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UPPER-LIMB ORTHOTICS

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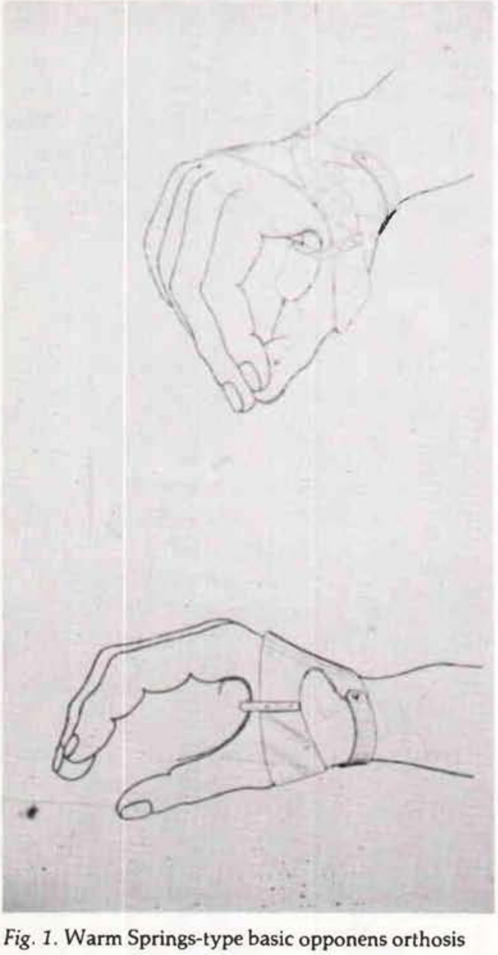


Fig. 1. Warm Springs-type basic opponens orthosis

The complexity of the functions provided by the hands and upper limbs necessarily makes upper-limb orthotics a very extensive and diverse area in practice. An attempt is made here to categorize the various areas of upper-limb orthotics.

Upper-limb Orthotic Systems

A number of institutions have developed a system of upper-limb orthotics which in all cases is based on a basic opponens orthosis to which various components are added for ameliorization of specific individual impairments (2). All systems include various prehension orthoses, including externally energized systems for various levels of quadriplegia.

These systems are best suited in the management of peripheral nerve injuries and other diseases, e.g., polio, Guilian Barre, in which partial or complete recovery is anticipated, as well as for quadriplegic patients. The systems are applied not only to enhance function, but also to protect the hand in a functional position and to prevent contractures while recovery takes place.

Listed in chronological order of development, the systems are:

1. Warm Springs System, developed at the Georgia Warm Springs Foundation (Fig. 1).

2. Rancho Los Amigos System, developed at the Rancho Los Amigos Hospital, Downey, California (Fig. 2).

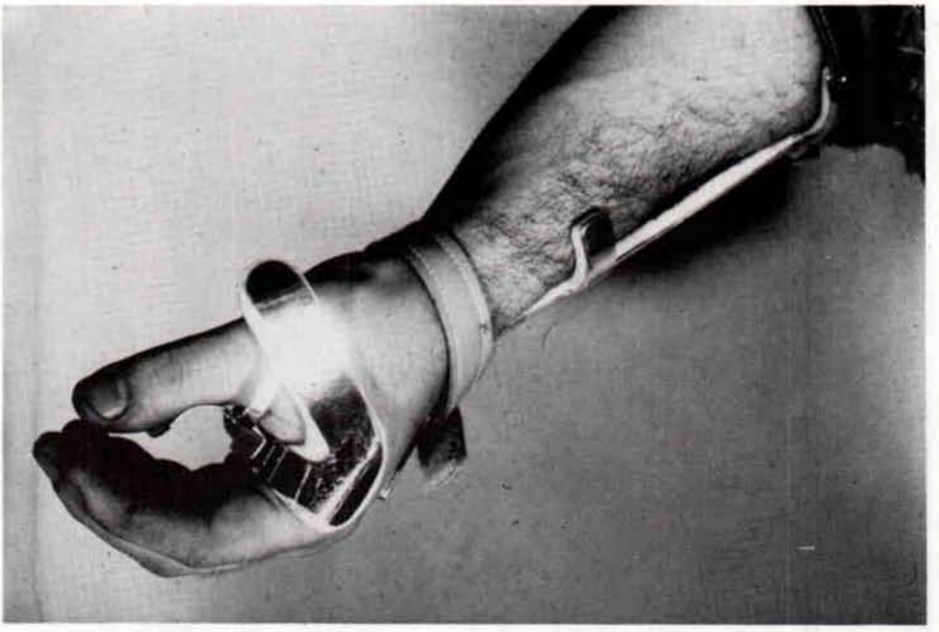


Fig. 2. Rancho-type opponens orthosis with dorsal-wrist support

3. Engen System, developed at the Texas Institute for Rehabilitation and Research, Houston, Texas (Fig. 3).

4. IRM-NYU System, developed at the Institute of Rehabilitation Medicine, New York University Medical Center (Fig. 4).

Components for the latter two systems are available through suppliers for individual adaptation to patients.

Pre-fabricated Splints

This category includes ready-made splints, available from a number of manufacturers such as Bunnell splints from Weniger, various resting and positioning splints from OEC, Zimmer, etc., and other devices for activities of daily living from RTC, Sammons, and others (8). While some of these devices serve a very useful function, e.g., adaptive devices for activities of daily living, some splints may in fact be considered harmful because of improper positions imposed by certain designs.

Acute (Temporary) Splinting

Considered in this area are devices which are applied in cases where immediate splinting is demanded, e.g., soft tissue trauma, burns, etc., or in cases where progressive changes in joint alignment are necessary. Most often this kind of splinting is provided by practitioners other than the orthopedic surgeon (7), i.e., occupational and physical therapists, general practioners, and nurses. Materials used for these purposes are:

1. *Low Temperature Thermoplastics*

An increasing number of low temperature thermoplastics has become available which, in general, lend themselves very well to this application since they are easily handled and require a minimum amount of equipment (Fig. 5). Each possesses unique physical characteristics such as color, stiffness, transparency, temperature range, etc.

2. *Plaster of Paris*

Plaster casts are often applied as a tempor-

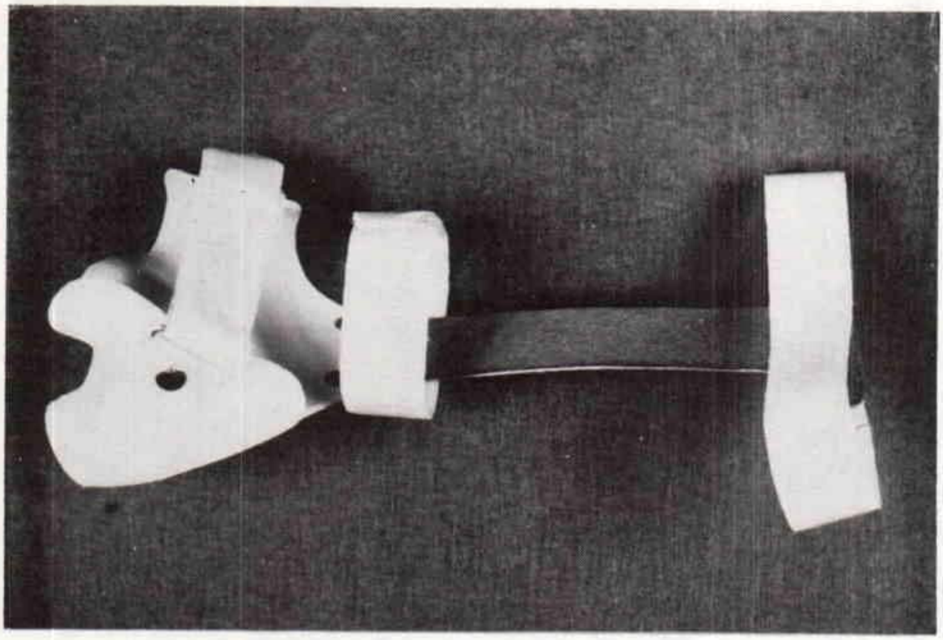
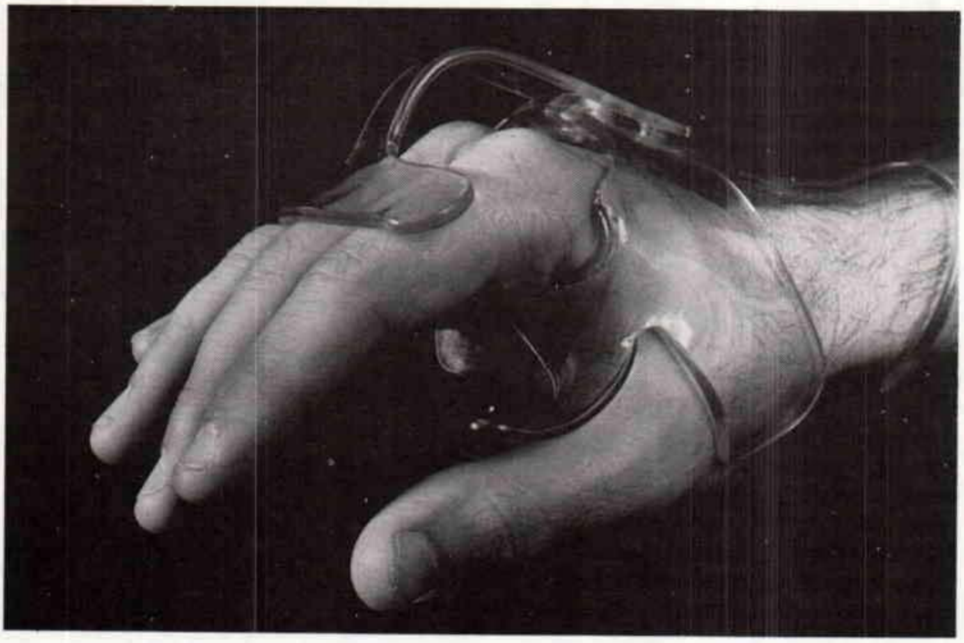


Fig. 3. Engen-type opponens orthosis with volar-wrist support



Fit. 4. IRM-NYU type opponens orthosis with dorsal-wrist support and metacarpal phalangial extension stop

ary measure in an emergency setting to stabilize a joint, or in progressive correction of contracted joints.

Pre-fabricated splints are useful when the prognosis for patient recovery is good, indicating short term use of an orthosis, or in cases when the patient awaits the fitting of a more permanent orthosis from the orthotist.

Special Cases

While most upper-limb impairments and injuries can be managed with orthoses and splints included in the three categories cited above, there are certain special cases in which very little progress has been made and in which orthotics management is considered generally poor. These cases are:

1. *Hemiplegia*

Current orthotic management of hemiplegia patients is confined to the fitting of a static hand-wrist orthosis to prevent flexion contractures and/or the fitting of an arm support sling to prevent shoulder subluxation and/or pain. Occasionally, passive prehension orthoses which are manually operated have been fitted to selected patients with mixed success.

2. *Rheumatoid Arthritis*

Both the Georgia Warm Springs Foundation under the direction of Dr. Robert Bennett and the University of Michigan have developed a number of orthoses specifically designed for the rheumatoid arthritic patient. However, there is a general lack of a systematic approach to orthotic management of the various pathomechanical conditions produced by rheumatoid arthritis.

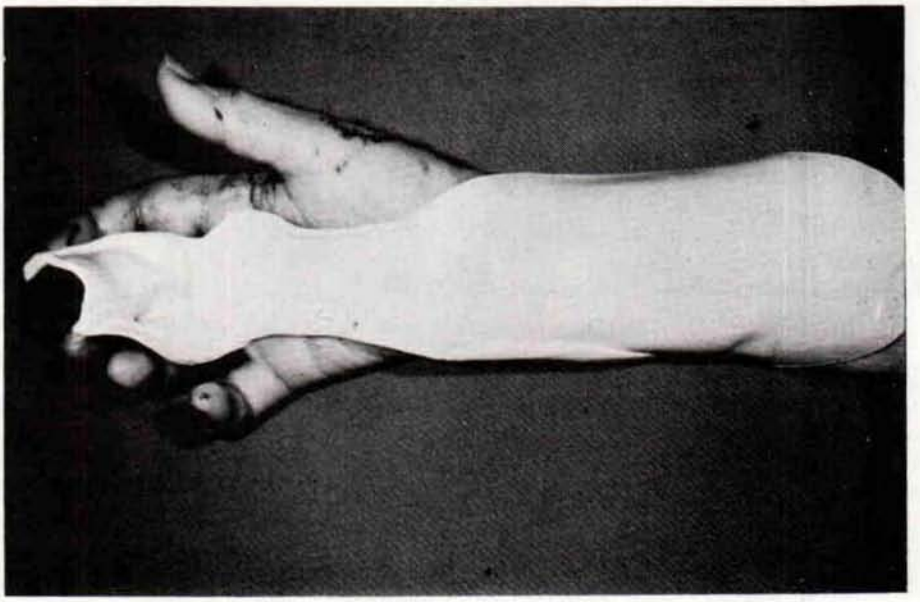


Fig. 5. Low temperature plastic splint (courtesy Maude Malik, OTR).

3. *Burns*

While some exciting work has been done in special burn centers and in particular by Maude Malick in splinting the burned upper limb to prevent contractures, patients seen in other locales are probably not treated optimally with orthoses.

Trends for Future Research and Development

There are three major areas which require future research and development.

Orthotics in Spinal Cord Lesions

Due to improved medical care, many more spinal-cord-injured patients survive than was the case in the past. Consequently, we are seeing more quadriplegic patients (9), and, the demand for improved and extended orthotic services is increasing.

1. *Review of Prehension Patterns for Orthotics*

Traditionally, the design of functional upper-limb orthoses is based on earlier research in prosthetics which resulted in a three-jaw chuck type of pinch, which is the most frequently used prehension patterns in normal use (1). It should be recognized that the quadriplegic patient is anything but normal in the terms of the kinematics of upper-limb function due to weakness in practically all elements of the kinematic chain.

Furthermore, the patient lacks sensory feedback and must rely entirely on visual feedback to handle objects. With this in mind it would be extremely useful to review, or conduct a new study of, prehension patterns specific to the quadriplegic patient, considering his overall weakness and other features unique to him, e.g., the need for transfer activity from wheel-chair while wearing the orthosis because it gets in his way or it may be damaged in the process. This discourages patients from using an orthosis full-time. Based on such basic motion research, orthoses might be designed to provide prehension patterns, e.g., lateral pinch, which would not, or only minimally, interfere with other activities, yet enhance visual feedback.

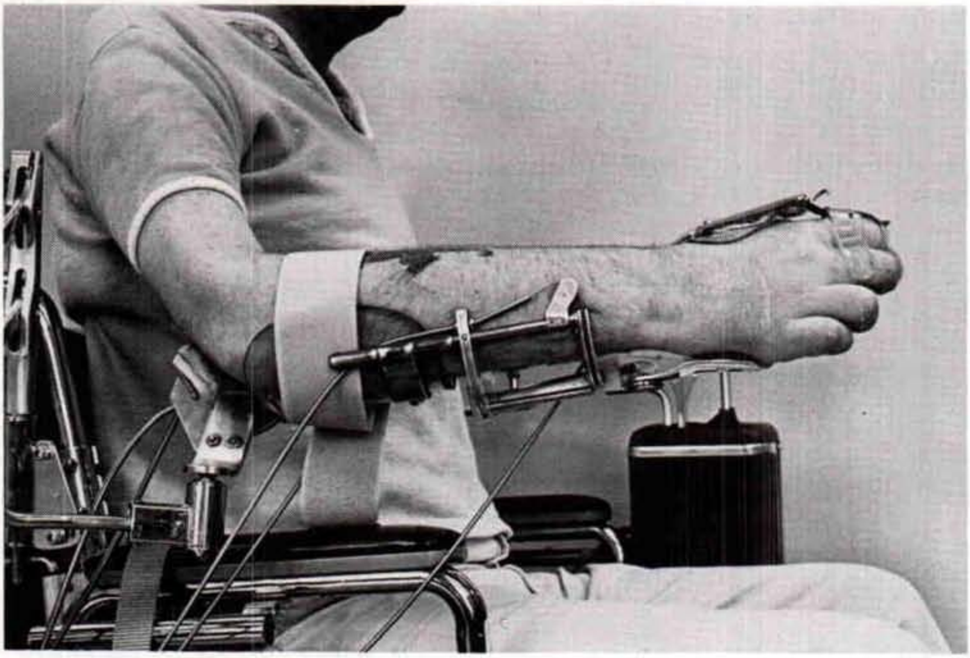


Fig. 6. IRM-NYU multiple degree of freedom electric arm orthosis

2. *Develop Multi-degree of Freedom System for High-Level Quadriplegics*

While multiple degree of freedom orthoses have been developed by various institutions, namely Rancho Los Amigos Hospital (10), TIRR (3), and IRM-NYU (5), only a few patients have benefitted from such devices. Further, it appears that there is a need to evaluate these orthoses comparatively and to incorporate the best features of the systems in an orthosis which is based on kinematic considerations of the quadriplegic as suggested above. Also, consideration should be given to a system which guides the hand with the prehensile device through an X-Y-Z coordinate system, by-passing the anatomical joints. Such a system may reduce the number of controls necessary and is, conceivably, a simpler mechanical system.

3. *Evaluation of Manipulators*

The evaluation of manipulators which ignore the patient's existing extremity completely has been initiated recently at the University of California, Los Angeles (9). This should be encouraged so that their usefulness can be determined and further development be undertaken if indicated in lieu of, or as an alternative to, orthoses.

4. *Evaluation of Environmental Control Systems*

An increasing number of environmental control systems is becoming available commercially and through research laboratories. A great need exists to delineate the advantages of the various systems with specific indications for use not only between the various environmental control systems, but also in comparison to externally energized upper-limb orthoses or manipulators.

5. *Design and Development of Control Systems*

For the most part, electromechanical control systems have been used in orthotic devices (Fig. 7). These are, however, limited because actuation of the transducers requires a certain magnitude of force and displacement. It is, therefore, believed that further investigation of other control systems should be explored such as:

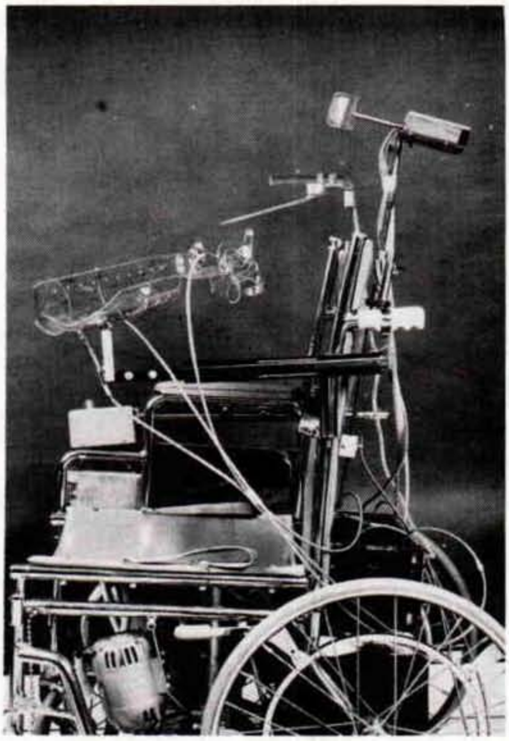


Fig. 7. Electromechanical head and shoulder control switches for multiple-degree-of-freedom powered electric arm orthosis

a. Myoelectric mapping of the facial and neck areas to determine which muscles are best suited for the control of an orthotic device or environmental control system without interference of other functions or inadvertent operation(11). This should include the study of conduction phenomena which has been demonstrated experimentally in picking up myoelectric potentials from muscles through remotely located electrodes. This would aid in the cosmetic considerations of electrode placement in the neck and facial areas.

b. *Electroencephalographic control*

Kalkstein at IRM-NYU(4) recently demonstrated the temporal relationship between EEG and EMG output in real time through filtering of extraneous noise. This development appears to have real potential in devising a control system based on EEG. Further research in this area should be encouraged to design a computerized recognition system of the EEG signal in quadriplegic patients for controlling orthotic or other devices.

Special Cases

1. *Hemiplegia*

Present research conducted under the Rehabilitation Services Administration and the Veterans Administration in electrical stimulation of the hemiplegic hand and arm at Rancho Los Amigos Hospital, the University of Ljubljana, and Case Western Reserve University should be continued.

2. *Rheumatoid Arthritis*

Research in this area should be greatly accelerated to provide this type of patient with an orthosis which not only prevents further deformity, but also enhances function without interfering with activities of daily living. At present there seems to be no systematic approach to this problem.

3. *Burns*

The role of orthotics in treatment of burns to prevent contractures should be clearly defined. The methods presently available at burn centers should be disseminated to all practitioners dealing with the orthotic management of burns.

Service Delivery

Delivery of orthotics services for the upper-limb should be improved through the following.

Central fabrication facilities should be encouraged to provide this service.

Pre-fabricated orthoses and splints should be vastly improved to conform with accepted principles of hand position and function and be made available to the medical, orthotics, and therapies professions.

Professional roles of the occupational therapist and orthotist should be more clearly identified in terms of the type of services provided by each profession.

Training of orthotists and other professionals providing orthotics services should be greatly accelerated, particularly in view of the ever-increasing sophistication of multi-powered and environmental control systems. This is a particularly crucial area since servicing of such systems will ultimately become problematical if orthotics training does not include consideration for these systems.

Early fitting of orthotic devices is at least as essential as it is in prosthetics to prevent contractures and to enhance maximum utilization of orthotic devices.

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