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Prosthetics and Orthotics International

April 1978, Vol. 2, No. 1

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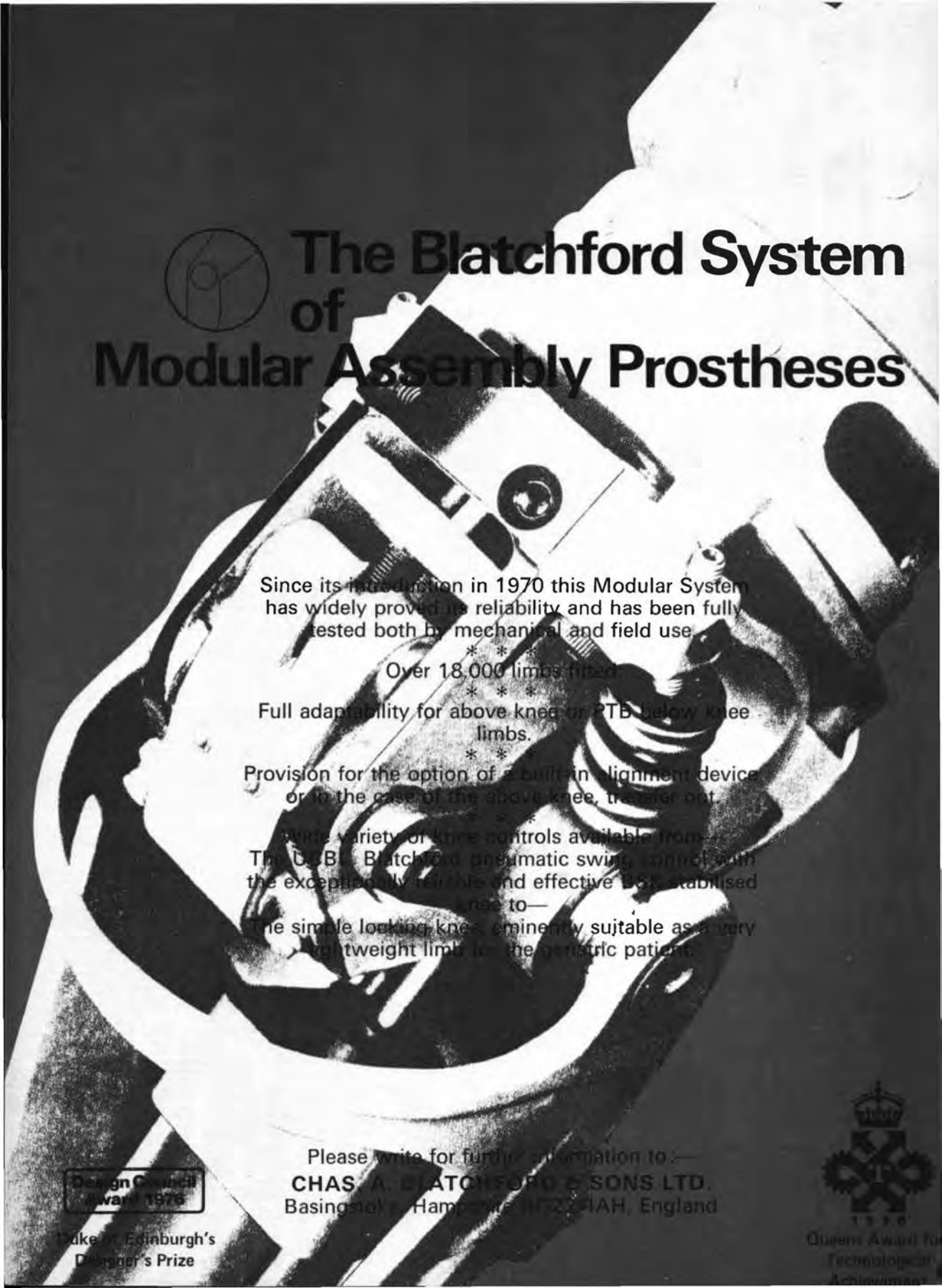
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Prosthetics and Orthotics International, 1978, 2, 1–2

Editorial

By the time members receive this copy of the journal, the first year of the triennium will be nearly over. For many members in remote areas their only contact with the Society during this time will have been through the pages of this publication. To them, and perhaps to others, this will be the only practical expression of activity. However, this is far from being a true picture—Officers, Members of the Executive Board, National Officers, members of the various standing and other committees are working steadily to further the aims of the Society in the continuing efforts to raise standards of treatment throughout the world.

In November the Executive Board met in Copenhagen for the first time since the New York Congress. Some comments on that meeting and some of the discussions which took place may serve to illustrate the spectrum of activity.

Attendance was very large. Of the ten Elected Board Members listed in this issue, eight were present at the meeting. Another five of the Standing Committee Chairmen and two of the Consultants also attended. This remarkable turn-out, at little or no cost to the Society, of a group of notable people whose time is so valuable, is a clear indication of the worth which they place on the Society's work.

Reports were received from a number of the standing committees.

The newly formed Protocol Committee under the chairmanship of Past President, Dr. Jansen, has started work in an advisory capacity to the Board. One of its first tasks is the examination of membership classes and the functions of the secretariat. This committee has special responsibilities in respect of advising the Board on the interpretation of the Constitution. A first stage in this is a study of the Constitution itself in the light of experience gained to date in its operation. The secretariat would be interested to hear from any member who believes he, or she, has identified any anomolies, or has suggestions which would lead to improvement.

The new Conference Committee is already offering guidelines and assistance to the Netherlands Congress Committee in its preparations for the 1980 World Congress. The Dutch group are presently considering alternative sites in Amsterdam, the Hague and Groningen and producing detailed budgets for Board approval. It is hoped that this Congress will once again take place in collaboration with our friends from INTERBOR.

The Evaluation Committee is presently developing an exciting proposal for an international programme of evaluation. The Society is unique in its capability of offering such a programme to governments on the basis of establishing protocol, identifying institutions and individuals to take part and co-ordinating work and results.

The Education Committee is planning for a follow-up event to the International Study Week on Prosthetic/Orthotic Education which took place in the University of Strathclyde in 1974. The new meeting in 1979 would concentrate on the clinical and practical content of training programmes and would be linked with the problems of developing countries. It is hoped to associate this activity with another ISPO event to be sponsored by Danida (the Danish overseas aid agency) which would take place in the same year and would study the lasting impact of training methods in developing countries.

The Membership Committee is continually fostering the development of new National Member Societies. Indeed at this meeting Pedro Prim reported on the formation of a National Society in Spain. Unfortunately, the chairman of the committee, one of the founder members of our Society and a tireless and meticulous worker for the Society and the Board, Dr. McKenzie, has resigned from chairmanship following a recent illness. Happily he has made an excellent recovery and we are sure members would wish to be associated with the President and the Board in expressing our gratitude to him for outstanding and dedicated work and in wishing him, and his wife Kay, a long and happy retirement.

Other items of interest were discussed by the Board which were not directly related to individual committee activity.

The Society's links with Rehabilitation International and, in particular, its International Commis-

sion on Technical Aids (ICTA) are being fostered. The President had attended a recent meeting in Mulhouse, France, and had himself been appointed to the Commission. It is hoped that a joint ISPO/ICTA workshop will shortly be held on an appropriate topic and that this will develop into a continuing collaboration.

Dr. Sidney Fishman had recently led an ISPO Commission to Nigeria, at the invitation of the Federal Ministry of Health, to advise on the development of prosthetic/orthotic services. The Commission spent ten days there visiting Lagos, Kano and Enugu. A detailed report will be submitted to the Nigerian government offering a development plan and continuing assistance. There was general discussion in the Board on the problems of the developing countries. One body of opinion has supported the concept of a new Standing Committee to deal with this area. The general view in the Board, however, is that the subject is so important that the Executive Board itself must be regarded as the Standing Committee for the developing countries. We are, however, investigating ways in which the Society may organize itself to respond more rapidly and efficiently to demands in this area.

The Finance Committee's discussions appear here, separated from the other committee activities, simply to emphasize their importance and to highlight certain aspects. The development of the Society and indeed its continued existence are directly related to our ability to generate income. The Board are presently concentrating on several areas—evaluation, foundation grants and overseas aids—in raising funds to sustain and develop our activities and, as has been discussed in an earlier editorial, to establish a permanent staff.

During the discussion on the Finance Committee business, Cliff Chadderton, one of the Board's new "Consumer Consultants", announced a donation of $5,000 from his organisation, the War Amputations of Canada, to assist in the operation of the Society. The President expressed the Board's gratitude to Cliff Chadderton and his association for this magnificent gesture of support.

Discussion on Prosthetics and Orthotics International centred on improving the content and securing the financial viability of the journal. Articles contributed to the journal are now being screened by referees and modified, re-written or rejected on their advice. National Societies had previously been invited to identify referees and also to encourage contributions from within their membership. The response to this invitation has been very disappointing. The cost of producing and distributing Prosthetics and Orthotics International accounts for a substantial part of our budget. However, it is our belief that the membership sees this as an important benefit and is a factor in attracting new members. It is our hope that the Journal will become self-supporting and eventually profit-making. The only way we can do this is to increase the circulation on the one hand and increase the income from advertising on the other. With regard to increasing the circulation, there are obviously two ways in which this can be done. One is by increasing our membership, and of course we know that all National Member Societies are steadily, by generating activity within the nation, attempting to do this. The second possibility, however, is to increase the number of subscribers from libraries and institutions. We would very much appreciate it if National Societies could do their best to draw the journal to the attention of these potential customers. Indeed, a subscription drive organized by National Member Societies to all Reference Libraries and Orthopaedic Units within their own country would inevitably meet with success.

On the question of advertising, we on the Editorial Board have been attempting to identify all those who might be interested in the journal and have approached about 220 potential customers. It is, however, very difficult for us to become aware of who all the potential customers are. In this area National Member Societies will be much more aware of the local firms who would be interested and must also have the possibility of direct contact. We would be very grateful indeed if National Member Societies, and individual members, could take this on as a task of great urgency.

We hope that this small insight into the deliberations and activities of the Executive Board and its standing committees will prove of interest. In the long run the Society is the membership. These activities are being carried out in your name and in the belief that they reflect a consensus of your wishes. Our continued growth, however, depends not on a small group of people, but in the willingness of the members to accept active involvement.

John Hughes
Honorary Secretary

Prosthetics and Orthotics International, 1978, 2, 3–7

Ideas on the suspension of the below-knee prosthesis*

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Abstract

Comparative studies with the PTB-suction prosthesis and the ordinary PTB prosthesis have provided opportunities to analyze and understand some functional differences in the suspension of below-knee prostheses. In a roentgenological study of the stump-socket contact significantly less vertical displacement in the PTB-suction prosthesis has been shown. A study of the pressure variations in the suction socket verified the theory of the necessary pressure gradient in the PTB-suction socket. Added negative pressure by muscle action was also observed. An electromyographic study suggested a muscular activity pattern in the suction prosthesis similar to that of a normal leg, as a contrast to the ordinary PTB prosthesis where simultaneous contractions of antagonistic muscles seemed to be the usual pattern. The latter is interpreted as a defence reaction. An optimal prosthesis has been deduced. It shall have a soft prosthetic socket with a perfect fit, a suction, adhesion and friction fixation and a pressure gradient between the skin and the socket wall with minimum compression distally. The plaster casting shall be done in a downward modelling manner making available space for soft tissue without compression.

Introduction

The basic purpose of any artificial limb is to enable the amputee to perform everyday activities in an easy, natural and comfortable manner (Radcliffe, 1955). The introduction of the Patellar-Tendon-Bearing (PTB) prosthesis (Radcliffe, 1961) represented a considerable advance in the prosthetic treatment of the below-knee amputee. The PTB, in general, has been a functionally successful prosthesis which has fulfilled the above purpose. However it is not problem-free for some wearers who have different types of sensitive skin or are used to heavy physical activity. These difficulties have demanded an alternative to the PTB (Bakalim, 1965; Eriksson and Lemperg, 1969).

Various attempts have been made in different centres to counteract the circumstances leading to skin sores. It would seem a natural solution to reduce the pressure on the tender parts of the stump and distribute the load to other less easily injured parts. A soft liner inserted in the socket may sometimes bring simple relief to a tender stump.

Sockets specially constructed with this aim have been produced, one of them being the PTB air cushion socket (Wilson *et al.*, 1968). Here, a sealed air chamber between the inner and outer sleeves of the socket provides support and distributes the load by virtue of tension in the elastic inner sleeve and through compression of the air. Another approach to this problem has led to a new design of socket for the below-knee prosthesis (Renström *et al.*, 1974). For a closer fit of the socket against the stump it has been constructed with a socket bottom consisting of a floating pad filled with water and connected to a pivot on the leg shell. Thus the socket is meant to be self adjusting to the circumferential and longitudinal variations of the stump.

Various auxiliary suspension aids such as thigh lacers, special straps and condylar wedges have been developed with the aim of improving the anchorage of the prosthesis and at the same time diminishing the piston action between the stump and socket (Wilson, 1969).[1] The PTS prosthesis (Pierquin, 1964) and the KBM prosthesis (Kuhn, 1966) are such constructions. The proximal brim of the PTS is extended to cover the patella and the medial and lateral condyles of the femur thus providing better lateral stability. The KBM socket is also

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

extended over the femoral condyles but does not cover the patella. Suspension of the KBM socket is provided by a wedge inserted between the medial lip and the femoral condyle. A recent simple device adaptable to any knee prosthesis that does not have mechanical joints or straps attached is the rubber sleeve suspension (Chino *et al.*, 1975; Giacinto, 1976). These improvements in the suspension of the PTB prosthesis are all directed towards the effects of the piston action, namely soft tissue movements and the effect on sensitive pressure points.

Many improvements on the PTB prosthesis have dealt with only one of these two components of the piston effect. An ideal solution for the patient, however, must take into account both the tissue movements and the distribution of the load. The well known above-knee suction-type prosthesis seemed the most natural model to use as a basis for an optimal socket construction for below-knee stumps with such problems as those mentioned above (Radcliffe, 1955). In a suction-type prosthesis the skin is immobilized and the load is distributed over its surface.

PTB-Suction Prosthesis

A trial with PTB-suction prosthesis was initiated in 1969 (Grevsten and Marsh, 1971) and two different sockets have been developed. One has a total rigid socket construction (Fig. 1). The other is a semi-rigid socket (Fig. 2) which is detachable and is put on separately (Fig. 3 left). It is then put into a below-knee leg construction (Fig. 3 centre and right). Both are called PTB-suction prostheses.

One problem with this prosthesis that was evident from the start was that of too much load and pressure being applied to the distal parts of the soft tissues. A relieving measure was therefore introduced—the socket was made wide enough distally to receive down-stretched soft tissue. If the soft tissues were pulled down, pre-stretched into the available space, they would be ready to retract and therefore in a position to reduce the pressure on the end of the stump and also distribute the load and pressure from the end of the stump in a proximal direction. The plaster casting is most important when constructing a PTB-suction prosthesis. One plaster cast is seldom enough. The plaster cast must be made in a downward modelling fashion to create the possibility of pre-stretching the soft tissue distally, thus achieving the gradient pressure which avoids disastrous pressure effects on the distal parts of the stump. In this matter the importance of frank and intimate contact between the prosthetist and the orthopaedic surgeon when dealing with the amputee's problems cannot be over-stressed.

Fig. 1. Top, the rigid socket version of PTB-suction prosthesis. The socket is not detachable from the rest of the prosthesis. Bottom, view into the socket.

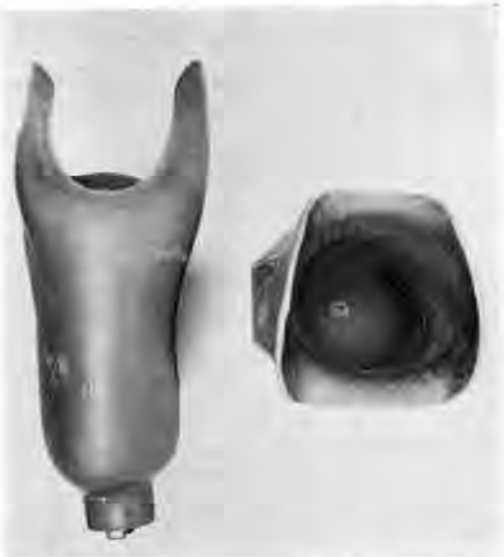

Fig. 2. The semi-rigid insert suction socket version of the PTB-suction prosthesis—the detachable socket.

Different studies with the PTB-suction prosthesis and the ordinary PTB prosthesis have been made to analyze and understand their function. In a roentgenological study the stump movements in simulated walking were analyzed (Grevsten and Eriksson, 1975). It was shown that the vertical displacement (Fig. 4) in stance phase was on average 11.3 mm less in the suction prosthesis than in the PTB prosthesis. No air was seen in the socket of the suction prosthesis in any of the simulated stride movements but this too was always the case in the ordinary PTB prosthesis. It was also shown that with the suction prosthesis the main sagittal compression of anterior soft tissues of the stump occurs when the prosthesis is suspended and at double support. This is compatible with the line of action of the floor reaction force acting posterior to the knee making a relaxed knee flex (Radcliffe, 1962).

A study of the pressure variations (Pearson *et al.*, 1974), in the suction socket verified a theoretical idea of a pressure gradient in the socket. Further added negative pressure due to muscle action, beside the pressure induced by the swing phase load of the weight of the prosthesis, was also observed. These analyses were made through a mathematical model of assumed forces acting on the below-knee stump. From this model a formula was derived giving predicted values for the pressure in stance phase and swing phase to be compared with the observed values.

Fig. 3. Left, donning the semi-rigid insert suction socket version of the PTB-suction prosthesis. Centre, the semi-rigid insert suction socket about to be put into the hard socket component of the prosthetic limb. Note the rubber sleeve around the socket opening which reduces the possibilities of air leakage into the socket encountered upon extreme flexion of the knee joint. Right, the semi-rigid insert suction socket being inserted into the hard socket component of the prosthetic limb.

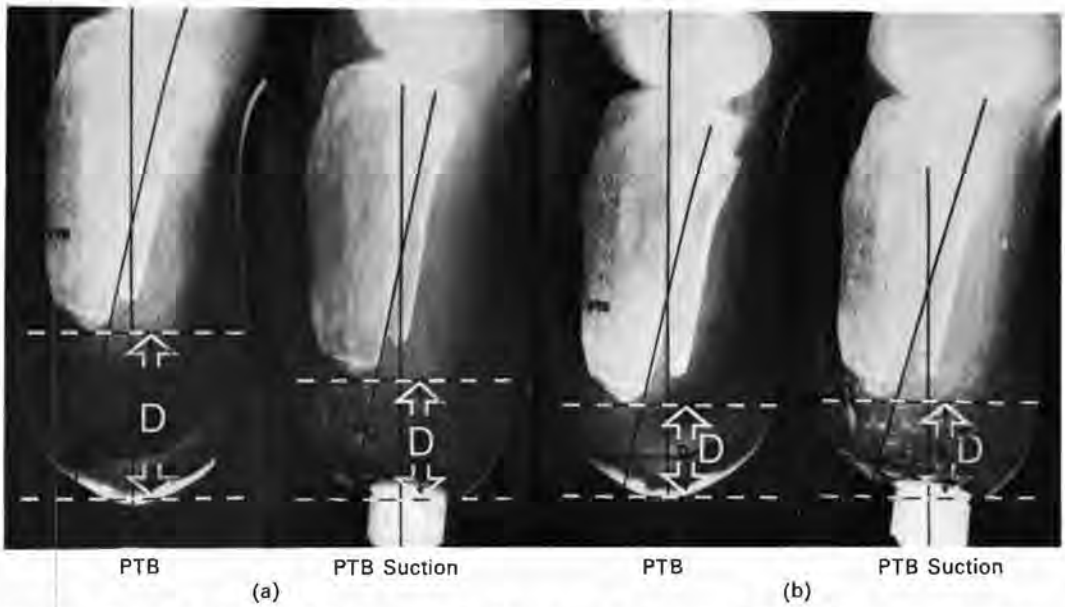

Fig. 4. Difference in downward displacement D of the stump between the PTB and PTB-suction prosthesis. (a) At mid swing; (b) At mid stance.

This study also illustrated an interesting relationship between the intercavity pressure in the socket and the blood pressure in the stump. When walking, the arterial and venous blood pressures are oscillatingly overlapped by the pressure variation in the PTB-suction prosthesis, accounting for a pumping effect which assists the normal pumping action of the below-knee muscles and thus improves the circulation (Wilson, 1969).[2]

In an electromyographic study of the residual muscles of the amputation stump while walking with ordinary PTB and PTB-suction prosthesis a muscular activity pattern in the suction prosthesis similar to that of a normal leg is suggested (Grevsten and Ståhlberg, 1975). Presumably the normal muscle activity is a spinal reflex easily elicited as long as no strong irregular sensory input is present. Walking with the PTB prosthesis often shows simultaneous contractions of antagonistic muscles which were assumed to be a defence reaction to the piston action resulting from the loose suspension of the PTB prosthesis.

From 1969 to 1976, 46 patients were fitted with PTB-suction prosthesis and 27 patients were converted to it (Grevsten, 1977). They represent the patients with the stump problems initially pointed out. In this group 12 patients were observed with healing of skin lesions while walking with the prosthesis. A further 6 patients with extreme excess of soft tissue (more than 30 mm) distal to the bony end of the stump and with great problems when using the PTB prosthesis became the best users of the suction prosthesis.

The PTB-suction prosthesis was introduced for those wearers of the ordinary PTB prosthesis who often sustained contact sores and skin irritation. It is seen in the clinical presentation that in such cases the skin lesions generally disappear in the PTB-suction prosthesis. There are still some groups of patients who are left unsatisfied, however, as all below-knee amputees are not able to use this suction model. With very short stumps fitting the prosthesis is a physical impossibility, and with too slender and bony stumps the problems for the prosthetist in fitting the socket to obtain sufficient sealing, preventing air being sucked in during activity, are too great. The PTB-suction prosthesis is, however, very practicable for stumps longer than 125 mm and with a reasonable amount of soft tissue. If these two criteria are fulfilled this prosthesis comprises a prosthetic therapy and an alternative for stumps with areas of sensory disturbances, frail skin, a tendency to contract sores or eczema and/or ischaemic problems.

The PTB-suction prosthesis is also cosmetically favourable, which has been particularly appreciated by the female amputees.

An optimal prosthetic suspension should both minimize stump movements and distribute the load evenly over the stump. The above studies have shown that the PTB-suction prosthesis fulfils the conditions for such an optimal prosthetic suspension which the ordinary PTB prosthesis generally does not do although, as a rule, it functions satisfactorily. Thus when the ordinary PTB prosthesis results in skin problems for the wearer there are good reasons to consider the PTB-suction model.

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Prosthetics and Orthotics International, 1978, 2, 8–11

Prostheses for partial hand amputations*

L. F. BENDER

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Abstract

Amputation of part of a hand may create significant functional limitations for the amputee which are difficult to ameliorate by either orthoses or prostheses. To help develop a logical approach to devices for partial hand amputations the patterns of losses have been studied and a division into four categories has been proposed. Transphalangeal, thumb spared; thenar, partial or complete; transmetacarpal, distal; transmetacarpal, proximal.

By utilizing basic principles of orthotics and prosthetics and by exercising ingenuity, it is often possible to provide considerable improvement in function and/or cosmesis to individuals with partial hand amputations. Case illustrations and their prosthetic solutions are presented.

The author has attempted to provide both function and cosmesis to many persons with partial hand amputations and has been confronted by a variety of patterns of amputation and many different vocational and avocational needs. Because of this great variation in patterns of amputation and also to help develop a logical approach to devices for partial hand amputations the losses have been studied and divided into categories.

Traumatic amputation of a part of the hand in an *industrial* accident usually occurs in a *straight* line through the phalanges or metacarpals but may be at *any angle* with relationship to a line through the distal row of carpal bones. The injury may remove, spare, or partially involve the thumb.

Farm accidents, on the other hand, are more often *uneven* at the amputation site due to the tearing, clawing or shredding action of farm implements.

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Fig. 1. Levels of partial hand amputation. 1. Transphalangeal; thumb spared. 2. Thenar—partial or complete. 3. Transmetacarpal, distal; thumb spared or involved. 4. Transmetacarpal, proximal; thumb spared or involved.

The loss classification proposed (Fig. 1) divides partial hand amputations into four categories:

1. Transphalangeal, thumb spared.
2. Thenar, partial or complete.
3. Transmetacarpal, distal; thumb spared or involved.
4. Transmetacarpal, proximal; thumb spared or involved.

Transphalangeal amputations usually involve the four fingers to similar or slightly varying degrees. Most often these patients need no device, but they may desire cosmetic fingers; these can be easily fitted if at least half of the proximal phalanx remains for each finger. Cosmetic fingers may be held on by suction or by special adhesives. Occasionally such a person needs and desires additional function.

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

Case illustration

A thirty year old male lost his right fingers in an industrial accident involving metal shears. A portion of the proximal phalanx of digits two through five remained with good range of motion and strength at the metacarpophalangeal joints, the thumb was spared. He was right dominant and wanted to continue to use tools with his right hand. However, the proximal phalanx of the fifth digit was considerably shorter than that of the second digit so power grip was not effective. A stainless steel prosthesis with Plastisol covering was designed and fabricated (Fig. 2).

Fig. 2. Transphalangeal amputation of the second through fifth digits. Prosthesis with dorsal metacarpal and phalangeal bars, side rivet pivot hinges at the MCP joint.

The side MCP hinge moves freely and permits the strength of the finger flexor muscles to flex the opposition bar and provide satisfactory grip of handles and tubular objects (Fig. 3).

Fig. 3. Effective grasp of a hammer handle between thumb and prosthesis.

Amputation of the thumb alone is relatively rare in our experience. When it does occur and involves the metacarpal, as well as the phalanges, a prosthetic thumb can be made (Fig. 4). Plastic laminates can be shaped to closely resemble a thumb and to provide a shallow socket that fits against the second metacarpal and is held on by a Velcro or Plastisol strap around the hand. If other digits adjacent to the thumb are also amputated, the prosthesis can be made with a wider socket and still provide a satisfactory prehension post.

Fig. 4. Thumb prosthesis.

Amputations through, the *distal transmetacarpal* area are quite common in the author's industrial location. Since most of these persons have been involved in hard working occupations and probably will continue to do skilled and semi-skilled labour, stout devices must be made for them.

Basically, two alternatives are available to the orthotist or prosthetist in dealing with *distal transmetacarpal* amputations. A prosthesis shaped like a mitt can be constructed or an open steel prosthesis can be designed to fill a specific need (Fig. 5).

Fig. 5. Plastisol covered, stainless steel prosthesis and mitt-shaped prosthesis for distal transmetacarpal amputation.

The mitt prosthesis must be particularly strong in the distal portion. The palmar area is lined with Neoprene so it will not be too slippery. This prosthesis provides a large prehension area for gross activities such as lifting furniture and also permits finger tip prehension along the rim of the mitt.

Poor skin coverage of the amputation site is an unusual problem. Surgical techniques usually permit satisfactory skin coverage of distal amputation sites.

Case illustration

A sixty year old farmer lost all fingers, including the thumb, at the distal transmetacarpal level in a corn-picker machinery accident (Fig. 6). Adequate skin coverage was not achieved because he did not permit additional surgery to cover the stump with skin graft. The amputation site was sensitive and needed protection. He also desired function; needing to grasp mechanical milkers firmly so he could attach them to his cows. A stainless steel

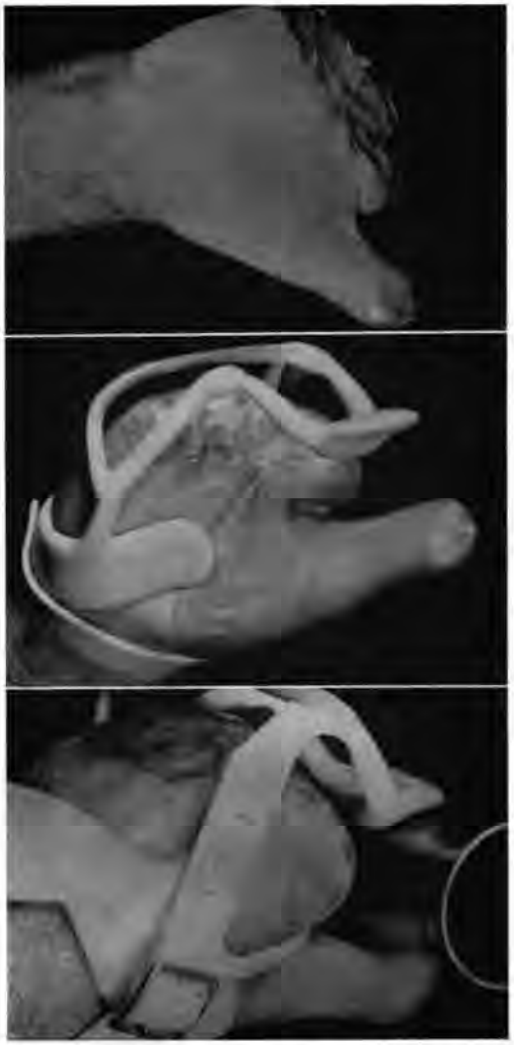

Fig. 6. Top, amputation through the distal transmetacarpal area of digits 2, 3, 4 and 5 with loss of the distal phalanx of the thumb. Skin coverage is inadequate for hand activities. Centre, stainless steel prosthesis designed to protect the amputation site and permit prehension. Bottom, picking up a tube with the prosthesis.

prosthesis was designed with a contoured piece of 1·2mm stainless steel dorsally which wrapped around the fifth metacarpal and stopped at the fourth metacarpal. A small steel rod was positioned in the thumb web space for stability and to prevent proximal movement of the prosthesis. Stainless steel rods, 4·5mm in diameter, were contoured dorsal and slightly distal to the sensitive amputation site to prevent bumping it and to add strength to the unit. A

second set of stainless steel rods were then positioned so that they would hold a semi-circular opposition post in place. The post is silver soldered to the rods at the appropriate angle to hold tubular objects such as milkers. Proper design and positioning of the post is important. One must consider carefully the length, range of motion, and strength of the thumb as well as the size, shape and weight of the objects to be picked up. Plastisol coating provides a non-absorbent, resilient, pleasing appearance but the Plastisol must be roughened on the prehension surface of the opposition post to provide adequate friction for good function.

The thumb may be spared, partially amputated, or absent in amputations through the *proximal transmetacarpal* area of the hand. Either cosmetic hands or functional prosthesis or both may be used to restore appearance and function.

Fig. 7. Amputation through the proximal area of all metacarpals as the result of a punch press accident. An orthosis with opposition post provides prehension.

Case illustration

A twenty nine year old female lost all right fingers and thumb in a punch press accident (Fig. 7). A right dominant person, she desired cosmesis and sufficient function to hold small objects and feeding utensils. Appearance of her hand was restored by a cosmetic plastic glove with semi-rigid fillers in the fingers and a zipper fastening on the volar aspect of the wrist.

An opposition post also was constructed with a short post to oppose the stump of the first metacarpal. It provided the desired function.

Fig. 8. Epoxy resin mitt-shaped prosthesis for amputation of fingers at the proximal transmetacarpal area with sparing of the thumb.

An alternative solution in *proximal transmetacarpal* amputations with *sparing of the thumb* is to fabricate an epoxy resin mitt (Fig. 8). To gain stability the mitt will usually have to encase the carpal area. It can be made sufficiently flexible yet semi-rigid that it can be slipped over the stump and held in place with a single Velcro strap. The rim of the mitt can be made to any desired shape so that utensils and small objects can be picked up as well as providing sufficient opening to grasp larger objects like an electric razor.

By utilizing basic principles of orthotics and prosthetics and by exercising ingenuity it is often possible to provide considerable improvement in function and/or cosmesis to individuals with partial hand amputations.

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Prostheses, pain and sequelae of amputation, as seen by the amputee*

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Abstract

Results of a survey of 19 organizations belonging to World Veterans Federation indicate that major complaints of amputees include; poor fitting, poor dissemination of knowledge to doctors and amputees regarding new prostheses, lack of opportunity for "input" from amputees at research level and inadequate measures to deal with phantom and stump pain. Suggested improvements by amputees; decrease in weight of prostheses, reduction in maintenance for swing and stance-phase control units, development of recreational prostheses, more frequent checks through use of X-ray and film techniques, particularly during the "break-in" of a new appliance. Older veterans showed increasing concern in regard to development of consequential disabilities arising from amputation; premature arthritic changes in spine and remaining limb, circulatory problems and gastro-intestinal problems due to ingestion of drugs to control pain.

Introduction

With the co-operation of the World Veterans Federation, information was requested from 19 veteran organizations in 14 countries. Replies were received of varying significance from all. The enquiries were based on a questionnaire, the basic elements of which were:

Legs

Weight of the prosthesis.
SACH feet versus articulated feet.
Wearing of rubber-soled shoes.
Cosmetic appearance.
Soft socket versus hard socket, below-knee.
Plug socket versus quadrilateral socket, above-knee.
Swing phase control units, above-knee.
Modular versus standard limb.

Arms

Münster fitting versus harness.
Myo-electric hands.
Cosmesis—hands.
Wearing of prosthesis, above-elbow.

Adjustment

Do you see yourself in your dreams as an amputee?
Psychological effect of dismemberment.
Sequelae (medical) of amputations.
Recreational limbs.

The replies to the questionnaire were, in the initial stages of review, sent to a computer firm for analysis. It was evident, however, that the response could not be measured in terms of "yes" or "no" and it was recommended that an attempt be made to obtain a "feeling" from the replies which might be useful. Therefore, this survey should not be considered as a fully accurate statement of response and the views herein must be seen in this light.

Fitting

It seems possible to draw a startling conclusion from the replies concerning comfort. It appears that many amputees were prepared to accept an uncomfortable fit as "part of the game".

A significant number of amputees suggested that use should be made of X-ray and film techniques and of biomechanical devices in measuring the accuracy of a prosthetic fit.

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

Information on new prostheses

The amputees seemed to be overwhelmingly of the opinion that there was a lack of information on the part of medical doctors in this area.

It was evident also that, with certain exceptions the amputees themselves were poorly informed on new prostheses. Understandably, a number of amputees commented that they knew far more about the new models of automobiles than about the new models of limbs.

Input at the research level

The respondees stated they were unaware of any concerted effort to obtain opinions from amputees concerning the types of research which should be done to improve prostheses. To be fair, some replies indicated that "amputee input" may be going on but they did not know about it. Significantly, however, they felt that there should be more liaison at the "user" level with the researchers.

Pain

Universally, phantom limb pain appeared to be a significant problem and the amputees felt that very little was being done to develop remedial measures. A review of the replies indicated that the usual advice was to take aspirin and a hot drink. Obviously this has not been effective and the amputee is looking for something more concrete.

Many amputees complained also of stump pain, as separate from phantom limb pain, stating that massage, heat treatments and sometimes surgery had been successful in its elimination.

Weight of prostheses

There were two distinct "camps" in the replies, some 62 per cent wanted lighter prostheses but 12 per cent stated some weight was essential and felt that good hardware should be used, despite additional weight.

Feet

No trend was evident on the question concerning SACH versus articulated feet. There was, however, a small but dedicated group of amputees who sincerely believed that an articulated foot was much superior. This group described the SACH foot as "too springy" or "unstable".

Rubber-soled shoes

By far the majority of leg amputees preferred rubber-soled shoes for stability and heel strike.

Cosmetic appearance

This did not appear to be a factor. However, the respondees were all war amputees whose average age would be 60 which is perhaps significant.

Sockets

By far the majority of below-knee amputees preferred a soft socket for reasons of comfort.

The question on the plug versus quadrilateral socket for the above-knee amputee elicited the information that, for the most part, the quadrilateral socket users were well aware of the advantages, stating them as being "better circulation", "more comfort", "easier standing", "taking the weight on the ischium", etc. Tragically, perhaps, many plug socket users were unaware of the difference between the two types.

Controls

The question concerning swing phase controls elicited a very high response, indicating that a large proportion of the amputees were not familiar with these devices. (We had not dared ask for information on stance phase controls as we were reasonably certain that the concept is not known to the majority of amputees.) It would seem, from the replies, that many more amputees would be prepared to try these devices if they knew of their existence!

Modular versus exo-skeletal

Here again the majority of the amputees replying (approximately 60 per cent) did not know the difference. There were, however, a dedicated group of modular users who recognized the advantages of alignment, light weight and cosmesis who were "sold" on modulars. Here again, a conclusion can perhaps be drawn regarding the necessity for the dissemination of more information.

Münster versus harness fitting

The answer was predictable. The below-elbow amputee is very partial to a light fitting for a passive hand. Alternatively, he seems to have a passionate love affair with his hooks and harness when he wants to do heavy work or

engage in recreation. This was an area in which the amputee seemed to be fairly well satisfied, except as brought out below.

Myo-electric hands

There was a distinct feeling among World War II veterans that they had been passed over by the myo-electric stage. Many had apparently been told that they were too old to adjust to myo-electric fittings. The majority of the replies stated "yes" to the question of whether they would like an opportunity to be fitted with a myo-electric hand.

Cosmesis

The replies on cosmesis (or lack of it) for hands contained comments such as "disgusting" and "lack of sensitivity". Surprisingly, many hand amputees appeared to have no knowledge of the cosmetic skins and stated they were wearing either brown or black leather gloves over their passive hands.

Wearing of prosthesis, above-elbow amputees

The rejection rate was predictably high. Some farsighted individuals (amputated one side only) suggested that they should get used to wearing a prosthesis in the event that they developed medical difficulties in their other arm, arising from strokes, arthritis, etc. The second part of this question indicated there was little knowledge of lighter prostheses now available through the use of modular designs.

Dreams

The question on dreams was thrown in only for general interest. The respondees seem to divide 50-50 as to whether they visualize themselves as amputees in their dreams or not.

Psychological effect

Perhaps surprisingly, a large number of war amputees describe their feelings about the loss of their limb in terms of being "grief stricken", "lost my best friend", "embarrassed", etc. It should be remembered that this survey asked for truthful answers. Psychological effect is perhaps an area which we tend to ignore as it could be interpreted as indicating a lack of machismo, etc. The Adolph Meyer school of psychiatric thought may be of interest on this subject should any one wish to develop it further, that is, depression can follow from a physical disorder such as amputation.

Sequelae

Most of the replies indicated consequential disabilities. Leg amputees; bad backs, arthritis in the remaining leg and foot. Arm amputees; cervical pain, headaches. Both; gastro-intestinal problems which were believed due to ingestion of drugs as well as "inner tension" associated with the continuing discomfort of amputation. The respondees were careful to suggest they were not trying to prove their case, but felt that more study should be done upon the medical after effects and side effects of amputation.

Recreational limbs

This question resulted in possibly the most significant response. There were requests for special legs for swimming, golfing, skiing, tennis, rowing and motor sports. The arm amputees were almost frightening in their requests for the development of special prostheses for fishing, playing baseball, cricket (for holding bats), golf, tennis and rowing.

Conclusion

It must be said that the information presented in this paper was not the subject of any strict statistical treatment. In this sense this is not a "scientific paper". This highlights the problem of communication in this field between the consumer on the one hand and the professionals involved on the other. However, it is essential that such communication be fostered if energies and resources are to be channelled in the most fruitful direction. It is hoped that against this background the views contained herein will prove useful, highlighting as they do the opinions of a substantial number of patients.

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Rehabilitation engineering as the crow flies

PART I—DEVELOPMENT OF THE BIOMECHANICS CLINIC TEAM

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Abstract

This series of five papers, three of which are presented here, provides an overview of rehabilitation engineering from the development of a clinic team through to problem-solving techniques. The first paper discusses the development of the biomechanics clinic team, identifies the differences in engineering and medical approaches to patient problems and proposes guidelines for successful teamwork. The second paper demonstrates that the five parameters of motion, force, neural function, shape and tissue quality are basic to information needs for biomechanical problem-solving. The third paper describes a framework for problem-solving that has been successfully employed for both device and process development. The fourth paper delineates the criteria and constraints that determine clinical viability of "products" in rehabilitation engineering and the last paper of the series outlines a very productive dynamic group problem-solving technique. The papers are intended to enhance communications and demonstrate a more disciplined approach to rehabilitation engineering. The remaining two papers will be published in a forthcoming issue of Prosthetics and Orthotics International.

The biomechanics clinic is the prime arena for rehabilitation engineering and hence factors which influence development and define functions of team members need to be considered. We have undergone the process of developing such a team at the Canadian Arthritis and Rheumatism Society in Vancouver, detecting in the process a number of factors which lead us to recommendations for others who may wish to develop such a team.

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The problems

It is the inclusion of engineers that creates both expectation and dismay among team members who are not really prepared for the dichotomy between the medical and engineering role.

The major differences are:

Medical people see the patient as a problem.

Engineers see the patient as an *example* of a problem.

The action period of engineers is long by medical time standards.

Medical people want an *immediate, unique and complete solution to a particular patient's problem*, while engineers want general solutions for populations. Once these differences are grasped, there is some hope that the team can work together toward real solutions. In the meanwhile, the pitfall for the engineers is that medical people may press for interim solutions to resolve this immediacy of need by having engineers adopt and modify existing solutions. Unless this serves as part of the educative process for the engineers that helps them to become familiar with existing solutions, it is a waste to have them do what prosthetists and orthotists are better trained to do. The engineering role is to define and solve problems. This is time consuming as it involves considerable personal education on the specific problem before anything useful can accrue.

The dichotomy eventually evaporates when good results are achieved through team action and when these results can be identified as a product of team action, that is, when a solution evolves which is clinically acceptable. For this to happen, there will be recognition that a given solution is transferable from the engineering to the regular treatment programme. New items can be transferred only when acceptable to the people who must use them.

Acceptability usually means that the solution fulfils such requirements as;

(a) improving the function of patients

(b) reducing work for the treatment staff

(c) having a cost benefit

(d) providing new insights.

Barriers to transfer need to be considered by the engineering people so that their solutions can be organized to offset these barriers.

The barriers are;

(a) new solutions make development of new skills necessary

(b) they cost money

(c) they make different demands on practitioner's time.

When these barriers are overcome by the benefits of either improved function, less work, lower costs, new insights or some worthwhile combination of these, then the new item will be accepted.

The solution and temptations to avoid

The team should be organized for mutual education. This can be achieved initially through involvement in modest practical research related to improving patient benefits through technology. Better use of what exists, trying new things (evaluation programme), literature reviews, using engineers in an advisory capacity at first, or using solutions they have already established competence in, are ways to initiate development. We have attempted to use and demonstrate positive problem-solving techniques, where negative feelings are reserved while team members strive to be supportive or to offer even better ideas as a solution is evolving. Members of the team will soon develop enough familiarity and confidence to cross each others professional boundaries under the influence of such positive feedback thus engendering the prospect for the overlapping of roles which exists in a mature team.

There is a temptation to get a "big gun" into the team during team development, and this can work well enough if he does not dominate. The truth is that local talent is too easy to undersell. The team can develop well through the mutual education that goes on spontaneously and formally in any community large enough to warrant a biomechanics clinical team. Academics appreciate the association with clinical research activities, especially when there is an education component and so here we use Master programmes to get the information we need for problem-solving and to encourage academic commitment. At the same time, we would like to see a portion of the other team mates' time earmarked for research on relevant aspects of clinical problems as a natural part of their service commitment. Academics, committed to science can also benefit from having clinical responsibilities when their professional area is relevant.

Another temptation is to believe that a sophisticated laboratory and equipment are basic requirements, this is sometimes fostered by people who are experienced in the biomechanics field because of their acquisition of skills in unison with the development of facilities in previous positions. The truth is that, for the engineers who are backed by academic personnel and their facilities, little is needed that cannot develop out of the sort of research that must be part of problem-solving in the clinic. What really is required is improvement of facilities, such as occupational and physical therapy, that deliver the services to the patient. Such improvements include instrumentation for measuring various functions (motion, shape, etc.) and equipment with which to make things, especially simple things that can be used to supplement existing aids and equipment. An example might be a vacuum former in an occupational therapy department. Approaching the facilities problem in this way has forced us as engineers to fraternize productively with both the academics and the treatment staff for mutual gain. As engineers, we have only office facilities and storage space. For everything else we depend on existing facilities tailored to other ends. You can imagine the benefits gained in terms of overheads, keeping machines busy or maintained, etc., but on the other hand there are the

demands made on us in order to maintain productive good will. Research is a good cement for all.

Consolidation

When seeding of the team through exploitation of what exists and what can be conveniently improved has reached a stage where demands on the team indicate it, then is the time to expand backup facilities to serve the treatment and research functions of the team. Thus, having reached close to that stage here, we would expect facilities which would allow us to make more complicated things of a one-off nature or to make pre-production runs which cannot be put into a manufacturer's hands and which are inappropriate in a university or other institutional facility such as a limb shop.

An inhibiting organizational fact is that biomechanics clinic teams are too strongly associated with research when in fact they should be identified with service at the interface between knowledge and ignorance. Besides the research and service function, their relationship to education is obvious. For the engineers, even more strongly identified as researchers, the big advantage is that they cross institutional and professional boundaries at will. Such mobility needs to be the right of all team members. Eventually, when the benefits that can derive from biomechanics clinic teams and the association with engineers are assured through the establishment of rehabilitation engineering, the aim should be to keep the engineers community and patient oriented and to keep access to technology open through a process of continuing education, a prolongation of post graduate studies.

Functions and responsibilities

In the day to day operation of the biomechanics team, among the influences on productivity are the willingness of those on the team to share functions, their flexibility in terms of time use, and their relationships with patients serving as test wearers or subjects. We set a morning aside for clinical activities, that is seeing patients, and followed up with a very flexible time allotment using "free" staff (usually the researchers) or treatment people with open time assignments.

On patients who are good representatives of the problem, the team will try out existing and new ideas in a mutually beneficial way. The purpose of this, besides improving a solution which is developing, is to uncover the prescription criteria which govern use of a particular solution at any stage. This is achieved by fitting patients who vary from ideal in ever increasing degrees of complexity to determine the boundaries beyond which the solution does not work. The patient on whom it does work defines the criteria for its use! This is an important function of the team. It may be evaluating the solutions of others as well as their own. The purpose is to have available for such a clinic a variety of solutions to a range of problems so that decisions can be made quickly and effectively to improve patient function and management.

Biomechanics clinic teams are responsible for developing prescription criteria for the devices they evaluate. When they have so established criteria for the clinical application of any device or procedure they are in a position to educate, field-test, and move on to other researches . . . their role is that of problem-solving. Others pick up where their functions are complete.

Summary

We estimate that a biomechanics team including a rehabilitation engineer can be supported by a population base of 200,000 or over, and that one engineer per 200,000 is a reasonable ratio.

The best setting is within a rehabilitation unit with occupational and physical therapy staff and associated social workers. The skills of these people will expand as they relate to engineers and to each other, each taking on some of the functions of the other. The skills of the engineers must be extended by further technical training as well as adopting the skills of others. Such administrative details as establishing engineering positions for rehabilitation will come in time.

The biomechanics clinic team needs to establish a position on the development of devices and procedures of potential economic value. The main purpose of the team is to get help to their patients and other considerations are secondary. The broader responsibility is to extend the use of good solutions as widely as possible. If this conflicts with economic interests, economic interests must yield.

PART II—INFORMATION NEEDS FOR BIOMECHANICAL PROBLEM-SOLVING

For rehabilitation engineers to be relevant beyond the ordinary in the clinic, they must aim to obtain hard data for use in problem-solving whenever possible. Some data can be found in scientific literature. Some must be found directly by measurements made on the patient.

When we measure for problem-solving in the clinic, we gain the advantage of information which is in a form easily grasped and which can be used to describe, compare and classify in universally useful terms. We mean by useful that the information be as exact as the end use requires. The basic aim is to use measurements to define the patient's existing level of function and to estimate his needs so that the gap can be narrowed through clinical action. Visualize a typical clinical situation in which a biomechanical approach to problem-solving is called for. We can easily recognize that the ability to move is a crucial factor to the patient; forces between body parts and between the body and the environment are also relevant. Neural function, the basis for control, is important. In order to do anything useful by means of external support of body parts, additional factors which are significant include the shape of body parts against which forces must be directed and the quality of the tissues which must bear them.

So, we recommend that rehabilitation engineers concentrate on measuring; *motion*, *force*, *neural function*, *shape* and *tissue quality*.

The objectives of making such measurements should be *clinical* and be intended to aid in *assessment*, defining *status*, identifying *changes*, classifying *disability*, providing *design data* and *comparing* results.

Such information will be used to aid in making *predictions*, giving *protection* and developing means for *improving function*.

Approach

We recommend that rehabilitation engineers approach clinical problems of a biomechanical nature with the view that the patient is central and that the measurements are incidental in the sense that their exactness is defined more by the results achieved for the patient than on their reproducability, exactness in detail, or how nearly they match ideals established by more exact scientific means. It is remarkable, for example, how much insight can be derived by nothing more complicated than comparing function on one side of the body to function on the other. We see *asymmetry* of gait as important for defining quality of function in prosthetic knee implants and have used this asymmetry to make predictions. We make this recommendation for a sort of opportunism in the use of measurements as a counter balance to the scientific obsession with exactness.

Measuring such quantities as motion, force, neural function, shape and tissue quality will then rest on the pragmatic premise that the quality need only serve the end. Often no more than go-no-go information is sufficient to aid in making an intelligent and useful clinical decision. For example, we note that people with prosthetic knees are maintaining their knees in a position of fixed flexion throughout stance phase. An obvious possibility is that they are splinting the knee with their muscles for some protective purpose. It would be very easy to demonstrate this with simple off-on muscle myography and then use biofeedback to aid them in judging the position of the knee as they stand on it.

Clinical viability

If immediate usefulness is the objective for data collection in the clinic, then some boundaries are placed on how data is processed. We recommend that data should be delivered while the patient is available, preferably within seconds or minutes, and that it be in a form which is easy to read. It can then be used for deciding right on the spot while attention on the person is keen, and all the other factors are in view. In our studies of motion we get a direct readout on a strip chart recorder. The records are considered at the time in some instances, and in others pondered over for the preparation of an analytical report. Records of motion, for example, are easy enough to make some sense of when the discrepancies are gross; the eye alone is also a good instrument at such times. The difference lies in the capacity to remember for purposes of later comparisons. We find that there *are* obvious things only the very best eye will detect but some which the eye may not detect yet which the instrument will easily find. As the patient is more important than the

measurement or the system of measurement, so the measurement is more important than the reference system when we speak clinically! We realize that this may not suit the purist, but in fact there are many measurements that can be made which are strictly related to the patient at an instant in time and which are not considered as fodder for future analysis or statistical collections. Just recognizing a pattern can be clinically useful. Just knowing that the force through a cane is under or over a given factor can be useful. What we look for in any information collection process is enough insight to make the intuitive mind click for a better clinical result. If such inspiration can be derived from *relative* information it would be folly to be pure.

Equipment

Of course, the question of equipment immediately arises. We see a number of high quality, technology-intense laboratories studying gait, for example, and we ponder on how the products of such laboratories can be brought directly into the clinic. If we allowed the demand for measurement to be generated out of patient needs we would see something quite different developing for clinical use. First of all, measuring equipment would be *portable* and have different modular elements (especially transducers) to permit varied, direct and convenient use in the clinic. Equipment would evolve which ensured that at every stage in development something of clinical relevance was gained. There might be motion measuring equipment that quantified only a small amount of information at a time, to be assembled as needed. Biofeedback equipment could be refined into force measuring systems in response to obvious clinical needs.

The temptation is to embark on a programme of developing equipment to carry out such clinical measurements, thumbing through the myriad catalogues of electronic components and handbooks while keeping in mind the last scientific advance. Better to check the equipment that exists first and proceed through a course of minimal modification toward the end that you *have* rather than *make* a measurement system. When you *must* (as you well may) have equipment that is different and new then the kind of product wanted needs to be thoroughly established before design and development work is considered. Easily 80 per cent of the costs before usefulness are in such developments, only a minor part being costs of defining a solution. Any attempt to upgrade equipment should relate to ease of operation, convenience to the patient and delivery of information of *more use* in the clinic. It is worth remembering that while we may wish to replace the medical professionals with instruments there is no chance that we will, and such information as can be derived from measurements will only be used if it speeds up clinical processes, cuts costs, improves results for patients and provides new insights. The information provided through measurements is only part of the information being used to make judgements. Clinicians will establish the criteria for the design of special equipment which they will ultimately use or abandon. Their criteria will relate to the clinical function. As an example, we know that a single curve rather than a stream of similar curves is favoured. This could lead us to microprocessing or some different way of displaying data. But ultimately it is for the clinicians to choose.

That aspect of equipment development which has no clinical relevance—the hardware aspect—is best kept right out of the clinical environment. If fundamental design factors are involved academic people should take them on. If they involve adaptations of equipment and techniques already in use, industry should deal with them.

Use of resources

No one or half dozen rehabilitation engineers who are trying to solve clinical problems can cope with doing everything that arises as attempts are made to use objective means to supplement subjective findings in problem-solving. It is better that there is co-operation between various laboratories and clinic teams so that sharing evolves. It is quite feasible for one group to become masters of motion measurement for clinical service, and another, through an interest in biofeedback, to become expert in force equipment use, or on matters of tissue quality or shape. Highly developed expertise in a limited area by specific individuals or groups can open the way for other groups to adopt the application of techniques and equipment which the more experienced recommend. We recommend a modular approach to the assembly of skills as well as equipment and procedures. If such a mood were created or existed, specified laboratories would take

responsibility for discrete parts of the whole process of using measurements in clinical processes until one day all would be able to use everything useful by this means, and therapists and doctors rather than engineers would be manning the pumps.

Well established laboratories designed to produce refined measurements would carry out work which provided statistical information and established standards. They would take data from clinics for analysis against standard information to give back results for use in the clinic and generally carry out what is accepted as scientific enquiry. They could also use their data bank information for modelling systems so that comparisons could be made between such models and patients for postulation of possible solutions.

People

Rehabilitation engineers should not be so equipment and process conscious as to forget the value of training and experience. Collectively we know very much more than any one of us. Part of this is training, part perception, and part experience of practice. All of this needs to be organized into a brain-bank which ensures that people with well defined problems can be matched as nearly as possible with people who possess solutions. This also means that there should be geographic fluidity so that people can move around and be shared without jealousy.

While we recommend that rehabilitation engineers become involved and informed in matters of measurement, and specifically in measuring motion, force, neural function, shape and the quality of tissues, we realize that they will also get involved in true research because they are involved in design, development and clinical measurements, but hopefully, they will resist the temptation to escape into purely scientific studies until they have ceased to identify themselves as rehabilitation engineers.

PART III—A FRAMEWORK FOR PROBLEM-SOLVING

Our interest in modern problem-solving techniques led us to examine our successful projects for a logical sequence. From this we derived the problem-solving framework shown below.

Problem-solving framework

Stage 1—developing a hypothesis;

phase i —problem identification
phase ii —problem definition
phase iii—solution generation
phase iv—solution selection
phase v —modelling.

Check against criteria for this stage. Abandon, recycle *or* go on to *Stage 2*.

Stage 2—testing the hypothesis;

phase vi —clinical prototype fabrication
phase vii —prototype development
phase viii—prototype evaluation
phase ix —test batch production.

Check against clinical criteria. Abandon, recycle *or* go on to *Stage 3*.

Stage 3—solution transfer;

phase x —field test quantity production
phase xi —field testing, functional refinements
phase xii —dissemination of information
phase xiii—supply development.

Continuing improvements through user-maker dialogue.

The three main stages through which our successful projects seemed to pass were (a) the assembly of information which would permit us to form a hypothesis; (b) collection of information which would establish the merit of the hypothesis; and (c) transferring the solution to users and producers.

We consider this framework a good model for others in rehabilitation engineering to adopt. It will enhance communications within and between groups by referring to the stage or phase of a project in a way that avoids confusion as to what is happening. This would be particularly useful to people who are working

on segments of a general problem which must eventually generate a total solution. Different workers could be paced to meet at a particular point in time and so be organized to optimize results. Granting agencies would find such a framework useful. They could fund to the level of each main stage, abandoning projects or continuing as results indicated, with the degree of risk well defined for each stage. Reporting would include reference to the stage and phase. The framework could also be usefully employed in support of grant applications. People within a group would have a clearer picture of project progress. This leads to other possibilities. When granting agencies or institutions have "skills" inventories combined with such a format as this framework, it would be possible to see that a project was getting beyond a group which had been handling it. Transfer to others more suitably organized for more advanced stages or phases could then be logically proposed and contracts let. This prospect of transferring projects to the best suited laboratory or workers suggests that grant applications themselves should be accorded a special status for which applicants could be rewarded, not necessarily by receiving it themselves, but by receiving funds for grant application development. When work on problems is considered in these terms it is quite apparent that different people suit different stages and phases. Rehabilitation engineering can be more fruitful by matching people and expertise to the most suitable phases.

It may be tempting to consider this as nothing new. We counter by noting confusion experienced in some of our own projects and in projects of others. Such an organizational form for problem-solving could start us on a path of enhanced communications without imposing a straightjacket. The outcome could be improved sharing of the work of rehabilitation engineering for more efficient delivery of solutions.

To clearly describe the problem-solving framework, we will work through the phases by example.

Stage 1—developing a hypothesis

Phase I—problem identification: We were told that lifting heavy flaccid children was a major problem and that a *lifting device* was needed. We looked at such children and watched them being handled by staff and parents; in and out of cars, on to work surfaces, into seats, beds, toilets, etc. We examined lifts and various other multipurpose devices. This involved about three months of strenuous effort and included development of many criteria against which we could evaluate some existing solutions. By the end of this exploratory period we felt confident enough to make a definition of the problem.

Phase II—problem definition: The result was to change the environment so that lifting was less necessary. We could see that by reorganizing our approach from "lifting" to "not lifting" we could solve the problem better.

More intense effort went into looking at what others had done to improve the environment as well as to lift such patients until we could, by checking these solutions against the criteria which were developing, see the advantages and shortcomings. It is important to do this because, not infrequently, something quite different emerges as a key factor. For example, it may be prohibitively expensive to "change the environment" to solve the lifting problem.

Phase III—solution generation: On another project, Fracture Bracing, we embarked on generation of solutions which involved going far outside the field of normal rehabilitation engineering. We looked at birds, snakes, geological processes, and a host of other things in nature to find a "bionic analogy" to our problem. The outcome was a variety of proposals for solving the problem that looked very different from what we had seen. The process of "measuring" with established criteria and defining the boundaries of possibilities or constraints ensured that any solution which rated high could be adopted. This solution could be something entirely new or something already in existence. When existing solutions are pertinent the rehabilitation engineer should be encouraged to adopt them. It is not necessary to reinvent the wheel.

Phase IV—solution selection: The solution that scores highest is the one to select. There is no need for procrastination at this point ("it will cost too much", "it will be too heavy", "etc.") because all the objections are accounted for in the criteria and constraints! This includes a statement on costs and time and skills needed to raise it to succeeding phases. Thus, with a *solution selected* the evidence to support continuing to phase V will be included.

Phase V—modelling: Modelling is intended to be a super communication. There is more of "how it works" than "use it on a patient" in this phase, and there may well be more than one model because even though the solution has been stated in general terms, its eventual form is far from established. In the case of the CARS-UBC Brace for example, there were sketches, cardboard models and more substantial models built over plaster models of legs as well as analogies formed to illustrate to other team members what was proposed. We even did "hands on" force demonstrations on each other and on patients. New criteria evolved out of this, some of which anticipated succeeding phases. Eventually, there was a demand to proceed to trials on patients (rather than to recycle through previous phases or abandon). The demand could as well have been to adopt an existing solution if it better met the criteria so far developed. Such an alternative solution would just as readily be cycled into the next stage.

Stage 2—testing the hypothesis

We had hypothesized that the knee brace for arthritics with medial or lateral instability should be an intermittent force application device which supports when the knee is extended and relaxes during flexion. With the experience of modelling, development of a clinical prototype is conceivable.

Phase VI—clinical prototype fabrication: A number of these can be made, each intended for a patient carefully selected to avoid extraneous factors. Thus for the knee brace, people with subluxation or flexion-extension instabilities were initially avoided. The braces were made on plaster cast models, with each prototype a variant on the theme in all but functional terms.

In another project, the Joint Motion Measuring System, reproducibility of curves was initially checked out on a joint motion simulator, but eventually came to be used on patients. This was a variation with the same aim, to develop confidence in those who apply it and in those who are subjects.

The emphasis in terms of team involvement is that non-engineering team members gradually shift from advisory to active roles as problem-solving reaches the stage of involving patients. Later, the emphasis shifts further as these members take over and the engineering members become advisory.

Phase VII—prototype development: This is very much the engineers' job but the other team members are getting involved via patient contact and through this are revising and adding criteria as they evaluate it. If the solution is fruitful, the engineers and supporting technologists are soon supplying devices in a fairly routine way to keep up with developing demand.

Phase VIII—prototype evaluation: In typical formal evaluation programmes everything is held constant as a device is tested. This is not the case in this phase. Rather, this is the time when engineers and other team members are on their knees around the patients. A great deal of pressure is felt at this phase (not only on the knees) because if the solution is good, it must be delivered in ever increasing quantity. This pressure is in itself a positive factor in design. It led us to mass production techniques, this being the only way we could cope. In making the shift from individual or custom fabrication to standardized fabrication, other improvements in design were adopted leading directly into the next phase.

Phase IX—test batch production: Just as first clinical trials represent the moment of truth in the clinic, test batch production is another moment of truth for potential production. The producer can inject new criteria into the design process to make the item producable and marketable. At the same time, if success is assured in the clinic, introduction of the device to a manufacturer relieves some of the pressure on designers and sets the scene for the final stage.

Stage 3—solution transfer

Barring obstacles that preclude further development, this stage is entered with the objectives of getting the process or device out of the hands of the engineers (as designers) and into the stream of clinical use. This involves essentially two things: (1) to ensure production; and (2) to ensure a market through education and the subsequent development of confidence among patients and treatment staff. There is no better way to prime the manufacturing or clinical pump than through field-test programmes. This time, the evaluation process is more formal because it is further from home and from the help of those who know most about it.

Phase X—field-test quantity production: This phase puts designers and the producer in close touch until they both deal confidently with the product. Emphasis will shift from the manufacturer advising to the engineers advising until the *transfer* is complete.

Phase XI—field-testing and functional refinements: At this phase, the designers advise on how the produced item can better serve its purpose as information arises out of field testing. There is now a three or four way stream of communication as the manufacturer faces the item as a product, the designers face users on issues of function and users face patients on issues of competence and function. As competence evolves at the clinical level through field testing, there can begin to develop a direct relationship between the users and producers to permit withdrawal of the engineers after successful transfer.

The dilemma designers face is when to let go. There is a reluctance to stay involved (tiring), especially if there is clearly success, but also some reluctance to make a clean break (anxiety —pride). This can be resolved by documenting and publishing results to aid in fostering general use of the system which has been developed.

Phase XII—dissemination of information: This takes many forms. Information is given in articles, through injection of new ideas and principles into the educational process, and so on. The manufacturer serves his interest by making his product known. Dialogue is generated between producer and user on an ever increasing basis. Enlarging programmes of field-testing may be necessary in some cases to improve the manufacturer's prospects for maintaining viability in the early stages and to develop familiarity among users and patients.

Phase XIII—supply development: The best compliment a design group can experience is demand for what has been designed. This is not necessarily a measure of merit however, nor is merit an assurance that this can happen. There will be of necessity a phase during which supply development may have to be promoted. This requires that the developers co-operate with others in furnishing information related to development of supply. Lecturing at conventions, writing articles, assisting on an advisory basis on demand are among ways supply development can be helped. Increasing geographic scope of field-testing in an outward wave from the design group using manufacturers and users as those who carry the message is warranted to keep a good idea from dying.

Conclusion

The problem-solving framework discussed is a viable way to organize solving any problem whether it is a process, a device or a programme. The terms may change slightly or be understood differently, but the process of evolution will endure. As an exercise, it was applied to the problem of alcoholism and absenteeism from work to see if it would hold up and it did. Within the phases of the framework are areas that require further consideration such as development of criteria for design in rehabilitation and more disciplined approaches to problem-solving but these will be discussed separately at a later date.

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A statewide amputee rehabilitation programme*

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Abstract

Patients are referred to the amputee clinic at the Medical College of Georgia from all areas of the State of Georgia. Most referrals are made a considerable time after amputation and most patients live from 50 to 250 miles from the amputee clinic. A special programme was designed to alleviate some of the problems incurred by the distance and the delayed referral. Physical therapists, prosthetists, social workers, the vocational counsellor and the orthopaedic surgeon co-operate to provide maximum care on the day of the amputee clinic. The co-operative efforts of all members of the team and the ability to plan ahead for optimum rehabilitation maximize the use of patients' time and his rehabilitation level.

The team approach to the management of the amputee is generally accepted as the optimum approach. It is also recognized that, ideally, the amputee should be referred to the rehabilitation team even prior to surgery. During this period the patient can be prepared both physically and psychologically for the adjustments he will have to make. If pre-surgery referral is not possible then post-surgical management should be initiated as soon after surgery as possible whether the patient was fitted with a rigid dressing or not. Early initiation of restorative programmes increases the likelihood that the patient will become a functional prosthetic wearer. This is particularly true among the elderly who require comprehensive therapeutic programmes to overcome the general debility which often occurs after a long period of incapacitating circulatory problems.

Unfortunately, situational factors such as time and distance often interfere with the ideal rehabilitation programme. A creative approach to prosthetic management may limit the negative influence of such factors and provide the patient with the best available rehabilitation programme. Such a programme was developed at the Eugene Talmadge Memorial Hospital of the Medical College of Georgia in Augusta, Georgia. The hospital is the teaching hospital of the Medical College of Georgia and the referral hospital for the State of Georgia.

Patients are referred to the amputee clinic in Augusta from all over the state, sometimes as far as three hundred miles. Some but not all have been amputated at the Medical College of Georgia. In some instances referral may be soon after surgery but often referral is delayed for many months. Both adults and children are seen in the clinic but the majority of patients are elderly because the leading cause of amputation is vascular disease. The majority of patients present multiple physical and social problems.

Amputee clinic is held on a bimonthly basis and the prosthetic rehabilitation team includes the clinic chief who is an orthopaedic surgeon, physical therapists, prosthetists from two local prosthetic facilities, occupational therapists, social workers, and a vocational counsellor. Also available on a call basis are a dietician and a nurse from the peripheral vascular disease service.

The major problems faced in rendering optimum service include:

1. The delay in patient referral from private physicians throughout the state. Patients are frequently not referred for many months after surgery.
2. The distance the patient lives from the clinic. The majority of the patients live in rural areas from fifty to two hundred and fifty miles from the hospital. Most are in the lower socio-economic strata and must depend

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on others for transportation to and from the hospital.

3. The lack of a local in-patient rehabilitation facility where patients can stay during their rehabilitation programme. Insurance and other third party payers usually will not finance hospitalization for rehabilitation care and most of our patients cannot afford to stay in a hotel or motel while undergoing prosthetic care.

The programme that was developed to try and alleviate some of these problems is designed to maximize the patient's time at the hospital. It requires the co-operation of all members of the prosthetic team and the ability to plan ahead. The physical therapy department co-ordinates the activities of the team to enhance effectiveness.

Amputee clinics are held in the afternoon and all patients scheduled to be seen that day are requested to report first thing in the morning to the screening evaluation clinic held by the physical and occupational therapists. All patients scheduled for the afternoon clinic are first seen in the morning clinic.

New patients on initial referral undergo complete evaluation to determine current physical and socio-economic status and needs. The physical therapy evaluation includes determination of muscle strength, range of motion, stump circumference, self-care capabilities, home situation and general condition. If the patient is diabetic a dietician is called to review his diet.

The social worker is contacted to help in determining financial status and to make plans for payment of prosthetic device, continued therapy and prosthetic training. The social worker will also assist the patient in obtaining appliances such as wheelchairs or meeting other social needs. If the patient is of an appropriate age the vocational counsellor may also be called that morning for an initial interview. The vocational counsellor provides liaison for clients of counsellors in remote areas and makes referrals to counsellors in the patient's home county. The social worker and vocational counsellor work closely together to help the patient meet his socio-economic needs.

If there is time during the morning session the patient will be taught proper stump bandaging, conditioning exercises and whatever transfer or ambulatory activities may be necessary. Depending on the patient's status, a determination is made if further therapy is indicated to maximize self-care at home. If daily pre-prosthetic treatment is indicated then the social worker may help the patient make arrangements for transportation to and from the department each day or for temporary living accommodation in Augusta. Sometimes the patient can be referred for pre-prosthetic treatment to a clinic or hospital closer to his home. The social worker and physical therapist work together with the patient to make that decision.

When the patient is seen by the total clinic team in the afternoon the physician has the benefit of the evaluation and a tentative rehabilitation plan. The physician reviews the data and makes final recommendations. If the patient is ready for prosthetic fitting, or if a temporary prostheses is prescribed, the initial measurements can be taken later that day at the prosthetic facility.

Prosthetists from the two facilities in Augusta work very closely and in co-operation with the rest of the team. All new limbs are checked out on the alignment instrument and the patient goes through the initial stages of gait training before the limb is finished. The prosthetist usually schedules the final fitting on a clinic day; he then sends the patient to the therapist for check-out that same morning. The open exchange of information and mutual respect between the prosthetists and the physical and occupational therapists make for co-operative activities and effective patient management. Both prosthetic facilities are within two blocks of the hospital so that, if a problem develops during the check-out, the therapist can contact the prosthetist and necessary adjustments can be made. The physical and occupational therapists involved in the prosthetic rehabilitation programme are competent to make minor alignment adjustments themselves.

The initial check-out for a new lower limb amputee is done only to determine if the socket fit is adequate to initiate gait training. The check-out is completed and final alignment is determined when the amputee has developed an adequate gait.

As soon as a prosthesis is prescribed, the social worker begins to help the patient plan for living accommodation during gait training. If

the patient lives within commuting distance only transportation arrangements need to be made. If the patient lives too far to commute, then the social worker tries to find a boarding house in the community where the patient can live during gait training. While there is one boarding house in the immediate vicinity, the patient must be independent in self-care to stay there. Sometimes a relative or friend can be found in the community but the problem of finding appropriate temporary living accommodation for our patients remains as one of the most persistent problems. Once the patient has been situated in the boarding house, the University's Public Safety department will provide transportation to and from the hospital and the prosthetic shop.

Prosthetic problems that arise during gait training are quickly resolved between the therapist and prosthetist. The ready availability of the clinic chief for more major problems also enhances the total programme. Once the patient has attained a satisfactory prosthetic function, he is again checked by the clinic team and the limb is finished.

During the time it takes to finish the limb the patient returns to his home. He comes back for the next clinic and may again undergo a few days of training to make sure he has retained his skill in the use of the appliance. Following initial discharge from the treatment the patient is expected to return for his first recheck in four to eight weeks. He is maintained on a regular review programme until the stump has stabilized.

No patient is ever discharged from the clinic. Once the stump has stabilized he is placed on a yearly re-evaluation. When the patient returns he undergoes a complete evaluation to determine his general condition, his physical status, his level of prosthetic adjustment and use and the condition of the prosthesis. Necessary prosthetic adjustments and repairs are made during this visit to the extent possible. Minor prosthetic repairs can be made in the morning prior to the afternoon clinic if payment is not a problem. Close co-operation between all members of the prosthetic team makes this possible.

Prior to the onset of the programme the clinic chief, physical therapists and prosthetists reviewed the types of problems that could be handled directly between physical and occupational therapists and prosthetists without first being evaluated by the physician. Routine repairs and upkeep fall into this category but if there is a question about the best course of action or if a new socket is indicated then the decision is delayed until the patient has been seen by the total team in the afternoon. The ability to tighten joints, replace worn leather, replace broken straps or broken feet without waiting for the afternoon clinic has greatly enhanced the use of the patient's time. Sometimes the social worker or the vocational counsellor will assist with a financial problem to further expedite repairs or maintenance of appliances.

Conclusion

This has been a brief description of a system that was devised to improve the quality and quantity of patient services and limit the number of trips a patient has to make to and from the prosthetic clinic. While it is not ideal and there are still problems to be resolved, the system does maximize the patient's time in Augusta through the co-operative efforts of all members of the team. The system is based on mutual respect, the ability of each health professional to work with other health care providers in the patient's best interest, the ability of one service to function as co-ordinator and of the other services to accept that role, and the ability to plan ahead and anticipate needs. The system worked so well in one hospital that it has been initiated in another hospital serviced by the clinic chief.

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Problems in the rehabilitation of the physically disabled in rural areas of India*

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Abstract

Some 550 disabled patients were examined by a rehabilitation team by organizing a rural camp at Meerut. This rehabilitation team consisted of orthopaedic surgeons, doctors, a prosthetist, an orthotist, a medical social worker and other skilled workers, Out of the 550 disabled patients, 271 were amputees, and 184 cases had poliomyelitis. Males predominated by 4:1. Disability was most common up to the age of 30 years. Of the 271 amputees, 146 were of upper limb while 125 were of lower limb. Only 86 lower limb amputees were suitable for fitting a prosthesis, while 39 others needed surgery or physiotherapy. Only 87 of the 184 polio cases were found suitable for appliances, the remainder needing surgery or physiotherapy.

Ways of reducing the numbers of disabled were examined and improved rehabilitation procedures suggested.

Introduction

It has been observed that although the percentage of disabled people in our district of India was quite high, their attendance at our city-based comprehensive rehabilitation centre was comparatively poor. The disabled residing in rural areas were not utilizing the services available due to various reasons such as ignorance of the available facilities, socio-economic causes, fears of surgery and city life, and lack of proper transportation facilities.

It was therefore thought that keeping our personnel in the bigger cities with adequate rehabilitation services would not help the masses residing in rural areas. The ultimate goal of providing modern rehabilitation services to the disabled would not be complete unless we ourselves moved to help the rural population. With this in mind a camp was organized in the rural area of Meerut 60 km from New Delhi, the capital of India.

A rehabilitation team comprising two orthopaedic surgeons, three resident doctors, an orthotist, a prosthetist, a leather worker, a medical social worker and three artisans, attended the camp. The team was equipped to fit temporary artificial limbs and to measure the patients for prosthetic and orthotic appliances. The funds for the camp were provided by philanthropic persons. Before the camp was set up it was publicised, patients were registered, and they were given appointments for their clinical examination.

A pro forma was used for assessing the disability and all the patients were screened by the rehabilitation team. The measurements of patients who required artificial limbs and orthotic appliances were taken. A few of the patients were also provided with temporary artificial limbs for immediate walking.

Observations

The response of the rural population was very encouraging and a total of 550 patients attended the camp. It was found that 386 patients were below the age of thirty years and males outnumbered females by 4:1. In males the numbers of disabled were at a peak between 11 and 30 years of age, while in females the peak incidence was up to the age of ten years of age (Table 1).

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TABLE I

Breakdown of patients according to age and sex.

AGE (years)	*MALE*	*FEMALE*
0–10	77	62
11–20	100	17
21–30	110	20
31–40	42	6
41–50	50	13
51–60	28	5
61 and above	17	3
TOTAL	424	126

It was found that 49·27 per cent of the disabled patients had amputations, 33·45 per cent had poliomyelitis, 8·18 per cent had cerebral palsy and hemiplegia, 1·09 per cent had degenerative conditions, 0·90 per cent had congenital anomalies, and 7·09 per cent had other causes (Table 2).

TABLE 2

Incidence of Disabilities

TYPE OF CASE	*No. OF CASES*	*PERCENTAGE*
Amputees	271	49·3
Lower limb	125	46·1
Above knee	42	33·6
Below knee	70	56·0
Upper limb	146	53·8
Above elbow	61	41·7
Below elbow	69	47·2
Poliomyelitis	184	33·5
Cerebral palsy and hemiplegia	45	8·1
Miscellaneous	50	9·1

Of the 271 amputations 125 were of the lower limbs and 146 of the upper limbs. Of the 125 lower limb amputees, only 86 stumps were suitable for fitting with a prosthesis. Surgery or physiotherapy was needed by the remaining cases. In 54 cases, a temporary artificial limb was fitted immediately (Table 3).

TABLE 3

Lower limb amputees

Stump fit for prosthesis	*Surgery*	*Physiotherapy*	*Total*
86	26	13	125

Of the 184 patients with post-poliomyelitis disability, 87 were capable of being fitted with orthotic appliances, and the remainder were advised to have surgery or physiotherapy before being fitted with appliances (Table 4).

TABLE 4

Poliomyelitis

Patients suitable for orthosis	*Surgery*	*Physiotherapy*	*Total*
87	76	21	84

Discussion

It was observed that the majority of disabilities were either amputations or due to poliomyelitis. Amputations of the upper limb were more frequent than those of the lower limb. This may be attributed to modern methods in agriculture and other agricultural-based cottage industries. In the lower limb, train and motor car accidents were the main factors leading to amputation. In the study, very few cases of amputation were due to tumour or vascular impairment.

In the present society in India females still remain confined to the home, while males are more exposed to the external environment which may be the reason for their greater incidence of disability. Many of the amputees were neglected for as long as thirty-five years and, in many of the cases, revision of the stump was also required as bony projections, flabby musculature, contractures and sinuses were common.

Close questioning by the medical social worker revealed many reasons for the patients not attending a city-based rehabilitation centre. Amongst them were lack of knowledge of the existence of a rehabilitation centre, socio-economic reasons, fear of city life, and lack of transport.

These observations have led us to believe that problems of the disabled residing in rural areas of our country are quite different from those of the urban areas. Some 80 per cent of our population reside in rural areas and serious thought must be given to their adequate rehabilitation.

Several improvements could be considered:

1. It can be made known through education and publicity that the disabled can be rehabilitated and can once more be independent and earning members of society.
2. There should be more emphasis on the prevention of disabilities. Oral vaccine campaigns could prevent poliomyelitis. Road safety campaigns could reduce car accidents and similar campaigns could be aimed at train accidents and cottage industry accidents.
3. Early management of the disabled should be encouraged as it would result in better rehabilitation as well as helping to prevent crippling complications.

4. It was also observed that the conventional type of artificial limb did not suit the amputees from the villages. They needed an artificial limb which would permit them to walk bare-footed, allow them to squat and which would also permit them to sit in a cross-legged position. In addition these limbs should be economic, strong, simple, and easily repaired.
5. Immediate fitting of temporary artificial limbs to these amputees in their villages, while they awaited their permanent artificial limb, would help tremendously in boosting their morale as well as resulting in early gait training and improvement in muscle power.

These improvements could be achieved by a three tier system of medical rehabilitation services:

a. At village level.
b. At city level.
c. At Medical College level.

In addition there should be some model comprehensive centres which would conduct teaching, training and research programmes.

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Moulded supportive seating for the disabled*

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Abstract

In severe cases of physical disability intimate supportive seating may be required to provide maximum comfort, a good position for functional activities, improved respiration, relief of localized pressure, control of spasm, protection, or improved management. A service for providing such seating has been developed at Chailey Heritage. The seat is vacuum-formed from thermoplastic materials, having a soft non-absorbent foam for the liner and a hard semi-rigid outer shell. A mould is obtained by casting the patient using the vacuum consolidation technique and by recording the resulting impression using plaster-of-Paris. Nearly 200 seats have been made using the technique with a high rate of success.

The importance of seating

Good seating contributes significantly to enjoyment and functional daily living for both the disabled and the able bodied. Most people spend several hours each day sitting, whether for eating meals, watching television or as part of their jobs. For the disabled the period may begin as soon as they are dressed in the morning and continue late into the evening, a period of perhaps 12-16 hours.

Despite this long and intimate contact people frequently accept very poor quality seating. Observations once made in a furniture store revealed that, on average, people spend less than one minute sitting in a chair to test it for suitability before making a purchase. All too often a similar uncritical approach is applied to the disabled by those responsible for specifying a particular seating arrangement.

What is the purpose of a seat?

Normally a seat can be specified from two considerations; firstly its function and secondly its relationship to the body tissues and anatomy. Functionally, the specification is usually clear, alternatives being for such purposes as relaxation, manual tasks, vehicle control, and so on. The critical features in a seat's relationship to the body are, however, less clear and may include both comfort and stability of the total body as well as distribution of pressure, skeletal support and protection of individual parts. All contribute to an improved quality of life.

Partial solutions to satisfy these criteria may be sought through a variety of approaches (Chailey Heritage, 1977). The simplest is by using a cushion, or by interposing, say, a sheet of lambswool between the seat and the patient. These help to distribute pressure and reduce shear forces within the tissues. Lambswool is also able to absorb perspiration, thus increasing comfort. More support can be achieved by using wedge shaped cushions in standard sizes or shaped to suit the individual. If even further support is required it may be provided by using a modular system, such as that produced by Trefler *et al.* (1977), in which vacuum moulded components can be combined in a variety of ways to build up an appropriate seat. Finally, if none of these approaches prove satisfactory, an intimate personalized seat shell, such as that produced at Chailey Heritage (Fig. 1), must be used (Nelham, 1975). In such a shell the whole seat is accurately contoured to the individual patient in order to provide support, relief and protection, as appropriate, over the whole seating surface.

Whichever seating system is used, it is important that the user shifts or relieves his weight at regular intervals. In the cases where seat shells are used this may require the assistance of an attendant. For many patients complete removal from the seat shell is necessary, say, every two hours.

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Fig. 1. The Chailey moulded seat mounted in a wheelchair.

Performance specification

In considering the provision of a moulded seat, it is important to be mindful both of the positive features and also of the limitations of such a piece of equipment. The seat will satisfy only certain criteria and care must be exercised to ensure that the medical requirements and the patient's personal desires can be accommodated within these criteria. The features offered by the seat shell system at Chailey are as follows:

1. *Pressure distribution.* By being accurately moulded to the body, the seat provides support over a large area and localized pressures are significantly reduced.
2. *Postural support.* The intimacy of fit gives good postural support which may be extended to include the head. However, the seat will provide little or no correction and where significant correction is needed an orthotic or other approach must be used.
3. *Improved respiration.* Improved postural support frequently produces improved respiration. This is especially true with cases of muscular dystrophy.
4. *Spasm control.* By holding the patient in a good postural position, spasm can frequently be reduced, largely, it is felt, because the patient is able to relax in a good position.
5. *Protection.* The construction of the shell, which combines a washable foam liner with a semi-rigid backing, provides good protection for such conditions as osteogenesis imperfecta or severe kyphosis.
6. *Improved management.* For transport the seat shell provides excellent support and improves safety in both a wheelchair and a car or other motorized transport. Further, for general nursing management, the seat can be used in a variety of ways. Some have found that it is easier to carry children in the seat. Also on the toilet an unlined seat (with a suitable hole) allows a patient to be independent of constant supervision.
7. *Increased independence.* In addition to the example cited above, greater independence may be achieved for, say, self-propulsion of a wheelchair.

The clinic and clinical considerations

The team, which is led by a clinician, includes a physiotherapist and occupational therapist and appropriate members of the rehabilitation engineering staff. Not all members are always present since frequently a child is escorted by a therapist or mother, under which circumstances one of the therapists from the team may not be required.

In organizing the clinic, emphasis is placed on the need for sufficient time to be available. The type of case seen has frequently been referred for this variety of seat as a "last resort" and two to five hours in the clinic may be required to ensure that the final seat will prove satisfactory.

Experience at Chailey has centred round four disabilities: cerebral palsy, spina bifida, muscular dystrophy and osteogenesis imperfecta. Scoliosis has been present in a high proportion of these cases. The best that can be achieved for the treatment of the scoliosis is to afford support by careful moulding over the prominent rib curve and the contralateral pelvis in the hope of holding the scoliosis or retarding deterioration.

Certain principles and techniques related to specific disabilities have been developed. For cerebral palsy a comfortable posture is sought to encourage relaxation and the attitude of the seat may be determined by function. In spastic cases a pommel is often incorporated to maintain abduction of the hips, which may also be held in a small amount of flexion to encourage relaxation. This can, however, be contra-indicated on other grounds, for example urine drainage, and such flexion should be carefully assessed.

The muscular dystrophy case is often floppy and difficult to handle. All round support is indicated with careful moulding in the small of the back to encourage extension of the upper spine, thus facilitating respiration. A pommel may be desirable, but should be considered in conjunction with toilet requirements since such cases may need to use a urine bottle while seated.

Osteogenesis imperfecta is less common than the above groups. The main consideration is protection and for this purpose the seat is not so closely contoured to allow freedom of movement while reducing the risk of accidental impact.

Assessment and casting of patient

The most important stages in the provision of a seat are the assessment and casting procedures. In assessing the patient, both medical consideration, as above, and functional consideration are vital, such as the type of usage (for example, at home or at school), any particular situations of usage (such as, in a car), cosmesis, and so on. Once an assessment has been performed and indications for a seat agreed, the casting procedure is carried out. Clearly, this represents the foundation for ultimate success, and sufficient time must be allowed to achieve this.

The technique used is based on vacuum consolidation, which has been widely reported elsewhere (Fitzgerald *et al.*, 1965; Nichols *et al.*, 1971; Germans *et al.*, 1975). Modifications to the technique have been introduced and it is now based on purpose designed latex bags which are filled with small (2 mm diameter) expanded polystyrene beads. Each bag, or compartment, can be independently evacuated and sealed to maintain a posture. Thus, once an impression has been taken of the patient he can try out the attitude and other features of the seat over an extended period in order to ensure the seat shape will provide the support and permit functional activity according to the team's recommendations.

The impression is normally recorded using plaster-of-Paris bandage. This produces a cast which, with a minimal amount of rectification, is suitable as a mould for vacuum forming. Rectification is carried out in three steps. First, a "skirt" is added to the cast, when inverted, to ensure it sits firmly on the forming table. Second, a thin cream of liquid plaster is spread over the working surface of the cast to fill any small irregularities in the surface. Third, the cast is strengthened inside with a build-up of liquid plaster to a thickness of about 20 mm to prevent the cast collapsing under vacuum.

Manufacture of seat

The seat is manufactured using a vacuum-forming machine capable of moulding plastic up to 1 metre square. The maximum depth of draw is 700 mm and the heater layout allows both top and bottom heaters to be controlled in appropriate zones.

The materials used are 15 or 18 mm Evazote (Ethylene Vynyl Acetate foam) and 5.5 mm ABS (Acrylonitrile-Butadiene-Styrene). The Evazote is a soft closed-cell foam which provides a comfortable liner for the seat and is able to accommodate small irregularities, such as creases in clothing. The seat is constructed by first forming a layer of Evazote over the cast and then a layer of ABS over the Evazote.

In this condition the seat is prepared for a trial

Fig. 2. First fitting—trim-line and attitude lines are marked.

Fig. 3. A second layer of ABS is vacuum formed to locate the base plate and stiffen the seat.

fitting by roughly trimming the excess plastic. At the fitting stage the correct attitude for the final seat is recorded, a trim-line is marked and the positions of any harnessing identified (Fig. 2). This fitting is also used to check the detail of the fit and, if necessary, small changes can be made by using a hot-air gun. As soon as the seat has been trimmed the patient sits in the seat for several hours, if possible, to ensure correctness of fit and maximum comfort.

Once the team is satisfied that all is as required manufacture of the seat is completed. This involves locating a circular base on the shell and forming another layer of ABS over the whole seat (Fig. 3). When this layer has been trimmed to the final trim-line the seat is edged with a commercial edging strip and fitted with a suitable harness (Fig. 4).

Logistics of service

The provision of a seat of this type almost inevitably indicates that the patient is severely handicapped. Thus, speed of supply is considered extremely important to prevent deterioration of the individual's condition. Normally a child is seen three weeks after the initial referral is received and he is then admitted, with his parents or escort, to a self-catering bungalow. Assuming that no complications occur, it is possible to deliver the seat on the same day as the child is first assessed. However, for practical reasons, manufacture is more reliably carried out over a three-day period, and the service has been developed according to this pattern.

Fig. 4. An edging strip and harness are fitted to the final seat.

TABLE 1

Moulded Seat Survey—December 1976

Disability	*Number of patients*	*Medical officer opinion*		*Patient opinion*	
		Favourable	*Unfavourable*	*Favourable*	*Unfavourable*
Hypotonic cerebral palsy	3	2	0	3	0
Hypotonic cerebral palsy with athetosis	11	8	2	9	1
Cerebral palsy with contractures	9	7	1	5	0
Neurological	10	8	0	8	0
Spina bifida	9	6	2	6	1
Muscular dystrophy/atrophy	8	5	0	6	0
Orthopaedic	3	3	0	3	0
	53	39	5	40	2

Follow-up

Up to September, 1977, 180 seats had been produced, 108 through the Chailey clinic and 72 on casts produced at the Wolfson Centre in London. Regrettably it has not been possible to carry out the detailed follow-up which is clearly desirable. However, a questionnaire survey was carried out in December, 1976, of both the parents and the referring medical practitioner in 53 cases in order to obtain some impression of the seating system both in terms of its acceptability and to identify any clear disadvantages. There was an 80 per cent return and the answers are summarized in Table I. Clearly, these results lack the specificity which one would desire and it is intended to launch a follow-up early in 1978 by visiting children in the user situation. However, the results obtained from such an encouragingly high return do, at least, give reason for cautious optimism.

Refitting of the seats has to be performed to allow for growth and, on occasion, deterioration. The period between refits is, of course, extremely variable but tends to be 9-12 months.

Conclusion

The seating system described has been developed since 1973 and has had wide clinical exposure. The seats clearly perform a valuable function provided they are supplied to match the criteria stated. The success of the service centres around three features, namely the rapid supply, the method of manufacture and the close team work. For this success, the authors would like to record their gratitude to all who have been involved in the development, particularly to Jill Rockey, Kim Barton and Steve Mottram, without whose expertise the programme would not exist.

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The Orlau swivel walker

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Abstract

A new design of swivel walker for the severely disabled is described which has advantages over previous types. Increased rigidity improves the confidence of apprehensive patients, greater strength gives better reliability for those with good ambulation function and a novel construction gives more opportunity for independent transfer into and out of the orthosis, besides easing the burden of those caring for users of swivel walkers.

Introduction

Swivel walkers have long been established as a means of ambulation for severely disabled children (Motloch, 1966). In the 1960's Rose introduced a design (Fig. 1) for paraplegics which was described by Edbrooke (1970), and the D.H.S.S. published Notes for Guidance (1973), setting out the biomechanical and medical criteria to ensure that the relevant details were available to consultants wishing to prescribe the device. As a result of early experiences, Rose and Henshaw (1972 and 1973) described an updated design which, with modifications, has subsequently been adopted by the D.H.S.S. for prescription on the National Health Service in kit form.

All these devices greatly increased mobility for many patients, but proliferation showed that the early designs provide only limited independence and are not sufficiently stable for timid or apprehensive children. Other patients discovered that the structural strength was sufficient only for swivel walking ambulation and that more adventurous activities such as swing through gait with crutches or independent transfer carried the penalty of early structural failure.

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Fig. 1. Early design of swivel walker.

The attempts of many orthotic firms to produce swivel walkers to their own design confirmed the wisdom of the kit approach advocated by Rose and Henshaw. Many swivel walkers have been constructed with scant regard for the mechanical principles with consequently discouraging results. Other firms have produced very satisfactory swivel walkers but have found the individual approach increasingly costly.

A major use for swivel walkers is for paraplegic patients in special schools for the handicapped. It enables them to ambulate with their hands free so that many school activities are much easier to perform. Whilst many of these schools accepted the advantages of swivel walkers, all complained of the difficulty of transferring patients into and out of the orthosis.

In an attempt to limit the number of times a patient needed to transfer, designs began to incorporate hinges in the structure, ostensibly to permit patients to sit whilst wearing a swivel walker. Experience soon showed that patients were unable to use this facility independently and that physiotherapists were reluctant to operate the mechanism because of the stress on themselves and the patient. Patients using swivel walkers in the special schools were thus standing in the orthosis for most of the day, but were not complaining of tiredness from this activity. Since no musculature is involved in standing upright in an exo-skeleton of the type used, this was—on reflection—not surprising. Joints in swivel walkers were therefore not being used and had the disadvantage of decreasing the rigidity of the exo-skeleton.

Necessary improvements

A study of the problems of patients and physiotherapists in the special schools showed that the most important need was for independent transfer into and out of a swivel walker from a wheelchair in order to limit the physiotherapist's intervention and so increase the efficiency of the school's staff particularly at arrival and departure times. Some highly motivated patients had developed an ability to do this by first descending to the ground, rolling into the device whilst laid down and then turning over face down to raise themselves laboriously into a standing position by using a dining chair. This technique held the promise of increased independence for a few, but it was enormously energy consuming and not practical for the majority of swivel walker patients.

Other factors were seen to inhibit the independence of some patients. Many appeared apprehensive when standing in a swivel walker due to a lack of rigidity in the structure and were most reluctant to commence ambulation. On the other hand some highly motivated patients developed the ability to use swing through gait with crutches, but were severely hampered by the constant need for repair of a structure not designed for that activity.

It became increasingly obvious that for the full potential of swivel walkers to be realised improvements in four areas needed to be made:

1. Independent transfer.
2. Structural rigidity.
3. Strength.
4. Ease of construction.

Two modes of transfer had been evolved for patients using swivel walkers:

1. Transfer from standing to sitting and vice versa.
2. Transfer to and from the device.

The first type of transfer was never achieved independently and without joints at three levels this is unlikely to occur.

When a normal person sits (Fig. 2), they flex their hips, knees and ankles in order to maintain their centre of gravity over the support area of their feet until the last possible moment, when they rock backwards into the chair, probably under the control of their arms on the sides of the chair. Thus swivel walkers require joints at the level of the hips, knees and ankles if loss of balance is not to occur in the very early stages of descent (Fig. 3) and existing designs incorporated joints only at the level of hips and knees.

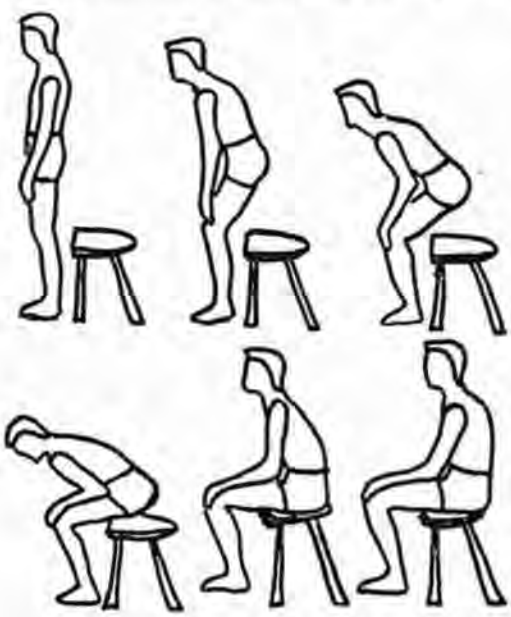

Fig. 2. Normal person sitting—flexing hips, knees and ankles.

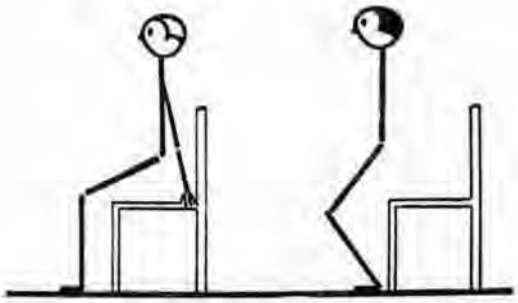

Fig. 3. Swivel walker patient sitting. Left, joints at hips and knees only, c.g. outside support area. Right, joints at hips, knees and ankles, c.g. maintained within support area.

No existing design gave the facility of easy independent transfer of the second type. Patients who could, found that it was time consuming because of all the buckles and straps and that it was expensive in energy. A typical time for transfer from wheelchair to orthosis for those who were capable was 4½ minutes, whilst the reverse process took approximately 1 minute. The two major tasks were securing all the buckles and raising themselves with the orthosis into the vertical position. The need to provide simple location devices for the four support areas was apparent, as was the need to eliminate raising the body from the ground.

A study of orthoses which demonstrated lack of rigidity causing patients to become apprehensive showed that it usually emanated from a combination of low structural stiffness in lateral and sagittal planes coupled with footplate bearing play and low footplate stiffness.

All existing designs of swivel walkers were ostensibly strong enough for their normal mode of operation, although most required adjustment and repair once or twice a year. None were capable of withstanding the rigours of swing through gait. The bearings were unable to cope with the extra bending moments applied by the impact loading on the front and back edges of the footplates and excessive play and bearing damage occurred very rapidly. Some structures failed under buckling and twisting from the additional loads imposed. Footplate covering materials were inadequate to cope with the extra abrasion at the front and rear and as a result the footplates themselves soon began to wear away. Swivel walkers used in this way required frequent attention to keep them operational.

Early designs of swivel walkers were manufactured individually for each patient. This had the advantage that idiosyncracies could easily be overcome and that a good fit should always be possible. However, the approach demanded a level of understanding and expertise of which only a few companies were capable. This made the provision of swivel walker kits an attractive proposition, especially if construction could be made simple.

Orlau swivel walker

The Orlau swivel walker (Fig. 4) provides an answer to the problems which occurred with the earlier designs. It consists of a rigid stable frame with improved lateral, sagittal and torsional rigidity, and presents an open aspect at the front for ease of transfer.

Fig. 4. The Orlau swivel walker.

The body stabilizing frame is constructed from a base plate of 10 swg half hard BS1470 aluminium sheet with pressed strengthening ribs, to which are bolted two sand cast side brackets of LM6M aluminium. Side members of 1″ × ½″ × ⅛″ (25 × 12 × 3 mm) HE30TF aluminium alloy channel section locate into the brackets and are bolted at one of two positions to permit some height adjustment. These side members are braced by ⅝″ (15 mm) O.D. × 16 swg HT19-WP aluminium alloy tubes which pick up on spigoted brackets machined from BS1476 EICM aluminium alloy which bolt to the rearward facing side of the channel section. The tube is located by a cross rivet through the bracket spigot and is bonded with Loctite 601 Superfast Retaining Compound. A depth suitable to clear

the patient's body is achieved by providing two bends in the aluminium alloy tube, each of 90 degrees.

The patient's knees are supported by hinged sections from each side of the orthosis, a development of the Parapodium (Motloch, 1971) as used on the Breda Splint (Orlau, 1976). These are located on the front facing side of the channel section. The hinged sections consist of BS1476 HE 30TF aluminium alloy strip $1\frac{3}{4}$" (44 mm) wide and $\frac{1}{8}$" (3 mm) thick to which are bonded 2" (50 mm) thick medium density Plastazote blocks. These are cut away to fit over the patient's knees and the two sections are locked together by means of an over centre toggle clamp, Protex 30593/02-502.

Chest fixation is achieved by means of a leather strap to which is attached a Plastazote pad, and this is anchored to one of the uprights by means of a clamp plate and screws. The second, shorter chest strap is similarly located to the second upright and the two straps are buckled together by means of a Britax car safety harness clip—the shorter strap being threaded through the tongue and the clip being riveted to the leather part of the chest pad.

Foot location is provided by a two hooped bar which is attached to an over centre tooling clamp, De Sta. Co. No. 202. This arrangement keeps the feet positioned with the heels adjacent to the bottom of the leg shute to maintain fore and aft location and also prevents the swivel walker from sliding off the body during swing through.

The footplates consist of a sand cast aluminium ribbed construction incorporating a machined bearing housing in which is fitted a FAG 3202 double row ball bearing located by an Anderton NAM 1300/137 circlip. This assembly is completed with Black 12 Iron Estasol bonded on to the bottom face with Evostik to give good grip combined with wear resistance for both normal swivel walking and swing through gait with crutches.

The footplates are attached to the baseplate with flanged cadmium plated M.S. bearing pins located into the inner race with an Anderton AM 1400/56 circlip. Four tapped holes in each flange pick up with four clearance holes in the base plate and take 5 mm diameter screws.

To give parallel footplate motion a spring loaded linkage connects the two footplates and a stop mechanism operating between the bearing pin flange and the footplate on each side permits a degree of overtravel to facilitate manoeuvrability.

Sacral fixation is provided by a 2 mm polypropylene band which is clamped to the side members with M5 × 12 mm countersunk screws and nuts. A series of holes permits limited adjustment so that an appropriate band depth can be easily achieved.

Figure 5 shows an exploded view of the Orlau swivel walker and indicates the relationship of all the components in the proposed kit.

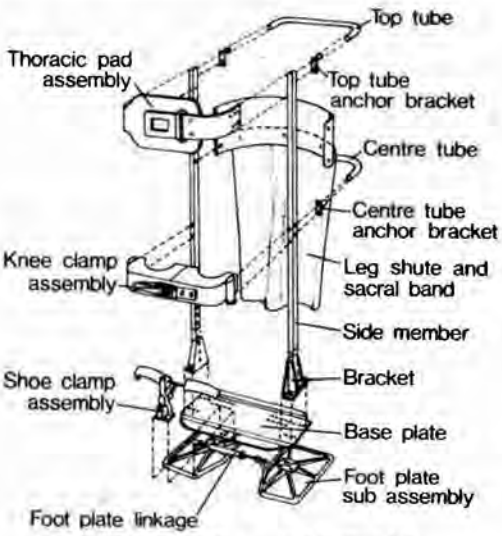

Fig. 5. The Orlau swivel walker kit.

In order to permit ease of transfer a moulded $1\frac{1}{2}$ mm thick polypropylene leg shute is provided which is riveted to the sacral band and screwed to the base plate. The shape has been developed so that the legs are guided into position as the patient slides down the shute. They do this from their wheelchair with the swivel walker top bracing tube lodged into the seat of the chair (Fig. 6a). Having lifted their legs into the shute, they control a sliding descent onto the base plate by grasping the side members (Fig. 6b). With their feet firmly held onto the base plate by gravity they are able to simply operate the footclamp lever, fasten the toggle clamp on the knee bar and clip the chest strap (Fig. 6c). By pushing up behind them on the wheelchair they rise to the standing position (Fig. 6d) and are quickly ready for swivel walker ambulation or swing through gait with crutches.

Fig. 6. Transfer into the Orlau swivel walker from a wheelchair.

Clinical trials

Five patients were selected for early clinical trials of the Orlau swivel walker. Each of these patients were experiencing problems with their existing swivel walker which the Orlau design was intended to overcome. All the patients were within the immediate care regime of Orlau and this enabled particular aspects of the design to be tested in a controlled manner. The physiotherapists responsible for the children were closely involved both in the monitoring and further development of the device.

The experience with each patient is reported below, and Table 1 shows both the details of the children concerned and, briefly, the changes brought about by the Orlau swivel walker.

Patient A

This patient, aged 10½, had been using a swivel walker from the age of 2½ years and had developed a degree of skill and endurance which gave him a high level of function.

Using crutches he was able to ambulate for distances up to half a mile with swing through gait. In addition he could transfer entirely independently into his swivel walker from a wheelchair and back again. This was achieved by sliding onto the floor from his wheelchair then, after preparing his swivel walker, rolling into it so that he was supine and then, by sitting up, securing the footstraps and knee bands. The chest strap was then buckled by lying down and the patient rolled into the prone position. A nearby dining room chair was then used to "climb" into the vertical position.

This procedure took approximately 4½ minutes, was extremely energy consuming and left the patient in a tired condition.

TABLE 1

REVIEW OF FIRST FIVE PATIENTS USING THE ORLAU SWIVEL WALKER

						AMBULATION		TRANSFER		REPAIRS & ADJUSTMENTS	
Patient	*Sex*	*Age (yrs.)*	*Weight (kg)*	*Height (m)*	*Level Lesion*	*Conventional Swivel Walker*	*Orlau Swivel Walker*	*Conventional Swivel Walker*	*Orlau Swivel Walker*	*Conventional Swivel Walker*	*Orlau Swivel Walker*
A	M	10½	44·54	1·244	L1	Swing through gait with crutches. Swivel walking 6·1m in 24 sec.	Swing through gait with crutches. Swivel walking 6·1m in 18 sec.	Independent transfer from wheelchair 4½ min. Independent transfer into wheelchair 1 min.	Independent transfer from wheelchair 1 min. Independent transfer into wheelchair 15 sec.	Average major repairs over 4 months—once every 3 weeks.	No repairs or mechanical adjustments in 9 months.
B	M	9½	31·3	1·219	L2	Hesitant swivel walking 6·1m in 47 sec.	After 2 weeks greater confidence in swivel walking 6·1m in 25 sec. After 3 months 6·1m in 18 sec.	Physiotherapist transfer 4½ min. Assisted rise from ground.	Independent transfer on ground 1 min. 50 sec. (after 2 months). Assisted rise from ground.	Frequent adjustment. No major repairs in 12 months.	No repairs or mechanical adjustments in 8 months.
C	M	3½	13·61	0·889	L3	Very unstable swivel walking close supervision necessary.	After 3 weeks independent swivel walking with no supervision.	Physiotherapist transfer 2½ min.	Physiotherapist transfer 1½ min.	Occasional adjustment.	No repairs or mechanical adjustments in 7 months.
D	M	5½	17·69	1·041	L5	Close supervision of swivel walking necessary. Steadying hand required.	Supervision to motivate required. No assistance necessary. 6·1m in 2½ min.	Physiotherapist transfer in approx. 3 min.	Physiotherapist transfer in 1 min. 40 sec.	Not known.	No repairs or mechanical adjustments in 6 months.
E	F	12½	36·74	1·270	T12	Insecure swivel walking close supervision.	Unsupervised secure swivel walking.	Physiotherapist transfer untimed.	Part assisted transfer in 1 min. 50 sec.	Not known.	No repairs or mechanical adjustments in 5 months.

Both swing through gait and the mode of transfer imposed stresses on the swivel walker structure for which it was not designed. Footplates and their bearings suffered frequent failures, as did the curved dural side sections of the body frame. In one period of three months his swivel walker had major repairs on four occasions with numerous minor adjustments.

When supplied with an Orlau swivel walker this patient quickly developed the new slide-in technique of transfer. This procedure took approximately 1 minute, and left the patient fresh for his activities.

In addition the extra rigidity improved his swivel walking performance so that typically he was able to ambulate 6.1 m in 18 seconds as opposed to 24 seconds in his conventional swivel walker.

In a nine month trial, during which all his activities and independence were maintained, the Orlau swivel walker did not require a single repair or adjustment, apart from a minor change after one week.

Patient B

As a younger child this patient had been a good swivel walker, but as he became taller and heavier his ability diminished to the stage when he was extremely apprehensive and required somebody close at hand before he would ambulate.

Standing still in his swivel walker the patient could be seen to feel insecure, making frequent adjustments to his arm positions in order to stave off an imagined loss of balance.

With this device the patient could ambulate 6.1 m in 47 seconds and had to be transferred entirely by a physiotherapist, this taking 4½ minutes.

When supplied with an Orlau swivel walker the patient's confidence increased very rapidly and within two weeks he managed to ambulate 6.1 m in 25 seconds, this time improved to 18 seconds in the following months.

Because of feelings of vertigo this patient was initially reluctant to adopt the slide-in transfer method. However, he did manage to roll into his orthosis and secure himself despite considerable finger disfunction. This took 1 minute 50 seconds, entirely independently, as opposed to 4½ minutes physiotherapist assisted with his previous device. The time to attain an upright posture using a chair was approximately 30 seconds with both swivel walkers. The patient is now content to slide into his swivel walker directly from his wheelchair and is developing the technique of pushing himself into the vertical position.

Patient C

This very young patient could not master the art of swivel walking due to a great feeling of insecurity and had to be very closely watched whenever he was using his conventional swivel walker. His mother was never more than a couple of paces away because he was prone to over-balancing.

After he was supplied with the Orlau swivel walker he became much more independent and his mother was happy to leave him in a room by himself.

The child was too young to manage independent transfer, but the mother felt the benefit of much easier transfer of the patient.

Patient D

Despite months of training this very poorly motivated patient would not ambulate in a conventional swivel walker without somebody in very close attendance, preferably holding the swivel walker as he rocked from side to side.

After a little training with the Orlau swivel walker the patient was prepared to ambulate without a physiotherapist in close attendance. However, his speed was still very poor and initially constant urging was required for him to indulge in sustained ambulation. With further training this patient became more willing to ambulate and was timed at 2½ minutes for 6.1 m.

Because of poor motivation this patient is unlikely to become capable of independent transfer.

Patient E

This very tall patient suffers with spinal instability. Existing swivel walkers gave her feelings of insecurity and presented restrictions to spinal orthoses of the type she required.

The Orlau swivel walker gave her much greater confidence and she became keen to use the device in contrast to her previous reluctance to use a swivel walker.

Spinal instability still caused her discomfort and a spinal orthosis was made to fit within the swivel walker to overcome that problem.

Discussion

The Orlau swivel walker offers the following specific advantages over earlier designs:

1. Ease of independent transfer.
2. Improved strength to withstand extra stresses of transfer and swing through gait.
3. Increased rigidity to give confidence to apprehensive patients.

Experience has shown that to eliminate problems of poor construction and incorrect mechanical adjustment of swivel walkers it is necessary to make them available in kit form. The Orlau design has been created for this method of assembly and a trial batch of 25 sets has proven to be simple to construct. To reduce the amount of small batch production, each component has, as far as possible, been standardized for the complete size range. Off the shelf components, for example, the footplate bearing, have been used wherever possible to increase reliability and reduce supply problems.

At 4.76 kg the Orlau swivel walker is heavier at the top end of its size range than the 4.66 kg of the lightest design of equivalent size, but significantly lighter than the heavier types.

The price of the kit is likely to be similar to existing kit designs, but reductions in assembly time should be possible.

Acknowledgments

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New plastics for forming directly on the patient*

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Abstract

Several newly available plastics become malleable when immersed in warm water or subjected to warm air; they return to a more rigid state when cool. Because fabrication requires that they be heated only to temperatures tolerated by the skin, one can mould them directly on the patient to produce custom-designed and individually-fitted devices. The new thermoplastics are modified readily upon reheating with warm water or air. Although varying in colour and texture, these materials all present a comparatively pleasing appearance. As a group, however, they are less rigid and less durable than other plastics or metals used in prosthetics and orthotics. While the initial cost of the new thermoplastics exceeds that of other materials, the finished appliance generally is less expensive because less time, skill, and equipment are needed for fabrication. Each plastic is analyzed in terms of its chemical and physical characteristics; commercial forms, whether marketed in sheet, tape, or precut splint form; and fabrication requirements. Although their principal use is in upper-limb orthotics, especially hand and forearm appliances, these plastics are suitable for selected application in spinal orthotics, such as collars and body jackets; lower-limb orthotics, particularly shoe inserts; and for the sockets of temporary prostheses.

Greater utilization of plastics is one of the most important trends in modern orthotics. In the past, orthoses were made almost exclusively of metal, plaster of Paris, or leather. These materials are still used, but, as in prosthetic practice, plastics are employed with increasing frequency.

Plastics are synthetic materials which may be moulded, extruded, laminated, or otherwise formed into various shapes. These materials may be categorized as thermoplastics and thermosets, the latter being formed by moulding liquid plastic over a positive model. Once solidified, thermosets cannot be reshaped, except to a minor extent, by subsequent application of heat; they are very suitable, however, where great rigidity is required.

Thermoplastics, in contrast, become formable when heated, and rigid when cooled. After they have cooled, they may be reheated and reshaped many times. This useful feature permits repeated alterations of the orthosis. Many newly marketed thermoplastics become malleable when heated to temperatures low enough to be tolerated by the skin and therefore can be applied directly to the patient.

Plastics which require no more than 80°C (180°F) to become workable may be termed low-temperature thermoplastics. Some foams must be heated to a higher temperature initially, but, since air convection cools their surfaces rapidly and they have low conductivity, they can be formed safely on the patient; such materials also may be considered as low-temperature thermoplastics. Since no cast is needed, low-temperature thermoplastics hasten provision of orthoses to the patient and are so relatively easy to work that most rehabilitation personnel can form devices with minimal practice and very little equipment. Even the most modestly furnished department should be able to supply hot water, scissors, and a source of hot air such as a heat gun, toaster oven, or electric frying pan with which to fabricate orthoses from most of the low-temperature materials.

Thermoplastics for orthoses are generally

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TABLE I—LOW-TEMPERATURE THERMOPLASTICS

The most common trade name precedes alternate versions of the same material.

Trade Name(s)	*Characteristics*	*Fabrication*
Aliplast, Plastazote, Surgical Orthopaedic Splinting (SOS)	Closed cell foamed polyethylene sheets. Resilient. Plastazote, SOS; perforated and unperforated. Aliplast; unperforated only. Matte opaque white; Plastazote also in black and pink. Very light weight; various densities. Flexibility depends on density. Low flammability; flame causes melting.	Cut with knife or scissors. Heat only with hot air 110°–140°C (220°–280°F) in oven protected with talcum, Teflon, or brown paper. Shape on stockinette-protected patient. Reinforce with polyethylene strips. Setting and curing time 1–5 minutes. Self-adherent.
Aquaplast	Polyester sheets. Waxy hard smooth surface. Perforated and unperforated. Glossy, opaque yellowish-white. Very rigid. Low flammability; flame causes melting.	Cut with scissors. Heat until transparent; 60°C (140°F) in pan protected with plastic net separator. Shape on patient whose skin has been lubricated with water, petroleum jelly, or soap to prevent Aquaplast from sticking to hair; extremely elastic when hot. Trim when hot. Setting time 10 minutes. Curing time 20 minutes. Self-adherent.
Bioplastics	Polyvinyl chloride sheets. Hard smooth surface. Shiny transparent pale blue. Very rigid, high impact strength, difficult to reshape. Low flammability; flame causes charring.	Cut with coping or band saw when cool or with scissors when warm. Heat to 80°–110°C (170°–220°F). Shape on stockinette-protected patient. Scrape, sand or buff edges. Setting and curing time 1–2 minutes. Not self-adherent.
Lightcast	Fibreglass and acrylic resin bandage. Hard porous surface. Opaque yellowish-white. Pliable, resists chipping and cracking, difficult to remould once set. Not flammable when cured.	Apply polypropylene stockinette over body part. Wrap the part with bandage. Harden by ultra-violet radiation, 3200 to 4000 Angstrom units. Setting and curing time 3 minutes. Self-adherent.

TABLE I—*continued*

Trade name(s)	*Characteristics*	*Fabrication*
Orthoplast, San-Splint	Synthetic rubber sheets. Hard smooth surface; perforated and unperforated. Semi-glossy opaque; Orthoplast; white, San-Splint; pink with grain on one side. Slightly rigid; dissolves in aromatic and chlorinated solvents, e.g., carbon tetrachloride. Flammable.	Heat to 65°–80°C (150°–175°F); if heated in oven use silicone release paper. Cut with scissors; minimal shrinkage; minimal elastic memory. Shape on patient. Setting time 10 minutes. Curing time 2 hours. Self-adherent.
Polysar	Synthetic rubber sheets and tubes. Hard smooth surface. Matte opaque pink. Very rigid. Flammable.	Heat to 70°–80°C (160°–180°F); if heated in oven, use separating material. Cut with shears. Shape on stockinette-protected patient. Setting and curing time 5–10 minutes. Self-adherent only if hot and dry.
Warm-N-Form	Polyvinyl chloride sheets and orthoses. Hard smooth surface. Transparent shiny amber on one side; gold knit fabric on other side. Very rigid. Flammable.	Cut with coping or band saw when cool or with scissors when hot; minimal stretchability, minimal memory, minimal shrinkage. Heat with dry heat only to 55°–80°C (130°–180°F). Shape on patient, fabric side next to skin. Setting and curing time 1–3 minutes. Not self-adherent.
Glassona	Cellulose acetate plastic bandage. Hard porous surface. Opaque white. Light-weight. Pliable, resists chipping and cracking, difficult to remould once set. Very toxic solvent activator; strong acids cause decomposition; strong alkalis cause swelling. Very flammable.	Moisten bandage in acetone. Wrap the stockinette-protected patient. Cut with scissors. Setting time 10–15 minutes. Curing time 24 hours. Self-adherent and adherent to other materials.
Hexcelite	Polycaprolactone bandage and splints. Hard, very porous mesh surface. Matte opaque white. Very rigid, difficult to reshape. Flammable.	Apply polypropylene or cotton stockinette over body part. Heat with hot water only 70°–80°C (160°–180°F). Wrap the part, discarding polyethylene separator. Fold edges to avoid roughness. If using splints, apply to limb. Cut with scissors or shears. Setting time 3–5 minutes. Curing time 15–20 minutes. Self-adherent.
Kay-Splint, Polyform	Polyester polycaprolactone sheets; Polyform also in preformed orthoses. Hard smooth surface, semi-glossy, opaque; Kay-Splint; pink, unperforated; Polyform; white, perforated and unperforated. Flammable.	Heat to 65°–75°C (150°–170°F). Cut with scissors; stretches, but has minimal shrinkage. Shape on patient. Setting time 2–5 minutes. Curing time 24 hours. Self-adherent only if surface is dissolved with methylene chloride, toluene, or aromatic hydrocarbon solvent.

manufactured in sheets. A few are sold as rolls of plastic-impregnated fabric. Such bandage can be wrapped easily around the body segment or can be applied as overlapping, layered splints.

Plastics provide a very wide range of choices in physical characteristics, especially strength, rigidity, and appearance. Strength is indicated by the amount of force necessary to cause failure, either by breakage or stretching. Rigidity is indicated by the force needed to cause deflection of the material for a given distance. These properties depend on the thickness, as well as the chemistry of the material. Consequently, orthotic design should include strategically-placed reinforcements, curves, corrugations, and rolled edges to increase rigidity selectively.

It is very easy to cut a pattern in low-temperature thermoplastics with scissors, particularly when the material is warm. The very process of cutting the heated plastic, in most instances, produces smooth edges without need for sanding or polishing. Some of the stiffer plastics, however, can be cut better with a coping saw, while others are easier to cut with scissors when cool.

Although all materials have shrinkage and elastic memory, some display one or both of these properties to a marked extent. Shrinkage is reduction in size due to thermal stress; heat modifies intermolecular bonds which reduce their length. A material which shrinks markedly requires that it be cut from a pattern which is large enough to compensate for shrinkage so that the orthosis, once completed, will not fit too tightly. Low-temperature thermoplastics have a relatively long working time, adequate to form complex shapes without resorting to repeated heating or the use of expensive equipment such as vacuum formers. Those materials which exhibit considerable elastic memory can be stretched a great deal when heated, yet will return to the original dimensions when cool. Elastic memory generally refers to the return to the original manufactured form after a material is mechanically stressed; when stress is relieved, the intermolecular bonds return to their relaxed state.

Most low-temperature thermoplastics are self-adherent when warm. Straps and other attachments can then be interlayered between folds of plastic. Some of those which are not readily self-adherent may be bonded by removing a thin portion of the surface with a solvent, then pressing the two sheets of plastic together. Others require the use of contact, epoxy, or solvent cements. An alternate method for securing attachments is by the use of rivets or similar fasteners. This type of hardware is not suitable for use in plastics which tend to creep, that is, deform slowly under sustained load; in such materials, fasteners may withdraw eventually from their holes.

These plastics permit rapid fabrication of custom-fitted orthoses. One may either trace a pattern from a pattern book or other source onto the plastic, or may design a pattern on paper toweling, cutting and piecing until the required contour is achieved; the resulting pattern is then traced onto the plastic. For those materials which are very elastic when hot, one need cut only general contours from the plastic, leaving broad margins, then shape and trim the plastic while it is draped on the patient. For standard applications, such as a wrist orthosis to prevent palmar flexion, it may be expedient to purchase a pre-cut splint. The flat plastic is then heated, shaped, and trimmed to suit the individual.

The principal use of low-temperature thermoplastics is in upper-limb orthotics where rapid provision of assistive or protective orthoses is often desirable. One can maintain the arches and interdigital spaces of the paralyzed hand with simple thermoplastic orthoses. Less rigid plastics, especially those which are foamed, may need to be reinforced in areas of high stress by interleafing metal or polyethylene strips. Greater rigidity is also necessary in hand orthoses which will incorporate outriggers. For support of the wrist, elbow, trunk, or other body segments which present relatively smooth curves, one should select stronger, more rigid plastic, perhaps adding a thin lining of polyethylene foam to improve pressure distribution. Foamed polyethylene is also useful for custom-made inner soles for patients with deformed feet, as well as for cervical collars. Many of the more malleable plastics are ideal for forming custom-contoured handles on utensils for patients with impaired grasp. Low-temperature thermoplastic, particularly that manufactured in tubular form, is appropriate for fabrication into sockets, especially for below-knee and below-elbow prostheses.

Low-temperature thermoplastics are not

suitable for all orthotic applications. Where high stress is anticipated for example, in an orthosis to be worn for a long period, or one to be applied to a severely spastic patient who will exert great force on it, thermoplastics which require higher heat for forming, thermosetting plastics, or metal may be needed for the requisite strength. Although sheets of low-temperature thermoplastics are generally much more expensive than other plastics, metal, or leather, the relative reduction in fabrication time and technical skill needed to complete an appliance usually results in an appreciable net economy.

Table 1 indicates pertinent information on the characteristics of plastics which can be formed directly on the patient. The comments are intended to highlight the distinctions of each plastic, rather than to provide the detailed analysis or fabrication instructions which can be secured from the manufacturer.

Low-temperature thermoplastics are an important addition to the professional armamentarium which may permit faster provision of custom-made orthoses to speed patient rehabilitation.

SUPPLIERS

ALIMED, 138 Prince Street, Boston, Massachusetts 02113 (Aliplast).

BRB INDUSTRIES, INC., 467 11th Street, Hoboken, New Jersey 07030 (Surgical Orthopaedic Splinting).

HEXCEL MEDICAL PRODUCTS, 11711 Dublin Boulevard, Dublin, California 94566 (Hexcelite).

JOHNSON AND JOHNSON, New Brunswick, New Jersey 08903 (Orthoplast).

MERCK SHARP AND DOHME ORTHOPEDICS COMPANY, INC., 2990 Red Hill Avenue, Costa Mesa, California 92626 (Lightcast).

ROLYAN MEDICAL PRODUCTS, Post Office Box 555, 14635 Commerce Drive, Menomonee Falls, Wisconsin 53051 (Polyform).

FRED SAMMONS, INC., Box 32, Brookfield, Illinois 60513 (Bioplastics, Kay-Splint).

SMITH AND NEPHEW LIMITED, 2100 52nd Avenue, Lachine 620, Quebec, Canada (Plastazote, Glassona, San-Splint).

THERMO-MOLD MEDICAL PRODUCTS, INC., Route 130, Post Office Box 36, Burlington, New Jersey 08016 (Warm 'n Form).

UNITED STATES MANUFACTURING COMPANY, 623 South Central Avenue, Post Office Box 110, Glendale, California 91209 (Polysar).

WFR CORPORATION, 199 Gregory Boulevard, Norwalk, Connecticut 06855 (Aquaplast).

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The international organizations — World Rehabilitation Fund Inc.

E. J. TAYLOR

Address given at the International Assistance Programmes Session, Second World Congress of the International Society for Prosthetics and Orthotics, 31 May, 1977 New York City

The World Rehabilitation Fund (WRF) began in 1955 as a very small organization. For the first few years our resources were expended to provide fellowships to bring people from other countries to the United States of America and, in particular, to the Institute of Physical Medicine and Rehabilitation, New York University Medical Centre for advanced training.

Most of the resources were spent to provide fellowships for physicians. The Centre had been training physicians from overseas countries prior to the founding of the WRF and many of the leaders in rehabilitation throughout the world have had training at New York University.

In those early days fellowships were also provided directly from the Institute of Rehabilitation Medicine and later from the WRF in the fields of prosthetics and orthotics. When the programme at the Institute was run by the late William Tosberg, I recall we had trainees from Japan, Korea, Burma, Thailand and Colombia.

In the early 1950's our President, Howard A. Rusk, M.D., made a trip around South America to visit a number of former physican trainees. When he returned he stated he was appalled by the lack of prosthetic-orthotic services. Those that were provided, primarily by unskilled persons in private shops, in many instances contributed to furthering the disability of a crippled child rather than correcting it.

I have always believed that the two essential services for a crippled child in the developing country are mobility and education. A child must have mobility and must have some education to have a fighting chance of becoming independent.

In 1957 the World Rehabilitation Fund gave a fellowship to Mr. Juan Monros, a professional soccer player from Spain who had played in Switzerland who recognized that he was approaching an age when he could no longer play soccer professionally and wanted to learn a trade.

At that time we noted that a new technology in prosthetics and orthotics was beginning to emerge based on the use of plastics and prefabricated parts. The WRF decided to test the hypothesis that a person with mechanical aptitude, even though he lacked formal academic preparation, could be taught orthotics in five months. This we did successfully in Peru and then in Brazil.

Since then we have been conducting training programmes throughout the world and have now provided courses for approximately one thousand students. In many instances, however, the student took a course in orthotics and subsequently took a course in prosthetics, therefore, the number of individuals is somewhat less than 1,000.

We have specialized in the developing parts of the world. No fellowships for such courses have been given to persons from Europe, the United Kingdom, Ireland, Canada, Japan, or the United States. Of the 1,000 persons trained, to our knowledge, the vast majority are practising their professions. Around twenty have died or were killed in Vietnam and we know of only four instances where the trained individual has left the profession for another occupation.

The WRF global programme in prosthetics and orthotics has been very carefully developed. After four or five years, the WRF established permanent regional training centres in prosthetics and orthotics. To staff these centres a number of potential instructors were brought

to the U.S. for a specialized course in 1971 at the Prosthetic-Orthotic School, New York University Medical Centre. From time to time we have brought individual persons to the U.S. to receive further training at the Prosthetic-Orthotic School, New York University Medical Centre, the Veterans Administration Prosthetic Centre in New York, the Newington Children's Hospital in Newington, Connecticut; and the Institute of Rehabilitation Medicine, New York University Medical Centre. We have received complete co-operation from these training sources.

In June of this year (1977) we will hold a two-week course in cosmetic restoration at the Veterans Administration Prosthetic Centre and a course in the use of plastics in orthotics at the Institute of Rehabilitation Medicine, for trainees from Brazil, Peru, Nicaragua, Taiwan, Korea, and Hong Kong.

In July of this year the eleventh course in prosthetics and orthotics will be held at the WRF Regional Training Centre in Sao Paulo. A total of approximately 200 technicians has been trained from all parts of Brazil and from every country in South America, including Surinam and Guyana. Trainees have been accepted from Haiti, the Dominican Republic, Jamaica, Trinidad, Nicaragua, Guatemala, and Mexico. We have also had a number of trainees from Angola and Mozambique, the former colonies of Portugal, who speak Portuguese the language of Brazil. We have also had trainees from other parts of the world including Hong Kong, and at the course starting in July, there will be one trainee from Korea and two from the Republic of China (Taiwan).

Earlier this month the WRF began a five-month course in Bangalore, India, which will be the third course held at the WRF Regional Training Centre in Prosthetics and Orthotics in Bangalore. This will be the fifth such course held in India. We have had trainees not only from India but also from Thailand, Indonesia, Turkey, Hong Kong and Sri Lanka.

The WRF started a regional training centre in Hong Kong. At that time there was a long waiting list for persons needing artificial limbs and braces. As a result of the courses there is no longer a waiting list, consequently, WRF has transferred its regional training centre from Hong Kong to Taipei, Taiwan. While the centre was in Hong Kong, it gave training to persons from Indonesia, Malaysia, the Philippines, Western Samoa, New Hebrides, and Korea.

The WRF has held two courses in Africa, one in Uganda and one in Ethiopia, and has trained people from Egypt, Kenya, Tanzania, Lesotho, Swaziland, Nigeria, Togo, Camaroon, Benin, Ghana, Guinea, Liberia, Mozambique, Angola, Zaire, Zambia, and Upper Volta.

The WRF entered into a tentative agreement with the World Health Organization, under which the WRF has agreed to provide consultation services, training of personnel, import equipment and supplies, and supervision for prosthetic-orthotic shops in all of the African republics. Mr. Monros was in West Africa in March of this year and was scheduled to spend time at the WHO Regional Office for Africa in Brazzaville, The Congo. As the President of the Congo had just been assassinated a few days prior to his arrival, the borders were closed and Mr. Monros was not able to enter The Congo. This programme has been completely funded.

We believe that prosthetic-orthotic services in Africa must be made available at low costs and should be provided as far as possible with supplies available within the country. We do not believe in long term training, particularly in overseas countries which results in trainees emigrating as their own Governments cannot pay wages comparable to those in the developed parts of the world. Nor do we believe in long term overseas training in which the technician becomes completely dependent upon supplies which must be imported. Neither the individual patient nor his Government can afford to import supplies. Using the same techniques and often the same components it is possible to produce, under the WRF approach, a PTB prosthesis in Africa for US$20-$50 and in India for US$20-$40. The huge difference between costs there and in the developed parts of the world results from the fact that the salaries paid to technicians in Africa and India are one twelfth to one twentieth of the salaries paid to a certified prosthetist-orthotist in the United States.

Prior to the beginning of hostilities in Lebanon, there were two major prosthetic-orthotic services there, one of which was at the American University of Beirut. The WRF provided minor assistance in the training of its director, Amin Haaj, and provided some of the equipment for

the shop and the physical therapy section. The second shop was at Al-Kafaat, a voluntary organization providing shelter workshop services for approximately 125 disabled persons, a school for the physically handicapped and schools for the mentally retarded and deaf, as well as the prosthetic-orthotic shop. The shop is intact, and the three principal technicians have remained throughout the hostilities in Lebanon. They have provided services for approximately 400 persons thus far in 1977, utilizing equipment and components flown to them by the WRF from Germany. The U.S. Agency for International Development has made substantial grants to American University, the International Red Cross, and the United Nations, all of which are starting from scratch and ignoring the fact that a well trained cadre of technicians with the equipment is available at Al-Kafaat.

The Dutch Government has sent an expert in prosthetics to Lebanon who has measured the amputees and the prostheses are being fabricated in the Netherlands. The Dutch will send a team of about 20 people to fit the prostheses and give patients training in their use. They have stated they cannot fit more than 450. Currently the British Government is also considering giving some assistance in prosthetics and orthotics. The WRF is concerned that when the foreign personnel leave, there will be no trained prosthetist-orthotist personnel for repairs or to manufacture new devices for children who need new braces as a result of growth. We consider this a prime example of "reinventing the wheel", when administrators who know nothing about prosthetics and orthotics make decisions to import personnel and totally ignore locally trained people who have had six to seven years of experience plus training in the United States.

The WRF estimates that the number of amputees in Lebanon is from 3,000 to 4,000. Actually no one knows. Persons without experience have reported there are 700 to 800 amputees. As so frequently happens, the original estimate has been recopied in all official reports but there is evidence there are far more than the original number.

The World Rehabilitation Fund has every intention of continuing its prosthetic-orthotic services until all the needs have been met.

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Education in prosthetics and orthotics*

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Introduction

At the time of the first World Congress of ISPO a "workshop" was held in Les Diablerets, Switzerland, to attempt to identify needs and establish priorities of action in prosthetics and orthotics throughout the world (ISPO, 1975). In response to questionnaires sent out six months prior to this event, 33 countries, representing nearly half of the world population, provided information on patient population, facilities, professional staff, etc. While there were gaps in the information obtained and although many of the statistics provided were clearly suspect, it was possible to get an impression of the extent of the problem. In the disability types considered, the number of physically handicapped was reported as being over 14,000,000 in a total population of about 1,200,000,000. This suggests that about one person in 100 might require some type of appliance. It appeared that only 1,800,000 have been provided with devices, leaving over 12,000,000 handicapped individuals for whom no appliance had been made. It was estimated that about 11 prosthetists, orthotists and technicians were needed to care for 1,000 patients. Thus, to provide service for the 12,000,000 handicapped presently uncatered for would require the training of 132,000 persons.

Even if these figures are substantially inaccurate, it can be seen that the problem is massive. It is not surprising that in this world survey, in a section for special comment, there were more requests for assistance in education and training than for any other service or facility.

It is apparent that in global terms present arrangements are grossly inadequate for the whole group of medical and paramedical workers involved in this field. The clinic team concept, already proven as the preferred means of treatment for the patient requiring prosthetic or orthotic provision, requires a high degree of professionalism of all its members. The key member in the team in this continuing process and the one whose education and training gives most cause for concern is the prosthetist/orthotist. It is this problem which is the primary consideration of this presentation.

The prosthetist/orthotist

The emerging pattern of practice throughout the world involves two levels of operatives, the prosthetist/orthotist and the prosthetics/ orthotics technician. Job specifications have previously been detailed in a number of documents (U.N. 1968, H.M.S.O. 1970) but the distinction is rather easily understood. The prosthetist/orthotist is the professional member of the clinic team who is directly concerned with the treatment of the patient. The technician, on the other hand, is concerned largely with the manufacturing and assembly process, working to the instructions of the prosthetist/orthotist. It is inevitable in this field that certain construction or adjustment work will be carried out by the prosthetist/orthotist and, on the other hand, the technician will, from time to time, be involved in working with the patient under the supervision of the prosthetist/orthotist. The two types of staff are, however, quite distinct in function and their selection, education and training must reflect this. To have one individual handling all stages of measuring, construction, assembly and fitting is inefficient in the use of high grade staff and puts excessive demands on the abilities of lower grade staff.

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*This is one of the lead papers on Prosthetic/Orthotic Education presented at the Second World Congress. It is hoped that a forthcoming issue of Prosthetics and Orthotics International will carry the other lead paper by W. Kreiger.

It is recognized that terminology differs throughout the world and that even where the terms prosthetist/orthotist and prosthetics/orthotics technician are not used, this two-tier structure of working exists. The only importance in formally recognizing its existence is clearly to identify that the two individuals involved would be selected for different attributes and attitudes, would require different entry qualifications and subsequently would be educated to a quite different level.

These statements are not incompatible with the best practice anywhere in the developed world. The training of the technician is broadly craft based and will be adapted to local needs and the skills and resources available. The education and training of the professional prosthetist/orthotist is much more demanding of resources and, moreover, is the key to the massive problem already identified of the world's untreated millions.

Professional education and training

The International Society for Prosthetics and Orthotics has a now clearly developed philosophy in respect of prosthetic/orthotic education and training. This philosophy has been documented in a series of publications which started with the Report of the United Nations Interregional Seminar on Standards for the Training of Prosthetists (U.N. 1968), the so called Holte Report, which was organized by the United Nations in collaboration with the Society's forerunner, the International Committee on Prosthetics and Orthotics (I.C.P.O.). The current status of the Society's views, which have not changed in concept over the years, is now embodied in two documents. The first, already referred to, "Needs in Prosthetics and Orthotics Worldwide" (ISPO 1975) is the report of the workshop held at the time of the first World Congress. In this report it is stated that the Society's "philosophy endorses formal long-term degree-level courses or the equivalent for prosthetists and orthotists". The second document is the "International Study Week on Prosthetic/Orthotic Education" (Hughes, Ed. 1976). The Study Week brought together representatives of most of the major education programmes in prosthetics/orthotics throughout the world to give detailed consideration to the current situation and make plans for future development. This second publication, the proceedings of that study week, spells out in substantial detail the content and format of properly constituted education and training programmes.

The Study Week Proceedings recognized that a wide spectrum of approaches exists ranging from the formal university course to the "guild" based. Irrespective of the approach however, the essential ingredients of any course leading to professional qualification were specified as:

a. Teaching of theoretical subjects.

b. Closely supervised practical instruction.

c. Structured and controlled clinical experiences

The theoretical subjects range over the basic physical and life sciences and the application of these to prosthetics and orthotics and related medical and social topics. It is not possible to specify a curriculum in absolute time allocations because of national variations in educational practice and conventions. The specification of degree level or equivalent establishes on a national basis such things as entry qualifications, total time content and educational level.

Closely controlled and supervised practical instruction in a laboratory or classroom situation was agreed as being essential to any of the various forms of training courses and a detailed minimum number of experiences was identified. These covered all the main prosthetic and orthotic devices and would take place in an instructor/student setting apart from the normal service clinic environment.

The normal clinical experiences required by the student which would take place during the course and the related internship were also identified as requiring structuring and control.

Without attempting to impose a uniformity of approach, this specification still sets the boundaries of any reputable course. The course with which the author is associated follows the formal university course pattern. This three year course leads to a nationally recognized award, the Higher Diploma, of degree equivalent status. The hourly breakdown of education and training is as shown in Table 1. It will be seen that the theoretical teaching amounts to about 2,160 hours. The students have university entry level qualifications and this establishes the duration and type of course which is required to bring them to degree level. The closely controlled and supervised practical

instruction amounts to another 2,415 hours. It is difficult to imagine that the experiences identified under this category by the Study Week Group could be covered in the laboratory situation in any less. The duration of a course using an alternative approach would require to be adjusted accordingly. However, it would still need to include both these elements and so would inevitably be longer—there can be no shorter path than concentrating both elements together.

TABLE I

THEORETICAL TEACHING

Life Sciences	580 hr.
Physical Sciences	350 hr.
Clinical Studies and Human Relations	328 hr.
Prosthetic and Orthotic Science	270 hr.
Biomechanics	200 hr.
Student Activity and Library Study	432 hr.
	2,160 hr.

PRACTICAL INSTRUCTION

Prosthetic and Orthotic Practice	1,750 hr.
Workshop Practice and Technical Drawing	350 hr.
Essay and Project Work	315 hr.
	2,415 hr.

Although flexible, there is nothing ambiguous about the ISPO philosophy. The educational level is clearly specified—degree level or equivalent. The educational aspects must be completely integrated with a clinical training programme which, in the controlled environment of laboratory or classroom, provides the trainee prosthetist/orthotist with a specified minimum number of experiences relating to the whole range of devices he will encounter in his clinical career. It hardly needs to be said that throughout the programme proper examinations and assessments would be carried out, records kept and gradings allocated. Standards must be maintained and one would expect to see similar wastage rates applying to this course as to any other university or college course. Within this flexible philosophy, courses or systems of education and training which do not conform to these outlines cannot be considered acceptable.

In consideration of the duties of the professional prosthetist/orthotist, it is difficult to visualize any different situation which would satisfy his needs, the needs of the clinic team and, of prime importance, the needs of the patient.

The world need

It was suggested in the introduction that there was a requirement to train 132,000 prosthetists, orthotists and technicians. This figure may not be very accurate. It does, however, indicate the size of the problem.

In January 1974 ISPO carried out a survey of established prosthetics/orthotics schools. Eighteen were identified of which it must be said that several, perhaps as many as ten, do not satisfy the criteria, already described, of providing a professional qualification. The existing schools are not even sufficient in number or size to deal with natural wastage. Since that time it does not appear that any new educational facilities have emerged—the situation is static. Yet even if the provisional estimates of need are exaggerated, and there is no reason to suppose that they are, the need is desperate. New schools should be developing. Existing schools should be inundated.

There is an urgent requirement for international agencies to channel resources into education and training—and education and training at a high level. As an ideal, the rehabilitation of the patient requiring prosthetic or orthotic assistance must be of similar standard, regardless of the part of the world where this treatment takes place. This infers an eventual move towards uniformity of education and training standards and subsequent qualification. This is part of the ideal of ISPO. The practical expression must come from the national and international groups who are responsible for committing funds. An investment made now in educating and training a prosthetist/orthotist will not mature for at least four years. An investment in an instructor may take twice as long. For the patients who need our services, a decade of Rehabilitation can only follow a decade of Education and Training.

REFERENCES

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INTERNATIONAL SOCIETY FOR PROSTHETICS AND ORTHOTICS (1975). Needs in Prosthetics and Orthotics Worldwide. ISPO, Denmark.

SCOTTISH HOME AND HEALTH DEPARTMENT (1970). The Future of the Artificial Limb Service in Scotland. HMSO, Edinburgh.

UNITED NATIONS (1968). Report of the United Nations Interregional Seminar on Standards for the Training of Prosthetists, Holte, Denmark. United Nations, New York.

Prosthetics and Orthotics International, 1978, 2, 54–56

Calendar of events

1–5 May, 1978
751C Course in Lower Limb Orthotics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.
752C Course in Lower Limb Orthotics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

1–5 May, 1978
772–B, 732–B Courses in Lower Limb and Spinal Orthotics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

8–12 May, 1978
622–G, 623G Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

8–13 May, 1978
741D Course in Lower Limb Prosthetics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

11–12 May, 1978
681–G Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

15–18 May, 1978
631–B, 632–B, 633–B Courses in Management of the Juvenile Amputee for Physicians, Surgeons, Therapists and Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

15–26 May, 1978
758 Course in Upper Limb Orthotics for Orthotists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

22–26 May, 1978
622–H, 623–H Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

25–26 May, 1978
681–H Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

31 May–3 June 1978
Scientific Congress and Exhibition Medizin-Technik 78, Stuttgart, Germany.
Information: Tagungsgeschaestsstelle, Medizin-Technik 78, Universitaet Stuttgart, Postfach 560, D-7000 Stuttgart 1, Germany.

June, 1978

8th International Congress of the World Federation for Physical Therapy, Tel Aviv, Israel.
Information: Secretary General, Miss M. M. McKay, W.C.P.T., Brigray House, 20/22 Mortimer Street, London W1P 1AA.

5–9 June, 1978

750B Course in Prosthetics and Orthotics for Rehabilitation Counselors.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

5–9 June, 1978

622–I, 623–I Courses in Lower Limb Prosthetics for Physicians, Surgeons and Therapists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

5–23 June, 1978

753 Course in Lower Limb Orthotics for Orthotists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

8–9 June, 1978

681–I Course in Immediate Postsurgical Fitting for Prosthetists.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

12–16 June, 1978

745B Course in Upper Limb Prosthetics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

19–21 June, 1978

755 Course in Spinal Orthotics for Physicians and Surgeons.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

26–30 June, 1978

757B Course in Upper Limb Orthotics for Therapists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

26–30 June, 1978

751–A Course in Fitting and Fabrication of the C.T.L.S.O. (Milwaukee-type Orthosis) for Orthotists
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

26–30 June, 1978

801–A Course in Pedorthic Management of the Foot.
Information: Charles M. Fryer, Director, Prosthetic-Orthotic Center, Northwestern University Medical School, 345 East Superior Street, Room 1723, Chicago, Illinois 60611.

2–7 July, 1978

3rd World Congress of the International Rehabilitation Medicine Association, Basle, Switzerland.
Information: Dr. W. M. Zinn, Thermes, CH 7310 Bad Ragaz, Switzerland.

2–8 July, 1978

7th Pan-American Congress on Rheumatic Diseases, Bogota, Columbia.
Information: Secretariat, Associacion Colombiana de Reumatologia, Apartado Aeteo 90331, Bogota, D. E., Columbie.

5–21 July, 1978

743 Course in Above-Knee Prosthetics for Prosthetists.
Information: New York University, Post-Graduate Medical School, Prosthetics and Orthotics, 317 East 34th Street, New York, N.Y. 10016.

8–11 August, 1978

Seminar on Functional Rehabilitation—Devices, Costs and Effectiveness, University of Strathclyde, Glasgow, Scotland.
Information: Professor R. M. Kenedi, University of Strathclyde, Bioengineering Unit, Wolfson Centre, 106 Rottenrow, Glasgow G4 0NW, Scotland.

13–25 August, 1978

British Council Course 836 on Biomechanics of the Human Body with Reference to Orthopaedic Implants, Prostheses and Orthoses, University of Strathclyde, Glasgow, Scotland.
Information: The Courses Department, The British Council, 65 Davies Street, London W1Y 2AA, or your local British Council Office.

23–28 August, 1978

9th Congress of the International Association of Educators for Handicapped Youth, Montreal, Canada.
Information: (President of the Organizing Committee) M. Marcel Saint-Jacques, C.E.C.M., 3737 Est, Sherbrooke, Montreal, P.Q., Canada.

28 August–1 September, 1978

The Sixth International Symposium on External Control of Human Extremities, Dubrovnik, Yugoslavia.
Information: Gordana Aleksic, Yugoslav Committee for ETAN, P.O. Box 356, 11001 Belgrade, Yugoslavia.

13–15 September, 1978

Third Conference on Materials for use in Medicine and Biology—Mechanical Properties of Biomaterials, Keele University, and Bioceramics Symposium (16 September).
Information: Dr. G. W. Hastings, Bio-medical Engineering Unit, Medical Institute, Hartshill, Stoke-on-Trent, Staffordshire, ST4 7NY, U.K.
Bioceramics Symposium information: Dr. G. J. Gittens, Department of Ceramic Technology, North Staffs Polytechnic, College Road, Stoke-on-Trent, Staffordshire, U.K.

20–22 September, 1978

Autumn Meeting, British Orthopaedic Association, London (combined with Spanish Orthopaedic Association).
Information: Miss M. Bennett, Honorary Secretary, B.O.A., Royal College of Surgeons, Lincolns Inn Fields, London WC2A 3PN.

4–7 October, 1978

VIII International Congress INTERBOR, National Congress and Exhibition Hall, Madrid.
Information: D. Oriol Cohi, General Secretary, Enrique Granados 131, Barcelona-8, Spain.

5–11 November, 1978

ISPO International Course on Above-Knee Prosthetics, Rungsted, Denmark. Registration form in this issue.
Information: ISPO Secretariat, PO Box 42, DK 2900, Hellerup, Denmark.

16–18 November, 1978

Course in Orthotics and Prosthetics for Consultants, Senior Registrars and Registrars (in Orthopaedics, Rheumatology, Physical Medicine) and Senior Orthotists. To be held at the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry.
Information: Mr. G. K. Rose, Director, Orthotic Research and Locomotor Assessment Unit, The Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, Salop SY10 7AG.

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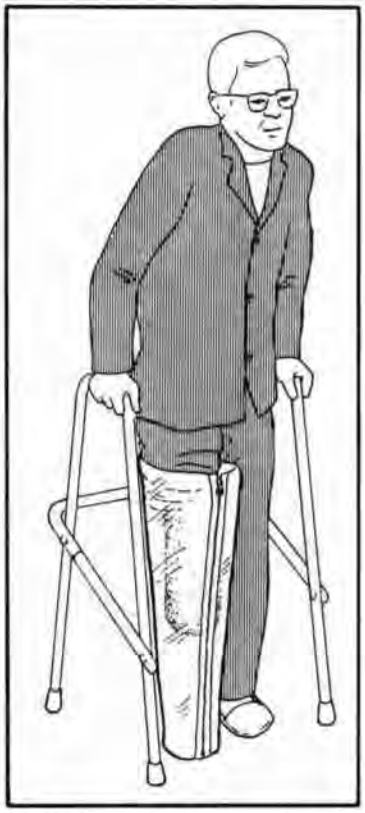

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Following acceptance of registration, remittance for fees and accommodation must be received by 15th September, 1978 (please make cheques, etc., payable to I.S.P.O.).

Information for Contributors

Contributions should be sent to Prosthetics and Orthotics International, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG. In the meantime considerable difficulty and delay is entailed in processing contributions in languages other than English. Authors are asked to provide three copies of text, tables and figures. Papers are accepted on the understanding that they may be subject to editorial revision and that no substantial part has been, or will be published elsewhere. Subsequent permission to reproduce articles must be obtained from the publishers. Manuscripts should be typewritten in double line spacing on one side of paper only with margins of 25 mm. Papers must commence with an abstract not exceeding 250 words. On a separate sheet must be:

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References in the text should follow the author/date system for example: Peizer (1971). If there are more than two authors—Solomonidis *et al.* (1974). References at the end of articles should be listed on a separate sheet in alphabetical order of (first) author's name, as follows: Marx, H. W. (1974). Lower limb orthotic designs for the spastic hemiplegic patient. Orthotics and Prosthetics, 28(2), 14–20. Journal titles must be given in full.

References to articles in books should include author, year of publication, article title, book title, edition, editor (if different from author), first and last pages, publisher and place of publication. For example, Hughes, J. (1975). Recent developments in prosthetics and orthotics. Recent Advances in Orthopaedics (2) Ed. McKibbin, B., 196–216, Churchill Livingstone, Edinburgh.

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