A PLASTIC HAND ORTHOSIS

By

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Treatment of paralysis of the upper extremities requires orthotic devices that can provide support of weakened muscle structures and increase the function of a totally or partially immobile body member.[1] Widespread use of such devices has been limited on account, in part, of the tedious individual fabrication and fitting that is needed. This frequently is the problem in paralysis due to poliomyelitis where patterns of muscular involvement and subsequent deformity are rarely identical. A great deal of time and effort on the part of the physician, orthotist, and therapist must be expended before upper extremity orthotics can be successfully applied to the patient, including also, careful preparation of the patient and functional training in their uses. Accordingly, there is a great need to investigate the possibility of simplifying and increasing the availability of upper extremity orthotic devices. Along with this, exploration of power assistance should also be undertaken. Since the hand is the most functional element in the upper extremity, it is obvious that an orthotic development program should begin with the hand and forearm.

It has not been possible to do much toward providing increased motor function for the completely flail hand beyond application of lever systems and the use of gravity forces. Effort has been chiefly directed toward comfort and deformity prevention through rigid mechanical devices. The McKibben muscle substitute combined with functional orthotics may provide both support and motor function.[2,3] It must be borne in mind that much research and development is needed to exploit the potentials for powering the paralyzed hand and arm in a practical way.

In view of the above considerations it seemed desirable to design a hand orthosis that lends itself readily to functional use and to power assistance should it be needed. Practical design indicated the desirability of achieving the following objectives:

1. Preservation of the natural posture of the hand, from which all hand movements commence.

2. Development of a design to permit either active or passive hand and finger movements.

3. Use of an inexpensive, simple method of fabrication lending itself to quantity production in standard modules, readily adapted and modified for individual needs.

This preliminary report describes how these requirements are being investigated with a plastic hand orthosis manufactured through a split casting method.*

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* *The split casting process has been extensively used in the dental profession where molds of multiple contour are necessary.*

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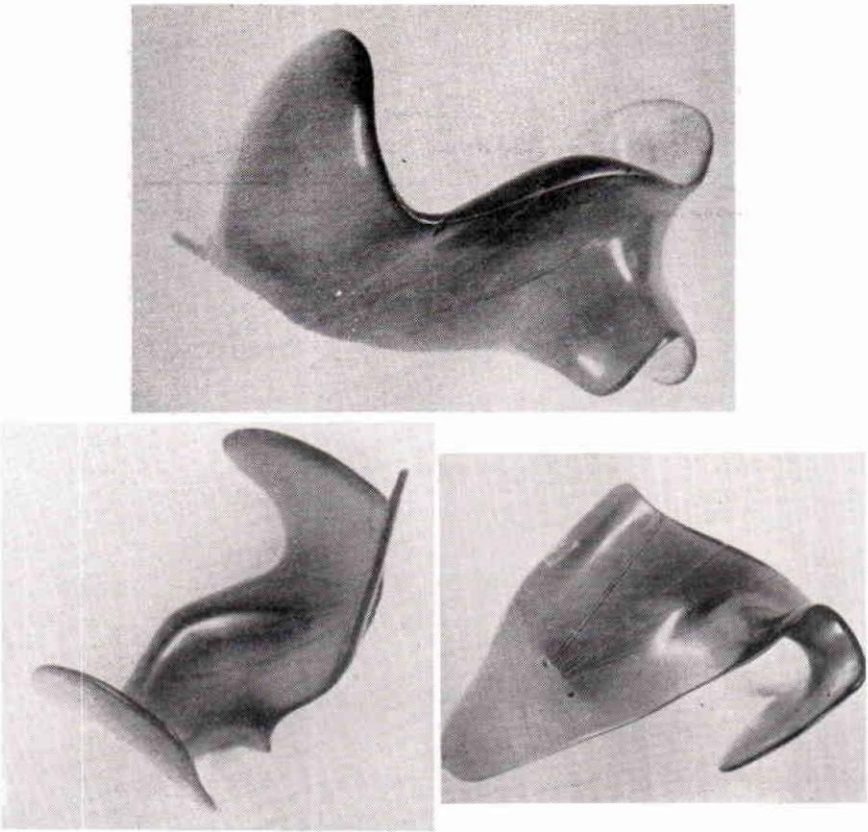

FIGURE 1, A, B and C

Figure 1, A, B and C shows the basic hand orthosis, constructed of thermo-plastic epoxy-resin. View A shows the orthosis from the front; B from the bottom (Volar); and C from the top-rear. Note the complex shape which achieves a supportive hand posture with preservation of the natural metacarpal arch and thumb position . This design maintains the entire hand in good functional position and at the same time allows adequate mobility of the digits.

Description of Hand Orthosis

It appeared to the author that the preservation of hand posture should be obtained by support rather than by suspension. Secondly, a material had to be chosen that would conform to the complex contours of the hand. The design should also permit digital movements of a practical functional range. Achievement of this should make possible a versatile hand orthosis for use with the partially or totally flail hand, as shown in Figure 1, A, B and C.

The plastic orthosis has the fundamental elements necessary for a basic hand splint emphasizing metacarpal arch support and pollisis position. The orthosis is produced of thermosetting plastics by a series of permanent molds in a variety of sizes. After setting, the orthosis is readily remolded and a custom fitting can be obtained.*

*** By applying heat to the orthosis, it becomes pliable. In this stage it can be remolded to fit the desired contour of the hand and after cooling retains its new shape.*

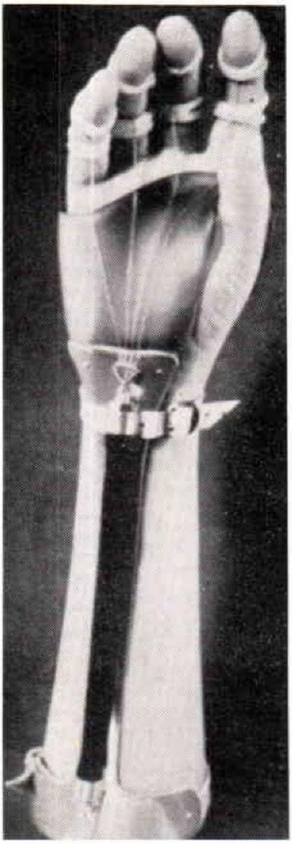

FIGURE 2. The forearm volar extension must be used with an externally powered orthosis because it serves as the proximal point of attachment or origin of the muscle substitute.

Plastic Orthosis With Power Assistance

In order to study the problems of power assistance, an anatomical hand and forearm model was made. The accompanying photographs show the general appearance and method of operation of the orthosis applied to a cosmetic glove for a prosthetic hand and forearm. The glove was filled with foam rubber in order to duplicate the behavior of a flail hand for experimental purposes.*** Flexion of the fingers is accomplished by the contraction of the McKibben muscle substitute for power assistance.

The phalangeal attachment of the tendons from the muscle substitute was made through partially split plastic polyethylene rings placed on the proximal and distal interphalangeal joints. Elastic nylon was used for tendon substitutes so that the flexed fingers could accommodate themselves intimately around an object of irregular contour.**** The "tendon" is free to slip through the middle ring and is attached to the terminal joint ring. This gives a paralyzed hand a much more natural function, minimizes mechanical aberrations, and applies the contractile forces in a natural manner. The tension generated by shortening of the muscle substitute is applied to the proximal attachment of the four tendons which pass through guides cast integrally in the plastic orthosis.

*** *This mannequin hand is only used for study and demonstration purposes. The relationship to the paralytic hand is only relative.*

**** *The elasticity of the nylon tendon substitutes combined with the proper ring attachment permits compound prehension.*

Several methods of achieving a passive finger extension in human use are being explored. Upon relaxation of the tension produced by the substitute muscle the fingers can then extend, for example, by means of rubber elastic extensors attached to the dorsal lateral surface of the finger rings.

Establishment of a mobile hand free of selective tightness is a necessary pre-orthotic physical treatment objective. The fineness of the finger movement can be easily regulated by the patient due to the rapidity of action of fill-empty-hold cycles of the electro-pneumatic control valve for the "muscle" pressuring gas shown in the illustration and described previously in this journal.[4]

The forearm volar extension must be used with an externally powered orthosis because it serves as the proximal point of attachment or origin of the muscle substitute. It is secured near the elbow by a strap. Flexor tendons pass through channels imbedded in the plastic portion of the hand orthosis so that the power distribution to the digits will be as much like natural anatomical movements as is possible and more mechanically efficient. This is shown in Figures 2 and 3, A, B and C.

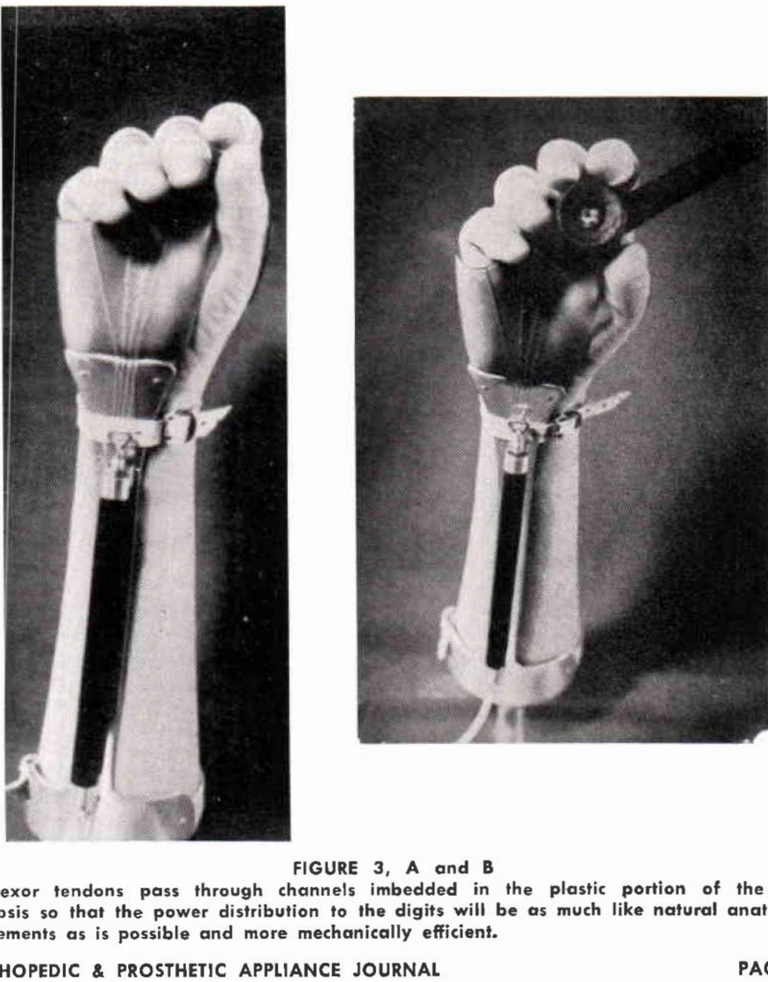

FIGURE 3, A and B

Flexor tendons pass through channels imbedded in the plastic portion of the hand orthosis so that the power distribution to the digits will be as much like natural anatomical movements as is possible and more mechanically efficient.

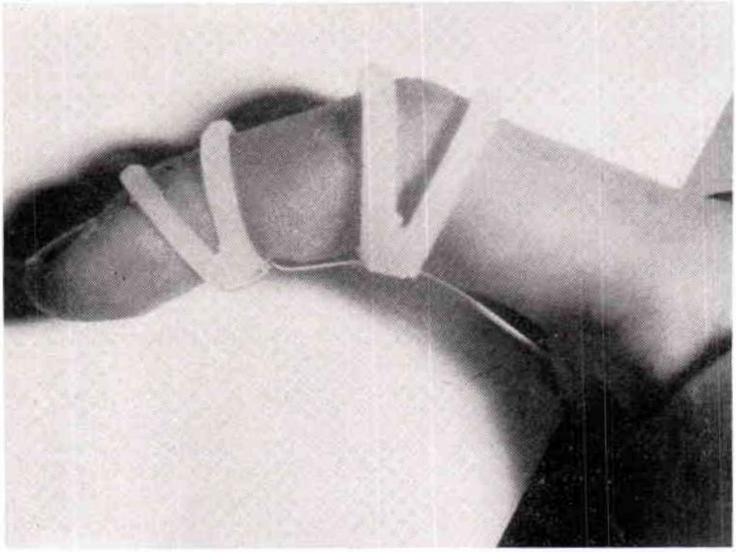

FIGURE 3—C

Wrist extension support, tendons, and the McKibben muscle substitute must be individually adapted at the time of the fitting.

The construction material chosen for the orthosis is a liquid plastic that has proper thermosetting and thermoplastic characteristics since it is composed of the following ingredients: Epon 815, Verxamids (nylons), Thiokol, and D.E.P. Catalyst. Optimal proportions of these ingredients were determined experimentally as follows:

Code 50	
Epon 815	45 parts
Verxamid 14	45 parts
Thiokol L.P.-3	10 parts
D.E.P. Catalyst	8 drops

Skin tolerance to these plastic compounds was evaluated with a total of 60 plastic patches of four different combinations of the ingredients used. The patches were coded with identification numbers and were worn as bracelets continuously for a thirty-day period. At the end of this observation skin reactions were noted and the following were the results:

	No Irritation	*Irritation*
Code No. 50	15	0
Code No. 75	10	5
Code No. 75A	13	2
Code No. 65	15	0

The mixture coded No. 50 was chosen because of the low skin irritation, its strength, and the ease with which it can be remolded by heat at a temperature range of 200 to 300 degrees Fahrenheit.

The orthotist can achieve custom fitting to the individual patient's hand by applying a simple heat treatment process to the semifinished module on account of its desirable thermoplastic properties. Tendon channels, if needed, are incorporated into the orthosis at the time of casting.

SUMMARY

A preliminary report on a method of manufacture of an upper extremity orthosis is briefly described. This device is well suited to the use of power assistance for finger flexion and incorporates the McKibben muscle substitute. The device was designed primarily to provide support and function for the severely paralyzed hand. Future development will be directed toward combining the motions of finger flexion and extension as described here, with supination-pronation of the forearm and elbow flexion. The design of such a device must allow each of these movements to be made independently or in combination; must avoid complexity of manufacture or complicated operation by the patient; and must lend itself to duplication or reproduction of natural patterns of movement. Development of modular systems appears to the author to be a requisite for a practical functional hand orthosis and such devices should anticipate advances yet to be made in the synthesis of human hand motions through power assistance.

This plastic hand orthosis preserves the natural hand posture and permits digital motion modifiable for individual need, either active or passive. The simplicity of construction and adaptation, once permanent molds are made, would make this orthosis readily available.

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REFERENCES

1. Snelson, R. and Conry, J. Recent Advances in Functional Arm Bracing Correlated With Orthopedic Surgery for the Severely Paralyzed Upper Extremity. Orthopedic and Prosthetic Appliance Journal, *12*: 1, 41 - 48, 1958.

2. National Foundation News, *17*, No. 3: 1, 1958

3. Scope (The Upjohn Co.) *3*, No. 9: 1, 1958.

4. Geddes, L. A., Moore, A. G., Spencer, W. A. and Hoff, H. E. Electro-pneumatic Control of the McKibben Synthetic Muscle. Orthopedic and Prosthetic Appliance Journal, *13*: 1, 33 - 36, 1959.