BiOM Prosthesis Adapter Team 1

Abdulla Ghayeb: Project Manager, Website Developer
Ebrahim Hubail: Budget Liaison, Document Manager
Leah Liebelt: Client Contact, Secretary

Project Description

Goal: Design an adapter to span from an ankle prosthesis to the bent knee of an able-bodied person to allow research to be conducted on the BiOM without the need of an impaired subject.

Constraints: fit different sized users, lightweight, comfortable, durable, safe, cost effective, and quick attachment

Clients:

- Dr. Zachary Lerner
- Dr. Kiisa Nishikawa

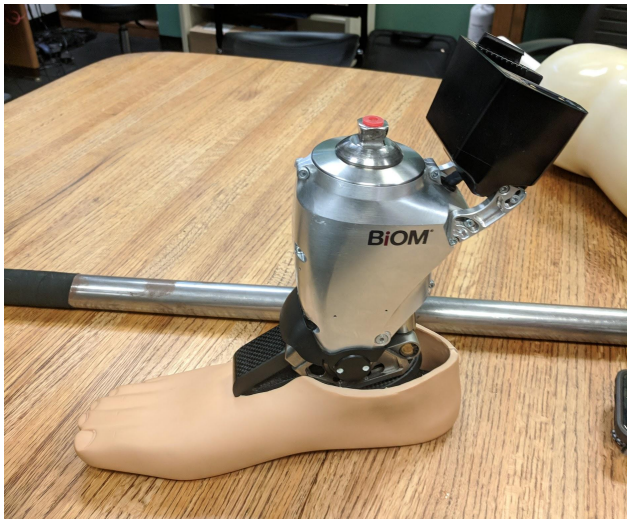


Figure 1: BiOM Ankle Prosthesis

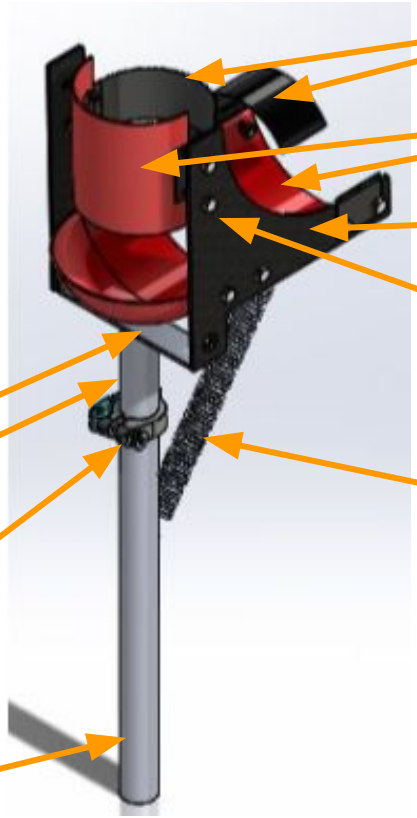
CAD Model

Key:

Green - Component Complete

Orange - In manufacturing progress

Red - Not manufactured



Velcro Straps

Leg cuffs

L-shaped Support

Chicago Bolts

Compression/expansion springs

U-shaped Attachment

Upper Pylon

Screw Lever Clamp

Lower Pylon

Figure 2: CAD Model of current design

Subsystem Updates

Old Design

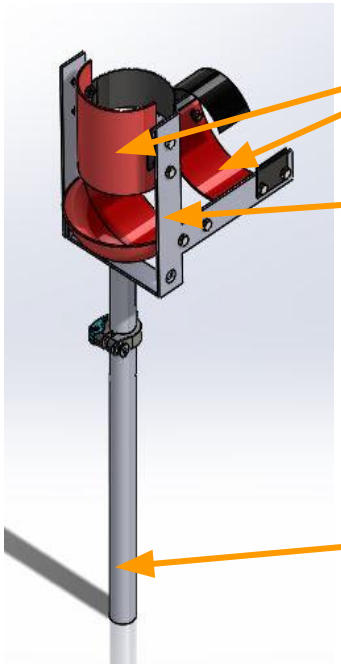


Figure 3: Old Design

Leg Support

Attachment

Pylon

New Design

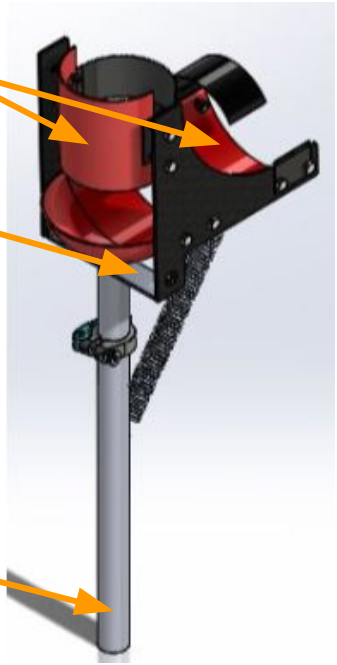


Figure 4: New Design

Pylon Updates

Manufactured the Aluminum pylon tubing

- ➢ Decreased the thickness of the end of the lower pylon to allow the BiOM attachment to fit over the aluminum tubing.

Telescoping Carbon Fiber Pylon

- ➢ Convert aluminum components to carbon fiber
- ➢ Light weight with easier attachment to the leg support

Addition of Spring Component

- ➢ Allows the pylon to return to extended position after gate cycle for dampened rotation about the knee.

Figure 5: Spring

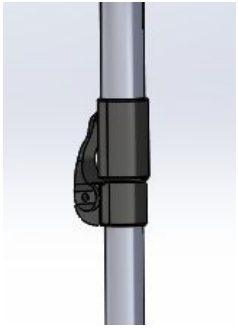


Figure 6: Telescoping Pylon

Figure 7: BiOM attachment

Attachment Updates

Attachment from pylon to U-bar

- Attachment piece used to secure the upper pylon to U-shaped support.
- Requires 4 additional holes to be drilled in carbon fiber U-support, and 8 in upper pylon.

Bearing integrated into L-shape/U-shape connection

- Allow U-support smooth rotation about the knee axis relative to leg support

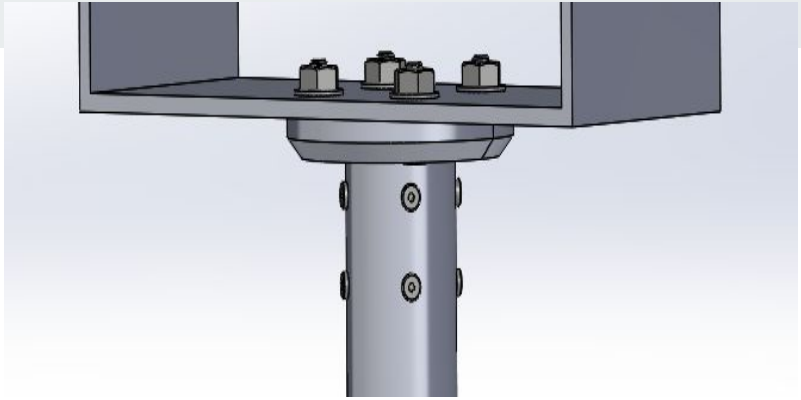


Figure 8: Attachment From Pylon to U-Shaped Support

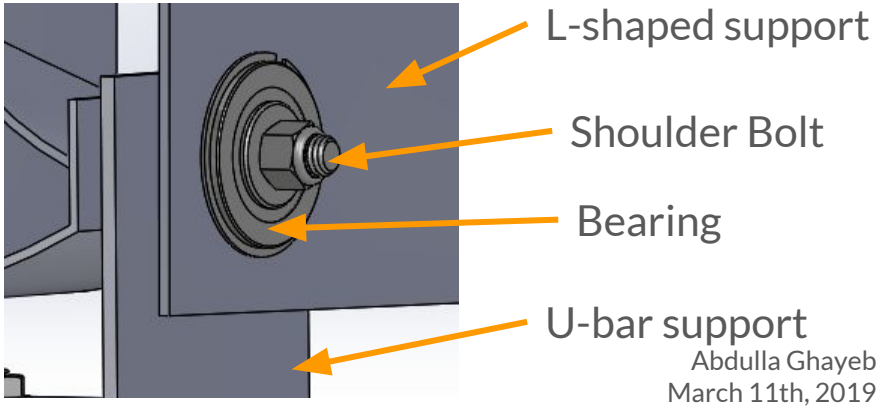


Figure 9: Bearing in L-support

Leg Support Updates

Use mini springs between leg cuffs and L-shaped supports

- ➢ Allow more customized attachment to users leg

Shoulder bolts updated to chicago bolts

- ➢ reduces irritation for user when it is flush with the inner cuff surface

Went from 2 bolts to 1 chicago bolt

- ➢ Allows better fit for users by angling cuffs to hug users leg.

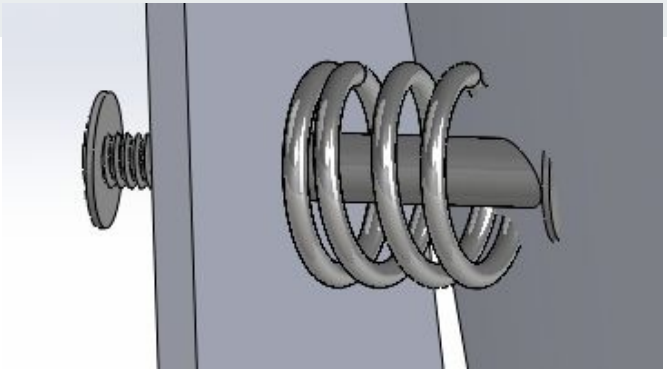


Figure 10: Mini-springs between leg cuff and L-support

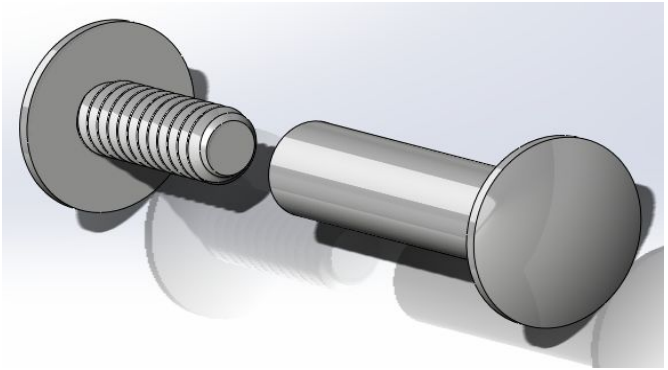


Figure 11: New Chicago Bolt

Leg Support Updates

L-shaped support updated with a large radius fillet

- ➢ Able to support more shearing stress due to calf cuff and avoids high stress concentrations in the corner.

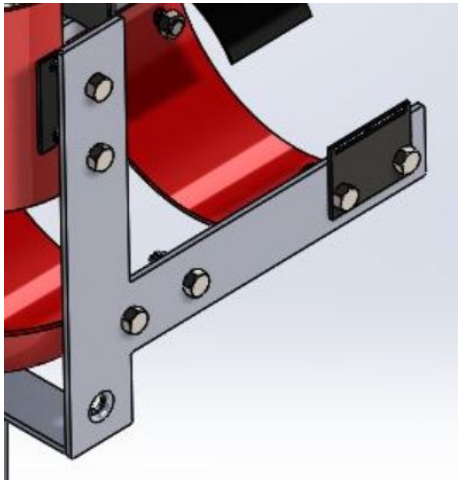


Figure 12: Old L-shaped support

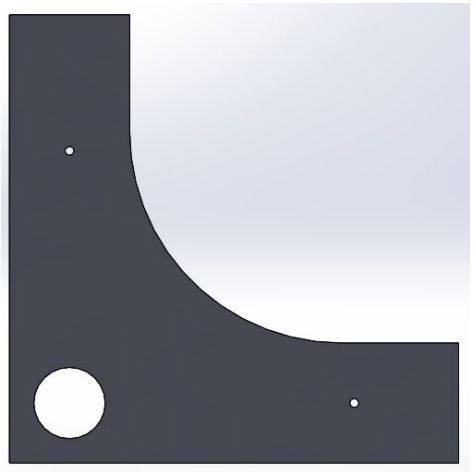


Figure 13: New L-shaped support

Moving Forward: Carbon Fiber Analysis

Carbon Fiber U-bar Analysis: Determine how many carbon fiber layers are needed in the U-bar attachment layup using a composites analysis.

- A minimum of 9 layers are needed for a factor of safety of 3 [1].
- Additional 3 layers were used to account for voids and delaminations within the component.

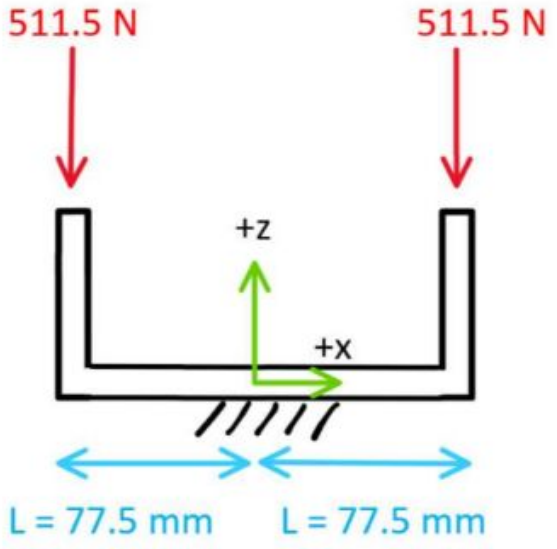


Figure 14: Simplified U-bar support

Moving Forward: Bearing Analysis

Bearing Analysis: Determine radial force acting on bearing location to determine the type of bearing needed [2].

- Ball Bearing
- Radial Force (C0)= 903 N
- Average bearing life = 4.033 L10 (about 1 year 10 months of constant use)

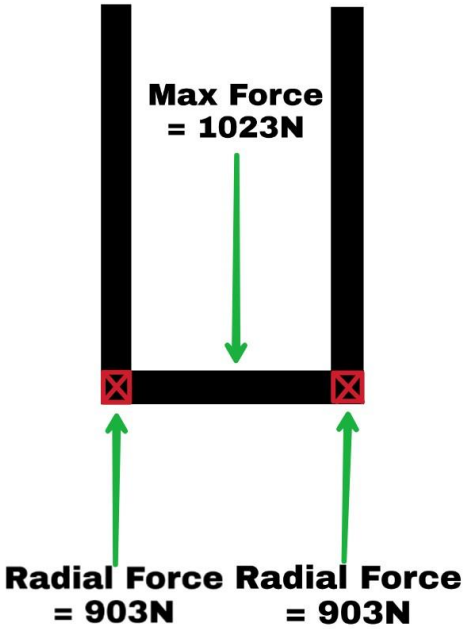


Figure 15: Bearing Placement

Moving Forward: Shoulder Bolt Analysis

Shoulder Bolt Analysis: Determine the right shoulder bolt that attaches to the bearing to the leg support [3].

- Force: 511.5 N
- 1/2" Shoulder Diameter
- Minimum Shear Strength: 84,000 psi
- Tensile Strength: 140,000 psi

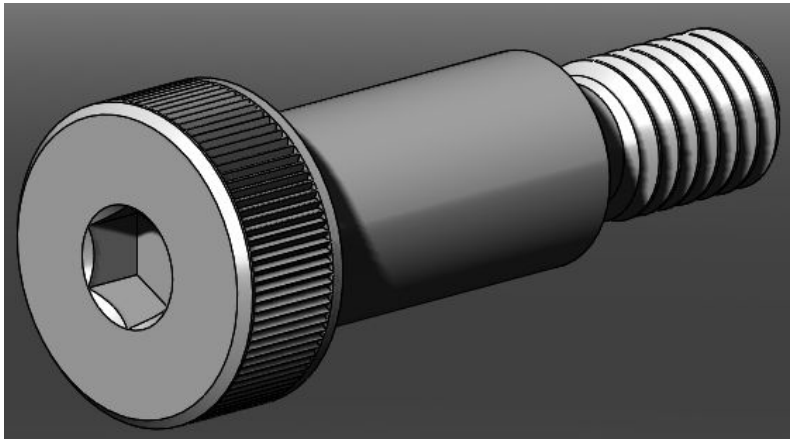


Figure 16: Shoulder Bolt

Moving Forward: Manufacturing

Pylon:

- ➢ Drill holes to allow spring attachment
- ➢ Epoxy the clamp to the upper pylon

Attachment:

- ➢ Layup new U-shaped attachment
- ➢ Epoxy the bearing to the L-shape

Leg Support:

- ➢ Attach velcro straps using chicago bolts

Entire System:

- ➢ Attach pylon to leg support
- ➢ Attach spring to upper pylon and calf cuff

Requirements

- Lightweight: less than 4 kg [4]
- Comfortable
- Quick Attachment: Attaches in less than 1 minute
- Adjustable: height adjustable to 15 cm, width adjustable between 7 and 20 cm
- Durable
- Affordable: less than $1000
- Safe: Factor of Safety of 3

Moving Forward: Testing Procedures

Pylon:

Test 1:

Measure maximum and minimum height adjustment of the pylon using a meter stick.

Test 2:

1. Stand pylon upright in extended position on top of a scale.
2. Extend pylon to 2 inches longer than the height of side-by-side tables
3. Place flat plate over top of pylon
4. Apply force over top of flat plate until pylon buckles/clamp slips to determine factor of safety.

Moving Forward: Testing Procedures

Attachment:

1. Place U-bar attachment on small rigid beam in geometric center.
2. Insert shoulder bolts through attachment at bearing location.
3. Apply downward force to shoulder bolts until U-bar breaks due to bending stress.
4. Calculate actual factor of safety of the component.
5. Factor of safety must exceed 3 for the attachment subsystem.

Moving Forward: Testing Procedure

Leg Support:

Test 1:

1. Get 10 volunteers with no background of project.
2. Have volunteers secure leg support without the attached pylon to their leg.
3. Volunteers will stand and put their weight on their bent knee while it is resting on a chair.
4. The volunteers will rate the comfortableness of the support from 0 to 10, 10 being very comfortable, 0 being unbearable pain.
5. The device must have an average of 8/10 comfortability rating for the 10 volunteers to pass the comfortability test.

Moving Forward: Testing Procedure

Leg Support Continued…

Test 2:

1. Use the same 10 volunteers to put the system on their leg
2. Determine the average time of attachment to the users leg for someone unfamiliar with the system.
3. Determine the average time of adjustment (pylon height and leg support width) for someone unfamiliar with the system.

Test 3:

1. Measure maximum and minimum diameters of the calf and thigh cuffs respectively.
2. Determine if the cuffs will range between 7 and 20 cm diameters.

Moving Forward: Testing Procedure

System:

1. Weigh entire system to determine if system is under 4 kg
2. Use bill of materials to determine if system is less than $1000.
3. Use system continuously for 2 hours to determine durability.

Schedule and Budget

Table 1: Gantt Chart

PROJECT TITLE	BiOM Prosthesis Adapter	DATE	03/10/2019

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION (Days)	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14	WEEK 15	WEEK 16	WEEK 17
1	Individual Post Mortem	Individual	1/14/19	1/18/19	4																	
2	Website Check 1	Abdulla	2/4/19	2/8/19	4																	
3	HR1 Summary	Ebrahim	2/11/19	2/22/19	11																	
4	Peer Evaluation I	Individual	2/22/19	2/25/19	3																	
5	Analytical Analyses II	Individual	2/4/2019	03/01/19	27																	
6	Midpoint Presentation	Abdulla	3/4/19	3/11/19	7																	
7	Midpoint Report	Leah	2/25/19	3/15/19	20																	
8	Peer Evaluation III	Ebrahim	3/15/19	3/17/19	2																	
9	HR2 Summary	Individual	03/04/2019	3/29/2019	25																	
10	Manual	Leah	3/25/2019	4/5/2019	10																	
11	Final Product Testing Proof	Ebrahim	4/1/2019	4/12/2019	11																	
12	Final Poster & Operation Manual	Leah	4/1/2019	4/19/2019	18																	
13	Final Presentation	Abdulla	4/15/2019	4/26/2019	11																	
14	Final Operation and Assembly Manual	Ebrahim	4/8/2019	4/26/2019	18																	
15	Final Report	Leah	4/22/2019	5/3/2019	11																	
16	Final CAD package and BOM	Abdulla	4/8/2019	5/3/2019	25																	
17	Website Check II	Abdulla	4/29/2019	5/6/2019	7																	
18	Peer Evaluation III	Individual	5/3/2019	5/6/2019	3																	

Schedule and Budget

Sponsored by: W. L. GORE

Budget: $2,000

Balance: $1,050.36

Anticipated final cost: ~$1,150

Table 2: Breakdown of Cost

	Price of Parts
Pylon	$185.26
Attachment	$75.04
Leg Support	$356.44
Tools	$87.53
Tax & Shipping	$245.37
Total Spent	**$949.64**

References

[1] R. F. Gibson, *Principles of Composite Material Mechanics*, CRC Press 4th ed, 2016.

[2] Shigley's Mechanical Engineering Design, 9th or 10th Eds., R.G. Budynas & J.K. Nisbett, McGraw- Hill, 9th Edition 2011

[3] Liu, J., Ouyang, H., Peng, J., Zhang, C., Zhou, P., Ma, L., & Zhu, M. (2016). Experimental and numerical studies of bolted joints subjected to axial excitation.

[4]Percentages of Total Body Weight, *Body Segment Data*, Available at: https://exrx.net/Kinesiology/Segments.

Questions?