Elbow flexion Assist Orthosis

Applications: motor nerve palsy, traumatic brachial plexus injury, isolated biceps weakness.

Introduction

In November 2006 I wrote a BAPO article detailing a contemporary approach to the management of complete arm paralysis, presenting a modernised upper limb orthosis design and an original shoulder subluxation orthosis. These orthoses offered advanced management of complete motor dysfunction but I was aware of the disappointing functional outcomes for patients who presented with only partial motor palsy. The article concluded with “The elbow orthosis is essentially a passive device and the next step would be to make it actively functional.”

At that time the patient group I had in mind was a subset of brachial plexus patients who present with isolated shoulder and biceps dysfunction but with preservation of normal triceps, wrist and hand function.

Aim

For these patients a static elbow locking orthosis offers little functional improvement. The purpose of this article is to introduce a new ‘dynamic flexion assist orthosis’ that would serve to improve the functional impairment caused by brachial plexus injury or similar and, as yet, not addressed by existing orthoses.

Objective

To design, develop and test a dynamic flexion assist orthoses, to improve functional limitation.
**Method**

**Design & development stage**

The orthosis interface and design was maintained as an appropriate basis for application of elbow flexion force. The production materials evolved from plastic to TFC carbon fibre in order to achieve a suitably rigid framework. Pre-impregnated carbon or carbon laminate would be equally suitable. The “power” source became the problem. Elastic bands and metal springs were trialled but failed to offer consistent useable force over the joint range. The best option found is gas springs:

![Gas Spring Diagram](image)

A gas spring is basically a system consisting of a pressure tube, rod and piston (see Figure 1); they examples of their use include opening a car boot lid and as a component part of the Becker G-knee. The energy for the spring is provided by gas at high pressure and the whole system is self-contained. Stroke length, cylinder diameter and Newton force are all specifiable. The uniquely usable aspect of this component is the force curve which has a surprisingly high "K-Factor"; \( K = P_2 / P_1 \) where \( P_1 \) is the force of a fully extended gas spring and \( P_2 \) the force of the same spring when compressed. The force vs displacement curve is illustrated in Figure 2:

![Force vs Displacement Curve](image)

The amount of flexion force needs to be balanced against triceps force, skin interface forces and gas spring dimensions. Our base level calculations found that a 140N gas spring is sufficient to raise an adult’s arm plus a 0.5kg object, assuming a 25mm lever arm to the orthotic joint centre. Further consideration is necessary to factor in the muscle length-tension relationship and the increased elevation force required as the hand passes into flexion gradually increasing the effective lever length from the joint centre. Rationalising the interplay of these force curves into a usable elbow flexion force requires a specific lever and attachment point; that gives an effective lever short in extension and long in flexion. This attachment point was welded onto a small free joint (see section A in Fig.3).
In order to aid donning and also to permit a tension free flexion point, suitable for relaxed posture and skin pressure relief, a secondary locking bar (section B, Figure 3) is utilised to take the force applied by the spring and lock the joint in 30° flexion. When disengaged this link sweeps posteriorly as seen in Fig.4 to allow the joint to move freely. The orthosis weighs ~400g.

Test stage

Patients were identified through the normal referral process at the Royal Orthopaedic National Hospital. Ethical approval was not required for this study as patients underwent standard orthotic treatment, thus this procedure was an evaluation of interventions within an orthotic department. A wearing regime was not specified, instead the patients were advised to be observant to skin condition and to utilise the orthosis in situations where they found it to be of benefit.

Results presented as a Case Study

Diagnosis: Central cord syndrome

Patient history: A 3 year history of bilateral upper limb pain and numbness. On October 2010, he underwent C3-C6 cervical laminectomy, foraminotomy and C3-C7 lateral mass screw fixation. Post operatively he suffered progressive weakness in the upper limbs. MRI showed anterior epidural swelling at C4-C6 with cord compression.

This gentleman attended for primary assessment in June 2011. His arms were typically positioned in full extension at all times with no functional flexion at the elbows or shoulders. He was unable to feed by himself; he had severe difficulty writing and was unable to do household chores. Examination found grade 2+ shoulder power; grade 4 triceps; grade 1 biceps; grade 1 supination bilaterally. Using the Disabilities of the arm shoulder and hand (DASH) scale he scored 99.2.
Our team at the RNOH supplied bilateral flexion assist orthoses of a less refined earlier version than that described here. It was necessary to support the wrist in this instance due to weakness but typically the wrist and hand are free from constraint. The functional improvements were significant: There was sufficient triceps power to actively position the elbow through a 0-95° range of flexion. Provision of elbow flexion decreased the lever arm at the shoulder effectively improving function to grade 3. This permitted hand to head movement facilitating eating, donning of glasses and personal grooming. Elbow flexion in the lower shoulder range permitted independent toileting and donning of clothing. Re-evaluation using the DASH measure give a score of 83.3, a 15.9 point improvement. A hastily shot video taken at the time of fitting can be found at www.middletonmedicolegal.com or using the QR code below to give an idea of the function achieved.

**Outcome Measure**

From 3 responses of 6 current users, using the DASH scale, the average functional improvement is 14 points. The most common aspects of improvement were found to be in the following actions: turn a key; prepare a meal; place an object on a shelf above your head and use a knife to cut foot.

For some of our other patients this modest objective improvement has equated to a major difference in lifestyle; one such lady achieved a return to horse driving, writing to me stating “I am sure it will be no surprise to know that I am a horse addict and have been so throughout my life...I am so absolutely delighted and relieved that I can drive her [again] thanks to help from the gadget. I need the brace to keep the elbow bent to manage the whip correctly in my injured right hand as well as operate the right rein. I do believe that it has been through using my arm for such activities has made it stronger but I would not have been able to manage to do this at all were it not for the brace.”

**Conclusion**

This orthotic device is shown to be an improvement on previous versions through its ability to provide dynamic functional improvement and as such I hope the design can be utilised elsewhere. If I can facilitate this by offering further experience or manufacturing guidance please do get in touch either through the RNOH or using contact details on the website below. I would like to take the opportunity to thank the skilled and knowledgeable in-house technicians (in particular Al, Andy and Dan) of the Royal National Orthopaedic Hospital, London for their valuable collaboration.

Martin Middleton
HCPC Orthotist, MBAPO, Expert Witness
www.moh.nhs.uk
www.middletonmedicolegal.com