DEVELOPMENT OF A UNIVERSAL TRANSRADIAL FITTING FRAME

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ABSTRACT

The Center for Bionic Medicine conducts research on upper limb prosthetic devices, components, and technologies. In order to maximize the amount of human subject research able to be completed, a universal fitting frame for subjects with transradial amputations is needed. This paper will outline the development of a universal transradial fitting frame which has been in use for approximately one year at the Center for Bionic Medicine, Shirley Ryan AbilityLab, Chicago. This device is easy to assemble, easy to use, and allows for testing a wide variety of prosthetic wrists and hands.

INTRODUCTION

There are approximately 100,000 people living with major upper limb loss in the United States [1]. Loss of a hand has been shown to cause great functional loss [1]. A prosthesis can improve functional use as well as quality of life for people living with limb loss [2]. Therefore, there is a strong need for research into prosthetic components and their effectiveness.

At the Center for Bionic Medicine (Shirley Ryan AbilityLab, Chicago, IL), research into device development, outcome measures, and new technologies are being completed on a yearly basis. In order to improve feasibility of human subject research, having a device to easily test componentry on any transradial limb is necessary. The current process for in-lab testing is to create a custom plastic socket and mock up a temporary prosthesis. This process requires at least two visits for each subject to ensure proper fit of socket. If this timeline could be reduced, study times could be reduced, and devices evaluated at a faster rate ultimately improving clinical knowledge.

The purpose of this project was to develop a universal fitting frame that would fit the majority of transradial residual limbs in order to use any available prosthetic wrist/hand combination for research purposes. The project had five main product scopes that needed to be addressed: 1. It needed to be adjustable to fit most transradial limb lengths, 2. It needed to be adjustable to fit any girth transradial limb, 3. It needed to be adaptable to a liner integrated with electrode domes, 4. It needed to be adaptable to work with the different commercial and research myoelectric wrists/hands currently used in experiments, 5. It needed to be able to withstand forces necessary to complete standard outcome measures including box and blocks, clothespin test, SHAP, and ACMC.

DEVELOPMENT OF THE FITTING FRAME

First Prototype

Based on the above project goals, we proceeded with development of the fitting frame in three main components. The first was the structure itself; the structure had to be light weight and adjustable. A channelled aluminium bar (6063 Aluminium Rectangular Tube, $^{1}/_{16}$" wall thickness, ½" high, 1" width) was used in conjunction with a piece of aluminium bar stock (6061 Aluminium, ¼" thick, ¾" wide). A series of holes ($^{10}/_{32}$") were tapped into the channelled bar and two set screws were then used to hold the solid aluminium bar in place inside the channel. This channel design allowed for adjustment in length for different length residual limbs. Two channelled bars and two solid bars in different lengths (short and long) such that they could be interchanged depending on length needs.

The second component was the suspension. A flexible cuff made from a combination of flexible and rigid lamination (Paceline Nano Matrix Resin) was used to grip the muscle belly just distal to the elbow joint. Two cuffs were made in two sizes to accommodate for small and large limbs. The cuffs purpose was to provide minimal support for the frame. The main source of suspension came from an adjustable ratcheting mechanism (Revoflex BOA kit). A BOA ratcheting dial, commonly used in prosthetic and orthotic applications, was embedded into two pieces of laminate lined with plastazote to create a sort of clamp system. This allowed for adjustability depending on the limb circumference and provided excellent suspension between the patient's limb and the posterior bar. For suspension between the liner and the wrist unit, a magnet connection (High-Pull Rare Earth Magnetic Disc with countersunk mounting hole, $^{7}/_{8}$" diameter) was utilized. One magnet was inlayed to the wrist connector and one was attached to the bottom of a locking liner. Finally, anterior straps were added to act as a counterforce system to offset weight of whichever hand/wrist combination was connected. These components can be seen in Figure 1.

The last major phase of development was the wrist connection. Custom 3D printed pieces were created in Solidworks and printed with a uPrint SEplus printer using ABS. The first piece created was a universal connection that would connect the structure of the fitting frame to whichever wrist unit was to be utilized. This piece included an extrusion which would fit into the channelled aluminium bar, a space for the magnet, and three wings which would be used to connect to all distal componentry. The second piece was developed to house the specific prosthetic wrist unit. This second piece could be easily altered to different wrist units by changing dimensions. The only thing that needed to stay the same was the three wings which are used to connect to the top connector. See Figure 2 below for a sketch of the completed pieces in Solidworks showing how the two parts mate together. Spacers of various heights with the same connection pattern were also fabricated so that the overall length could be extended to match the contralateral limb when using a shorter wrist system.

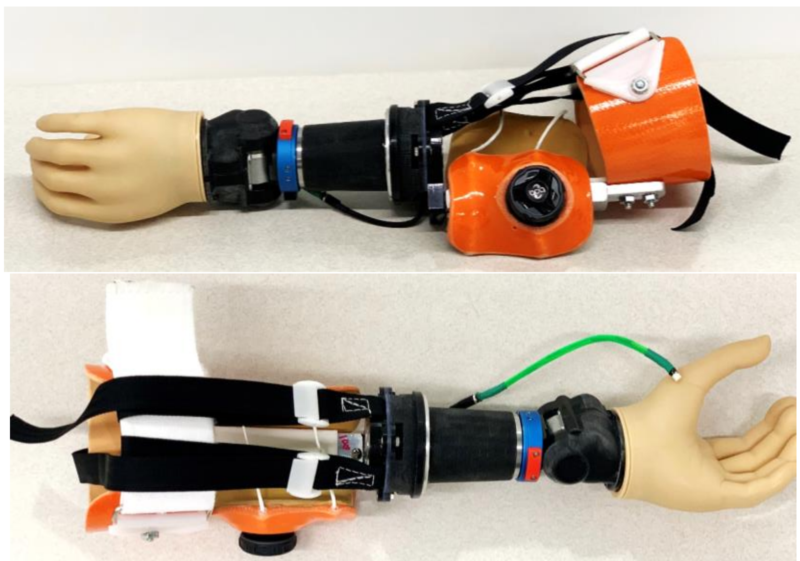

Figure 1: Photograph of assembled fitting frame (first iteration) with BOA clamp design.

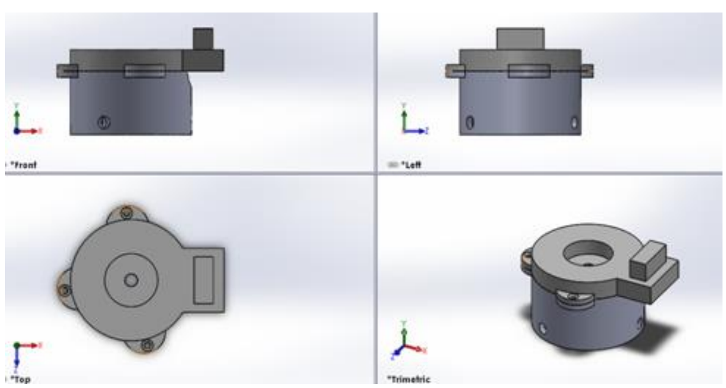

Figure 2: Solidworks image showing both custom 3D printed pieces as they would work together to connect the frame to the prosthetic hand.

Second Prototype

After trial use of the initial prototype, several modifications were made. Originally, the counterforce straps were attached using Velcro that attached to the cuff strap. However, to improve line of pull, the design was altered to a buckle attachment. The second change was the switch from the custom BOA clamp system to an off the shelf BOA strap mechanism. This makes it easier to duplicate the device as well as reduces overall bulk.

Figure 3: Photograph showing all components of the second iteration of the universal transradial fitting frame including the new counterforce straps and BOA strap. In the center is the assembled device with extra components surrounding.

Figure 4: Photograph of all components of the second iteration of the universal transradial fitting frame broken down to show each part individually.

STRENGTHS AND LIMITATIONS

The biggest strength of this fitting frame is its adaptability. It is possible to quickly configure the device to fit different lengths and shape residual limbs. This allows for ease of set-up for experiments and reduces time to actual testing. The device is lightweight and simple in design. It is easily replicated from materials that are fairly easy to acquire. The most unique component is the 3D printed wrist connection which does require access to a 3D printer.

While the fitting frame does work well for most situations, there are a few limitations to this design. The major limitation is that it does not work with very short residual limbs (length under 10cm from lateral epicondyle to distal end of residuum). The second limitation is that it is not ideal for heavy components, especially when on a short residual limb. It relies on dacron straps to act as the counterforce for the wrist and hand componentry. If the patient presents with a short residual limb, the lever arm is shortened and more force is needed from the counterforce straps to maintain alignment.

CLINICAL AND RESEARCH IMPLICATIONS

The universal transradial fitting frame is easy to use, adaptable to fit any residual limb length and shape, and has been used to test a variety of current prosthetic wrists and hands. To date, the fitting frame has been used on seven subjects with success. Four different wrists have been used; two commercial wrists (Ottobock and MotionControl) and two research wrist systems. EMG has been connected to the system via Motion Control snap electrodes in the locking liner and reliable and consistent signals were obtained. A sample image of a subject with a transradial amputation wearing the fitting frame is shown in Figure 5. The design is simple and easy to replicate in any research or clinical application.

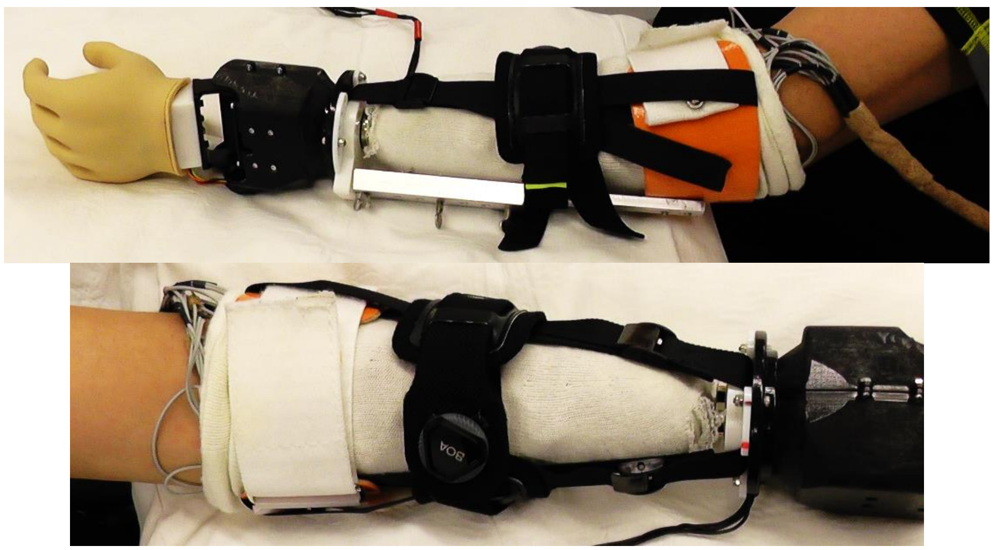

Figure 5: Photograph of a transradial subject wearing the fitting frame.

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