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THE "GRANGER" ORTHOSIS FOR RADIAL NERVE PALSY[1]

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Lesions of the radial nerve result in a characteristic wrist- and finger-drop deformity. Because the synergic extensors of the wrist are paralyzed, an effort to grasp is accompanied by excessive flexion of the wrist joint. As a result, the patient finds it very difficult to grip an object.

To reduce the disability until such time as spontaneous recovery occurs or corrective surgery is performed, the hand may be fitted with an orthosis to fix the wrist in a position of functional extension to allow the active muscles to function, and to keep the muscles at their proper lengths to avoid capsular contraction. Several orthoses have been reported in the literature which incorporate springs or elastics to hold the hand in extension. The orthosis reported here, which was designed by C. V. Granger, makes use of gravity instead of a spring force.

FUNCTION OF THE ORTHOSIS

The splinted hand in positions of extension and flexion is shown in Figure 1. Note that the horizontal support extends from the forearm cuff to the proximal phalanx, then angles upward to provide a fixed center of rotation for the finger stirrups. Because of the constraint imposed by the orthosis, as the finger flexors contract two things happen simultaneously: the wrist extends and the fingers flex, assuring a strong and complete grasp.

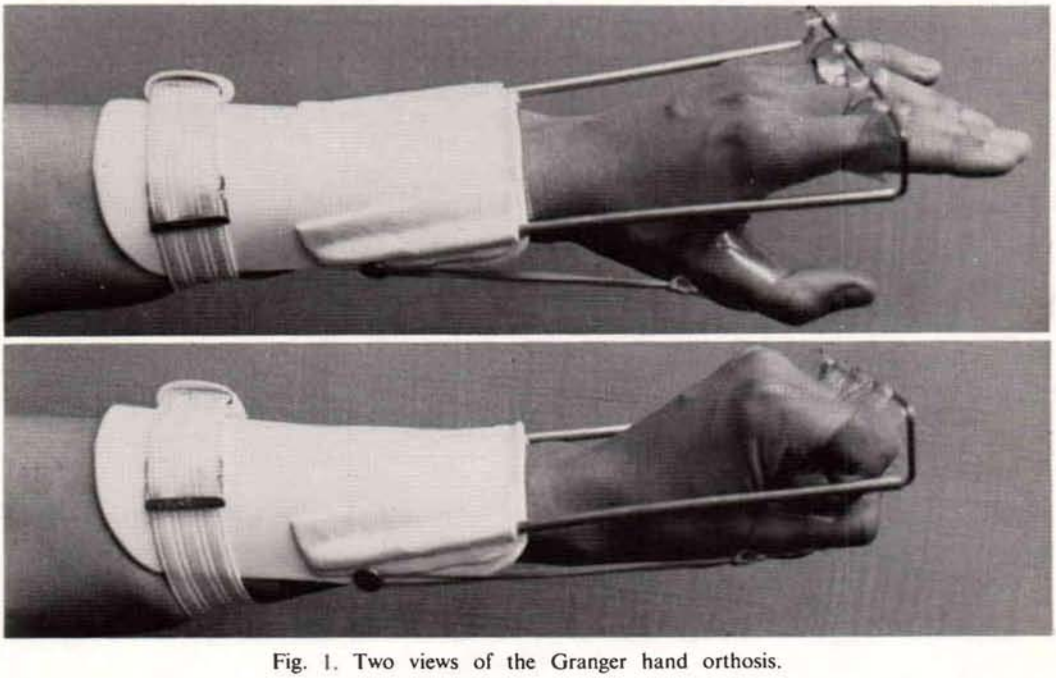

Fig. 1. Two views of the Granger hand orthosis.

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Conversely, when the finger flexors relax, the wrist flexes under the influence of gravity, and the fingers extend.

DESIGN SPECIFICATIONS FOR THE ORTHOSIS

Except for the lengths of the stirrups, all of the dimensions of the orthosis are determined so as to fit the size and shape of the hand. *It is very important, however, that the stirrup lengths be sized properly or the orthosis will not function properly.* If they are either too long or too short, the orthosis will not allow the hand to close completely. A kinematic analysis of the hand/orthosis combination which derives this principle is in the appendix.

To determine the optimal stirrup lengths, one must first of all measure the lengths A and B on the patient's hand as shown in Fig. 2a. Length A is measured from the center of rotation of the MP joint of the index finger to the point where the hand will be supported by the stirrup. Length B is measured from the center of rotation of the MP joint to the center of rotation of the wrist joint. The value B/A is then computed and entered on the graph in Figure 3. The corresponding value of L/A is then selected. Multiplying this value by the measured value of A then gives the optimal stirrup length for the index finger (L1). This same procedure is also repeated for the fifth finger to yield L2.

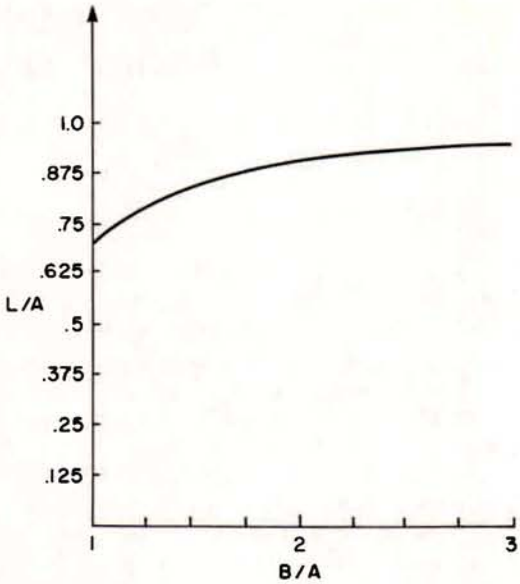

Fig. 3. Graph for determining optimal stirrup lengths (L).

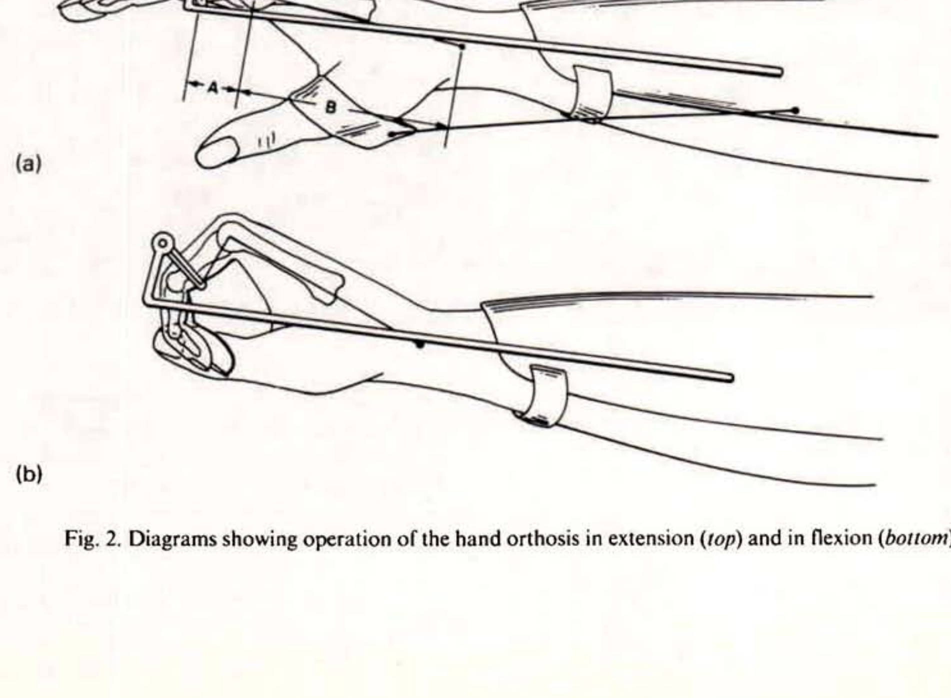

Fig. 2. Diagrams showing operation of the hand orthosis in extension (*top*) and in flexion (*bottom*).

Obtaining the stirrup lengths in this way yields the theoretically optimal values. Because of the difficulty in measuring and maintaining a high degree of accuracy, however, a more practical approach which gives very good results is to make the stirrup lengths about .9A (90% of length A). These values are then used to construct the orthosis by either of two methods as shown in Figure 4. In Figure 4a, individual stirrups are shown, whereas in Figure 4b the individual stirrups are replaced by a padded stirrup bar which supports all four fingers. In either case, the function of the orthosis is the same.

BENEFITS OF THE ORTHOSIS

This orthosis is most beneficial for a patient with radial nerve palsy simply because it allows him to function in a near-normal manner throughout the day. This activity level is an excellent way of maintaining normal range of motion, and good strength of those muscles unaffected by the radial nerve injury. A patient who is *active* while wearing the orthosis is even able to maintain normal thumb range successfully without wearing a special outrigger for abduction/extension. However, when necessary it can be added as an elasticized

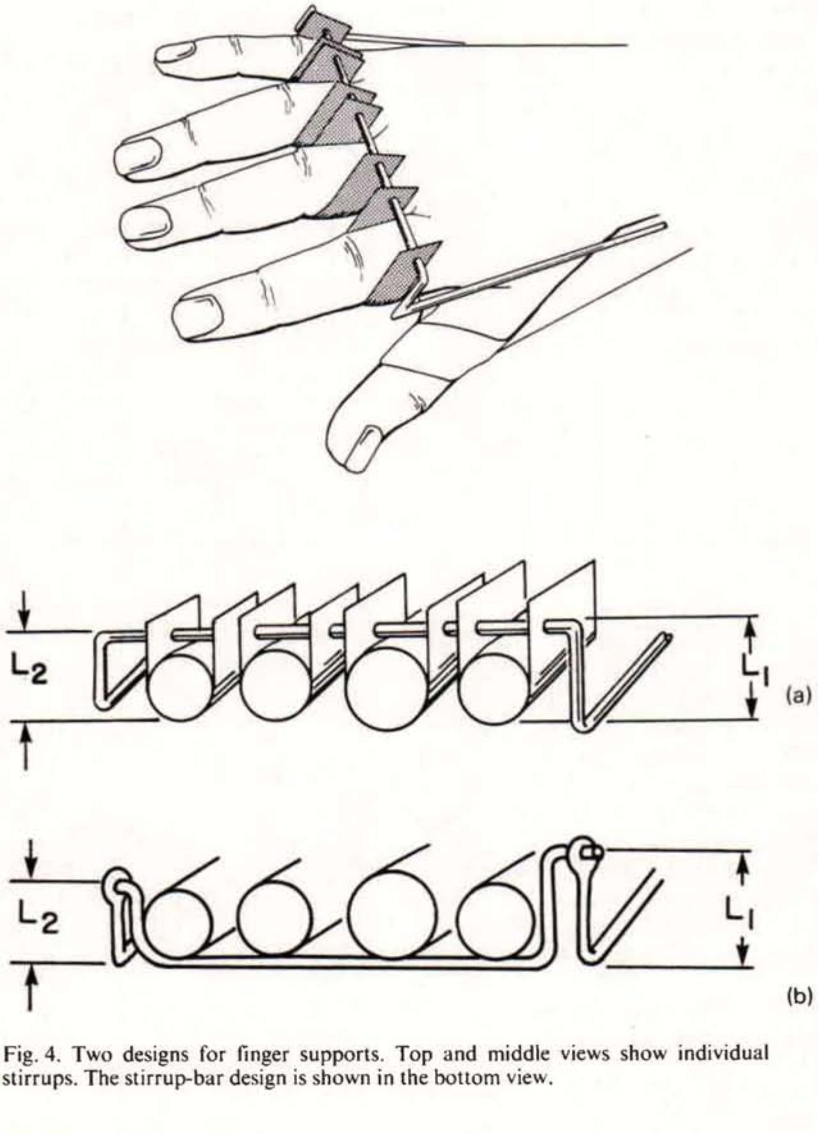

Fig. 4. Two designs for finger supports. Top and middle views show individual stirrups. The stirrup-bar design is shown in the bottom view.

band as shown in Figure 1a, without the need for an outrigger. The patient is able to flex and extend his fingers fully. He can oppose all fingertips to his thumb, and he can accomplish lateral pinch. The volar surface of his hand is uncovered completely and available for maximum sensory feedback. Unlike other dorsal "wrist drop" or dynamic splints, the outrigger on this splint is less bulky and does not present a problem in donning most clothes.

Patients have found that the orthosis allows considerable freedom and function at home or at work. The patient may work with water or other liquids. He is limited in wrist supination/pronation, but this can be compensated for at shoulder and elbow. To date, 11 orthoses of this type have been fitted and used successfully at the Rehabilitation Institute, Tufts-New England Medical Center hospitals.

REFERENCES

1. Penner, Dorsal splint for radial palsy. *Amer. J. Occup. Ther.*, **26**:1:46, January-February 1972.

2. Thomas, G. B., *Calculus and Analytic Geometry*, Addison-Wesley, 1968.

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APPENDIX

KINEMATIC ANALYSIS

The sketch shown in Figure 4 is a kinematic representation of the four-bar linkage which is formed by the hand-orthosis combination. The linkage is shown in positions of extension and flexion. Note that the approximation is made that the horizontal projections of links A and B are equal to A and B. A coordinate system has been added for convenience.

At full flexion, the angle between links A and B is 90 deg. The problem is to find the optimal link length L such that, when the MP joint is fully flexed, the lift of the hand will be a maximum.

Since link L rotates about a fixed center, its free end describes a circle described by:

$$X^2 + (Y - L)^2 = L^2 \qquad (1)$$

In the flexed position, links A and B form two sides of a right triangle. The hypotenuse has a length $\sqrt{A^2 + B^2}$ and forms an angle (α) with the horizontal. The coordinates of the free end of this member are given by,

$$X_1 = A + B - \sqrt{A^2 + B^2} \cos \alpha \qquad (2)$$

$$Y_1 = \sqrt{A^2 + B^2} \sin \alpha \qquad (3)$$

This point must be coincident with the free end of link L. Solving equations (1,2,3) simultaneously yields,

$$L = \frac{(A + B - \sqrt{A^2 + B^2} \cos \alpha)^2 + (\sqrt{A^2 + B^2} \sin \alpha)^2}{2\sqrt{A^2 + B^2} \sin \alpha}$$

letting $K = B/A$ and reducing,

$$\frac{L}{A} = \frac{1 + K + K^2 - (1 + K)\sqrt{1 + K^2} \cos \alpha}{\sqrt{1 + K^2} \sin \alpha} \qquad (4)$$

This yields a family of curves of L/A versus α for various values of K as shown in Figure 5. Notice that as B/A increases L/A also increases. Note also that, except for the lowest point on each curve, there are two values of α for each value of L/A. Referring back to the linkage diagram on Figure 4, the single value for α corresponds to the configuration where link A is tangent to the circle described by link L. It is, therefore, impossible for the linkage to assume the larger values of α unless the angle between links A and B (the MP joint angle) becomes less than 90 deg., a physical impossibility. The angle which corresponds to the lowest point on the curves of Figure 5, therefore, represents the maximum lift of the hand. This may be determined analytically by differentiating equation (4) with respect to α and setting it equal to zero (horizontal tangent).

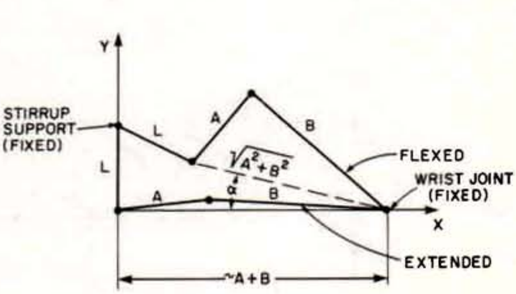

Fig. 5. The hand orthosis combination viewed as a linkage.

$$\frac{d(L/A)}{d\alpha} = \frac{\sqrt{1+K^2}\sin\alpha\,[(1+K)\sqrt{1+K^2}\sin\alpha] - [1+K+K^2-(1+K)\sqrt{1+K^2}\cos\alpha]\sqrt{1+K^2}\cos\alpha}{(1+K^2)\sin^2\alpha} = 0$$

$$\alpha = \cos^{-1}\left[\frac{(1+K)(1+K^2)}{(1+K+K^2)\sqrt{1+K^2}}\right] \qquad (5)$$

This expression was evaluated on the digital computer for values of K ranging from 1 to 3 in increments of 0.1. The results are plotted in Figure 6. This curve of α versus B/A represents the maximum value that α can attain for the given value of B/A. The hand will have this maximum lift only if the proper value of L/A is selected according to equation (4). This expression was also evaluated on the digital computer using the above values of α, and the results are plotted in Figure 7.

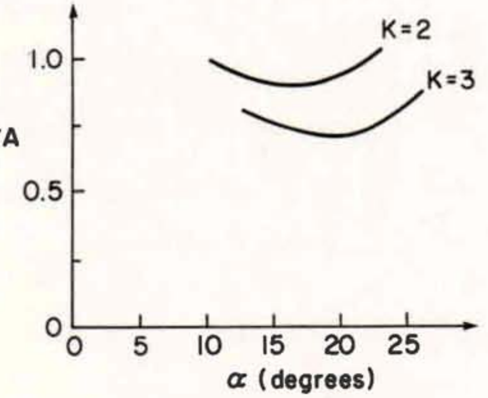

Fig. 6. Graph showing that the lift angle (α) is bivalued except for the minimum value of L/A, with K = a constant.

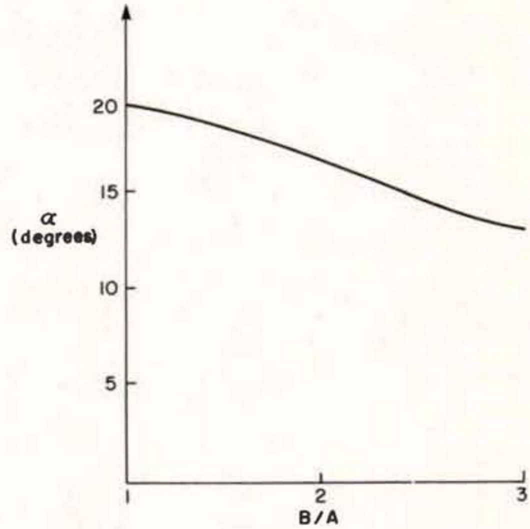

Fig. 7. Maximum possible lift angle (α), for differently proportioned hands (B/A).