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

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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 prepositioned, 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

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

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:

—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.

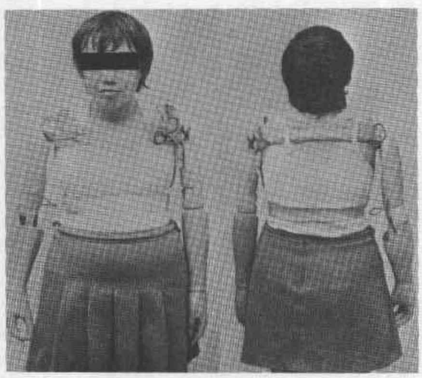

Fig. 2. Prosthetic system with active arm on the right side with pneumatically lockable shoulder and elbow joint, pneumatic pronation and supination and pneumatic hand; on the left side, a free swinging shoulder and elbow friction joint, and built-in CO_2 storage cylinder in the upper arm. Both arms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

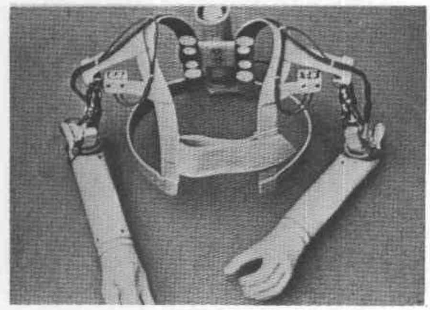

Fig. 3. Former frame construction for pneumatic prostheses for a child with phocomelic upper limbs.

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

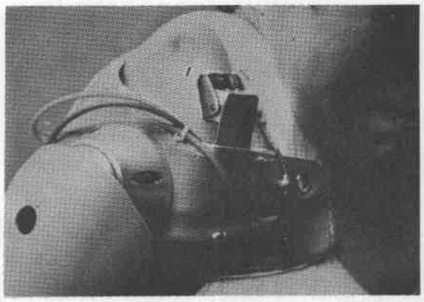

Fig. 4. Detail of doublepoint pressure valve in front of the shoulder and doublepoint traction value fitted to the Simpson frame.

attached to a modified "Ringbandage" 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.

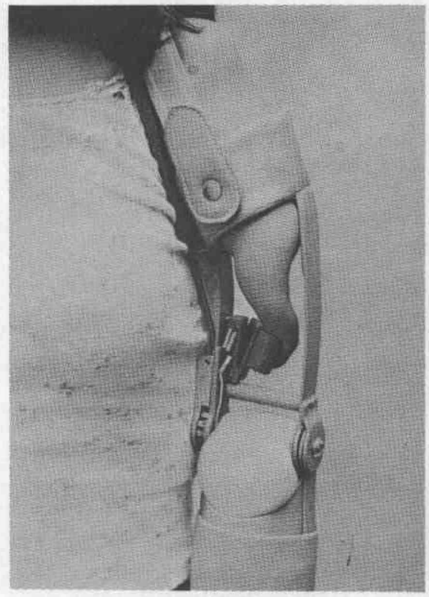

Fig. 6. Microswitch which is operated by the movements of the one finger phocomelia.

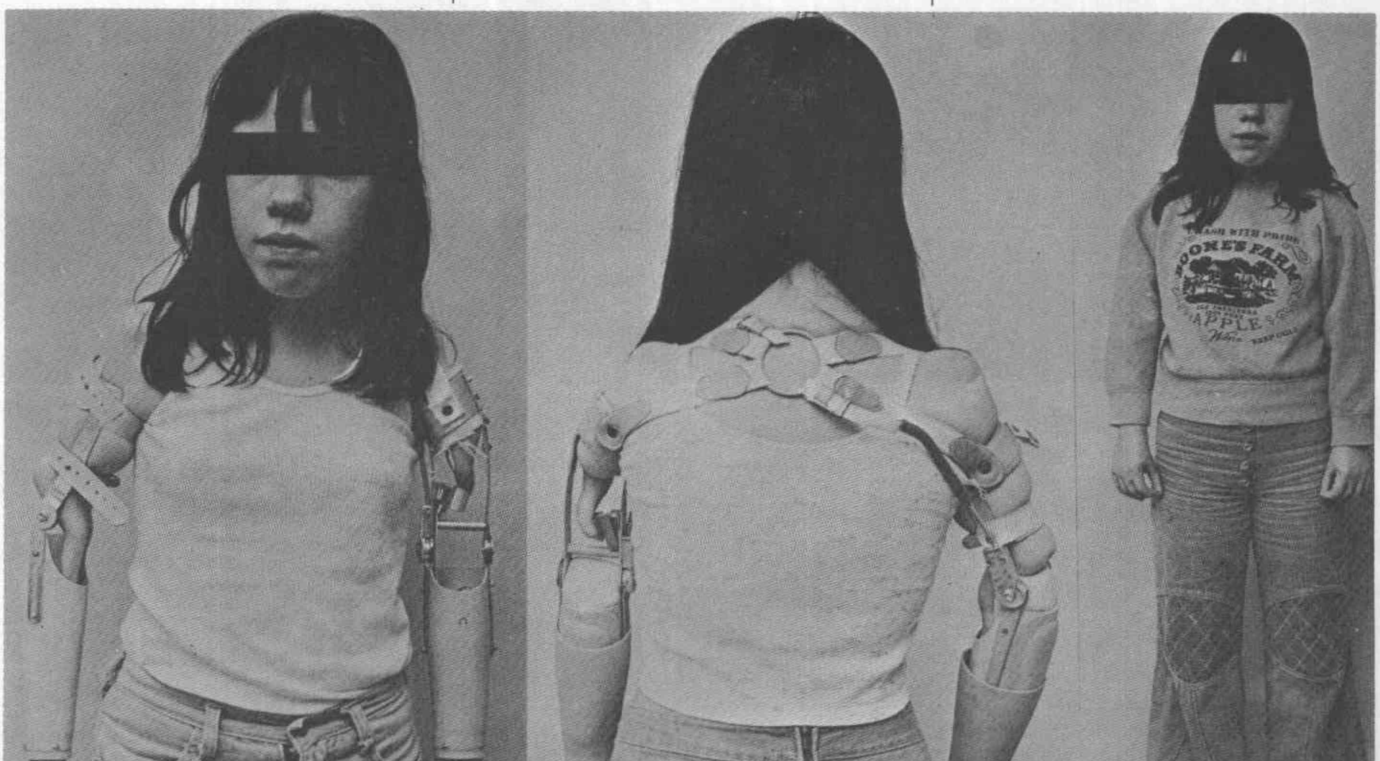

Fig. 5. Recent prosthetic fitting of a phocomelic girl with electromechanical prostheses and suspension on a modified "Ringbandage"; Hosmer outside locking for elbow joints. Extreme right, cosmetic result.

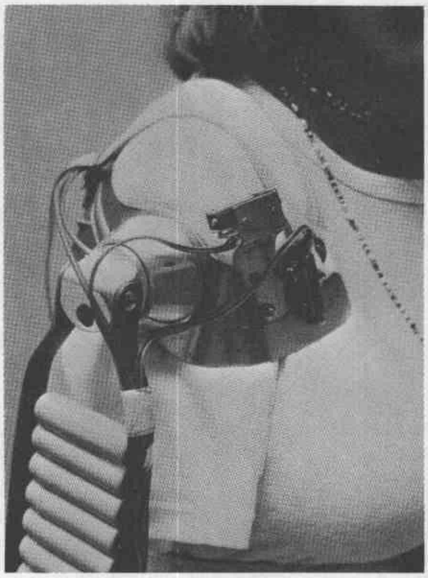

Fig. 7. Hybrid prosthesis in bilateral amelia with pneumatically lockable shoulder joint (controlled by valves in the left side) and pressure and traction microswitches for gripping and forearm rotation. Built-in accumulators f fitted to the frame of the right upper arm.

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.

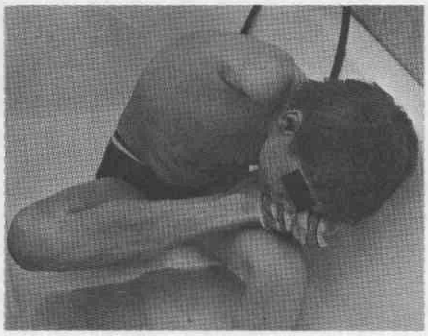

Fig. 8. Result of slef-care foot training, independence from prostheses in daily activities at home.

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*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.