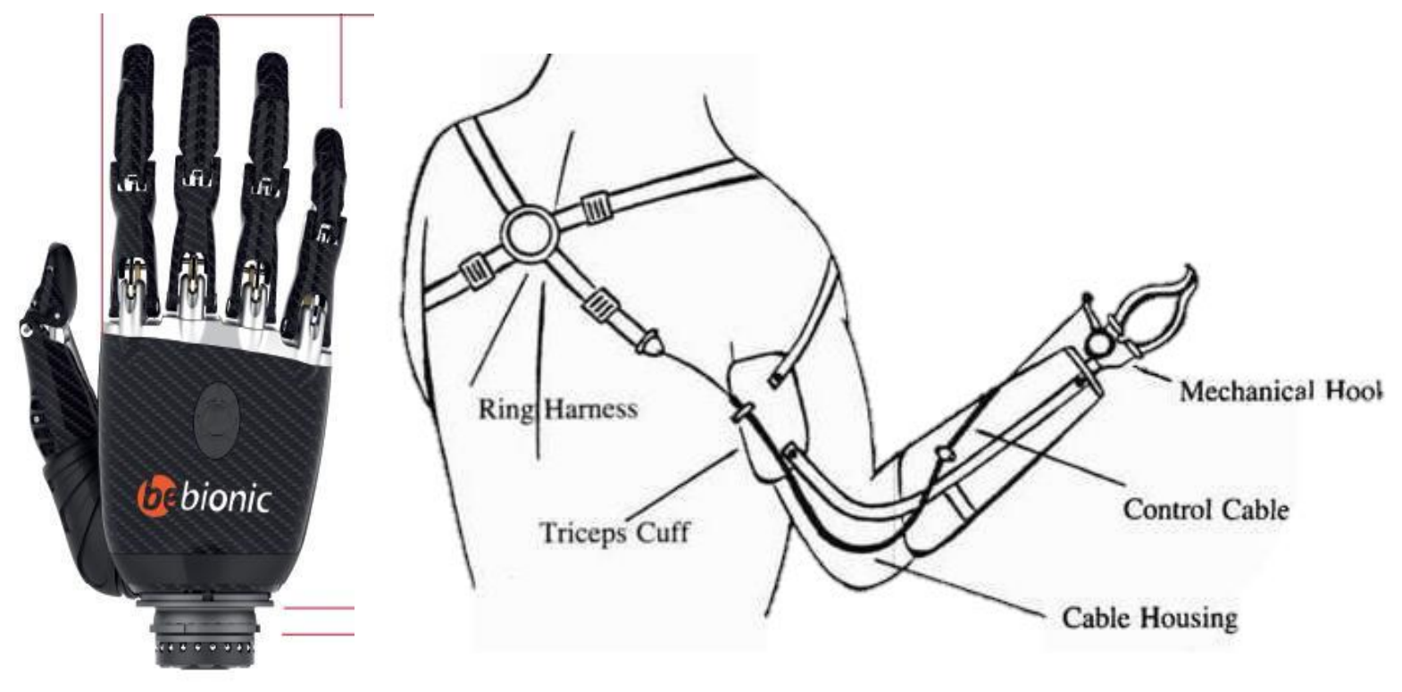

Figure 3: Commercially available prosthetic hands. Left: Bebionic Myoelectric Hand [5]. Right: Generic Split-Hook Prosthetic [6].

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 one 12 oz can of soda (<1lb)
- Total budget: $200

Final Prototype: Raptor Locked and Reloaded

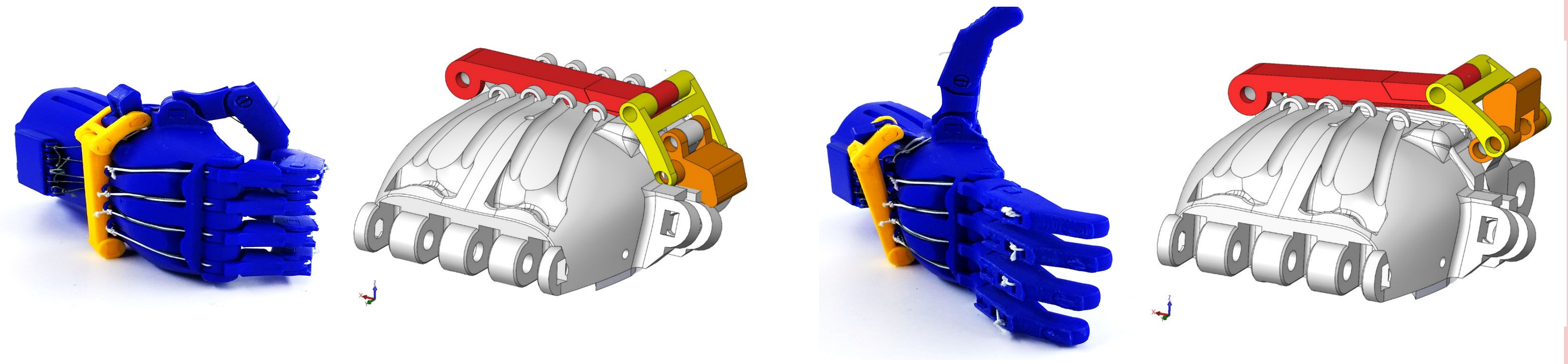

Figure 4: Photos of final design palm piece and SolidWorks of clamp closed (left) and open (right).

- Changes to original Raptor Reloaded:
  - Added clamp attachment pieces and surface grooves.
  - Moved extensor cable attachments distally (in front of clamp).
  - Rerouted thumb groove so its flexor cable is clamped as well.
- Changes from last semester:
  - Designed plastic pins.
  - Adjusted component shapes to improve printability.
  - Reinforced weak joint areas of clamp.

Clamp Distributed Force Testing

- Initial data from last semester revealed an uneven clamping force distribution.
- During testing this semester, a force gauge was used to measure the force at which each string visibly slipped through the final clamp.
- This experiment was intended to determine the maximum tension that each string may undergo before failure.
- Two common sizes of flexor cables, 0.41mm fishing line and 3mm string, were tested to determine which is best for the 120% and 150% sized hands.

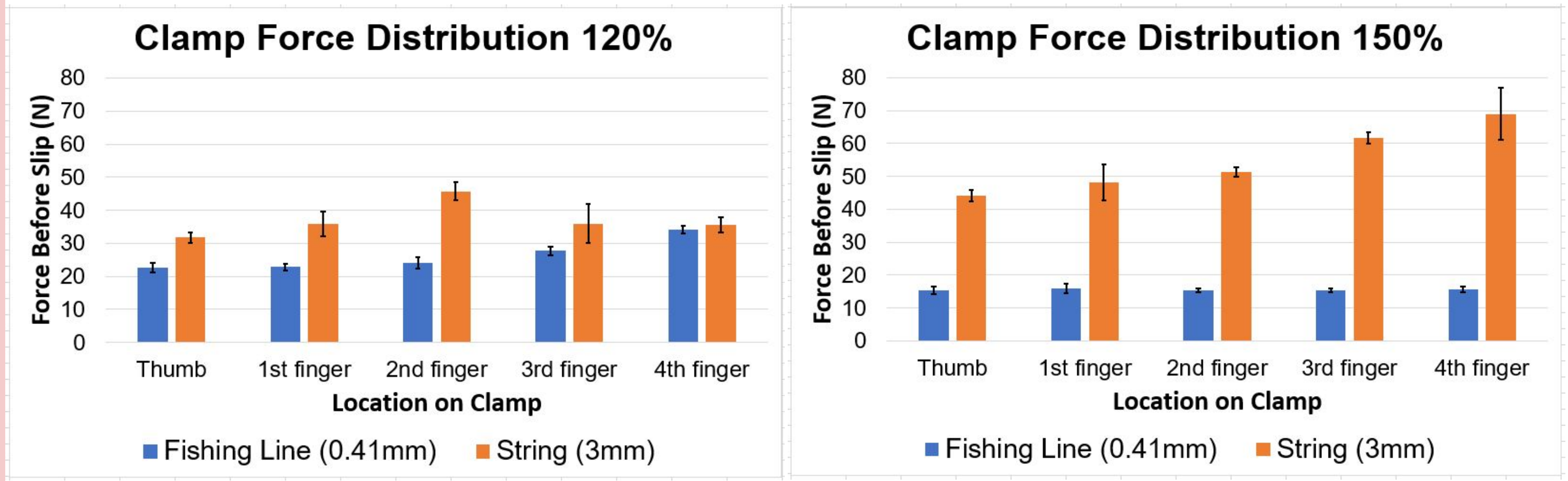

Figure 5: Tension applied to either 0.41mm fishing line or 3mm string at different positions measuring when string slip occurs.

Object Grip Force Testing

- The clamp was tested on three different geometries: hemisphere, block, and cylinder.

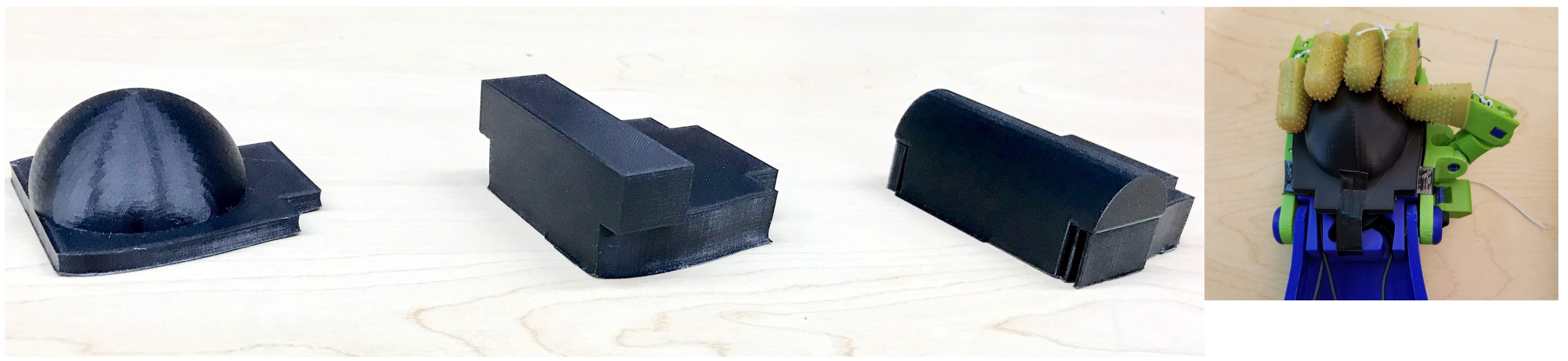

Figure 6: Images of the various object shapes tested for maintained grip force of the hand. Measurements represent force the fingers can produce to grip the object against the palm.

- To minimize variations between tests, the fingers were wrapped around the object each time. The base and top test pieces were taped together very lightly so they would stay in place for proper data acquisition. Grippies were attached to the fingers (a common ENABLE practice) to give the fingers more friction.

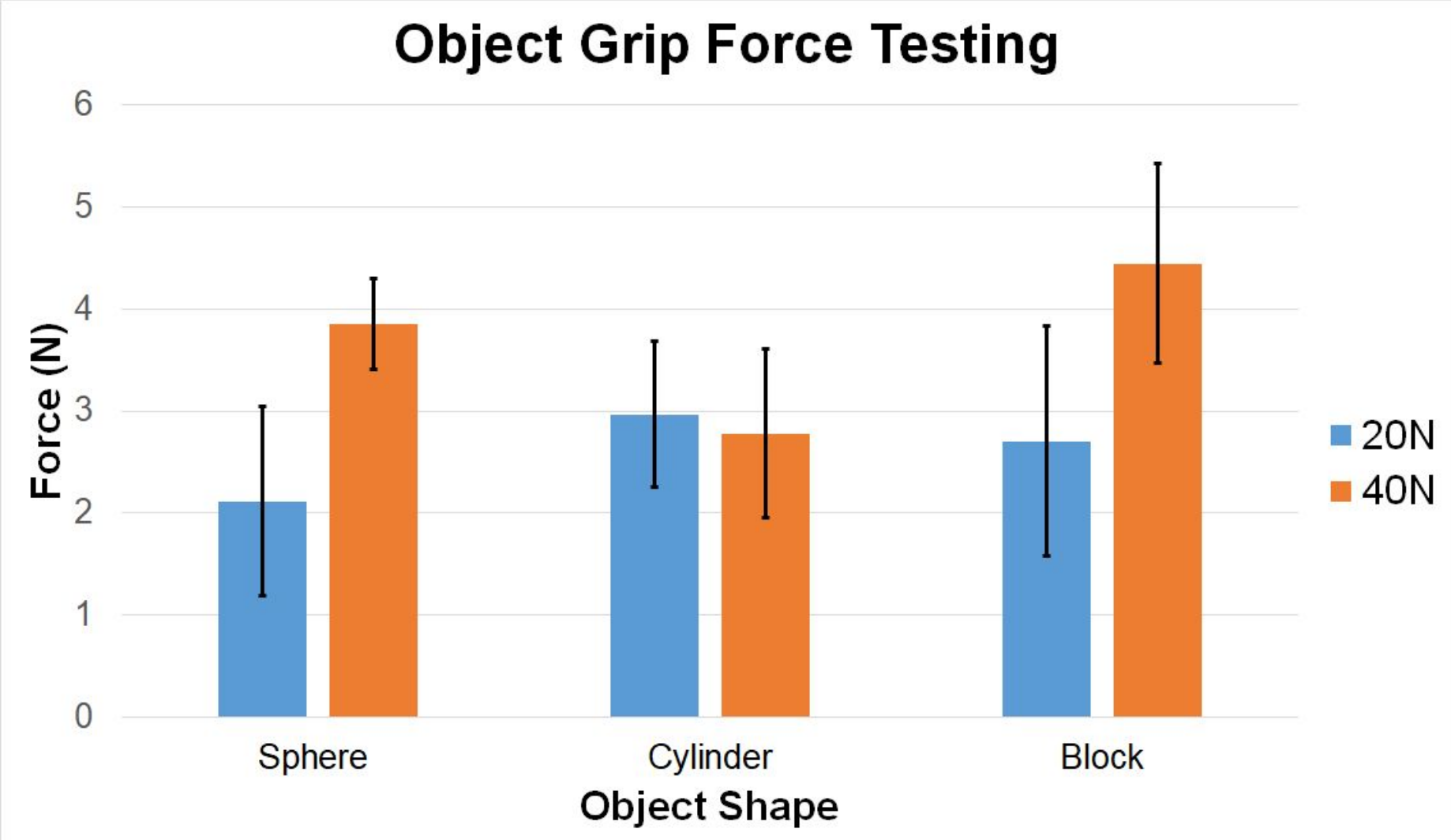

Figure 7: Average grip force for each geometry at the two initial tension forces. No significance via two-way ANOVA.

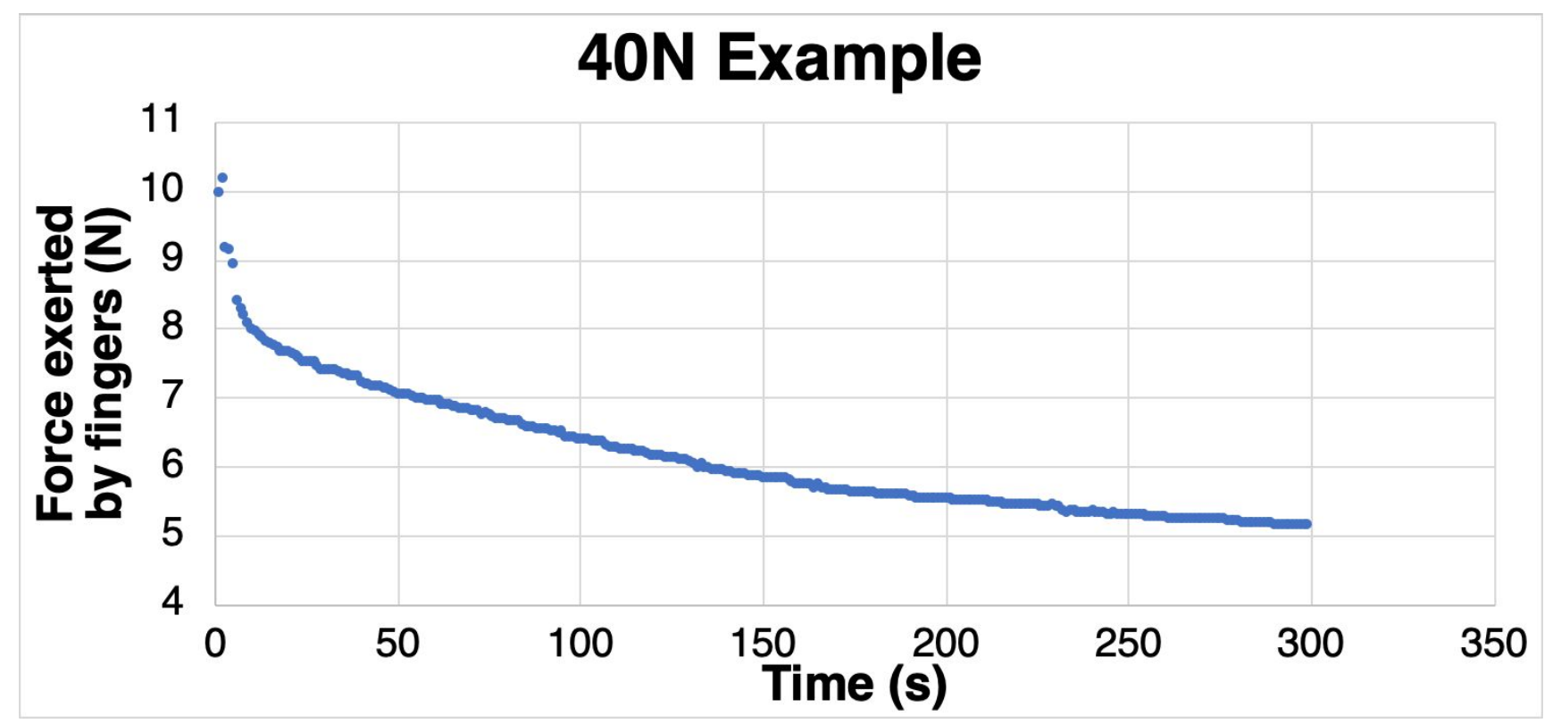

Figure 8: Raw sample of data from continuous force testing.

	20N	40N	20N	40N	20N	40N
	Sphere		Cylinder		Block	
Time Constant	-0.000863	-0.00092	-0.00161	-0.0019	-0.00072	-0.00048

Table 1: Average time constant for each set of force data. None of the values were significantly different using two-way ANOVA.

Conclusions and Future Work

- Testing showed that there is a force distribution, but its shape varies based on the diameter of string used (Figure 5).
- There is no significant difference in grip force between the tested object geometries. This means that objects of varying shape may be held with the design.
- An exponential decay was observed in maintained grip force testing.
- Based on these results, this clamp design meets function specifications. However the hand's finger positions should be redesigned to improve grip.

References

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