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A Modular, Prefabricated Orthosis for Treatment of Elbow Flexion Contractures[1]

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A simple and adjustable orthosis has been designed and several prototypes have been built to aid in increasing the limited range of extension available in disability involving flexion contracture at the elbow. The present prototype, positioned 5 degrees larger than the angle of maximum passive extension, applies a small extension moment to the arm, slowly lengthens the musculature, and leads to a gradual decrease of the contracture. When used in conjunction with therapy it helps maintain the benefits achieved by daily stretching exercises.

Key design features include modularity with discrete, easy to fit and adjustable components that are compatible with anatomical constraints—without left or right sided parts—simplicity, cosmesis, and low cost.

As a result of research and development in upper-limb orthotics in the past two decades, restoration of useful function in upper extremity motor impairment has been much improved. Efforts at such institutions as the Texas Institute for Rehabilitation and Research, the Rehabilitation Institute of Chicago have resulted in the development of the modular concept with emphasis on lightweight finger prehension orthoses. However, despite the many available functional devices an acceptable orthosis for the prevention of upper limb deformity due to elbow contracture has not yet been achieved. Flexion contracture at the elbow in particular is disabling in itself and is a difficult problem to correct (6). In certain spinal cord injuries this contracture may lead to reduced patient mobility by preventing reach to the propulsion handrim of the wheelchair.

This paper presents the design and the application of a simple adjustable orthosis designed to prevent and help correct contractures at the elbow. The prototype has been fabricated in three sizes for application by clinicians. Clinical trials are now underway.

Methods of treatment of elbow flexion contractures may be surgical or they may be non-operative. Surgery involving tenotomy to lengthening the biceps tendon has been successful in improving arm function in paralytic diseases other than spinal cord injury (5). Another surgical technique, using percutaneous electrodes, has also been successful. Mooney (4) implanted electrodes to stimulate the extensor muscle group and reduce the muscle imbalance that caused the flexion contracture at the joint.

Among the non-operative methods, serial or wedge casting of the patient's arm in forced extension has been used with success. However, the weight and bulk of the cast, the pressure sensitivity and inaccessability of the skin are real shortcomings of this method. Traction is another non-invasive treatment that has been tried (7). Unfortunately, traction requires stationary positioning of the patient in a bed or chair which in spinal cord injury cases, may encourage formation of pressure sores and thus is seldom used.

Orthotic devices to correct elbow flexion contractures have been described as well. Goller and Enders (2) have used a dynamic plastic elbow-extension orthosis on five patients with moderate success for an average of 15 degrees reduction in flexion contractures. More recently Green and McCoy (3) have described a turnbuckle orthosis which accomplished in 12 patients an average reduction in deformity of 37 degrees in an average treatment period of 20 weeks. This custom-fitted orthosis has been tried in existing short term contractures of traumatic fracture origin where little or no impairment of skin sensation was present.

Expected Benefits

The orthosis at the University of Virginia Rehabilitation Engineering Center was developed with the expectation that this modular system will make the correction and prevention of an elbow flexion deformity easier to be resolved by the therapist. It is hoped that the availability of three sizes in stock components will make possible the application and fitting of the orthosis by the therapist immediately upon need in the hospital setting.

It is assumed that this orthotic system will be worn by the patient during non-therapy sessions and, thus, maintain the increased elbow extension achieved in therapy. The orthosis is expected to benefit any disability involving a flexion contracture at the elbow with particular emphasis on C4-6 quadriplegia, brain injury, burns, and some forms of rheumatic diseases.

Fig. 1. Elbow extension orthosis used by a C5-6 tetraplegic individual.

Description

The modular orthosis (Fig. 1) consists of a biceps cuff and a forearm cuff, each with Velcro straps, a leaf hinge with a protective sleeve, and two "book-binder" screws. The cuff type can be distinguished by its shape and the number of Velcro straps. The biceps cuff has only one strap while the two straps of the forearm cuff are fastened to each end.

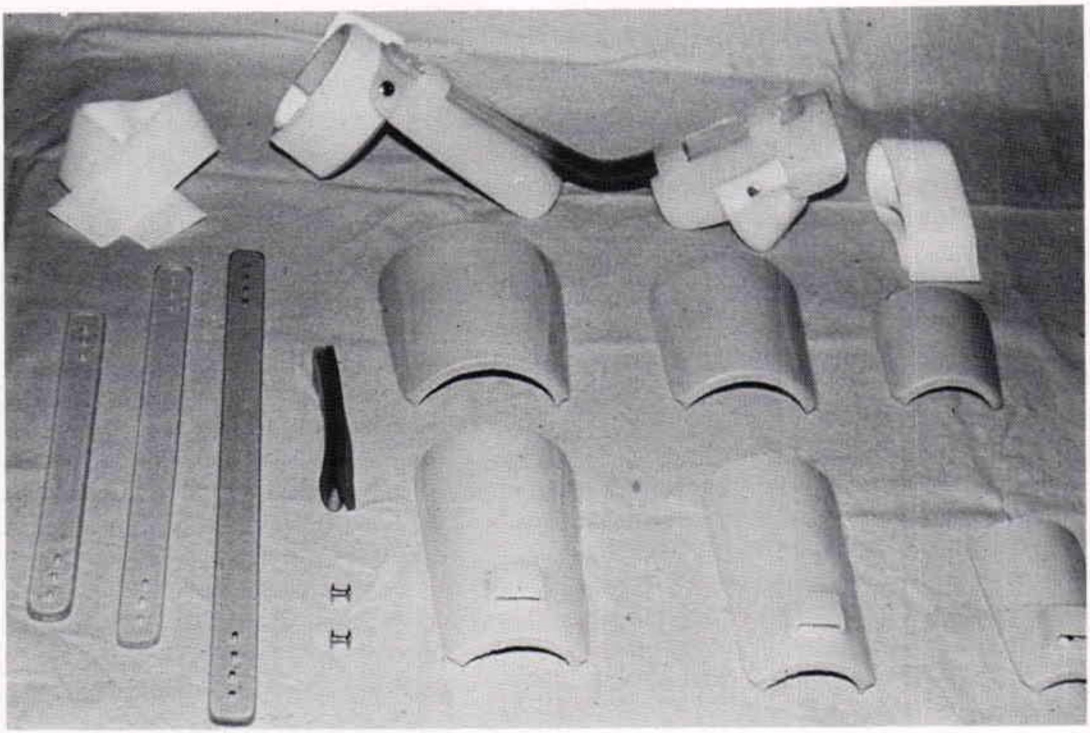

Fig. 2. Three sizes and interchangeable components of the modular adjustable orthosis.

Each cuff type is available in three sizes; small, medium, and large.

The leaf hinge is a thermoplastic material also available in three sizes. The large leaf hinge (46 centimeters long) with four screw holes at each end are made of acrylic and available in two lengths of 38 and 30 centimeters. Figure 2 shows an assembly and the interchangeable three sizes of the components. The "book-binder" screw is a two piece fastener consisting of a slotted threaded screw and its base nut.

Initial designs used the three-point principle for application of correcting forces to the upper limb with the olecranon area as the central point. This principle was abandoned because the pressure applied at the center was such that it could result in skin breakdown.

The current design uses force couples based on the four-point principle acting on the arm segments and produces a constant extension force from the spring action of the plastic hinge. The force application is shown on Figure 3. It can be seen that elbow extension is maintained by application of slight pressure to the arm.

To prevent tissue ischemia, the applied pressure must be less than the capillary pressure of 40 mm Hg. When the angle of the brace is larger than the angle of the arm with the contracture arm the brace must bend when applied. The resulting deflection of the leaf hinge will generate the applied force necessary for the extension moment across the elbow joint. For a brace angle of 5 degrees greater than the contracture angle, the

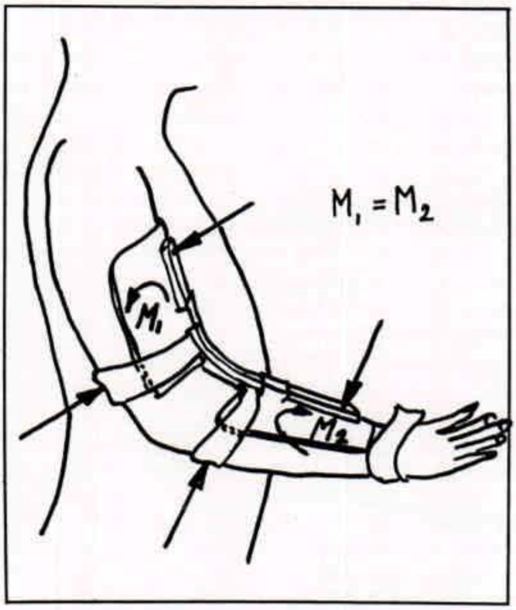

Fig. 3. Four point principle of elbow extension orthosis, showing moments M^1 and M^2 maintaining extension. The orthosis can be adjusted by heating the hinge strap with a heat gun.

applied force, using medium size components, was measured to be 4 lbs. and was calculated to be less than 20 mm Hg of pressure applied to the skin.

Application

Patient Selection

The orthotic system is an adjunct to the patient's therapy treatment of stretching and will assist in the maintenance of the newly acquired range of motion. This orthotic system will be an aid to those patients with flexion contractures at the elbow of 60 degrees or less as defined by the American Academy of Orthopedic Surgeons (1).

Because this system utilizes direct pressure from the cuffs to the underlying skin, the therapist must take precautions to periodically check the skin for pressure sores. It is recommended that the therapist applies this device for half an hour at the first application and gradually increases the wear time if no problems are apparent.

Patient Measurement and Components Selection

The proper cuff size is determined from four circumferences and length measurements of the fore and upper arm. The measurements are to be made with the elbow flexed at 90 degrees with the wrist rotated to its neutral position as shown in Figure 4. The therapist is then able to choose the small, medium or large cuffs for the orthotic assembly from the conversion chart shown in Table 1.

Hinge length and stiffness selection are determined by the summation of length measurements.

Flexion Contracture Angle Measurements

Measure the flexion contracture angle passively under the effect of gravity. This measurement is used to establish the extension angle of the orthosis. Once this procedure has been accomplished, add approximately 5 degrees to the extension angle to compensate for the leaf hinge flexibility. The result will be the initial extension angle of the orthosis.

Setting The Leaf Hinge Angle

While the elbow is passively extended to the contracture angle, place one end of the leaf hinge on the volar surface of the arm proximally to the radial styloid. The other end of the hinge should be lateral to the antecubital fold of the elbow. Mark the leaf hinge in line with the antecubital fold. Once this has been accomplished, mark the hinge 3 cm proximal and 3 cm distal to the fold line.

Heat the leaf hinge between the marks with a heat gun until the plastic is soft and pliable in this region. Place the

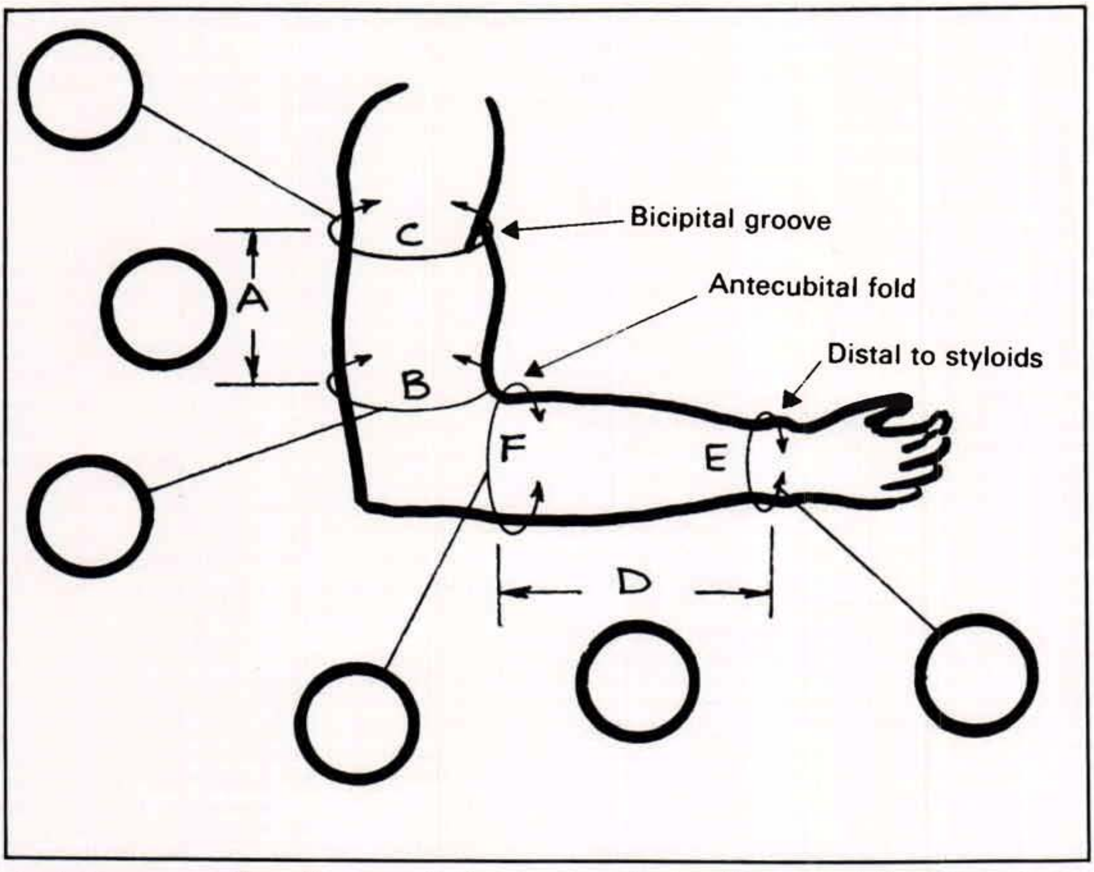

Fig. 4. Measurement Chart. Measure arm dimensions in centimeters. Measurements A and D are lengths, C, B, F and E are circumferences as indicated below. Record values in circles, and refer to Table 1, Conversion Chart.

heated hinge flat on a table surface. While holding the distal (longest) end on the table proceed to lift or bend the other end until the orthotic extension angle is achieved. Hold this angle until the hinge cools (about 3 minutes).

Assembly

First, slide the distal end of the hinge into the forearm cuff tunnel. Next slide the proximal hinge end into the biceps cuff such that the cuff tunnel is near the hinge bend. Position both cuffs on the hinge to fit the contour of the arm. Align the screw holes in both cuffs with the nearest screw holes in the hinge. Mark the position of the aligned holes on the hinge. Remove the orthosis and fasten the cuffs to the hinge with the bookbinder screws.

Fitting and Check Out

Reapply the assembled orthosis to the patient. Test for excessive pressures and cuff misalignments. Make any necessary adjustments. Finally, trim the velcro straps to the patient's need. Again, remove the orthosis and apply the protective sleeve to the hinge.

TABLE 1:
Conversion Chart

Cuff Selection

Circumference C	Biceps Cuff
Less than 25 cm	Small
25 to 31 cm	Medium
Greater than 31 cm	Large

Circumference E	Forearm Cuff
Less than 14 cm	Small
14 to 19 cm	Medium
Greater than 19 cm	Large

Leaf Hinge Selection

Length A + D	Leaf Hinge Length
Less than 32 cm	Small
32 to 42 cm	Medium
Greater than 42 cm	Large

Readjustment

Periodic readjustment of the hinge angle is required with changes of the contracture angle of the elbow. It is recommended that the hinge angle be changed with each 5 degree change of elbow contracture. To achieve a change in the hinge angle, remove the protective sleeve from the hinge and reheat the area with a heat gun. It is necessary to disassemble the orthosis to accomplish this task.

Summary

An orthosis has been designed to aid in increasing the limited range of arm extension available in disability involving flexion contracture at the elbow. When used in conjunction with therapy it helps to maintain the benefits of daily stretching exercises.

Important contributions of the orthosis are modularity with interchangeable components in three sizes, simplicity, cosmesis and low cost. Copies of the

prototype have been fabricated for application by clinicians, and clinical trials are now underway.

Footnotes

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