

ADAPTATION OF LOCKING SHOULDER JOINTS TO INCREASE FUNCTIONAL RANGE OF MOTION FOR BILATERAL UPPER LIMB DEFICIENCIES

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INTRODUCTION

Patients with "high" level bilateral upper extremity deficiencies require maximum rehabilitation to increase functional independence and self-care skills. When the deficiency includes one or both shoulder joints, functional range of motion is compromised immensely. This limitation in shoulder joint range of motion reduces the overall level of function as well as the ability to perform basic activities of daily living (ADLs).

BACKGROUND

Current prosthetic shoulder joints allow for shoulder flexion, extension, adduction and abduction. Other joint types have been proposed in related research. While most joints utilize passive friction for positioning, a limited number allow for positive locking in flexion and extension. Friction type joints do not adequately support the weight of most prosthetic systems (body powered or externally powered) while in a flexed position. Positive locking type joints allow the prosthesis to be utilized throughout a greater range of motion.

The limitation of these joints has been the actuation of the locking mechanism. Typically, a manual release cable is attached to a mechanical lever switch for operation. The lever switch is very difficult for the high-level bilateral amputee to operate. Also, this requires the amputee to utilize the contralateral limb/prosthesis for operating the lever switch of the shoulder side. Chin nudge switches have been used with minimal success in this application as catastrophic failures have been experienced when high forces are placed on the control cable for operation. In addition, the amount of force required on the nudge to activate the unlocking mechanism is excessive and very difficult to operate with the chin. Some patients may not have the range of motion necessary to operate such a device.

DISCUSSION

The unique challenges presented by such patient profiles necessitate the development of a powered actuation system for the shoulder joint. The system utilizes a simple electronic switch to control an actuator that in turn operates the shoulder unlock mechanism. This actuator allows the patient to reposition the arm in flexion and extension independently, without utilizing the contralateral prosthesis.

Components

The powered shoulder unlock mechanism consists of several individual components discussed below and shown in Figures 1, 2, and 3. There are a variety of prosthetic options and combinations of externally and body powered elbows, wrists, terminal devices and controllers that will effectively address the needs of the patient. Specific component selection must be determined on an individual basis.

1. **Switch.** An Otto Bock rocker switch was used to activate the actuator. A variety of push or pull type switches would also be effective depending on the individual situation.
2. **Actuator/motor.** A Michigan hook actuator was modified for use in the shoulder by disengaging the breaking mechanism to allow for rapid return for shoulder locking. The actuator is mounted on the distal-lateral aspect of the shoulder socket to enable effective pull on the shoulder lever unlock mechanism.
3. **Power supply.** Power supply can be provided by standard 6 volt Otto Bock (or comparable) battery or accessing the power supply at the elbow.
4. **Pulley.** A force amplification pulley is attached to a cable from the unlock lever to decrease the force on the motor. This will increase the amount of excursion required. An excursion amplifier pulley was used.
5. **Cable.** Spectra cable was used for ease of adjustment and replacement. Spectra cable is available from IRS.
6. **Extended unlocking lever on joint.** The unlocking lever was extended to reduce the force required to operate the joint and to position the alignment of the pull cable.

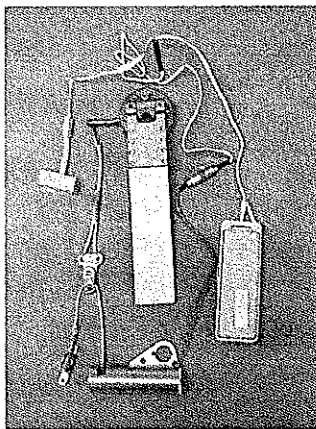


Figure 1. Unassembled Components

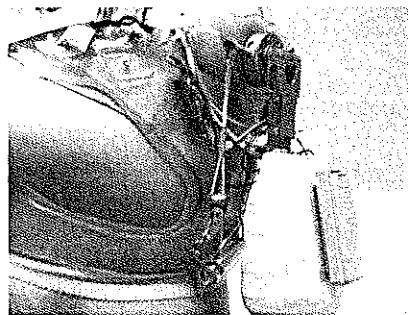


Figure 2. Diagnostic Test Prosthesis

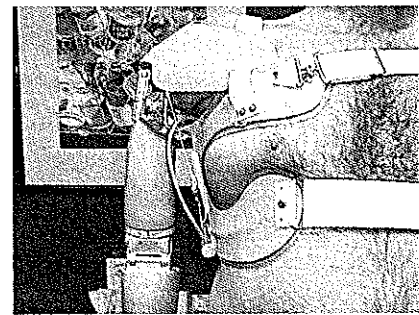


Figure 3. Finished System

Operation / Positioning

Patient applies continuous pressure to the rocker switch with their chin while bending forward and allowing gravity to position the arm in flexion or by positioning the arm against an external object. Once the desired position is obtained, the rocker switch is released and the shoulder joint automatically relocks. To reposition the arm back to anatomical position, the procedure is reversed by first decreasing the load to the joint (with gravity or against an external object) and applying continuous pressure to the rocker switch.

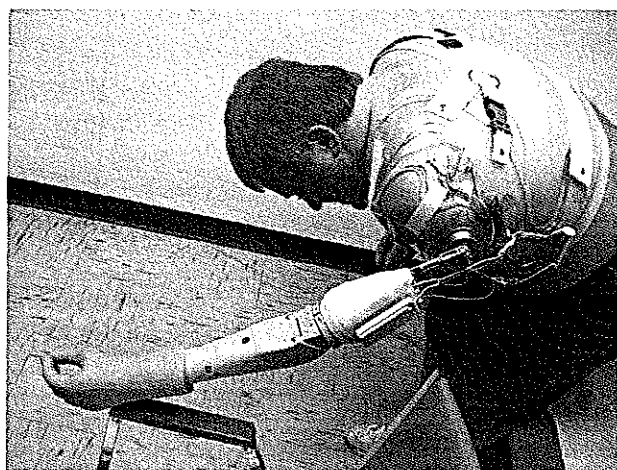


Figure 4. Patient using "object" to position

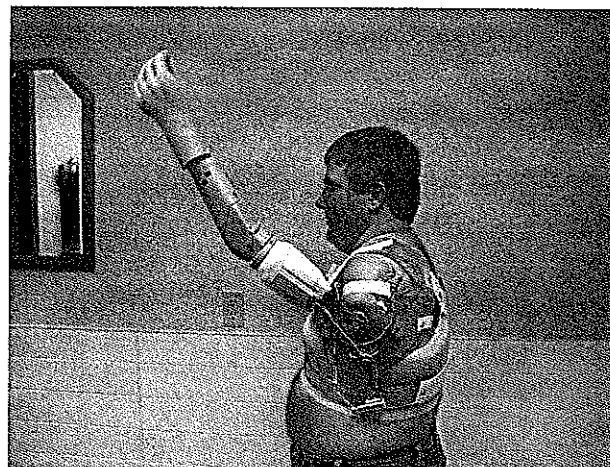


Figure 5. Prosthesis positioned for use

FUTURE

Features for the next generation of shoulder joint locking mechanisms are outlined below:

1. An alternating locking/unlocking actuator which would allow natural free swing of the shoulder during ambulation. This would also reduce battery drain when maintaining the shoulder in the unlocked position.
2. Reduced size of both the locking actuator and actual shoulder joint.
3. Integrate control and power of the locking actuator into the control system for prosthesis using a programmable controller.

CONCLUSION

High-level bilateral amputees require systems to improve functional abilities for activities requiring full forward flexion and above-head orientations. The ability to initiate and sustain these alignments without dependence on the contralateral limb/prosthesis dramatically enhances the ease of use of the prosthetic system. As a result, greater independence leads to greater function.

Four powered shoulder joint unlocking mechanisms have been successfully fit to date. Each patient was able to independently position the prosthesis. Each patient experienced an increase in independence and function after being fit with this system.

Further research and development will continue to maximize functional independence and activities of daily living for such complex patients. Applications for unilateral amputees will also be addressed in future research.