# Use of Myoelectric Limb Orthoses for Elbow Flexion in Patients with Brachial Plexus Injury: A Case Series

Gregory R. Anderson, MD, Taylor R. Beahrs, MD, Michelle F. Kircher, RN, Alexander Y. Shin, MD

## ABSTRACT

**Introduction:** Myoelectric limb orthoses (MLOs) are powered devices that assist with specific motions in patients with neuromuscular deficits or inadequate motor power. MLOs enable patients to self-initiate and control movements using their own muscle signals. While these devices have been used for patients that have sustained neurologic deficits from cerebrovascular accidents, their use in traumatic adult brachial plexus injuries is novel.

**Materials and Methods:** This case series presents three patients with traumatic brachial plexus injuries treated with MLOs to improve elbow flexion after inadequate recovery. The MLO was used as both a rehabilitation device and a functional device.

**Results/Conclusions:** MLOs demonstrate potential for improving patient clinical outcomes and satisfaction after brachial plexus injuries with incomplete recovery or inadequate function after surgical intervention. (*J Prosthet Orthot.* 2019;00:00–00)

KEY INDEXING TERMS: brachial plexus injury, myoelectric limb orthoses, powered orthotic devices



Myoelectric limb orthoses (MLOs) are powered orthotic devices used to assist with specific motions in patients with neuromuscular deficits and inadequate or absent motor power. They enable self-initiation and controlled movements of a partially paralyzed limb using native muscle signals. Stein et al.[1] reported on eight stroke patients with severe chronic hemiparesis whose function improved with use of an MLO. Application of MLOs in traumatic brachial plexus injuries has been previously reported in a case study by Ogce et al.[2] in 2000. Since this report, design improvements combining low profile/lightweight materials with advanced electromyography (EMG) technology have occurred. Newer sensors can detect minute electromyographic activity and, with the use of microprocessors, amplify the acquired signal to an electrical motor recreating the desired motion. The sensitivity and amplitude of the device is modifiable to adapt to a wide range of functional deficits. The goal of the device is to assist the patient in performing activities of daily living (ADLs) that would otherwise be too difficult or unfeasible.

GREGORY R. ANDERSON, MD; TAYLOR R. BEAHRS, MD; MICHELLE F. Kircher, RN; and ALEXANDER Y. SHIN, MD, are affiliated with Division of Hand Surgery, Department of Orthopedic Surgery, Mayo Clinic, Rochester, Minnesota.

Informed consent was obtained. Patients (three patients) provided informed consent for treatment.

Disclosure: Dr Shin is on the Veterans Advisory Board for Myomo, Inc. (no monies paid for this). No other author on this manuscript has any disclosures or conflict of interest related to the subject of this study.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.



*Correspondence to: Alexander Shin, MD, Division of Hand Surgery, Department of Orthopedic Surgery, Mayo Clinic, 200 First St SW, Rochester, MN 55905; email: Shin.alexander@mayo.edu*

Traumatic brachial plexus injuries are lower motor neuron injuries in contrast to stroke and traumatic brain-injured patients who often have upper motor neuron injuries. Traumatic brachial plexus injuries result in functional deficits in the upper limbs for which surgical options are time sensitive and limited.[2] Outcomes after surgical treatment are not universally successful, with some patients regaining inadequate elbow flexion.[3] Application of MLOs in patients with inadequate elbow flexion after brachial plexus injuries is both unique and novel. We present three patients with brachial plexus injuries treated using MLOs with the goal of improving elbow flexion after insufficient recovery.

## METHODS

This study was approved by the Institutional Review Board at the Mayo Clinic. Health Insurance Portability and Accountability Act–compliant informed written consent was obtained from each patient involved. This study conforms to all CARE guidelines and reports that required information accordingly (See Supplementary Checklist, http://links.lww.com/JPO/A23).

### CASE 1

A 60-year-old right-hand–dominant man was involved in a motorcycle accident and sustained an odontoid fracture with an associated spinal cord epidural hematoma and bilateral brachial plexus injuries. He presented to our Brachial Plexus Clinic 15 months after injury to discuss treatment options for inadequate elbow flexion.

He demonstrated a grade 2 bilateral biceps and brachialis strength with poor endurance per manual muscle test (Figure 1A; Supplementary Digital Content, Video 1, http://links.lww.com/JPO/A24). EMG demonstrated severe bilateral C5 to C7 brachial plexopathies with incomplete reinnervation. At 15 months after injury, surgical options included tendon transfers or a free functioning gracilis muscle transfer. He was offered bilateral Myomo devices (Myomo, Cambridge, MA, USA) to assist with elbow flexion. The goal of the MLOs was to assist in ADLs as

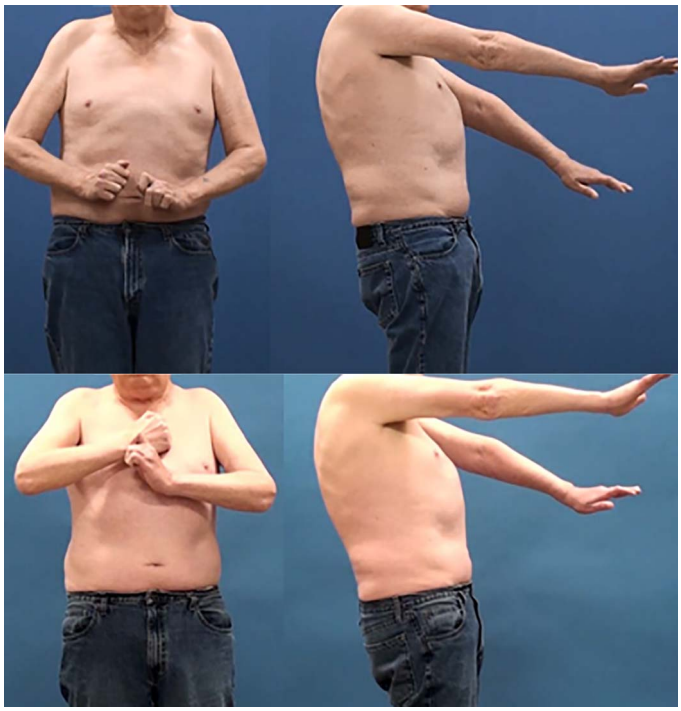

Figure 1. Case 1 (A) baseline clinical photographs 15 months after injury demonstrating elbow and shoulder flexion. B, Clinical photographs 22 months after initial injury, 7 months after rehab with an MLO demonstrating elbow and shoulder flexion.

well as a rehabilitation tool to improve range of motion, strength, and endurance of elbow flexion (Supplementary Digital Content, Video 1, Video 2, http://links.lww.com/JPO/A25).

After 7 months of MLO use, the patient obtained grade 3 strength. He was able to use his right arm to feed himself. He began to overpower the MLO, and the settings were adjusted to increase the activation threshold. On the left side, he was able to flex his elbow 90° against gravity (Figure 1B; Supplementary Digital Content, Video 3, http://links.lww.com/JPO/A26).

He continued daily use of bilateral MLOs to assist with elbow function and ADLs. At 15 months after initiation of the MLOs, his strength improved to grade 4 bilaterally and he discontinued their use. Anecdotally, he related that the MLOs provided encouragement and hope for recovery of an injury he thought was permanent.

### CASE 2

A 19-year-old right-hand–dominant man sustained a left upper trunk brachial plexus injury when he hit a tree with his car at high speed. He had no shoulder abduction or elbow flexion until 4 months after the injury when he noted trace elbow flexion (1/5). At 6 months, he regained weak elbow flexion (grade 2/5). However, deltoid and rotator cuff function remained absent. EMG demonstrated fibrillations in the deltoid, supraspinatus, and infraspinatus muscles.

In order to restore shoulder function, he underwent a triceps nerve branch transfer to the anterior division of the axillary nerve and a spinal accessory nerve transfer to the suprascapular nerve. He was prescribed a MyoPro (Myomo Inc, Cambridge, MA, USA) for rehabilitation of elbow flexion.

The MLO was applied for 6 to 8 hrs a day, and he used it for all ADLs. The unit was adjusted as his strength improved. The MLO allowed him to position and use his normal functioning hand for ADLs. After 6 months of MLO use, his elbow flexion strength improved from 2/5 to 4/5 and the MLO was discontinued.

### CASE 3

A 28-year-old left-handed man was involved in a motorcycle accident and sustained a complete left brachial plexus avulsion of C5 to T1. He also had severe chest wall trauma with bilateral pneumothoraces and multiple fractures (ribs, vertebral compression fractures, and a right displaced scapula fracture).

Six months after injury, he presented to our clinic with normal trapezius function and a flail left upper limb. There was evidence of a severe, complete, and preganglionic brachial plexus injury based on clinical examination, CT myelography, and electrodiagnostic testing.

He underwent a brachial plexus reconstruction with a free functioning gracilis muscle transfer innervated by two motor branches of intercostal nerves for elbow, finger, and thumb flexion.[4] Two additional intercostal motor nerves were transferred to the musculocutaneous nerve. The spinal accessory nerve was transferred to a triceps branch with an interposed sural nerve graft, and sensory intercostal nerves were transferred to the lateral cord contribution of the median nerve. Four months later, he underwent a planned wrist arthrodesis, thumb carpometacarpal arthrodesis, and thumb interphalangeal joint arthrodesis.

Eight months after surgery, his free gracilis muscle had a 2/5 muscle strength. He found it very weak and was unable to sustain a contraction (using his intercostal nerves activated by a Valsalva maneuver). He underwent aggressive rehabilitation and therapy to strengthen and improve active range of motion of elbow flexion. Fourteen months after surgery, he obtained 80° of elbow flexion with gravity eliminated but was only able to obtain 40° of elbow flexion against gravity. At 34 months postsurgery, his improvement had plateaued with 50° of elbow flexion against gravity with a grade 2/5. Despite the aggressive physical therapy, there was little improvement in movement and he found the arm nonfunctional. He was prescribed a MyoPro (Myomo Inc, Cambridge, MA, USA) device to improve his elbow flexion strength, active range of motion, and endurance.

He used the device for all ADLs in addition to using it as a rehabilitation tool. He found it most helpful for carrying things such as a full laundry basket or boxes at work. He stated that the MLO allowed him to be productive at work and enabled him to keep his job. As his recovery progressed, he began overpowering the device and ultimately discontinued its use having gained grade 4/5 elbow flexion strength with 130° of active flexion.

## DISCUSSION

Alongside recent advancements in surgical treatment for brachial plexus injuries, opportunities exist for physician-directed therapeutic modalities to optimize functional recovery. In this category, we have observed substantial benefit from using MLOs

in carefully selected patients recovering from brachial plexus injuries and surgical reconstruction. MLOs have been successfully used in the past as rehabilitation tools for patients with weakness resulting from neuromuscular disease and stroke.[1] In this case series, we present three unique applications for MLOs to improve elbow function. The first patient, who presented too late for primary nerve reconstruction, used the device to augment spontaneous inadequate recovery of elbow flexion. The second patient, who presented at an ideal time for primary nerve reconstruction, used an MLO during a period of spontaneous early recovery of elbow flexion. The third patient, whose surgical reconstruction resulted in insufficient elbow flexion, obtained meaningful elbow flexion after 3 years of being unable to improve with traditional rehabilitation techniques. Based on these patient experiences, we believe there are potential benefits of using MLOs.

Once fitted and trained on how to use their MLO, the patients enjoyed the ability to perform simple tasks and ADLs with the injured limb. The patients received continuous and immediate positive feedback when using the device. The MLO acted as an active assist motion therapy tool allowing for strengthening of the biceps/gracilis muscle in its entire arc of motion. Patients were able to adjust activation thresholds as their elbow flexion strength increased.

All patients reported that the MLO was useful in maximizing therapy and functional recovery. The MLO enabled patients to move their elbow through full range of motion while activating the elbow flexor muscle (biceps or gracilis) without the need for an assistant or physical therapist. Even when spontaneous biceps recovery occurred, it was often inadequate as demonstrated in the first patient who had insufficient elbow flexion nearly 15 months after the injury.

Patients in this series were anecdotally able to perform more ADLs when using MLOs than without. This allowed independent living for two patients and helped the third patient return to work. Each patient reported increased ability to lift objects such as baskets, boxes, groceries, and other small items. MLOs have the potential to improve quality-of-life and return-to-work metrics in this specific patient population. However, it is important to recognize that outcomes depend on multiple factors including type of brachial plexus injury (complete vs. upper trunk), type of reconstruction, remaining shoulder function/stability, overall health, and patient motivation.

There are several downsides to this technology. MLOs are currently cost prohibitive without third party payers and are currently bulky and heavy with limited battery life span. Proper use requires instruction and close follow-up with a skilled orthotic specialist and therapy team. MLOs may not be suitable in all brachial plexus patients, and careful patient selection is imperative for optimal outcomes. As availability and application of MLOs become more widespread, it will become possible to perform comparison studies to determine the effective contribution of MLO devices to therapy regimens.

In summary, we demonstrated that MLOs can be used to augment and improve functional elbow flexion after traumatic brachial plexus injury and reconstruction. The MLOs benefited patients with insufficient elbow flexion in patients who had limited surgical options to improve flexion. In this case series, all patients found benefit from MLO use as a rehabilitation tool as well as a functional tool for ADLs.

## REFERENCES

1. Stein J, Narendran K, McBean J, et al. Electromyography-controlled exoskeletal upper-limb-powered orthosis for exercise training after stroke. *Am J Phys Med Rehabil* 2007;86:255–261.
2. Ogce F, Oztalcin H. A myoelectrically controlled shoulder-elbow orthosis for unrecovered brachial plexus injury. *Prosthet Orthot Int* 2000;24:252–255.
3. Barrie KA, Steinmann SP, Shin AY, et al. Gracilis free muscle transfer for restoration of function after complete brachial plexus avulsion. *Neurosurg Focus* 2004;16:E8.
4. Maldonado AA, Romero-Brufau S, Kircher MF, et al. Free functioning gracilis muscle transfer for elbow flexion reconstruction after traumatic adult brachial pan-plexus injury: where is the optimal distal tendon attachment for elbow flexion? *Plast Reconstr Surg* 2017;138:128–236.