Newsletter...

Prosthetics and Orthotics Clinic

Vol. 3, No. 1 / 1979

Spring (Issued Quarterly)

INSTEP STRAP

Ankle-foot orthoses are prescribed for a variety of reasons, but chief among them is the control of undesirable positions of deformities, the most common being equino-varus. Gravity alone will cause the ankle-foot complex to adopt the equino varus position, but spasticity or contracture of the triceps surae can only complicate the situation.

A conventional metal ankle-foot orthosis, with either a single or double uprights, can be effective in combating this deforming position, but success depends on proper construction and application of the orthosis. While in most instances the shoe is strong enough, in the presence of severe spasticity it is necessary to reinforce the shank of the shoe lest it break down at the anterior edge of the tongue and thus allow the shoe and foot to adopt a position of equinus. To properly control the foot the shoe should fit snugly when laced up. This latter point can be difficult to achieve and it is not uncommon to find that the heel has ridden up in the shoe. It may be necessary to prescribe a high-top surgical boot with undesirable economic and cosmetic side effects that weigh against use of the orthosis, as does the stipulation, when necessary, that the orthosis be worn at night. It is unconventional, uncomfortable, inconvenient, and unsanitary to wear shoes to bed.

The situation with unmodified plastic ankle-foot orthoses is much the same, although it is somewhat easier to apply the orthosis properly than is the case with the shoe. For this reason it has proven popular to modify the basic orthosis by the addition of straps in various configurations. The attraction of this course of action should be obvious. First it makes it possible to don the orthosis and maintain the desired position without a shoe, and thus eliminates the need for expensive high-top surgical boots and it is practical to wear the orthosis in bed. The clear view afforded by these orthoses (as well as the translucency of polypropylene when used) and the strap makes it easy to secure the foot in the proper position before donning the shoe, which obscures the view. Moreover, the use of an instep strap makes the selection of a proper shoe even less critical than it is with the unmodified ankle-foot orthosis. While selection of proper heel height is unaffected, the instep strap allows the use of loose floppy shoes and slippers. This can be important for people who must get up at night or who desire to use the orthosis at poolside.

In the hospital the use of an orthosis modified by an instep strap allows ambulation to proceed with an ordinary bedroom slipper while a proper shoe is being obtained. Frequently, delays can be encountered in obtaining shoes, with needless extension of the hospital stay.

What is less clearly appreciated is the proper positioning of the strap. For our purposes in this instance the shin-foot complex can be considered as two arms, the tibia and the foot, set at right angles to each other and articulating at the ankle. In combating equinus the orthosis imposes two anteriorly directed forces, one at the top edge of the orthosis, and the other at the metatarsal heads. If unopposed by an anterior third point the leg will ride up in the orthosis, pivoting about these two points with the ankle moving forward. In effect, the leg bowstrings about the two most extreme points. To be maximally effective and comfortable the third force should be as far as possible from the two end points so as to develop the maximum resistance with the minimum force and thus minimum pressure under the strap. In the ordinary course of events this third force is provided by the lace closure of the shoe over the oblique instep of the foot. Since this surface is oblique the force provided normal to this surface can be resolved into two right-angle forces, each of which opposes one of the two anteriorly directed forces of the orthosis. If an accessory strap is added in this bony area it is likely to prove uncomfortable owing to the relatively small area underneath it and the fact that it is positioned too far distally to oppose the anterior motion of the tibia with minimum force. Moreover, if a shoe is worn over it the additional bulk in the shoe is likely to prove undesirable. Conversely,

Prepared by the American Academy of Orthotists and Prosthetists, 1444 N St., N.W., Washington, D.C. 20005. Editor: A. Bennett Wilson, Jr., B.S.M.E.: Managing Editor and Design: Brian A. Mastro, B.A.; Editorial Board: Joseph M. Cestaro, C.P.O., Charles H. Epps, Jr., M.D., Robert B. Peterson, R.P.T. Second class postage paid at Washington, D.C. Subscriptions: Domestic, $8.00 per year; Foreign, $9.00 per year. USPS 017-S90

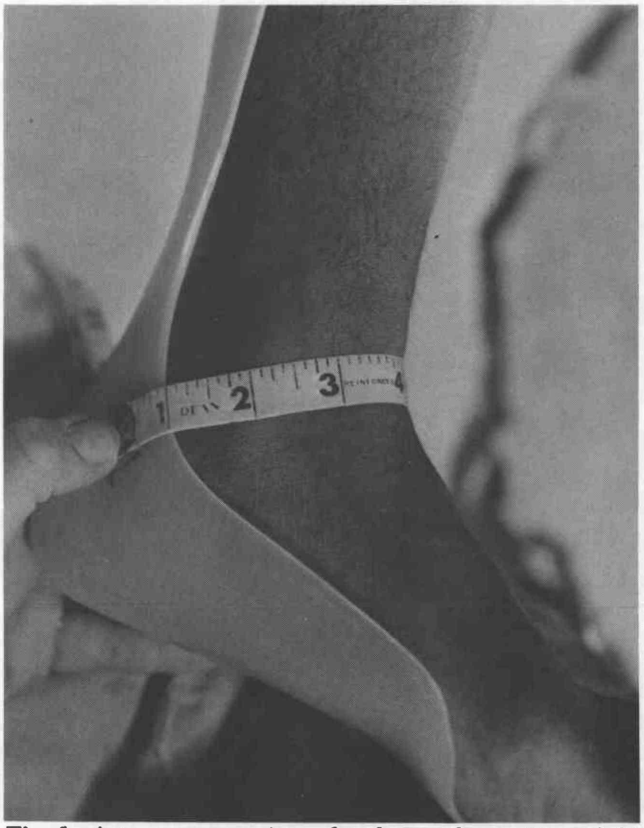

Fig. 1. A tape measure is used to locate the position of the rivet hole for attaching the Velcro strap. This can be done on the patient or around the positive model.

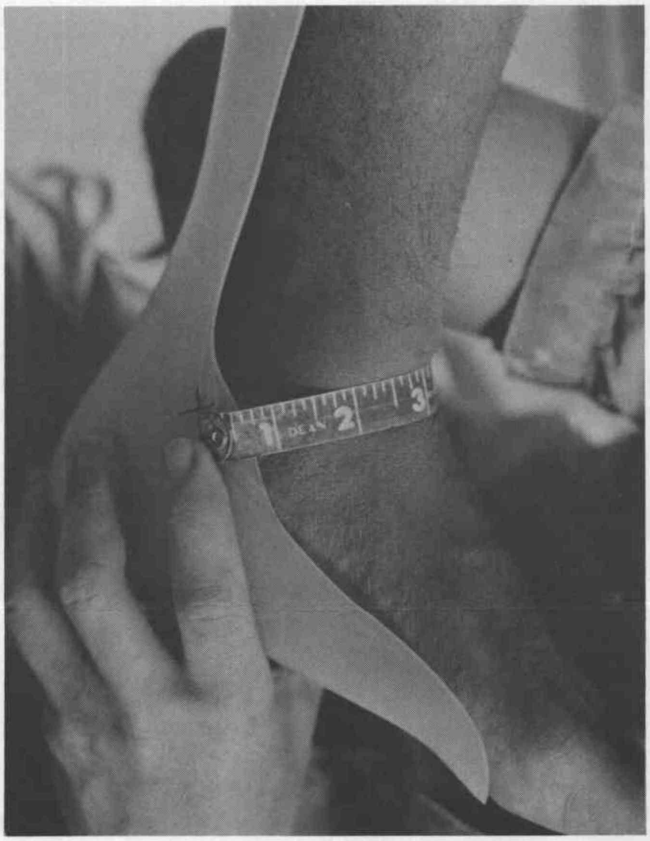

Fig. 2. Similarly, a tape measure is used to plan the location of the slots to be cut in the orthosis.

if the strap is added proximal to the malleoli it will be in good position to control the tibia but inadequate to affect the foot.

Unless opposed by a second strap or the shoe, equinus is likely to occur and since anterior motion of the tibia is prevented all the motion is likely to occur in a proximal direction with the malleoli riding up and shear taking place under the strap.

Following the foregoing analysis then, it seems logical to locate the strap at the deepest point of the radius connecting the oblique dorsal surface of the foot and the vertical tibia, roughly equidistant to the ankle mortice and the subtalar joint. In this position the instep strap is as far as possible from each of the two end points, well positioned to control motion in each segment, and free of the lace area of the standard low-quarter shoe. Instep straps have been used in this configuration a number of years now and, contrary to expectations, irritation under the strap in this relatively unpadded area has not been a problem. This can be attributed, in part, to the fact that the strap is well placed to develop maximum torque with minimum pressure. It is, of course, possible to pad the strap if so desired.

Method

Two methods of adding the strap have proven successful. In one the strap and a narrow loop are riveted to the orthosis on either side along the intended line of force. In the second two slots are cut in the material of the orthosis if the orthosis extends far enough anteriorly to permit it. One end of a Velcro strap is passed through one of the slots and sewn back on to itself. The free end of the strap can then be passed through the other slot and placed back on itself to secure the orthosis. In each case a flexible tape measure can be used to measure the proper length of strap and to plan the proper points of attachment (Figs. 1-4). This procedure can be done either over the positive model or the involved extremity itself and a strap can be added at any time.

SUMMARY

A rationale for the use of an accessory strap to control equino-varus in an orthosis without the shoe is given. Some thoughts about its placement and descriptions of two methods of attachment are also given.

Richard Rosenberger
Director, Prosthetics and Orthotics
Department of Orthopaedic Surgery
University of Virginia
Charlottesville, Virginia 22903

Charles H. Pritham
Director, Orthotics and Prosthetics
Rehabilitation Engineering Center
Moss Rehabilitation Hospital
Philadelphia, Pennsylvania 19141

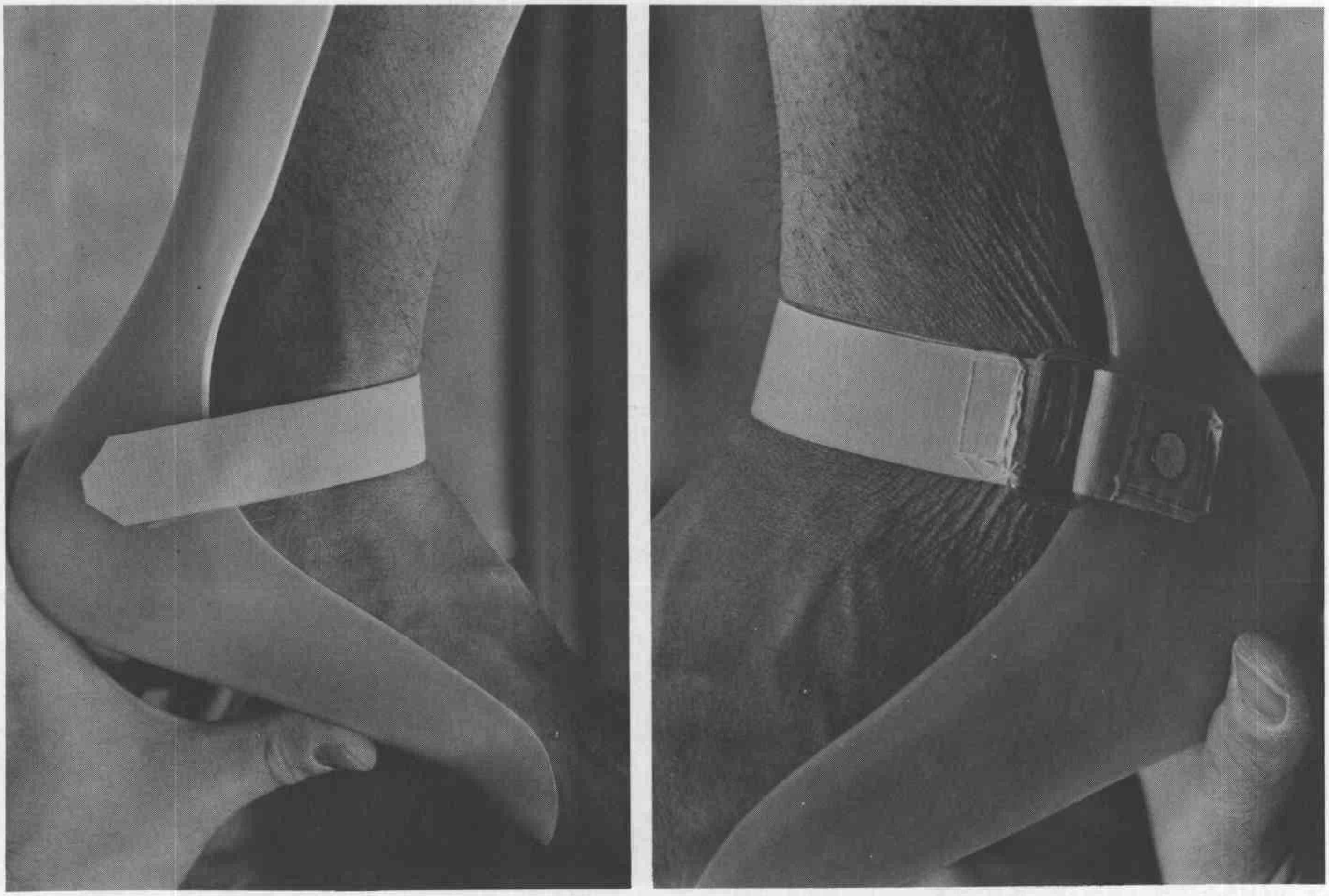

Fig. 3. Appearance of the Velcro strap and metal loop once they are riveted to the orthosis. Normally, of course, the patient would be wearing a stocking. The metal loop should be located further posterior so as not to impinge on flesh.

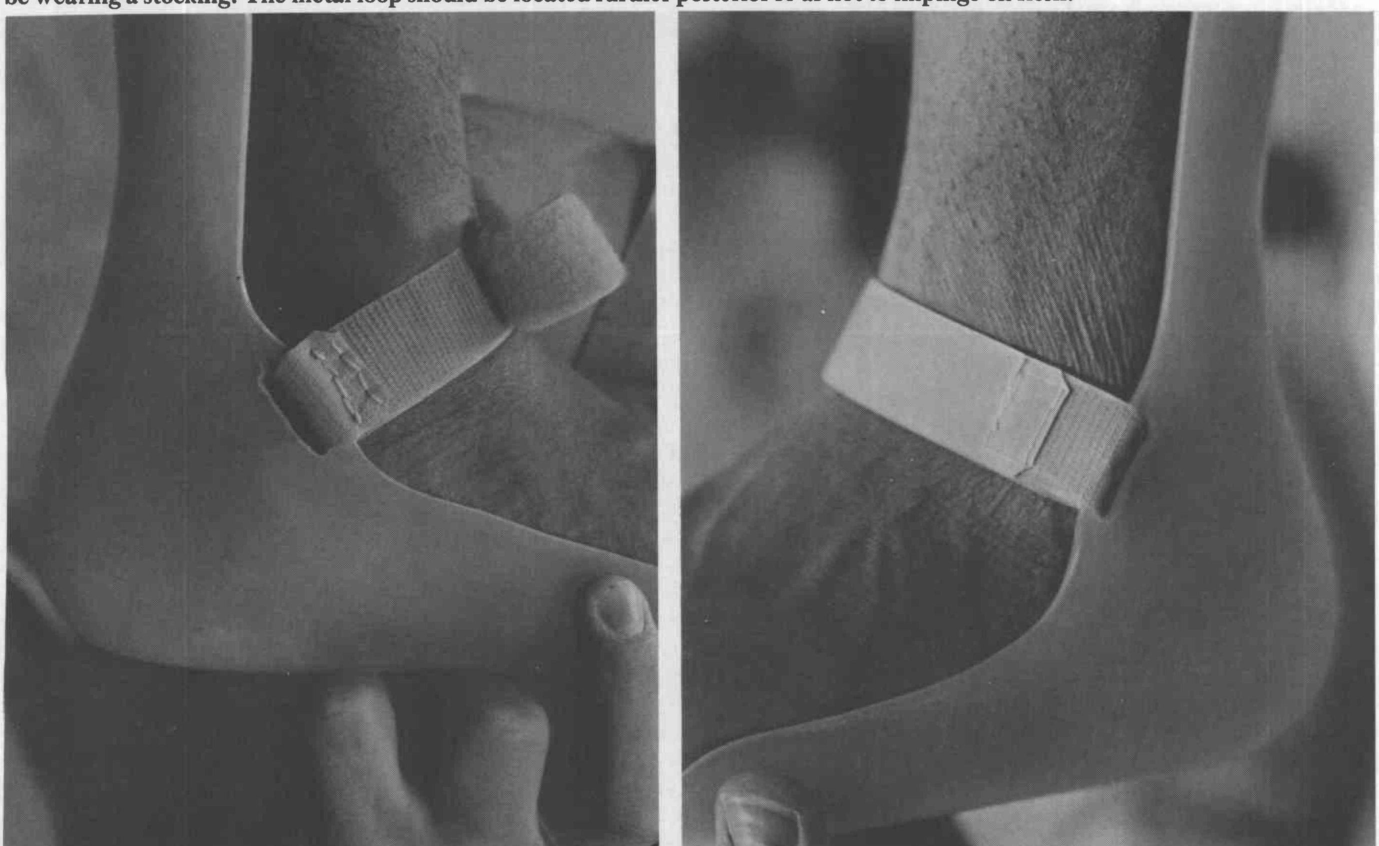

Fig. 4. The Velcro strap attached to an orthosis through slots cut in the orthosis. Excess material has been cut away from around the slots to present a neat and finished trimline.

Prosthetic principles in bilateral shoulder disarticulation or bilateral amelia[1]

G. NEFF

Orthopadische Universitatsklinik, Tubingen

The following article by Dr. Neff originally appeared in German in the November 1978 issue of *Orthopaedie Technik*. At the suggestion of Siegfried Paul we had the article translated for publication of the Newsletter because it seems to supplement the material on external power included in earlier issues of the Newsletters. As we were about to begin editing the rather literal translation provided by the commercial service, Volume 2, Number 3, of "Prosthetics and Orthotics Internation" arrived and we were pleased to see that it included an excellent English version of Dr. Neff's article. Accordingly with permission from the editors of both journals we are pleased to provide the readers of Newsletter the English version developed by the International Society for Prosthetics and Orthotics.

This article is presented not with the idea that the hardware shown is available for use, but rather to provide the readers of this publication with the findings of a very experienced clinical team as given in the discussion.

A. Bennett Wilson, Jr.

Abstract

Following a brief survey of the historic development of pneumatic prostheses the actual principles of prosthetic management in bilateral shoulder disarticulation or bilateral amelia are explained.

The active functions are restricted to active pronation and supination, active gripping of the terminal device "hook" or "hand", combined with pneumatic locking of free swinging shoulder and elbow joints in one artificial arm; the cosmetic arm provides only space for the power package in the resin socket of the upper arm. Both arms are suspended on a Simpson frame.

Thus optical control is concentrated on the movements of the functional arm. The reduction of valve control makes prosthetic training and use easier.

Recently hybrid systems came into use because electric power proved superior to pneumatic power for pronation and supination and gripping, whereas CO_2 is still necessary for locking the elbow and the shoulder joint. The accumulator can be recharged daily at a plug socket, the CO_2 container need only be refilled after one or two weeks ensuring more independence for the disabled. The advantage of such a prosthesis is the better appearance in public combined with a certain functional use.

However only intensive foot training without prostheses provides independence in daily activities, because even sophisticated prosthetic systems cannot make up completely for body loss.

Introduction

Whereas an amputee with shoulder disarticulation and one healthy upper limb generally finds a cosmetic prosthesis without active functions adequate, there is an obvious problem in the fitting of cases of bilateral disarticulation or congenital absence of both upper extremities with functionally satisfactory prostheses. No unexplored possibilities remain for the body powered positioning of artificial arms and for opening and closing the terminal device "hook" or "active hand"; so external power for a functional prosthesis becomes indispensable.

In 1948 the first experiments with CO_2 driven pneumatic protheses were undertaken by Hafner and Weil; CO_2 was used as a safe, easily controllable, easily applied and at the same time cheap propellant. In 1957 Marquardt and Hafner first fitted a child with bilateral amelia of the upper limbs with pneumatic prostheses.

The initial aim of the most extensive motorisation possible of both prostheses rapidly proved itself inexpedient. The absence of suitable body parts for operating the control valves and the limited capacity of coordination, even in the most intelligent patients, was opposed to the increasing number of necessary control signals. The insufficient sensory "feedback" necessitated an exclusively optical control over the actions of the terminal devices. The independent use of each prosthesis at the same time beyond a small, optically controllable area was bound to fail for this very reason. The heavy weight and increasing energy consumption required finally led to reflection on the practicability of such "fully motorised" prosthetic systems. As a consequence there was a step by step reduction to the necessary functions and the improvement or new development of better suitable fittings.

Present practice

Partly manufactured by the industry and partly handmade in our own workshops the following pneumatically driven modular parts are available today:

—a hook for children,

—a hook for teenagers,

—the pneumatic Otto-Bock-system hand,

—joints for pronation and supination,

—an active pneumatic elbow joint with lock,

—a free mobile elbow joint with pneumatic lock,

—for children, a free swinging shoulder joint manufactured from a standard modular elbow joint with pneumatic lock and extremely small CO_2 consumption combined with a friction joint for abduction,

—for older children and teenagers a free swinging shoulder joint with pneumatically lockable forearm linkage.

The philosophy of prosthetic fitting of such seriously disabled patients, as described by Marquardt, is based on the idea that the prosthesis is only to be prépositioned, that is, a rough adjustment is obtained and held. Fine coordination is achieved by body movements, for example by bringing the mouth to the cup or to the spoon, which is already prepositioned with the prosthesis within the range of the body movements (Fig. 1).

Connected with this is the reduction of prosthetic technique to the minimal yet indispensable functions. The dominant side is provided with a functional arm for active use. The opposite side is fitted with a cosmetic arm without active functions; in the moulded resin socket of its upper arm the CO_2 storage cylinder is accommodated. The functional arm has at its disposal:

Fig. 1. Prepositioned prosthesis permits the patient to bring the mouth to the spoon.

—a free swinging, pneumatically lockable shoulder joint,

—either a free or pneumatically movable elbow joint, in both cases pneumatically lockable,

—a pneumatic joint for active pronation and supination,

—a pneumatic "hook" or a pneumatic "system hand" (if possible interchangeable) for active gripping.

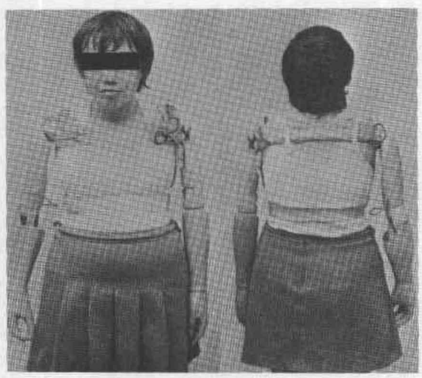

Fig. 2. Prosthetic system with active arm on the right side with pneumatically lockable shoulder and elbow joint, pneumatic pronation and supination and pneumatic hand; on the left side, a free swinging shoulder and elbow friction joint, and built-in CO_2 storage cylinder in the upper arm. Both arms are suspended on a Simpson frame.

The cosmetic arm of the opposite side has only a free swinging shoulder joint and a passively adjustable elbow friction joint. Occasionally the hand of the cosmetic arm may be additionally pneumatically activated to allow a certain amount of hand to hand coordination. Both artificial arms are suspended on a Simpson frame (Fig. 2), which has replaced our former frame constructions (Fig. 3) due to its reduced weight and superior confort in wearing.

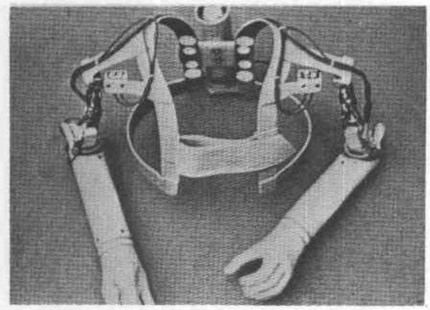

Fig. 3. Former frame construction for pneumatic prostheses for a child with phocomelic upper limbs.

The individual functions are controlled by means of valves. For locking or unlocking of the free swinging shoulder and the elbow joints, flip-flop valves have proved successful since in these the pressure points are clearly defined. The pronation and supination of the forearm is controlled by means of a doublepoint pressure valve, situated above the acromion, or by a doublepoint traction valve, operated by a shoulder strap while lifting the shoulder (Fig. 4). The opening and closing of the gripping device is effected by activation of a flip-flop valve in front of the shoulder.

The few active functions can be easily controlled and, in general, learning problems in prosthetic training do not occur. The optical control is directed exclusively towards the activity of the functional arm. Energy consumption is limited, the contents of a CO_2 container, corresponding to about 500 actions, is sufficient for a normal day's use, as shown by experience. The weight of such a complete prosthetic system for a 10 year old child is about 1750 g with a pneumatic hook and about 1950 g with an Otto-Bock-system hand.

One thing which remains unsatisfactory, is the dependence on refilling the CO_2 storage container carried in the prosthesis from a stationary CO_2 pressure cylinder by means of a reduction valve and a special adaptor. With regard to this inconvenience electrical power from batteries or from rechargeable accumulators has proved superior to CO_2 pneumatics.

On this account we changed over to electromechanical prostheses. The first patients were children with phocomelic upper limbs; their forearmlike prostheses were

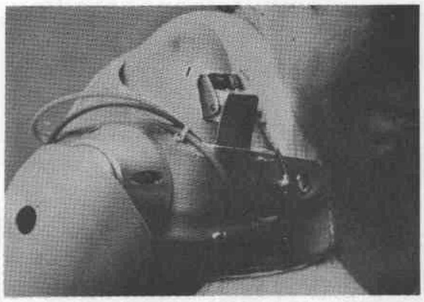

Fig. 4. Detail of doublepoint pressure valve in front of the shoulder and doublepoint traction value fitted to the Simpson frame.

attached to a modified "Ring-bandage" instead of the uncomfortable stiff frame, permitting maximum freedom of movement (Fig. 5). The phocomelic limbs were fitted into the moulded resin sockets in such a way as to give the impression of an actively movable elbow joint and to enable the fingers to operate microswitches which in turn controlled the electromechanically driven hands (Fig. 6). The result was an improvement upon wearing comfort, cosmetic appearance and function.

For the reasons mentioned above it seemed sensible to convert also the prostheses for patients without arms to electrical power. So far, however, no comparably efficient electromechanically lockable shoulder and elbow joints have been developed. Thus in the meantime, we are developing hybrid systems which exploit the advantages of the pneumatic as well as of the electrical external power (Fig. 7).

The shoulder and elbow joint of the functional arm is pneumatically lockable as before. The CO_2 consumption for these actions is extremely small; the volume of the container carried in the prosthesis is now sufficient for one or two weeks, according to the amount of use, assuring greater independence from the stationary energy reservoir at home. The energy consuming functions, such as pronation and supination and gripping movements, are electrically driven. The accumulator can be recharged at the nearest, most convenient plug socket or, with little interruption in prosthetic use, it can be exchanged for a charged second accumulator. In our experience this hybrid system can be most recommended.

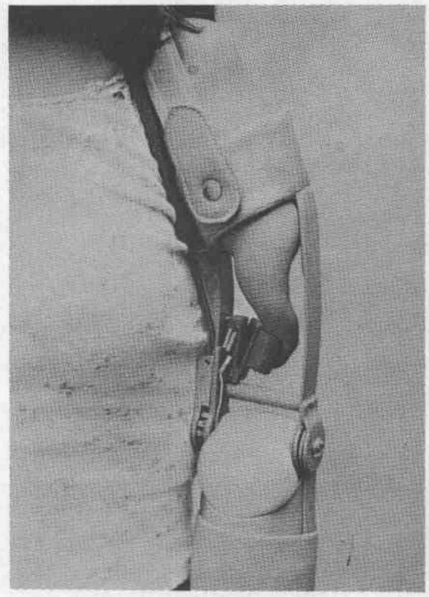

Fig. 6. Microswitch which is operated by the movements of the one finger phocomelia.

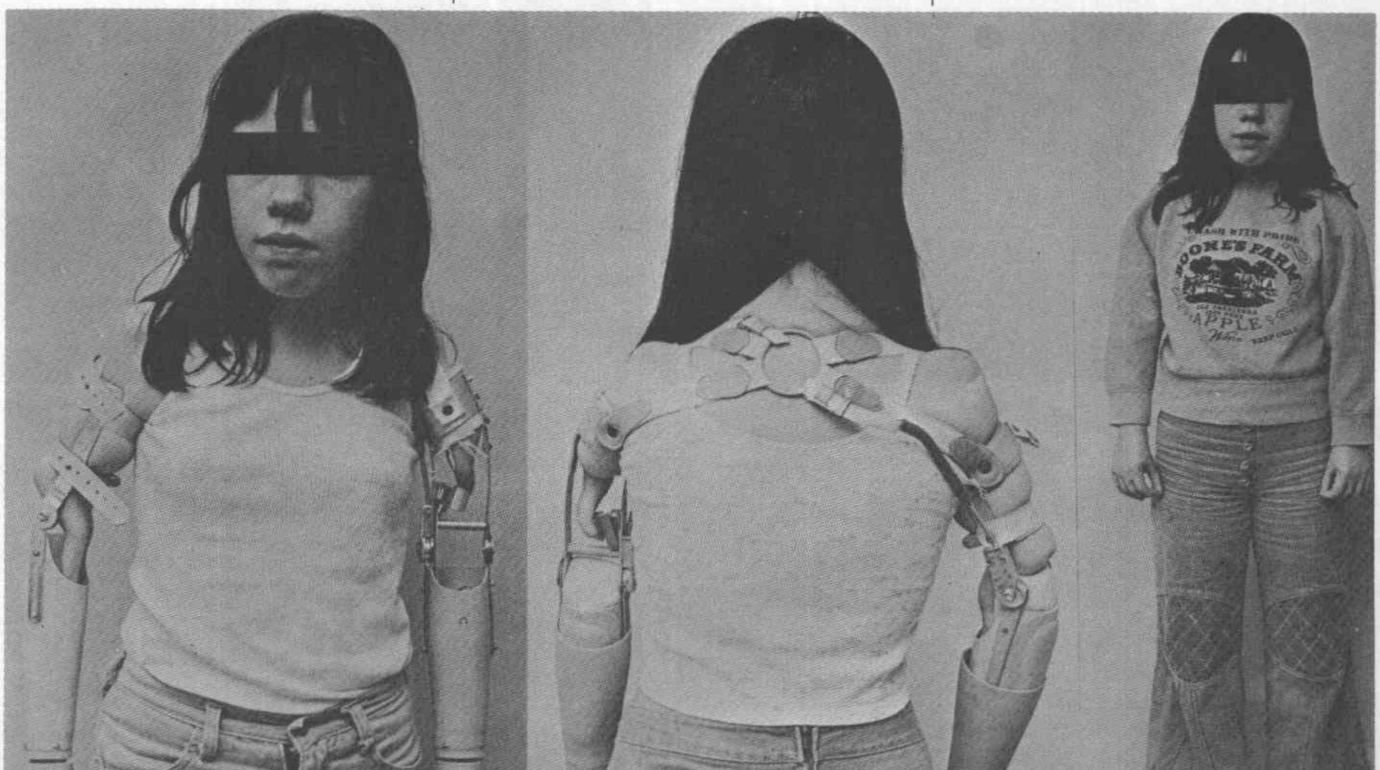

Fig. 5. Recent prosthetic fitting of a phocomelic girl with electromechanical prostheses and suspension on a modified "Ringbandage"; Hosmer outside locking for elbow joints. Extreme right, cosmetic result.

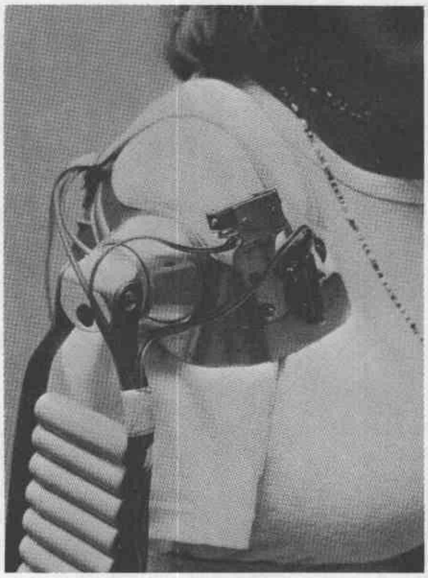

Fig. 7. Hybrid prosthesis in bilateral amelia with pneumatically lockable shoulder joint (controlled by valves in the left side) and pressure and traction microswitches for gripping and forearm rotation. Built-in accumulators f fitted to the frame of the right upper arm.

Discussion

In spite of these improvement excessive enthusiasm concerning the extent of functional use of such prostheses in daily life is out of place. Their actual value lies in the indisputable "normalization" of the patient's appearance in public (one should perhaps say: *for* the public), combined with an optimizing of the functional possibilities of such prostheses by exploiting the technical knowledge available today. Therefore an intensive training in daily activities without prostheses is also essential. Besides simple technical aids, as for example, an eating aid attached to and moved by the leg, foot training is of the utmost importance, especially for overcoming daily recurring problems not only in toilet use, dressing and undressing, washing (Fig. 8), combing hair, teeth cleaning, but also in eating, drinking and in writing (with or without typewriter). Not only can many things be *handled* better with the feet but functional independence of (meaning freedom *from*) the prosthesis—at least at home in privacy—releases the patient from the unpleasant feeling to be capable of living only as a "perfect operator of a sophisticated prosthetic robot". This consideration should be uppermost in the mind while prescribing such a costly AID: it protects against the over-evaluation of technology and the concomitant under-evaluation of the individual, whom the technology should serve.

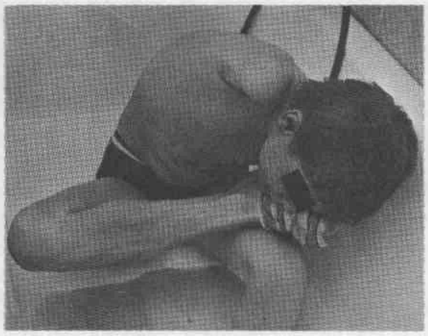

Fig. 8. Result of slef-care foot training, independence from prostheses in daily activities at home.

BIBLIOGRAPHY

MARQUARDT, E. and HAFNER, O. (1956). Technische Bewahrung und prakhische. Anwendung der Heidelberger pneumatische Prosthese. *Archiv fur Orthopadische und Unfallchirurgie* 48, 115-135.

MARQUARDT, E. (1957). Muskelsteuerung von pneumatischen Unter-und Oberarmprothesen. *Archiv fur Orthopadische und Unfallchirurgie,* 49, 419-426.

MARQUARDT, E. (1965). Erfahrungen mit pneumatischen Prothesen. *Verh. Dtsch. Orthop. Ges.*, 52, 346-352.

MARQUARDT, E. (1974). Pneumatische Prothesen, Eigenkraftprothesen und technische Hilfen fur schwere Armfehlbildungen in:[10]*Jahre Entwicklung und Erprobung von Hilfen und Hilfmitteln fur behinderte Kinder.* Hrsg.: AG Technische Orthopadie und Rehabilitation, R. Schunk Verlag, Konigshofen.

NEFF, G. MARQUARDT, E. (1977). Stand der Versorgung mit pneumatischen Prothesen in: *Amputation und Prothesenversorgung bein King.* Ed.: R. Baumgartner, F. Enke Verlag, Stuttgart.

NEFF, G. (1978). *Prinzipien der prothetischen Versorgung nach beidseitiger Schulterexartikulation oder bei beidseitiger Amelie Orthopadie-Technik,* (In press.).

SIMPSON, D.C. and KENWORTHY, G. (1973). Entwurf eines vollstangigen Amersatzes (Teil 2) *Orthopadie-Technik,* Feb. 41-44.

[1]Based on a paper presented at the Second World Congress, ISPO, New York, 1977.

*Developed by H. Kramer, Research Lab. of the Dept. for Dysmelia and Technical Orthopaedics, Heidelberg University.

Technical Meetings and Seminars

1979, May 22-26, Orthopadic-Technik 79, International, Exhibition Center/Convention Building, Nuremburg Germany.

1979, June 10-14, Canadian Orthopaedic Association, Annual Meeting, Montreal, Quebec Canada. Charles Sorbie, M.D. Secretary, Queens University, K7L 3N6, Kingston, Ontario Canada.

1979, Juen 18-21, American Orthopaedic Association Annual Meeting. Dorado Beach, Puerto Rico. William H. Harris, M.D. Secretary, 444 North Michigan Avenue, Chicago, Illinois 60611.

1979, August 26-31, Interagency Conference on Rehabilitation Engineering, Atlanta Hilton, Atlanta, Georgia.

1979, September 26-30, AOPA National Assembly, Washington Hilton, Washington, D.C.

1980, April 27-May 2, "Third International Congress on Physically Handicapped Individuals Who Use Assistive Devices." Shamrock Hilton Hotel; Houston, Texas, U.S.A.

Newsletter... Prosthetics and Orthotics Clinic

Enclosed is my check for $8.00 for a 1-year subscription to the Prosthetics and Orthotics Clinics Newsletter. (Foreign Subscription Price is $9.00)

Mail to:
AAOP
1444 N Street, N.W.
Washington, D.C. 20005

Name ____________________
Address ____________________
City ________ State ________ Zip ________

Newsletter... **Prosthetics and Orthotics Clinic**
American Academy of Orthotists and Prosthetists
1444 N Street, N.W., Washington, D.C. 20005

SECOND CLASS
POSTAGE PAID AT
WASHINGTON, D.C.

ADDRESS CORRECTION REQUESTED

Mr. A. Bennett Wilson M
Director, Rehab. Eng. Center
Moss Rehab. Hospital
12th Street & Tabor Rd.
Philadelphia, PA 19141