Evaluating Design Specifications of an Activity-Specific Prosthetic Arm to Aid Mechanics

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Abstract

Upper limb amputations affect millions of people worldwide and in the United States. The use of mechanical tools is one of the leading causes of upper limb injuries. Prosthetic devices have been designed for the restoration of limb function; however, most products have been either costly or unattainable. A prosthetic dedicated to provide function to those that use tools is needed. This work aims to develop an affordable prototype for an activity-specific upper limb prosthesis.

Introduction

As of 2008, ~3 million people worldwide have an upper limb amputation and this makes up 30% of all amputees. 1.77 million have an amputation below the elbow, 0.84 million people have an amputation above the elbow (elbow disarticulation), 0.24 million have a shoulder amputation, and 0.15 million have a hand or wrist amputation [1]. Amputation occurs when a physical part, such as a finger, toe, hand, foot, arm, or leg, is lost or removed [2]. One of the causes of upper limb amputations is the use of parts, materials, and tools.Given that 22% of amputations are due to tools, parts and materials; many of these people likely work in professions that involve hands-on mechanical work. The aim of this work is to make a prosthetic for people who work in these professions and suffered a work-related amputation. This activity-specific prosthetic that allows a tool to be attached to the prosthetic to perform the job with reduced risk.This work provides hope for those with a work-related amputations to return to their profession.

This research paper is an attempt to design a prosthetic that will be useful for these work-related amputations. It is an activity-specific prosthetic with different attachments that can be used for many different tools. This design is meant to be washable, rotatable, lightweight, compact, multi-functional, and fit the user. The design can fit these requirements with the joints and designs listed in the mechanical components section. These joints and designs were researched and chosen based on which one is presumed to be the best for this activity-specific prosthetic.

Methods:

These user needs listed in Table 1 were decided based on which ones could be the most beneficial for amputees working with tools. They were chosen after reading and reviewing multiple papers on how prosthetics are normally made. Computed Aided Design (CAD) software was used to design prototypes with these user needs for the activity-specific prosthetic.

Table 1: User needs

User needs	Design features to support user needs
Maintenance	Upper arm and forearm are made out of titanium which is a washable material.
Rotation	Elbow and wrist can both rotate due to their joints.
Weight	All the materials and joints are lightweight so they aren't difficult and don't have a high user abandonment rate.
Size	The prosthetic and joints are small so they will be able to get into small places and still be able to work.
Applications	The terminal device allows for the user to be able to do their work with different tools.
Custom fit	The device will be made out of titanium which is designed to fit the user perfectly.

Results:

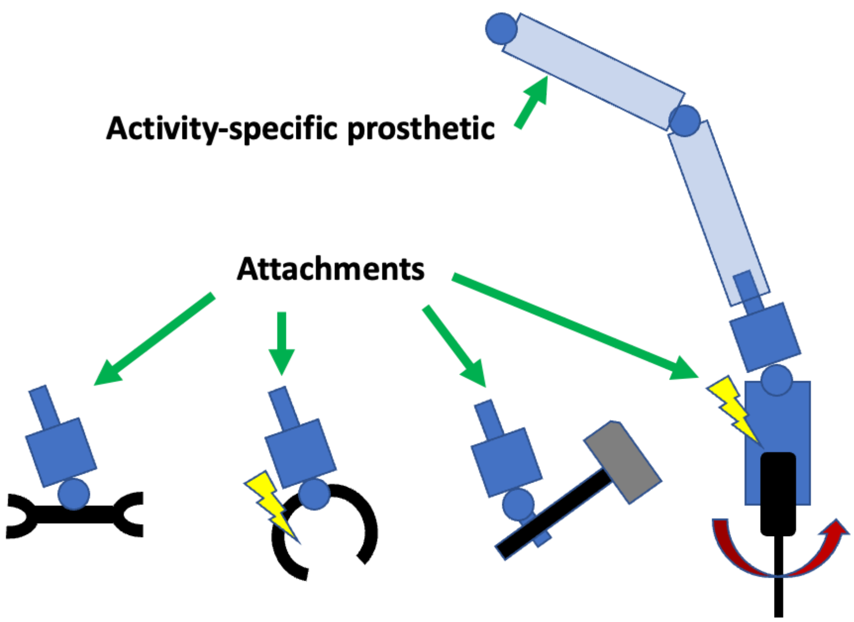

Figure 1. *Examples of a terminal device for the activity-specific prosthetic arm. A wrench, pliers, hammer, Screwdriver/drill (from left to right). The pliers and the screwdriver/drill can be electrically powered.*

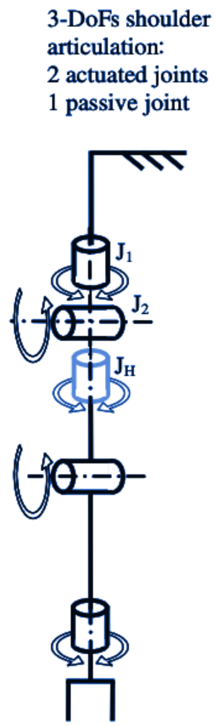

Figure 2. *Degrees of freedom requirements for prosthetic arm (adapted from [4]).*

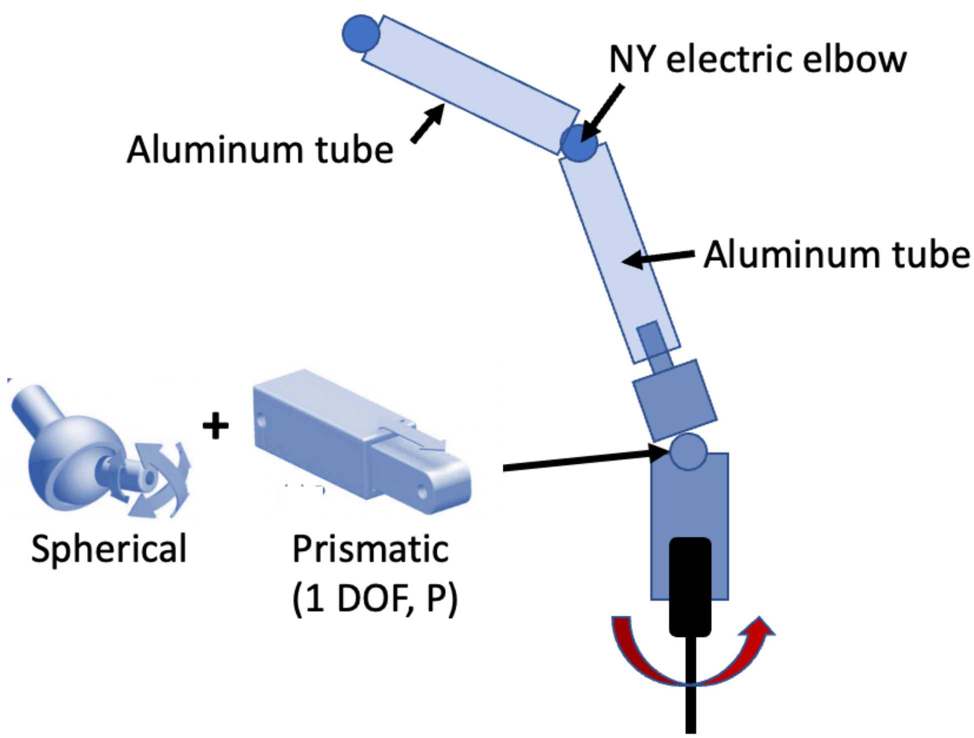

Figure 3. *Components of the activity specific prosthetic arm.*

Mechanical components:

I. **Shoulder**

The best shoulder joint would be one with 3-DoFs shoulder articulation: 2 actuated joints, 1 passive joint [4]. This would match with the rest of the joints and is the best for this type of prosthetic. Example is on figure 2.

II. **Upper arm**

The optimum material for this kind of prosthetic is titanium since it can be made to fit the person and retain an activity-specific prosthetic. It also has a low density, is lightweight, and has a high strength to weight ratio. It also has a great resistance to corrosion [5].

III. **Elbow**

NY Electric Elbow is the best elbow design for this prosthetic because it is compact and can turn 135 degrees. This is enough for the terminal device as it can be used for many different tools. It also works for 8 hours so that means that it will work for the whole workday [6].

IV. **Forearm**

Titanium is the best material for this type of prosthetic because it will be able to be designed to fit the user and would be able to hold the activity-specific prosthetic. Additionally, it is low in density, light in weight, and strong in relation to its weight and density. It also has high corrosion resistance [5].

V. **Wrist**

A passive wrist prosthetic with the joints S & P. The joints S & P will allow the wrist to rotate and move forward and backward [7]. This will be useful for the amputee as they will be able to do the work required for someone who uses tools, parts, and other devices.

VI. **Terminal device**

Several terminal extensions were designed to allow for attaching the prosthetic arm to a variety of mechanical tools (As shown in Fig. 1.).

Discussion

This work represents the first attempt to design an activity-specific prosthetic device for performing mechanical work. Several design concepts were evaluated for activity-specific prosthetic device. After 12 weeks, Several design approaches for this prosthetic were considered.The work presented herein suggests that it is feasible to manufacture several end-pieces for the prosthetic to fit different users. The prosthetic is being made out of a material that can be fitted for every person and can satisfy a wide spectrum of needs.

This work is mostly theoretical, therefore, more experiments using physical prototypes are required to assess the feasibility of the design.

In the future we plan on manufacturing the prosthetic based on the aforementioned user needs and the design criteria. This is the first design, so based on the trials, the design will be enhanced so it can better accommodate the users. Rapid prototyping can be used to customize designs for different types of patients which could reduce the cost.

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