

Powered Humeral Rotator for Persons with Shoulder Disarticulation Amputations

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Abstract: There are no commercially available externally-powered humeral rotators. This paper describes the development of a new powered-humeral rotator based on an LTI Boston Elbow II drive train suitable for use on persons with short transhumeral amputations or shoulder disarticulation amputations. An initial fitting of the device as part of a six motor arm demonstrated the efficacy of the device and anecdotal evidence suggested the patient found the device to be of benefit.

Introduction: It is estimated that out of a total of about 100,000 upper-limb amputees in the USA that about 18% have trans-humeral amputations or higher [Laplante & Carlson, 1997; Millstein et al., 1985; 1986]. For the upper arm the normal range-of-motion for humeral rotation is 90° of medial (inward-towards the midline) humeral rotation and 40° of lateral (outward-away from the midline) humeral rotation. However, persons with high-level arm amputations (trans-humeral amputation or above) often do not have the mechanical advantage to rotate their prosthesis through a normal range of inward and outward humeral rotation. Without an effective means to transmit rotation from the shoulder joint to the prosthesis, users are impaired in their ability to properly orient and position the hand in space. Humeral rotation is particularly important in activities-of-daily living for those tasks that need to take place at the midline of the body such as eating, toileting and dressing.

Surgical solutions exist in the form of the Marquardt angle osteotomy which places a piece of bone at an angle of 70°-110° to the humerus creating an angled piece of bone that can be used to capture humeral rotation [Marquardt, 1992]. A variation on this idea was to use an implant in the distal end of the bone to again provide a means to mechanically capture humeral rotation.

Non-surgical prosthetic options for humeral rotation are typically achieved with manually positioned friction joints, or turntables located on the top of the prosthetic elbow. Body-powered systems such as the Rimjet body-powered humeral rotator (Rimjet Corp, Sarasota, FL) [Uellendahl & Heckathorne, 1999] or the rotation unit built into the Automatic elbow from RSL Steeper Rotator also exist. There are no externally-powered humeral rotation devices currently available.

The Northwestern University Prosthetic's Research Laboratory (NUPRL) has developed a number of humeral rotators over the years. A working prototype of a cable-actuated locking humeral rotator was built [Ruberté, 2004]. This design had 180 locking positions spaced 2° apart along a full 360° of humeral rotation. It required a cable pull force of about 2 lbs (9 N) and a cable excursion of 0.43" (11 mm). The final prototype weighed 0.6 lbs (270g). The device also had a large central opening (0.875") to allow electrical connections to pass through, thereby increasing its capability of mating with a variety of commercially available elbow joints. This device evolved from an earlier NUPRL Multi-disk Rotator prototype [McCall, 1996]. The goal

of these projects was to develop a prosthetic component that would allow the user to easily control the inward and outward rotation of the forearm about the humeral axis using cable operation.

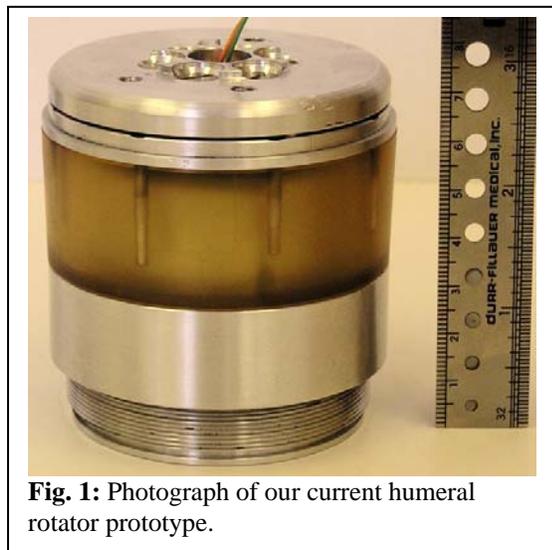


Fig. 1: Photograph of our current humeral rotator prototype.

Current Project: The goal of this project was to develop an externally-powered rotator that used myoelectric signals or electro-mechanical switches for control. This humeral rotator evolved from an old Boston I elbow drive train. It was noticed that the drive for this elbow was very compact and the authors believed it would lend itself to use as a humeral rotator simply by turning it on its side. The Boston I drivetrain consists of a brushed DC electric motor connected to the elliptical wave generator of a harmonic gear transmission. Both the motor and elliptical wave generator are housed within the flexible spline of the harmonic transmission. A harmonic gear transmission allows for high gear ratios in a compact space. The elbow case provides the annulus with which the flexible

spline engages. We took an impression of the annulus using RTV rubber and then made an epoxy resin duplicate of this gear. This epoxy housing was then machined to center it and to fit it into aluminium pieces designed to provide standard interfaces to a Boston Elbow and a standard laminating ring. The laminating ring was later replaced with an interface for EMAS Shoulder joint so that the humeral rotator could be used in a 6 DOF arm fit to a subject who undergone targeted Reinnervation [see other papers in this proceedings for more information](**Fig. 1**). EMG signals from Latissimus dorsi and the deltoids were used to control inward and outward rotation on this subject. Current limiting provided by the Boston Elbow III motherboard was used to detect stall at either end of the range.

We plan to build a second generation humeral rotator based the drive system of an elbow we are currently developing. This drive system has a hollow shaft, which is an important feature for a humeral rotator as it allows wires to be easily and cosmetically routed from the prosthetic interface down to the distal components of the prosthesis.

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