GNG2101

Technical Report

Deliverable J:
User Manual

Submitted by

Team E11

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Abstract

This document aims to contextualise the reader to the details of our product, the Exo-boot. The Exo-boot is a device created in response to the needs of our clients at a Biomechatronics laboratory, who required a device that would allow healthy individuals to wear foot prostheses to simulate walking on one and to test their function. The composition of the device is included to allow for others to reproduce the Exo-boot and make future improvements to it. Detailed instructions on maintaining the device and the reasoning behind design choices are also included.

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1. Introduction

The goal of this document is to display and explain the purpose of our product (the Exo-boot), how it was made, how it is used, how to maintain the product and the reasons for the chosen design solution.

1.1. The Problem

There is a lack of a suitable device for healthy, able-bodied individuals to wear foot prostheses in order to test their function and to simulate what walking on a prosthesis would feel like. The researchers at the University of Monterrey's Biomechatronics laboratory found it difficult to allow their students and associates to test various foot prostheses directly. The solution would allow for different types of foot prostheses to be worn through an adjustable height mechanism and take minimal time to change parts.

1.2. User Requirements

The device allows able-bodied researchers to mount various prostheses, in order for them to simulate walking with a prosthesis. It also contains a height adjust mechanism which allows the user to test multiple prostheses of different heights at the same time, without dealing with being unbalanced. Attached to the bottom of the height adjust is a quick connect piece which allows for quick interchangeability, so our clients will be able to select different prostheses at random and fit them together with proper tolerances. Restriction of the user's ankle motion is an important requirement to recreate because the researchers are to be completely reliant on the prosthesis for walking. Otherwise, there may be calibration problems once their solutions are fitted to actual transtibial amputees. While the cost of production is low, because our clients are looking to provide first world solutions to a third world country, the device is still capable of bearing a maximum load for users below 100kg. Anyone heavier would not be fit for prostheses.

1.3. The Best Solution

The biggest benefit to choosing our product is the time that it will save our clients. The time it takes for a biomechatronics laboratory to swap from one prosthesis to another is on average five (5) minutes. This is due to there being many little set screws that need to be loosened and tightened to detach, and reattach different protheses. With our *Quick Connection Concept* that utilizes spring loaded ball bearings, swap time is reduced to seconds. No tools are necessary to use this design, the user only needs to pull back on a sleeve, slide out the prosthesis and slide in the new desired one.

A secondary benefit to our product is the *Height Adjust Concept*. If a user wishes to use two prostheses at the same time but have a difference in height, our design will allow them to set the heights equivalent to each other for a level walk. Our product is able to extend up to

100mm in length. This design allows for the user to quickly and easily adjust the height for most protheses.

2. Main Body

2.1. Features and Functions

Important features of the product, as well as its function and capabilities are highlighted below.

2.1.1. Height adjust concept

The height adjust feature will be made out of two tubes, an inner and outer tube with an outer clamp to keep them together. The height can be adjusted by loosening a ⅜ inch bolt and sliding the inner tube up and down to the user's ideal required height. This feature is most important when a user wants to wear a device on each leg, since the prostheses being tested might be at variable heights. This feature will allow the user to adjust both devices to be able to have both at the same height. The height adjust feature is capable of accommodating up to 50mm of adjustments.

2.1.2. Quick connect concept

The quick connect feature is a simple mechanism made out of spring loaded ball bearings which will allow users to switch between different foot prostheses under ten seconds. To switch out a prosthesis, the user only needs to slide the sleeve up to detach it and a new prosthesis can be attached to replace the previous one. This feature requires no tools and will save users plenty of time because the swap can be done in seconds.

2.1.3. Boot

The boot is not part of the device, but the device has been designed in a way that any standard orthopedic boot can be attached to the plate of the height adjustment system. The standard orthopedic boot already meets the requirements we need in terms of limited ankle motion and most of our clients will have access to one. Once the user obtains an orthopedic boot it is relatively easy to attach it to the plate of the height adjustment system.

2.2. How it's Made

All components of the design were created using CAD software, specifically Solidworks. The entire design can be broken down into components, and then further down into specific parts. There are two main components to this design that use a total of nine parts that work together.

The first group of parts that make up the *Quick Connection Concept* consists of six pieces. The first piece, the male pyramid connection (Part 1), is the base that will be on top of all protheses. This component is easily purchasable but could also be manufactured out of aluminium. It has a wide base with a 20mm diameter and machined such that set screws/ball bearings can lock it in place. The second part is the female pyramid connection (Part 2) that slides over and rests on top of the male pyramid connector. This part houses the 4 ball bearings (Part 3) that lock the two pieces together. The bearings rest in the holes that are bored through sides of the housing to the hollow inside. It also has a bottom extruded lip that holds the sleeve (Part 4) in position. The sleeve covers the bearings and keeps them pressed against the male pyramid connection which locks and secures all the parts together. The sleeve is also held down against the lip of the female connection by a ¼" spring (Part 5) The spring is a simple helical spring that is ½" in length and held in place by a spring housing (Part 6). The spring housing can be 3D printed, unlike most parts that are made of aluminium.

The second component is the *Height Adjustment Concept* consisting of an outer post (Part 7) which sits on top of the female connection by either welding or manufactured from the same rod stock. It has a slit in the top that allows for tightening on the inside post (Part 8). The inner post can slide up and down so that the height of the device can change and be locked in place by the clamp (Part 9).

The spring housing piece can be 3D printed, while most of the other parts can be manufactured with aluminium. The exceptions are the spring and ball bearings, which have other material options.

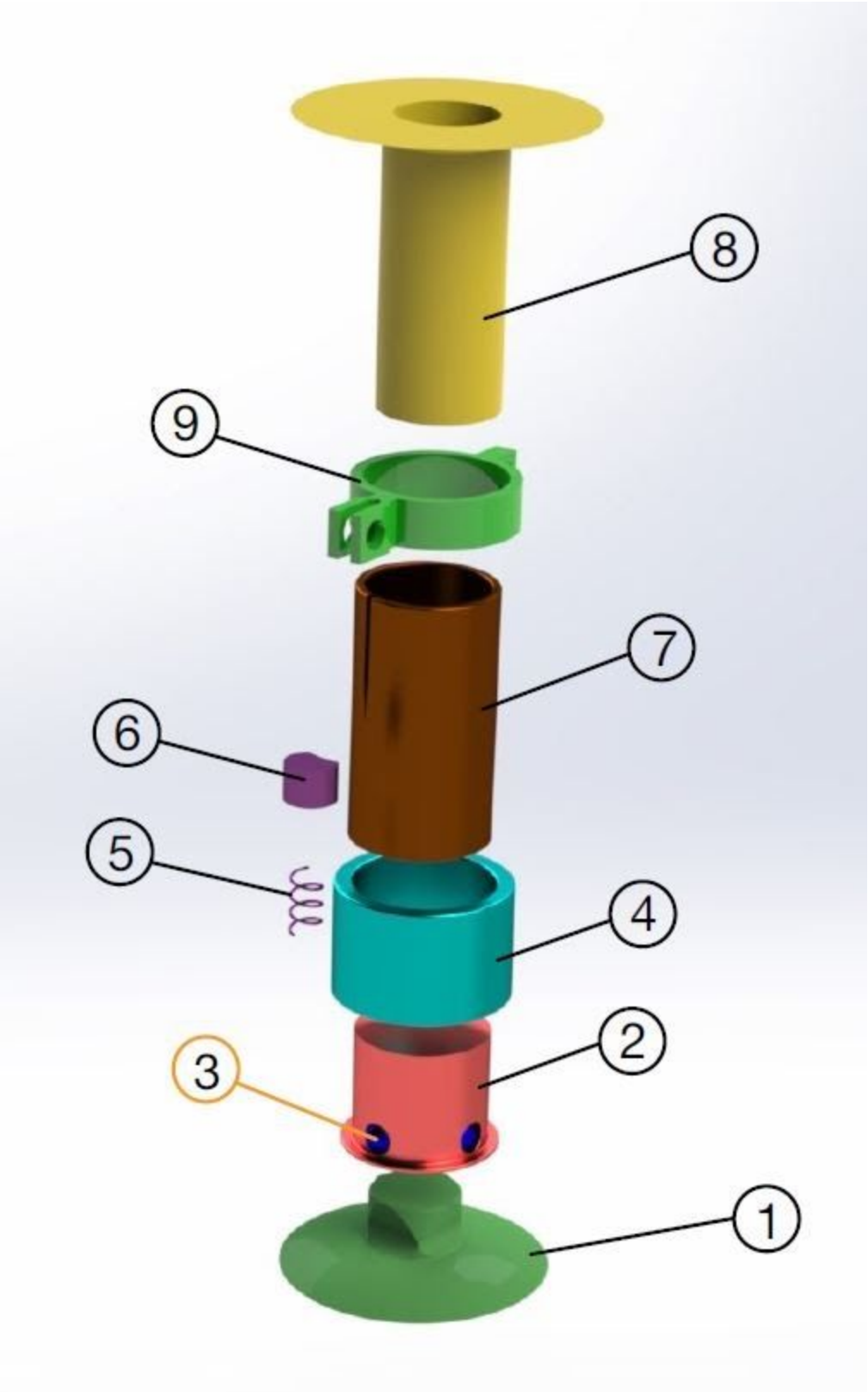
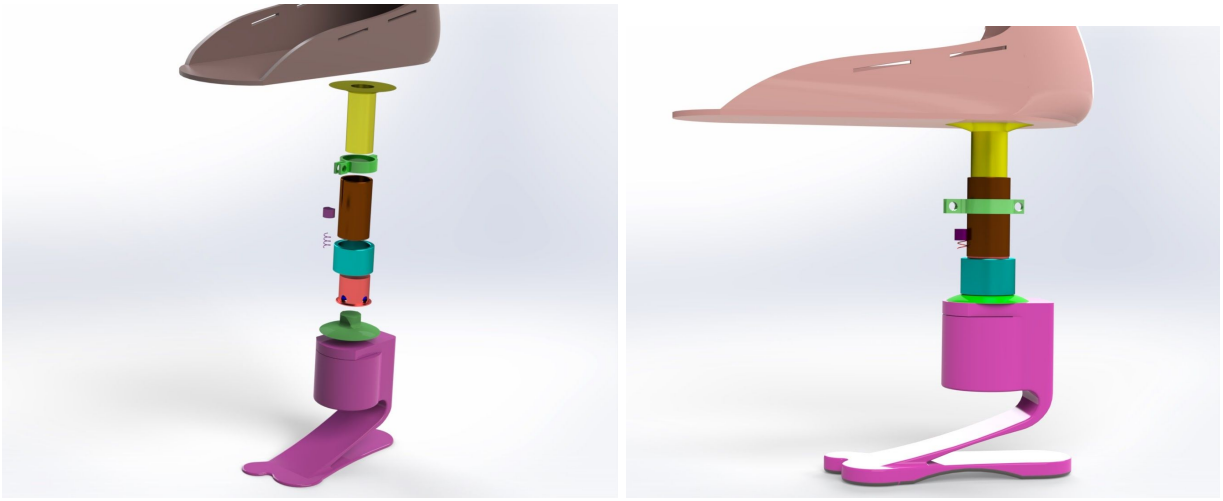


Figure 1: Exploded view of quick connection and height adjustment

Component	Part Number in Figure #
Male Pyramid Connection	1
Female Pyramid Connection	2
Ball Bearings	3
Sleeve	4
Spring	5
Spring Housing	6
Variable Height Outer Post	7
Variable Height Inner Post	8
Clamp	9

Table 1: Device parts



Figures 2 and 3: Exploded and collapsed views of Exo-boot

2.3. Health and Safety

- Put the device on from a seated position to avoid losing balance and prevent injury.
- Do not run or jump on the device.
- Do not use this device for a user over the weight of 100 kg as that is outside of the current design.
- Use only in a controlled laboratory environment.

- Standard machine shop health and safety instructions when machining the parts.
- Users should not lean or tilt too far forward as they might lose balance.

2.4. Troubleshooting and Technical Instructions

To replace any part or piece of the device that is damaged or worn out:
- First, follow the instructions in 2.2 “How It’s Made” and take apart the device.
- Change the relevant piece and reassemble

Troubleshooting device assembly:
- Make sure all parts are the correct size. In particular the inner and outer height adjustment tubes, refer to section 5.1, table 2: Bill of materials for sizes
- Ensure that you are working with the correct tools to put everything together
- For more information, please refer to section 2.2 “How it’s made”

3. Conclusion and Recommendations for Future Work

The Exo-boot has been developed using an iterative design process, with the design constantly changing with input from team members, the client, potential users and project managers until we had a product that we were proud of. Given more time, other improvements can be made to our product such as the development of a boot to be used with our device and developing a camera mount for our device. Throughout this project, various skills were developed along with an overall ability to work in a team setting.

Lessons learnt and skills developed:
- Understanding our own limitations when designing
- Setting realistic and achievable goals
- Time management and organizational skills
- Teamwork and communication
- Drafting skills and using CAD software
- 3D printing

Future development:
- Develop a functional boot for the device
- Develop a camera mount
- A storage and transportation method
- Develop a new spring mechanism for the quick connection
- Refining the tightening clamp to be more effective (changing from C-clamps to a lever)

4. Bibliography

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5. Appendices

Number of Parts	Part	Supplier	Price
1	30x0.5mm aluminum tube custom	https://dakunlun.en.alibaba.com/?spm=a2700.details.cordpanyb.4.327639b71R9TXe	$0.20 per unit
1	2in x 12 Aluminum Rod Stock	https://www.amazon.com/ALUMINUM-ROUND-SOLID-Lathe-Stock/dp/B01F80WG1W/ref=sr_1_6?dchild=1&keywords=aluminum+rod+stoCk&qid=1602197740&sr=8-6	$24 $4 per unit
4	¼ inch ball bearings	https://www.bearingscanada.com/100-1-4-inch-Diameter-Carbon-Steel-Bearing-Balls-p/100-1-4-inch-Carbon-G40.htm?gclid=Cj0KCQiAhs79BRD0ARIsAC6XpaVFCXgOBgjzFhot38TKz7jPuPY9y3Jt74BilBSPj0r_g4qJh9JxvfcaAvmmEALw_wcB	$5.68 $0.23 per unit

Table 2: Bill of Materials

Metric	Unit	Ideal values	Marginal values
Number of Pyramid Adapters	Qty	1	1
Variable height	mm	100	+/- 10
Load bearing	kg	100	+/- 10
Permitted Ankle Motion	Deg	0	+/- 0.5
Total Weight	kg	0	<2.2
Cost	$ (CAD)	80	+/- 20
Prosthetic swap time	seconds	10	+/- 5
Mount to leg	seconds	30	+/-30
Mount off leg	seconds	20	+/-20
Dorsi/Plantarflexion	degree	0	1 or 2

Table 3: Target specifications