The Journal of the International Society for Prosthetics and Orthotics

Prosthetics and Orthotics International

August 1977, Vol. 1, No. 2

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Prosthetics and Orthotics International

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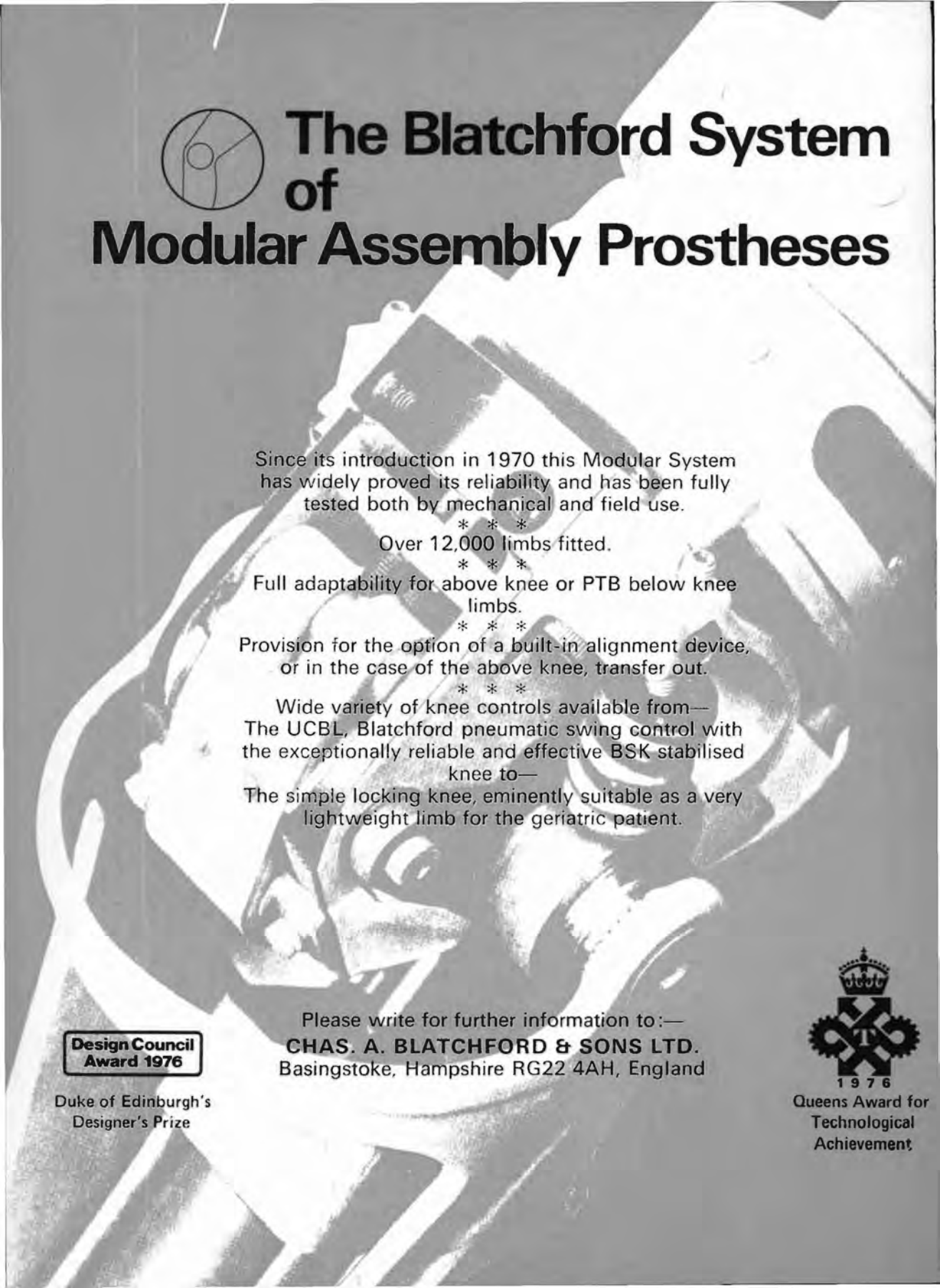

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Editorial

The first number of "Prosthetics and Orthotics International" was distributed to the membership on target at the beginning of April.

By the time this issue reaches you, our second World Congress will have been held in New York. The next number will carry material from the Congress but, of course, the copy for this one was safely with the printer before the Congress took place.

The Congress is the one event in the structure of our Society which provides the opportunity for our international community to meet and exchange views and opinions. It is perhaps also the one event which reminds us that although we may be organized in National groupings, this is secondary to our primary commitment to the International Society and its purposes. The aim of ISPO is defined in the Constitution as "to promote high quality orthotic and prosthetic care of all people with neuromuscular and skeletal disabilities". This aim is pursued within the various parts of our organization in different ways—by our International Committee, our Executive Board, our Standing Committees, our National Member Societies, the Membership. The one element which is vital to all our endeavours is communication.

It is a gigantic task to attempt to provide the essential means of communication within a membership which spans more than seventy countries. Communication must take place at many levels. The concept of the National Member Society is intended to provide not only a national forum, but also a system of representation of each nation's views in all the workings of the Society through membership of the International Committee which is our policy making body. Thus the national members through their National Committees have the means of expressing their views on and influencing the activities and priorities of the Society. It is true that a number of nations have so far failed to form National Member Societies, although they satisfy the Constitution in terms of numbers. This, of course, deprives them of one direct means of communication and anyone in this situation willing to take an initiative in the formation of a national group would be enthusiastically supported by the Executive Board, the Membership Committee and the Secretariat.

In a number of countries National Member Societies are extremely active, thriving and providing a much needed facility and focus for a national group. This is not, however, an end in itself. They are part of a larger organization from which they stem and this international influence should not be lost sight of in the enthusiasm of national success, important though this may be. First and foremost we are members of an international society. Nothing has delayed progress so much as insular, introspective attitudes. If clinical service is to be extended to the millions in the developing, and indeed the developed, world who require the services of our professional group and who do not have them, then ISPO acting as a co-operative of nations is the best hope for the future.

Although the mechanisms for communication are available, this is not to say that they are effectively used. The biggest single problem facing the secretariat is lack of response. Communication is always at least a two-way business. If the individual member wishes to have an effect on the Society's philosophy, influence and activity, the onus is on him to initiate communication by the means available to him. Not least "Prosthetics and Orthotics International" is the vehicle for sharing any aspect of professional experience and a means whereby opinions may be exposed to one's peers.

We invite you to communicate!

John Hughes,
Honorary Secretary ISPO.

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Amputation surgery in the lower extremity

G. MURDOCH

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Introduction

This contribution is intended to be a review of amputation surgery as it is today; yet, to present a purely surgical viewpoint would be uncomfortable for the author and inappropriate if the best interests of the patient are to be preserved. It is hoped that the review will be understandable to those others in the clinic team who are essential to the best management for the patient. Knowledgeable readers will no doubt recognize that in certain sections a highly personal viewpoint is displayed.

Advances in amputation surgery as in other branches of surgery reflect not only the increased understanding of physiology and pathology but also improvements in the technology of measurement and in prosthetics.

Causal conditions, levels and factors in amputation of the leg

In tackling this subject there are essentially three sets of information available to the surgeon and his team, namely the causal conditions, the available levels of amputation and the factors to be considered prior to operation.

The causal conditions can be listed thus:

Vascular disease
Trauma
Tumours
Infection
Congenital limb deficiency
Limb discrepancy, deformity, paralysis and joint instability, etc.
Special situations; e.g. frostbite, trench foot, etc.

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The levels of amputation available are:

Hemipelvectomy
Hip disarticulation
Above-knee amputation
Transcondylar amputation
Supracondylar amputation
Knee disarticulation
Below-knee amputation
Syme's amputation
Partial foot amputations
Toe amputations

The following are the factors to be considered in the final decision to amputate at a given level:

The pathology
The anatomy of the proposed level of amputation
The surgery proposed: in effect, tissue management
Prosthetic considerations: socket, devices, suspension, etc.
Personal, e.g. age, sex and occupation.

This approach does display the information required but by itself becomes uncomfortable because of the degree of cross referencing needed.

Another approach to the subject is via the state of the tissues at the site of the operation. In tumours, congenital limb discrepancy, and amputation in cases of gross paralysis and ugliness the tissues are essentially "normal", whereas in vascular disease and trauma the viability of the tissues is highly variable and often in doubt. Even in these latter two groups of pathology the patients involved are widely different and the objectives have a quite different temporal scale. In the case of the dysvascular amputee the patient has a very short life span and is beset with many other problems. The objective here is to provide a reasonable and feasible quality of life and a measure of independence and this can only be achieved by the application of a total care programme. In the

case of trauma, the patient is usually in the prime of life with a long life expectancy and many options for the future. The emphasis here must be on high quality, often imaginative surgery coupled with equally high level prosthetic competence and suitable hardware to ensure that in physical and psychological terms the patient is offered the best opportunity for the interplay of social legislation, vocational rehabilitation and community integration.

Patient management by the team

1. Is amputation the appropriate or only solution?
2. Levels and limiting factors.
3. The development of the long term objectives of the amputation.
4. Pre-operative preparation of the patient.
5. The surgical event.
6. The environment of the stump.
7. Immediate post-operative care.
8. Prosthetic fitting and integrated rehabilitation.

1. Amputation or not?

In trauma and vascular disease this question is very often answered by the pathology itself but in other situations, for example, in cases of malignant tumours, chronic infection and in a variety of conditions involving leg shortening, deformity and joint instability, alternatives do exist. Unlike many operative procedures there is no retreat once amputation has been performed. From a philosophical point of view the situation is even more complicated in that once the leg has been removed the problem posed to the surgeon has also been removed. Where the surgeon has alternatives the decision must be based on a careful examination of the situation as it presents and also an equally careful study of the likely future of the patient and what options are available. This is particularly important in the case of a child where amputation might seem to solve many problems. The parents may welcome amputation if only because it will remove what for them may be an intolerable ugliness in their child, but in this circumstance the patient has no say in the decision. In some situations such as congenital absence of the fibula there is a fairly general agreement that ablation of the foot at about the age of ten months provides the best solution both in the short and long term. In other situations the decision may be very marginal indeed and demand that amputation be delayed until the child is sufficiently developed to take part in the decision.

2. Levels and limiting factors

The problems regarding level selection are usually connected with the interplay of what the pathology permits and what other considerations are significant, such as the prosthesis to be fitted and the effect of such a fitting on the patient's personality and social integration. In the case of a young personable girl, the pathology may permit a knee disarticulation but the surgeon in proposing this procedure must have regard to the prostheses available, the total cosmetic effect, and in turn her resultant opportunities in terms of marriage, occupation and the like. Similar problems present if an amputation at Syme's level is permitted by the pathology. Here again the surgeon may have to consider a below-knee procedure if the best cosmesis is to be achieved. These problems have to be faced in a continually changing situation when prosthetic advances may swing the balance towards one or other closely located levels.

3. Definition of objectives

In developing the objectives the clinic team must be involved. Objectives should be defined as critically as possible, it is rarely just a question of removal of the leg. The problems requiring solution are extremely varied and range from the extreme of the dysvascular patient with the emphasis on rapid, effective, but often limited rehabilitation, to the other extreme of amputation of a leg as part of the treatment of trauma in a young man. In this case, ablation of the leg may simply be the first stage in the programme of management and a second stage envisages the careful construction of a stump which will have to last perhaps forty or fifty years. The team should be aware that after a temporary fitting is made for the first stump and, paradoxically, especially if that fitting is performed by a highly competent prosthetist, the patient may refuse the second procedure. In these circumstances the decision may seem justified in the short term as he can return to his job, wife and family at a much earlier date

without apparent detriment. However, the second procedure might have provided him with a stump capable of accepting a more sophisticated prosthetic prescription and one which was capable of withstanding much higher loads and in turn offering more job opportunities. The clinic team must have a clear understanding of the ultimate objectives and the prosthetist in particular, without denigrating his own skills, must ensure that the patient's long term needs are satisfied.

4. Pre-operative care

Once a programme of management has been developed with the full understanding and collaboration of the patient so far as this can be obtained, the pre-operative preparation must have regard to the mental adjustment of the patient and to the physical state required to face up to major surgery.

In an elective procedure in the younger patient there is no reason why the detail of what will happen to him following surgery cannot be outlined. He should be given information regarding what pain he is likely to have and how this will be overcome, how long he is likely to be in bed, when the drain is likely to be removed, when dressings or plaster are likely to be changed, when he can expect to have the stitches removed from his wound and when it is likely that he will be fitted with his first prosthesis. The patient should have some understanding of the likely functional loss and to what extent this can be compensated for by the prosthesis which will ultimately be provided. In furtherance of this it is often useful for the patient to talk to someone who has undergone the same procedure and been fitted with a similar prosthesis. A discussion should be developed outlining the extent to which he will be able to undertake his previous employment or alternatively what retraining will be required. He should have some understanding of how well he will be able to negotiate the physical obstacles of life. Whatever communication is necessary and pertinent to the patient's needs should be established with his family, employer, and those persons involved in his social welfare.

In the case of the vascular amputee there is frequently little opportunity to discuss the procedure in any detail and, very often in their toxic state, to consider anything other than the removal of their extremely painful appendage. A careful assessment of the patient is required so that the concurrent disabilities can be identified and treated whether they be cardiac, pneumonic, diabetic or renal. Where time permits any infections should be intensively treated and diabetes stabilized.

Vasodilation is encouraged by the administration of intravenous low-molecular-weight Dextran. Before proceeding to the operating theatre the affected foot should be isolated within a plastic bag extending to just above the affected area and sealed to the skin. The skin itself is prepared with povidone-iodine on the days prior to operation and by compress from groin to protected foot for thirty minutes preceeding operation. Benzyl penicillin is given, 500,000 units intramuscularly, six-hourly from two hours prior to operation continuing for two or three days and thereafter orally for a total of one week. The length of time during which intramuscular dosage will be necessary will be linked to the removal of any drainage tube. In cases of penicillin sensitivity, erythromycin should be given, the dose being 500 mgm six-hourly. Intramuscular administration will be necessary for the first few doses switching to oral dosage as soon as the patient's general condition permits.

A study on the use of "mini-heparin" for five days (5,000 international units subcutaneously), three times a day starting two hours pre-operatively, is presently under way and no general advices can be given at this time.

Perineal pads are routinely employed and the perineal area is securely draped off from the operative field.

A unilateral block spinal anaesthetic is given employing heavy Nupercaine at lumbar 2–3 level the patient being left lying on the affected side for three minutes. We believe spinal anaesthesia of this kind is advantageous as post-operative confusion is lessened due to the complete relief of pain post-operatively for one to two hours and, therefore, less post-operative narcotics are required. As the spinal anaesthesia is unilateral there are less problems with hypotension. Moreover in the case of the diabetic, liquids and a light diet can be given much sooner after operation and there are fewer chest complications in patients with chronic bronchitis. There is diminished intra-operative blood loss and the sympathetic block gives a

clearer line of demarcation useful to the operating surgeon.

5. Surgical technique

The surgery itself should encompass two basic essentials—a clear objective in tissue management and gentle handling of all tissues. Each tissue demands a particular approach.

Where bone is transected it must be sculptured so that it will best accommodate the transfer of the high forces involved in walking. This is particularly applicable in the below knee amputation but rounding off the anterior edge of the cut femur may also be required. Where feasible the medulla should be closed by a periosteal flap to retain normal intramedullary pressures. (Askalanov and Aronov (1959)).

It seems eminently sensible to attach divided muscle to the end of the stump bone. The early German workers stressed this although their objective was to produce a muscle "pad". Since then Dederich (1967), Burgess (1968) and Weiss (1969) have emphasized this requirement. The author is equally convinced but so far there is little scientific evidence to support this view which is readily appreciated in clinical practise. It is said to be more physiological, providing a more stable shape, less muscle wasting, better proprioception with retention of existing neuro-muscular mechanisms, more efficient vascular dynamics, etc., but few studies exist. Dederich (1967) demonstrated improved vascular supply to the stump end after myoplastic revision and Hansen-Leth and Reimann (1972) demonstrated in laboratory animals a better blood supply to the stump end when muscle stabilization was used.

A Dundee study (Condie 1973) suggests that muscle stabilization does give a rhythmic, phasic muscle activity on walking in contrast to the continuous but irregular pattern of EMG activity in unsecured muscle.

Management of the divided nerve has been a subject of controversy for a very long time. It has become generally accepted to undertake a high clean cut to ensure that the inevitable neuroma becomes located in such a situation that it neither interferes with prosthetic fitting nor produces significant symptoms. Swanson *et al* (1972) propose in both stump revision and primary amputation that the nerve be capped with a silicone device. Further evaluation of this work is required.

The management of skin as a tissue is basic to the success of any amputation. The higher the ratio of the base to the length of flap the better the chance of primary wound healing. Equally important is gentle handling and the close apposition of the skin edges.

All those who require to take the patient through his whole rehabilitation programme are aware that wound haematoma is the curse of amputation surgery. All but a few recommend drainage and most advocate closed suction drainage.

6. Stump environment

The stump environment imposed on the operating table must be consistent with the proposed patient management programme and may be as important as the surgery itself. The effect of surgical trauma is to produce a response from the injured tissues resulting in the clinical phenomenon of oedema and the effect is greater the more distal the wound. The responsibility of the surgeon is to ensure that this response does not adversely affect the blood supply. If oedema is permitted then interstitial pressure may rise sufficiently to depreciate an already precarious blood supply and produce ischaemia.

It is clear that bandaging techniques can be fraught with danger. Spiro *et al* (1970) showed that a sustained pressure above 15 mm Hg decreased blood flow. Other contributions such as those of Muller and Vetter (1954) and Wood (1968) confirm values of the same order and the latter emphasizes the influence of posture. When the bandage is applied above the knee, Husni *et al* (1968) suggest that pressures of that order applied to the popliteal fossa create a tourniquet effect. Johnson (1972) goes further and suggests that no dressing or bandage exerting a pressure of 10 mm Hg or more should be left on overnight. Isherwood *et al* (1975) in reviewing the subject outline the dangers of bandaging and review more recent techniques such as Puddifoot's (1973) pressure sock which exerts much lower sustained pressures. This is compared with the effects of the very high pressures produced by both skilled and unskilled "bandagers".

Since the work of Berlemont (1961), the dissemination of his work by Weiss (1966) and later by Burgess (1968), the use of the rigid plaster cast as a post-operative dressing for the

amputation stump has become widespread. Mooney *et al* (1971) defined the place of the rigid cast dressing and demonstrated its superiority over the soft dressings in a strictly controlled study. The extension of the rigid cast dressing to include a pylon and foot within the philosophy of immediate post surgical fitting remains a matter of controversy involving as it does factors relating to psychological impetus, the gradual application of functional mechanical stress, the discriminate apportionment of blood supply to different tissues on exercise, and the effect of "training muscle" with a subsequent decrease in blood flow demand, all making for individual prescription in post-operative management.

Recent work by Redhead *et al* (1974) now under study in a multi-national trial relates to a more ideal approach to stump environment encompassing control of the essential parameters of pressure, humidity, temperature and sterility—so-called Controlled Environment Treatment. Further reports of this technique are awaited with interest as early publications, e.g. Redhead (1973) suggest there are significant benefits for the patient in terms of wound healing and early maturation of the stump.

7. Immediate post-operative care

Apart from the environment of the stump the immediate post-operative care relates to the judicious deployment of analgesics and appropriate application of the elements of rehabilitation. Those undertaking amputation surgery routinely will be aware of the pattern of pain incidents under given circumstances and should be in a position to provide analgesics before the build up of pain to distressing levels. Too often analgesics are given when the pain is already intense and sustained. Once the patient has recovered from the immediate effects of surgery then he or she should be encouraged to wear day clothes and, whatever mode of mobility is chosen, be involved in an increasing programme of self-help and training in the activities of daily living. The physiotherapy programme should involve general exercises, if need be, crutch exercises and even muscle setting exercises of the muscles of the stump. The latter part of the programme will depend on the surgery applied and the stability of the proximal joint. If, for example, a rigid cast has been applied after below-knee amputation then muscle setting exercises can begin without detriment to the patient. The speed of development of the rehabilitation programme will clearly depend on how early a prosthesis is fitted, on the stump environment, and on the general condition of the patient. In those centres with a full clinic team a programme of early post-surgical fitting can be applied with confidence based on the experience of Burgess *et al* (1971), Sarmiento *et al* (1970), Jeffrey (1974) and others. If employed, this programme must ensure very carefully graduated weight bearing along the lines recommended by Burgess. The team must be sensitive to any changes occurring in the stump or in the relationship between stump and rigid cast and be prepared to change the cast at any time if there are signs indicating ischaemia, infection, haematoma or a significant discrepancy in volume. Most centres will apply a less aggressive regime and change the initial rigid cast at 5–7 days and retain the rigid cast until the 18th or 21st day when the sutures can be safely removed. Earlier removal of the sutures is not advocated in the case of the dysvascular amputee. In the young and fit, sutures can probably be removed about the fourteenth day.

8. Prosthetic fitting and integrated rehabilitation

Whatever philosophy is practised immediately following surgery, in the uncomplicated case the patient should be ready for initial prosthetic fitting somewhere between 3–4 weeks. It is essential that the arrangements are such that the patient does not require to wait more than a few days for provision of the initial prosthesis. As the physical therapy programme develops both stump volume and shape are changing rapidly and it is essential that the team are sensitive to this situation and by one means or another ensure that a good stump/socket interface is maintained. After initial fitting, walking training is introduced into the overall rehabilitation programme. At this time the rehabilitation goals set for the individual patient should be reassessed and adjustments made. In a limited programme the accent must be on self care and the activities of daily living.

The more ambitious programmes should include progressive development of the prosthetic prescription, the performance of more

difficult mobility tasks, plans for vocational rehabilitation where required and other elements of social integration.

Amputation techniques

Hemipelvectomy

The incidence of this procedure is low, perhaps of the order of one amputation per million of population per year, and usually performed for chondrosarcoma. The procedure itself is an anatomical exercise and I suggest that the best description of the operation is that of Monro (1952). It is suggested further that one surgeon in each community should take responsibility for this demanding and mutilating procedure.

Hip disarticulation

This procedure too is normally undertaken because of tumour and is again an anatomical exercise and many descriptions including that of Boyd (1949) are available for the surgeon to study.

Above-knee amputation

Amputation in the thigh can be carried out at different levels depending on the factors already outlined and thus the surgeon must be sensitive to the anatomy of the part at which amputation is to be performed.

Generally equal anterior and posterior flaps will be employed but variations may be required. The general rule will be that the ratio of the base of the flap to its length will be as great as possible. It is important that there is an adequacy of skin so that the flaps can be sutured without undue tension. Those practising amputation surgery can usually guess this with accuracy and accommodate the terminal bulk of the stump. The inexperienced would be wise to retain a sufficiency of skin in the flaps which can later be tailored to the needs of the stump at the end of the operation. The criteria in the management of muscle should be to ensure a firm attachment of severed muscle to the end of the stump. This is essential as following amputation there is less muscle to do more work, the muscle contractions are of longer duration thus limiting blood flow in the muscle during contraction with an earlier onset of fatigue. Moreover a divided muscle has a reduced velocity of contracture and a reduced excursion. It is accordingly essential that divided muscles are securely attached. The adductors, which normally contribute to stability during lateral rotation of the thigh will, after amputation if properly managed, stabilize the femur within the stump and prevent its lateral migration. The hamstrings after division forfeit their two joint functions and have instead a primary role in stabilizing the prosthetic knee and their secure attachment is equally important. The author's procedure described in detail elsewhere (Murdoch, 1968) involves suture of the hamstrings and any adductors involved via drill holes to the end of the divided femur. The medulla is closed with an anterior periosteal flap and the quadriceps drawn over the end of the stump and sutured to the posterior muscles (Figure 1). As in other amputations the nerve is drawn down gently and divided with a high, clean cut to ensure that the inevitable neuroma will be remote from any distal scarring. The main vessels are isolated, ligatured and divided low in the wound to ensure optimum terminal blood supply.

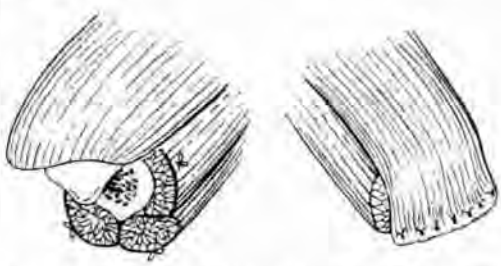

Fig. 1. Schematic illustration of procedure advised by author. Lateral and medial hamstrings and adductors sutured under tension to bone via drill holes and cut flush with bone end. Medulla closed with anterior periosteal flap. Quadriceps left long and drawn over stump end to be sutured to posterior muscles.

Transcondylar and supracondylar

A variety of these procedures have been described Callender, (1935, 1938); Gritti (1857) and Slocum (1949) and some still have their protagonists. Surgeons concerned only with early wound healing may be persuaded to perform these procedures but the resultant stump is often unable to tolerate any significant end bearing and its length will often preclude the use of a number of knee devices. Moreover the resultant stump can produce

many problems for the prosthetist, particularly in the case of the Gritti-Stokes procedure. One can accept, however, that there are special circumstances where the surgeon may elect to perform one of these procedures for reasons such as cosmesis but he should not, until evidence is available, defend his decision by referring to end bearing properties.

Knee disarticulation

This procedure provides a stump capable of true end bearing with good proprioception, excellent rotational stability between the stump and socket and, because of its bulbous end, ensures excellent suspension. It is clearly a valuable procedure in childhood as it retains the epiphysis and in the elderly too, if a below-knee amputation cannot be performed.

The surgical procedure itself is simple and non-traumatic. Few muscles are cut and haemostasis is easily obtained. Kjølbye (1970) describes this procedure in detail and advocates lateral flaps rather than long anterior flaps. The author's experience has led him to use the lateral flap techniques exclusively (Figure 2). The technique described by Kjølbye is based on that of Velpeau (1830) and Smith (1825).

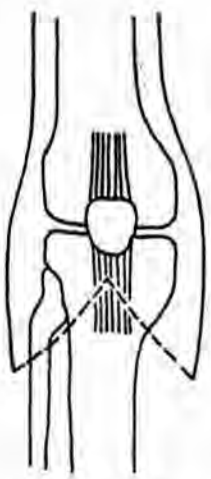

Fig. 2. Sketch showing disposition of lateral flaps in knee disarticulation amputation.

Ideally the patient is placed prone on the operating table providing easy access to both anterior and posterior aspects of the knee. The incision is planned by carefully outlining bilateral flaps in methylene blue. The incision is started just below the tip of the patella continuing downwards vertically to the upper border of the tibial tubercle then curving laterally for the lateral flap and medially for the inner flap over the sides of the knee, ending in the mid line at the popliteal crease posteriorly at a level approximately 25 mm above the joint line. The lowest point of the lateral flap should be half of the antero-posterior diameter below the knee joint line or about 30 mm below the upper border of the tibial tubercle. The medial flap should be 20–30 mm longer than the outer in order to secure adequate covering of the slightly larger and more prominent medial femoral condyle. The incision is carried down through skin, subcutaneous tissue and fascia and the flaps raised keeping close to the periosteal covering. The patellar tendon and medial and lateral hamstrings are divided.

With the knee flexed the lateral and medial cartilages are freed from their tibial attachment and the capsule and collateral ligaments of the knee incised at the margins of the joint surfaces leaving the menisci in contact with the femoral condyles. The cruciate ligaments are divided and the posterior capsule of the joint dissected from the tibia. The popliteal vessels are identified, secured, divided and ligated. Both tibial and common peroneal nerves are isolated, pulled down gently and severed as high as possible and allowed to retract. The disarticulation is completed by dividing the remaining soft tissues.

The patellar tendon is sutured to the remainder of the cruciate ligaments. The divided hamstrings may be sutured to the intercondylar notch or to the remaining part of the capsule. The patella and fat pad are left undissected and all articular cartilage left undisturbed. The wound is closed in layers. In doing so it is extremely important that sufficient skin is present for a loose closure.

Closed suction drainage is employed and after appropriate dressing a rigid plaster of Paris cast applied.

Below-knee amputation

A variety of procedures are available including the so-called "conventional" procedure employing anterior and posterior flaps. As it happens there are few indications for this

procedure. The author's preference is for an osteomyoplasty technique (Ertl, 1949) in all conditions other than vascular deficiency. In the dysvascular patient the posterior flap procedure, Ghormley (1946), Burgess (1969), is appropriate to most cases. Increasing experience is likely to demonstrate the value of the sagittal flap technique of Persson (1974) and other flaps designed individually for the patient.

Osteomyoplasty

The procedure employed by the author is almost precisely that described by Loon (1962). The level of operation when the pathology will allow is usually just above the musculotendinous junction of the calf muscles. Vertical incisions are made on the antero-lateral and postero-medial aspects of the stump distally from a point about 25 mm above the anticipated level of bone section. With the need to expose some 75–100 mm of tibia below the anticipated level of ultimate bone section two vertical incisions are carried down far enough to permit this and are joined by a circular incision. The two flaps thus formed are elevated subcutaneously to ensure an intact deep fascia and muscle aponeurosis. A vertical cut is made through the deep fascia of the limb just lateral to the anterior tibial crest avoiding the periosteum. A further vertical incision is made through the deep fascia overlying the fibula. The whole of the anterior lateral group of muscles including the peroneals is then elevated by sharp dissection from the distal part of the operative field from the bed formed by the tibia with its overlying periosteum, interosseous membrane and fibula, to a point just proximal to the level of bone section. The posterior muscle flap is treated in a similar manner. The fibula is now divided at the intended level of tibial section along with the attached interosseous membrane. Two vertical incisions are made in the periosteum of the tibia so that roughly equal osteo-periosteal flaps can be elevated. The antero-medial flap of periosteum is raised with a medium sized gouge, with small flakes of bone remaining attached to the parent periosteum, to a point above the anticipated level of bone section. The same procedure is employed in elevation of the postero-lateral flap. Only now is the tibia divided and the anterior distal end sculptured.

The posterior tibial vessels are secured, isolated and divided, and the nerve divided cleanly under light tension. The postero-lateral osteo-periosteal flap is then reflected upon itself and sutured to a small cuff of periosteum elevated from the fibula. The antero-medial osteo-periosteal flap is then brought over the end of the tibia and sutured to the fibular periosteal cuff. Suture of the two flaps is now completed forming a rather firm osteo-periosteal tube bridging both bones (Figure 3). The anterior and posterior muscle flaps are then cut to length, trimmed, contoured and sutured over the periosteal tube. In the process the remaining vessels and nerves are isolated and dealt with. It is essential that both groups of muscles are separately anchored to the periosteum of the tibia and to the base of the bridge. The two skin flaps are now carefully tailored and sutured over the muscles of the stump. Closed suction drainage is employed, the wound dressed and a rigid cast applied.

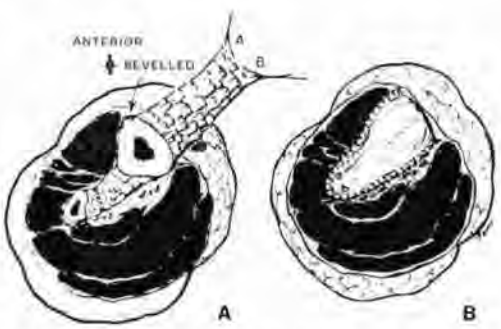

Fig. 3. Osteomyoplasty. Sketch (A) shows the postero-lateral osteo-periosteal flap reflected laterally and sutured to periosteum of fibula. The antero-medial osteo-periosteal flap displayed demonstrates attached osseous chips. It is brought over the end of the tibia after bone sculpture (sketch (**B**)) and sutured to the periosteum of the fibula (note points A, B) forming a firm tube.

(From *Artificial Limbs* 6, No. 2, June, 1962, 90–91).

Early ossification of the osteo-periosteal tube can be expected in seven to nine weeks after operation and the resultant stump is a particularly tough organ of locomotion subject to little change in volume and retaining muscles which on test demonstrate very satisfactory phasic muscle activity (Figure 4).

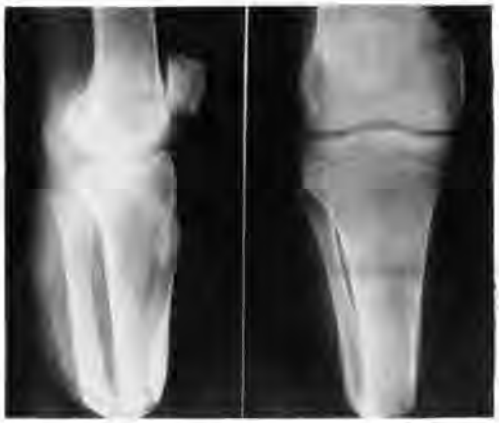

Fig. 4. Radiographs (lateral projection on the left, antero-posterior on the right) show established bony bridge between the tibia and fibula some three years after operation.

The posterior flap operation

A very short anterior flap and a long posterior flap are employed. The anterior flap is at the level of anticipated bone section and if it has a dimension of length would normally be no more than 10 mm. The flaps are outlined in methylene blue or a similar dye and the anterior incision carried down through deep fascia to the tibia. The antero-lateral muscles are divided, the artery and veins ligated and the nerve cut and allowed to retract. The fibula is divided with a Gigli power saw about 25 mm above the line of tibial section. The tibia itself is divided in a similar way. The posterior flap is deepened through the fascia and the muscles divided to complete the amputation. Practice varies with regard to the treatment of the posterior flap. Many surgeons taper the posterior flap towards the distal end to reduce the amount of tissue in the muscle mass. The author's practice is to excise not only the deep posterior muscles but the soleus as well because of the common finding of large clots in the soleal venous sinus. Whichever method is used the peroneal and posterior tibial neurovascular bundles are dealt with. The tibial bone end is then carefully sculptured to produce a smoothly contoured antero-distal aspect. After further tailoring the gastrocnemius is sutured to the anterior tibial periosteum and the fascia overlying the anterior tibial compartment. Trimming of the posterior skin flap may be required before its final closure. There should be no concern if small "dog ears" are left at each end of the wound as they readily disappear.

Sagittal incision for below-knee amputation

This procedure described by Persson (1974) is said to improve the healing possibilities by using medial and lateral flaps (Figure 5) and avoiding the all too common occurrence of ischaemia of the short anterior flap in the procedure described above. Persson's procedure should be part of the surgeon's armamentarium.

Fig. 5. Sagittal incision for below-knee amputation in ischaemic gangrene as described by Persson.

Syme's amputation

This procedure first described by Syme in a series of articles dated from 1843 to 1857 remains a useful procedure and produces a stump which in a child retains the distal tibial epiphysis and at all ages provides for a measure of end bearing. The best description of this procedure is to be found in a classical article by Harris (1966). His description does not differ in essence from that described by Syme himself.

Both incisions, dorsal and plantar are made from the tibia to the lateral malleolus to just below the medial malleolus. Both are carried down to bone. The dissection is thenceforth developed throughout with the knife against the bone thus ensuring integrity of the heel flap to the posterior tibial artery and the stabilized subcutaneous fibro-elastic tissue of the heel pad (Figure 6). The bones are divided at the dome of the ankle joint with the saw cut parallel to the ground and not necessarily at right angles to the shaft of the tibia. The heel flap is now placed precisely over the cut end of the bone, sutured, and secured in position.

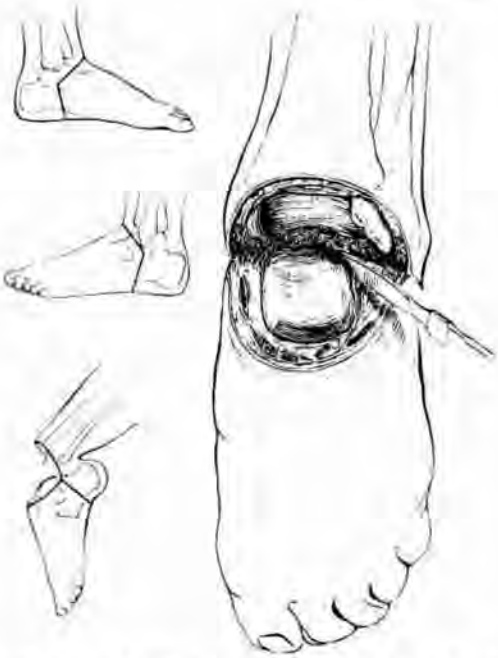

Fig. 6. Line drawing illustrating bone section and heel flaps in Syme's amputation.

Closed suction drainage is employed. It is essential to ensure the continued firm location of the heel pad. Harris recommended a strapping technique. Transfixion pins have been employed but prevent early post-operative weight bearing and can be lost in the wound. The author employs a tension sock and rigid cast. The history of this procedure is such that adherence to Syme's technique is mandatory if a good result is to be maintained; or, to quote Syme:—

> "The amputation is easily executed and proves in the highest degree satisfactory .... if done in accordance with certain principles which have been carefully explained but it is difficult and disastrous if performed incorrectly."

Modifications of this procedure (Elmslie 1924) which require a higher bone division are doomed to failure (Murdoch 1976) because of the reduced area presented by the divided bones and the inability to locate the heel pad.

The resultant stump from the classical Syme's procedure has one defect and that is primarily due to the large medio-lateral diameter which leads to poor cosmesis. Murdoch (1976) demonstrated that the Syme's stump in a modern prosthesis is not wholly end bearing. This would seem to justify the modification of a procedure suggested by Mazet (1968) who recommended removal of the malleolar projections. This practise is now standard in Rancho Los Amigos (Wagner, 1975—personal communication) who perform the procedure in two stages as recommended by Hulnick *et al* (1949).

Partial foot amputations

A variety of these procedures have been described over the years, Chopart (Fourcroy 1792), Lisfranc (1815), Pirogoff (1854). Pirogoff's procedure retains part of the os calcis and its associated heel pad and provides excellent end bearing properties. However it requires that bony union takes place between the os calcis and the cut end of the tibia and the resultant stump is so long that a modern prosthesis cannot be fitted. Even so within certain cultures it may remain a valuable procedure.

Chopart's procedure located at mid tarsal level has few adherents today because of the tendency of the stump to become inverted and plantar flexed even when the tendon to tibialis anterior is attached to the neck of the talus. The stump is very short and difficult to fit.

In Lisfranc's procedure the forefoot is disarticulated along the tarso-metatarsal line. This operation also has few adherents today because of the short stump and because of its poor cosmesis.

The transmetatarsal amputation is widely used in a variety of situations, for example in trauma and diabetes. It is essential that there should be an adequate plantar flap sufficient to cover the divided and sculptured metatarsal bones.

Amputation of all five toes remains a valid procedure. The technique recommended is that described by Nissen (1957). Flint and Sweetnam (1960) provided evidence of its value. The procedure may be used in a variety of conditions and provides a stump which requires no more than a special insole incorporating an arch support and toe spacer within a normal shoe.

Part II will cover the subjects of amputation in a variety of disease and disability categories, in certain special situations, and comment on recent advances and their implications for the future.

REFERENCES

ASKALANOV, I. N. and ARONOV (1959). Comparative experimental evaluation of some methods of bone revision in amputation with primary and secondary healing. *Ortopediya, travmatologiya i protezirovanie*, **20**, 30–33.

BERLEMONT, M. (1961). Notre experience de l'appareillage precoce des amputés de membre inferieur aux establisements. Helio Marins de Berck. *Annales de médecine physique*, **4**, 4.

BOYD, H. B. (1949). Disarticulation of the hip. Campbell's Operative Orthopedics (1). Ed. Speed, J. S. and Smith, H. 824–828. The C. V. Mosby Co., St. Louis.

BURGESS, E. M. and ROMANO, R. L. (1968). The management of lower extremity amputees using immediate post-surgical prostheses. *Clin. Orth. and Rel. Res.*, **57**, 137–146.

BURGESS, E. M. (1968). The stabilization of muscles in lower extremity amputations. *J. Bone and Joint Surg.*, **50A**, 1486–1487.

BURGESS, E. M. (1969). The below-knee amputation, Inter-Clin. Inform. Bull., VIII, No. 4.

BURGESS, E. M., ROMANO, R. L., ZETTLE, J. H., and SCHROCK, R. B. (1971). Amputations of the leg for peripheral vascular insufficiency. *J. Bone and Joint Surg.*, **53A**, 874–889.

CALLENDER, C. L. (1935). A new amputation in the lower third of the thigh. *J. Amer. Med. Assoc.*, **105**, 1746–1753.

CALLENDER, C. L. (1938). Tendoplastic amputation through the femur at the knee. *J. Amer. Med. Assoc.*, **110**, 113–118.

CONDIE, D. N. (1973). Electromyography of the lower limb amputee. *Medicine and Sport*, **Vol. 8, Biomechanics 3**; 482–488, Karger, Basle.

DEDERICH, R. (1967). Technique of myoplastic amputations. *Annals of the Royal College of Surgeons*, **40**, 222–227.

ELMSLIE, R. C. (1924). In "Carson's Modern Operative Surgery". 1st. ed. 132, Cassel & Co., London.

ERTL, I. (1949). Uber Amputationsstumpf., *Chirurg.*, **20**, 218.

FLINT, M. and SWEETNAM, R. (1960). Amputation of all toes. *J. Bone and Joint Surg.*, **42B**, 90–96.

FOURCROY, A. F. (1792). La médecine éclairée par les sciences physiques, Vol. 4, 85–88. Chez Buisson. Contains first description of Chopart's method of partial amputation of the foot.

GHORMLEY, R. K. (1946). Amputation in occlusive vascular disease. In "Peripheral Vascular Diseases". 1st. ed. Ed. Allen, E.V., Barker, N. W. and Hines, Jun., E. A. 783: W. B. Saunders Company, Philadelphia.

GRITTI, R. (1857). Dell' amputazione del femore al terzo inferiore e della disarticolazione del ginocchio. *Ann. Univ. Milano*, **161**, 5–32.

HANSEN-LETH, C. and REIMANN, I. (1972). Amputations with and without myoplasty on rabbits with special reference to the vascularisation. *Acta orth. Scand.*, **431** 68–77.

HARRIS, R. I. (1966). "History and development of Syme's amputation". In "Selected articles from Artificial Limbs." January 1954–Spring 1966, p. 233.

HULNICK, A., HIGHSMITH, C. and BOUTON, F. J. (1949). Amputations for failure in reconstructive surgery. *J. Bone and Joint Surg.*, **31A**, No. 3 639–649.

HUSNI, E. A., XIMENES, J. O. C. and HAMILTON, F. G. (1968). Pressure bandaging of the lower extremity. *J. Amer. Med. Assoc.*, **206**, 2715–2718.

ISHERWOOD, P. A., ROBERTSON. J. C. and ROSSI, A. (1975). Pressure measurements beneath below-knee amputation stump bandages, elastic bandaging, the Puddifoot dressing and a pneumatic bandaging technique compared. *Brit. J. Surg.*, **62**, 982–986.

JEFFREY, A. K. (1974). Below-knee amputation and immediate prosthetic fitting in vascular disease. *New Zealand Med. J.* (in press).

JOHNSON, H. D. (1972). Mechanics of elastic bandaging. (Correspondence) *Brit. Med. J.*, **3**, 767–768.

KJØLBYE, J. (1970). The surgery of the through-knee amputation. Prosthetic and Orthotic Practice. Ed. Murdoch, G., 255–257. Edward Arnold (Publishers) Ltd., London.

LISFRANC, J. (1815). Nouvelle méthode opératoire pour l'amputation partielle du pied dans sons articulation tarso-métetarsienne; méthode précédés des nombreuse modifications qu'a subies celle de Chopart. Gabon, Paris.

LOON, H. E. (1962). Below-knee osteomyoplasty. *Art. Limbs*, 6(2), 86–99.

MAZET, R. (1968). Syme's amputation. A follow-up study of fifty-one adults and thirty-two children. *J. Bone and Joint Surg.*, **Vol. 50A**, 8, 1549–1563.

MONRO, R. and SIR G. GORDON-TAYLOR (1952). The technique and management of the 'Hindquarter' amputation. *Brit. J. Surg.*, Vol. XXXIX, **158**, 536–541.

MOONEY, V., HARVEY, J. P., MCBRIDE, E. and SNELSON, R. (1971). Comparison of post-operative stump management: plaster vs. soft dressings. *J. Bone and Joint Surg.*, **53A (2)**, 241–249.

MÜLLER, E. A. and VETTER, K. (1954). The effect of pressure loads upon blood supply to the skin. Arbeitsphysiologie, **15**, 295–304.

MURDOCH, G. (1968). Myoplastic techniques. *Bull. Pros. Res.*, **10–9**, 4–13.

MURDOCH, G. (1976). Syme's amputation. *J. Royal Coll. Surg. Edin. Jan.* **Vol. 21, No. 1**, 15–30.

NISSEN, K. I. (1957). Amputation of all five toes. In Operative Surgery. Vol. 5, 301. Ed. Rob, C. and Smith, R., Butterworth, London.

PERSSON, B. M. (1974). Sagittal incision for below-knee amputation in ischaemic gangrene. *J. Bone and Joint Surg.*, **56B** (1), 110–114.

PIROGOFF, N. I. (1854). *J. Military Medicine, St. Petersburg*, **63**, 83.
—*see also* Farabeuf (1881) p. 500.

PUDDIFOOT, P. C., WEAVER, P. C. and MARSHALL, S. A. (1973). A method of supportive bandaging for amputation stumps. *Brit. J. Surg.*, **60**, 729–731.

REDHEAD, R. G. (1973). The problems of the post-operative and stump environment interface. First International Congress of Prosthetic Techniques and Functional Rehabilitation. 65–73. Egermann Druckereigesellschest, M. B. H. & Co., K. G., Vienna.

REDHEAD, R. G., SNOWDON, C., BURGESS, E. M., and VITALI, M. (1974). Controlled environment treatment for the post-operative management of wounds of the upper and lower limb including amputation stumps. Presented at the First World Congress, International Society for Prosthetics and Orthotics, Switzerland, October.

SARMIENTO, A., MAY, B. J., SINCLAIR, W. F., MCCOLLOUGH, N. C. III and WILLIAMS, E. M. (1970). The impact of immediate postsurgical fitting. *Clin. Orthop.*, **68**, 22–31.

SLOCUM, D. B. (1949). The rounded epicondylar tendo-plastic amputation. Campbell's Operative Orthopedics (1). Ed. Speed, J. S. and Smith, H. 819–822. The C. V. Mosby Co., St. Louis.

SMITH, N. (1825). Amputation at the knee joint. *Amer. Med. Rev., Philadelphia*, **2**, 370.

SPIRO, M., ROBERTS, V. C. and RICHARDS, J. B. (1970). Effect of externally applied pressure on femoral vein blood flow. *Brit. Med. J.*, 719–723.

STOKES, W. (1870). On supra-condyloid amputation of the thigh. Med.-chir. Trans. London, **53**, 175–186.

SWANSON, A. B., BOEVE, N. R. and BIDDULPH, S. L. (1972). Silicone rubber capping of amputation neuromas—Investigational and clinical experience. *Inter-Clin. Inform. Bull.*, **11**, No. 5, 1.

SYME, J. (1843). *Edinburgh Monthly Journal of Medical Science* 3, No. XXVI, p. 93. (1843) Ibid 3 No. XXVIII, p. 274. (1844) Ibid 4 No. XLIV, p. 647. (1845a) Ibid 5 No. LIII, p. 341. (1845b) *Monthly Journal of Medical Science* 5, No. LIII, p. 337. (1846) Ibid 6, No. LXVIII, p. 81. (1857) *Lancet* 2, 384, 394, 480.

VELPEAU, A. (1830). Mémoire sur l'amputation de la jambe dans l'articulation du genou, et description d'un nouveau "procedé" pour pratiquer cette operation. *Archives générales de Médecine*. **24**, 44–60.

WAGNER, F. William (1975). Personal communication.

WEISS, M. (1966). Neurological implications of fitting artificial limbs immediately after amputation surgery. Report of Workshop Panel on Lower Extremity Prosthetic Fitting. Committee on Prosthetic Research and Development. National Academy of Sciences, Washington, D.C.

WEISS, M. (1969). Physiologic amputation, immediate prosthesis and early ambulation. *Pros. Int.*, 3, No. **8**, 38–44.

WOOD, E. J. (1968). The venous system. *Sci. Amer.* **218**, 86–96.

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Techniques of lower limb prosthetic manufacture using Lightcast II

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Introduction

Lightcast II is an orthopaedic casting system consisting of an open weave fibreglass tape impregnated with a photo-sensitive resin which will harden in three minutes when exposed to light in the 3,200—4,000 angström range.

A total of 393 lower limb amputees have been fitted to date with the Lightcast II system which has now become the standard temporary fitting procedure of the West Park Amputee Centre.

TABLE ONE

Numbers of prostheses fitted to date

	Temporary Stage	Definitive Stage
Hip disarticulation	20	0
Above-knee	3	0
Knee disarticulation, Callander or Gritti		
Stokes	50	10
Below-knee	250	35
Syme	25	0
TOTAL	348	45

Lightcast II tape has been found to be especially useful for the fitting of the below-knee amputee. It has also found occasional use in the construction of definitive prostheses for geriatric amputees.

In almost all cases the Otto Bock modular endoskeletal prosthetic system has been used. This is the authors' choice of system, however the technique can be easily modified to suit all modular systems provided that the same principles of attachment of the modular hardware to the Lightcast II socket are followed. A Lightcast II socket can also be incorporated in an exoskeletal prosthesis. However, the advantages of the porous socket are lost in this case.

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Lightcast II has a rough surface texture which necessitates the use of some padding material to separate weight bearing surface tissues from the socket wall. Various materials have been tried. A porous P. E. Lite* material has been found to be most satisfactory, since it can be moulded easily and directly to the amputee's stump and complements the porosity of the Lightcast II tape.

Although the finished socket is strong, the bonding between layers of Lightcast II can be comparatively poor unless each layer is rubbed well into the previous layer.

The techniques for constructing prostheses using Lightcast II are outlined below. An instruction manual has also been written and may be referred to for a more detailed description (Ruder *et al* 1976).

Prosthesis for the below-knee amputee

To fabricate a Lightcast II socket for a below-knee amputee it is best to have the patient lying in a supine position on a stretcher. A foam rubber distal pad is placed so that it will also cover the anterior distal aspect of the tibia. If necessary, extra relief pads can now be adhered directly over any other prominent bony areas. A cast sock, suspended firmly, will hold the pads in place and also sufficiently compress the soft tissue.

A conical sleeve is constructed from P. E. Lite to the stump measurements, heated until soft, and quickly pulled over the residual limb well proximal of the femoral condyles. A P. E. Lite cap is glued to the distal end.

Several strips of approximately 300 mm in length are cut from a roll of Lightcast II tape (100 mm wide). The first strip is applied distally from a posterior to anterior direction. The second strip is started medially and carried around the distal end in a lateral direction. The remaining strips should cross the first strips diagonally. Three or four strips are now placed

*P. E. Lite 60245P obtainable from Fillauer Orthopedics, Chattanooga, Tennessee, U.S. 37401.

starting just above the patella medio-laterally, overlapping each other by half, moving distally and leaving the popliteal area open. Circumferential wrapping is now started distally and under firm but controlled tension carried proximally well over the femoral condyles. The completed socket wrap is well moulded and rubbed to ensure good adhesion between layers. A close fit in weight bearing areas is ensured by applying pressure during the curing process in the Lightcast II lamp. The amputee's knee should be held in a slightly flexed position (5 to 10 degrees) during the whole of this procedure.

The best way to attach modular hardware to the Lightcast II socket is to fabricate a special laminated cup. This cup is formed from 3 or 4 layers of nylon stockinette and 2 layers of glass fibre. An aluminium base plate 80 × 80 mm is incorporated between the laminations. The cup forms a cylinder of about 120 mm in height and 110 mm in diameter. It is split in several places to allow spreading and easy moulding over the distal end of the Lightcast II socket. The hardware is bolted to the reinforced base of the cup. It is necessary to sand the outside of the cup to aid the adhesion of Lightcast II tape.

A mixture of resin and sawdust can be used between the socket and the cup to provide an even more secure attachment. Once the distal cup has been moulded in the proper alignment a roll of Lightcast II tape (100 mm wide) is wrapped circumferentially to secure it to the socket. Buckles for the cuff suspension are fastened to the socket.

After final curing of the socket it is removed from the amputee's stump. The proximal rim is outlined and trimmed with a cast cutter. To finish the proximal edge of the Lightcast II socket a strip of P. E. Lite is moulded over the outside rim and adhered to the internal lining as it extends above the Lightcast. The prosthesis can now be assembled and fitted with a regular wool sock (Figure 1).

Prosthesis for the Syme's amputee

The method of construction is similar to that used for the below-knee prosthesis. In order to permit removal of the prosthesis after completion a 25 mm foam rubber pad is adhered to the P. E. Lite liner just proximal to the most prominent malleolus (usually medial). In some cases it is necessary to cut an obturator

Fig. 1. Temporary below-knee prosthesis with Lightcast II socket.

in the socket without cutting the P. E. Lite liner which serves as a protecting tongue.

A prefabricated cup is bolted to a Syme SACH foot, heated and held in place with proper alignment and then secured with 1 or 2 rolls of Lightcast II tape (100 mm wide). Minor alignment corrections can be made by adding a wedge between the base of the SACH foot and the plastic cup.

Prosthesis for the knee disarticulation amputee

In the past it has always been difficult to construct a temporary prosthesis at reasonable cost with a satisfactory fit for a knee disarticulation, Callander or Gritti-Stokes amputation. The Lightcast II system again makes this a relatively easy task.

In most cases it is possible to fabricate the socket directly on the amputee's residual limb thus eliminating lengthy casting and modification procedures. The socket construction follows the same technique as outlined above. A distal pad or relief pads are rarely needed.

Several methods can be used to allow for removal of the socket depending on the bulbous nature of the amputee's stump. Often a vertical cut in the socket is all that is needed to provide sufficient flexibility. This cut should

begin distally to the widest part of the bulbous end of the stump and should extend proximally to a level where the stump has the same diameter. If necessary this cut can be continued to the proximal brim of the socket or, if so desired, an obturator can be cut. Again the P. E. Lite liner should not be cut since it will serve as a tongue.

After completion of the Lightcast II socket the prosthetic unit can be attached. This may be external hinges, the four bar linkage unit, or if sufficient clearance allows, the Otto Bock knee unit 3R16 bolted to a stainless steel cup which is then adhered to the socket with epoxy paste and reinforced with Lightcast II. A cosmetic foam cover may be added.

Prosthesis for the hip disarticulation amputee

The fabrication of a temporary hip disarticulation prosthesis is best done with the patient lying on his sound side on a stretcher. A dacron felt wrap is tailored to fit the amputated side of the pelvis snugly. The wrap extends around the sound side and overlaps anteriorly. It is held in place with tape.

Several strips are cut from a roll of Lightcast II tape (150 mm wide). The middle of the first strip is applied distally and both ends are pulled firmly around the pelvis, one posteriorly and the other anteriorly. More strips are now applied, each overlapping the previous one by a half, moving proximally well over the iliac crest and enclosing the lumbar region posteriorly and the abdomen anteriorly. A second layer of strips is now applied beginning distally and medially, crossing the first layer of strips at right angles and finishing at the proximal edge of the basket. The Lightcast II lamp is placed over the completed wrap which is cured while hand moulding over the lumbar and abdominal areas, as well as over the iliac crest, continues in order to achieve both maximum suspension of the basket and distal flattening to aid weight bearing (Figure 2).

With the patient now in a supine position the base plate of an Otto Bock modular system is fitted as close as possible to the Lightcast II basket in the proper place of alignment. It is adhered with a mixture of resin and sawdust. More strips of Lightcast II tape are now

Fig. 2. Temporary hip disarticulation prosthesis. Application of pressure during curing to ensure a good fit.

applied to cover the base plate and reinforce the basket.

After curing, the dacron felt liner can be pulled down over the edges of the basket and glued in place. Two velcro straps fasten anteriorly for suspension and the modular prosthetic system can now be reassembled and dynamic alignment performed (Figure 3).

Fig. 3. Temporary hip disarticulation prosthesis completed.

Prosthesis for the short above-knee stump

Every prosthetist is sometimes faced with an amputation at a very high level above the knee which may not be suitable for fitting with a conventional prefabricated adjustable temporary socket. Yet a definitive prosthesis may not be financially feasible at the time. Lightcast II provides a useful alternative by enabling the construction of a custom made socket at a reasonable cost.

The construction technique is similar to that used for the hip disarticulation prosthesis. A dacron felt prosthetic sock is tailored to the residual limb measurements with extra material left laterally and posteriorly. It is pulled lightly onto the residual limb well over the greater trochanter laterally and the gluteal region posteriorly.

The patient is placed so that he is lying on his sound side on the stretcher. Strips of Lightcast II (150 mm wide) are applied beginning high up posteriorly and pulling around the distal aspect anteriorly, or vice versa, depending on the muscle coverage over the distal end of the femur. More strips are applied overlapping each other by half in such a way as to provide for good tissue cushioning distally when the socket is completed. The brim of the socket should be very high posteriorly and laterally but low enough anteriorly to allow for at least 90 degrees of hip flexion.

Fig. 4. Temporary prosthesis for very short above-knee stump, ready for dynamic alignment.

During the curing process in the lamp, rapid and correct modification and moulding are of the utmost importance to provide:

1. Firm support in the gluteal region.
2. A well formed ischial seat.
3. Compression of Scarpa's triangle.
4. A flattened medial wall.
5. A relief channel for the adductor longus tendon.

After curing a modular prosthesis is attached using a plastic laminated cup or the wooden base supplied with the Otto Bock modular unit. The latter may be adhered with a resin and sawdust mixture. The edges of the socket can now be covered by folding over the dacron sock and a silesian band is added for suspension. The prosthesis is now ready for dynamic alignment (Figure 4).

Advantages of the Lightcast II system

Lightcast II is a most welcome addition to the material available for the management of lower extremity prosthetic fittings. It is strong, light in weight, porous and fairly easy to use.

Time is saved in constructing a temporary or definitive prosthesis and the amputee can begin ambulation immediately enabling the prosthetist to complete the dynamic alignment in the same session. A definitive prosthesis can therefore in many cases be completed without delay at any amputee centre and only requires the addition of a cosmetic covering.

REFERENCE

RUDER, K., KOSTUIK, J. P. and FERNIE, G. R. (1976). Lightcast 11 Casting System, Prosthetics Casting Manual. Merck Sharp and Dohme International, Rahway, New Jersey 07065, U.S.A.

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A cosmetic functional hand incorporating a silicone rubber cosmetic glove

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Abstract

A body powered hand prosthesis has been developed with a view to meeting some of the more common criticisms made against currently available designs i.e. weight and cosmetic appearance. An overall weight reduction of about 30 per cent has been achieved and the use of silicone rubber as the cosmetic glove material has resulted in greatly improved cosmesis and stain resistance. The prosthesis also incorporates a new style of prehension that is felt to give improved visibility when picking up small objects.

The hand has been produced in conjunction with the endoskeletal arm system also under development at the Orthopaedic Bio-Engineering Unit, Edinburgh.

Introduction

The hand prosthesis described was developed initially for use in conjunction with the body powered modular arm system being designed at the Orthopaedic Bio-Engineering Unit, Edinburgh, but it is also compatible with the standard wrist socket fitted to artificial arms supplied in the United Kingdom.

There were several reasons for choosing to develop a new type of hand rather than use an existing prosthesis. Firstly, the prostheses available at present generally have limited functional capacity, using simple criteria such as maximum opening and the ability to pick up and hold commonly used objects. They also tend to be rather heavy. These judgements are based partly on clinical experience but also on the performance specifications that have been laid down by several groups, an excellent example being that of Peizer *et al* (1969). These criteria can be applied to both the externally powered and body powered hands that are available, although the various experimental multi-degree of freedom prostheses which are currently being developed do not really qualify for comparison because they could not at present be fitted routinely in the clinic. The second reason for development of the hand is the production of new types of silicone rubber with a sufficiently high tear strength to be suitable for cosmetic gloves. These materials, with their ease of processing and inherent non-staining characteristics, have considerable potential for improving cosmetic appearance. The excellent results of Dr. J. Pillet, Chef du Centre Prothèse Plastique et Restauratrice de L'Hôpital St. Antoine, 76 Avenue Marceau, Paris V111e demonstrate the point. A significant objection has always been the high cost of such material but this has now fallen to the point where, although still expensive compared with polyvinyl chloride (PVC), it accounts for a relatively small proportion of the cost of the prothesis as a whole. Whilst it might be argued that existing protheses could equally well be fitted with silicone rubber gloves, it was felt that in the interests of cosmesis the mechanism of the hand should be shaped to fit the cosmetic glove rather than *vice versa*. The results seam to bear out this point of view although it has necessitated the development of new techniques for the design and construction of the hand mechanism. Fortunately, these new techniques have also led to a significant weight reduction, the overall weight saving being around 30 per cent compared with currently available prostheses.

The gripping geometry of the hand which has been developed is also different from the usual arrangement of thumb moving in opposition to the first and second fingers in a "pincer" action (Figure 1). It has often been pointed out that a single degree of freedom artificial hand will, of necessity, be a compromise when faced

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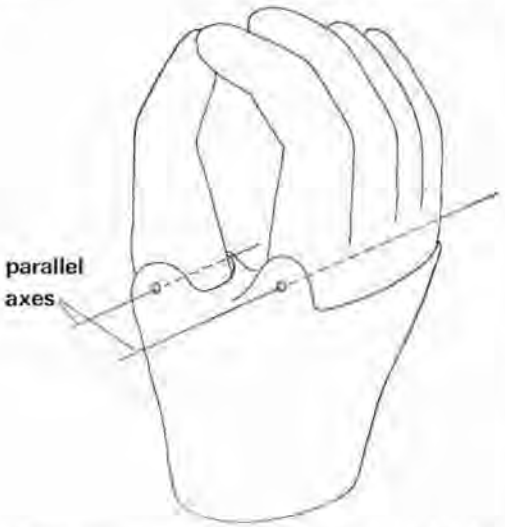

Fig. 1. Geometry of typical "pincer" action hand.

with the enormous variety of tasks that it will be asked to perform. Thus the gripping geometry used will reflect the designer's idea of the correct compromise to achieve a satisfactory engineering solution to the problem of prehension. The fact that the "pincer" action hand is virtually universal in routinely fitted prostheses would indicate that it might be a reasonable choice, although the fact that both it and the covering glove are easy to make probably plays a considerable part in contributing to its popularity. The geometry of the new hand is basically a modification of a "pincer" action combined with a lateral grip in order to improve visibility when picking up an object. It also appears to offer a more stable grip in most situations, helped by the use of the "powder grip" technique first developed by Simpson (1971).

The detailed description of the hand that follows is divided under three headings: Cosmetic glove, gripping geometry, and hand mechanism.

Cosmetic glove

Although the stain resistance of silicone rubber has always made it attractive as a cosmetic glove material, its high cost and poor tear strength in any easily processable form have been fundamental drawbacks. Fortunately, the last few years have seen the development of new higher tear strength types of room temperature vulcanising (RTV) silicone rubbers and, with their increased use, the cost has fallen. The RTV used in the development of this cosmetic glove was supplied by Chas. F. Thackray Ltd.

The glove making process itself is essentially a slush moulding technique using a flexible female mould also made from RTV. The flexibility of the mould allows gloves with any degree of finger flexure to be made. Briefly, the mould is made by taking a cast of an appropriate hand using another quick setting type of RTV (Silcoset ICI Ltd.) into which has been mixed a liquid paraffin as a release agent, a technique described by Barrachina (1972). The cast is then used to slush mould a rigid replica of the hand in polyester resin. This replica of the hand is then coated with the high tear strength RTV which, when cured and removed, becomes the finished (female) mould. After applying a release agent (paraffin wax dissolved in xylene) the slush moulding of the finished glove can begin, having first dispersed the RTV in a suitable solvent to a pourable consistency. The solvent subsequently evaporates leaving a thin layer of RTV behind. About six to eight coats are needed for 1.5 mm build up of thickness. By the use of different coloured layers, very realistic skin simulation can be achieved, and the reproduction of skin physical detail is virtually perfect. The glove is produced with moulded recesses for acrylic finger nails which are attached with silicone adhesive.

It is intended to develop the glove making technique further into the area of partial hand replacements where it is felt that the very soft, elastic nature of this particular RTV will enable maximum use to be made of any remaining movements in the stump.

Gripping geometry

As mentioned above, the diversity of situations in which a prosthetic substitute for a human hand may be used is so great that any "solution" arrived at will necessarily be a compromise. Thus a reasonable policy is to try to achieve a design that functions well in those situations in which the lack of ability to accomplish the task is a serious inconvenience to the majority of amputees. It must also be said that the functional requirements of unilateral and bilateral amputees are different. For the unilateral amputee the natural hand

will almost always be dominant, with the prosthetic hand being used in a supporting role. The act of picking up an object is relatively less important than the ability to hold it securely because picking up and manipulation will be done by the natural hand, followed by transfer to the prosthetic hand. This is not to say that the ability to pick up should be ignored, on the contrary this should be made as easy as possible in the hope that a genuine bimanual ability will develop.

By comparison, a bilateral amputee makes far greater demands on the prosthesis. Picking up now becomes very important and it is unfortunately true that in this situation the lack of degrees of freedom and sensory feedbacks compared to the human hand make any prosthetic replacement a very poor substitute. It can be argued that the approach to, and picking up of, an object now uses two main sources of information. Firstly, knowledge of the position of the stump leads to a knowledge of the position of the prosthesis as an extension of the stump (Simpson, 1976). The second source is a visual appreciation of the position of the prosthesis relative to the object. Whilst knowledge of the position of the stump itself may often be quite accurate, movement of the fingers or any play in the socket leads to a loss of proprioceptive accuracy, a situation which worsens as the amputation site changes from below to above elbow. Vision, on the other hand, is independent of amputation site and it is argued that during the final approach to an object visibility of the gripping area is of primary importance. The same conclusion was reached by Kenworthy (1974) in his design of a side pinch type of hand for use with the CO_2 powered extended physiological proprioception arms (Simpson, 1973) currently being fitted in this centre. The geometry of this hand is shown in Figure 2.

Thus, considering the conventional "pincer" grip type of prosthesis from this point of view, some experimentation shows that although it is easy to pick up tall objects (greater than about 25 mm above the surface), the only way that low objects (25 mm high or less) can be grasped is by approaching the object from above with the forearm axis at a relatively large angle to the horizontal as the above-elbow amputee demonstrates in Figure 3. Thus, whilst not impossible, such tasks are made considerably more difficult, the degree of difficulty increasing with the height of amputation because of the greater amount of abduction required of the upper arm.

It was with this difficulty in mind that the geometry of the new hand has been developed, whilst hopefully not compromising performance

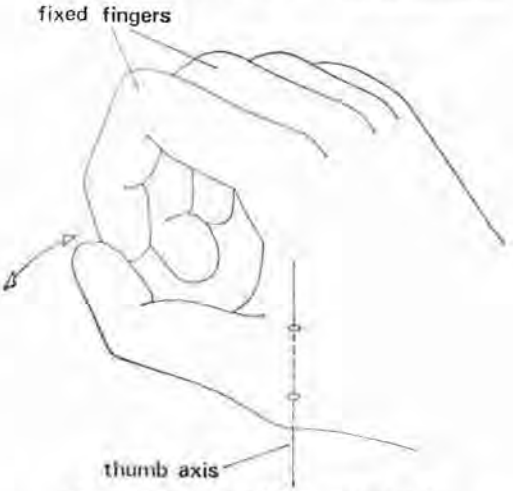

Fig. 2. Geometry of Kenworthy hand.

Fig. 3. Above-elbow amputee using "pincer" action hand.

in other areas such as the maximum width of grip. Further advantages have since become apparent, particularly the ability to hold a long thin object such as a pencil in a stable grip, an activity in which "pincer" type hands are only marginally successful.

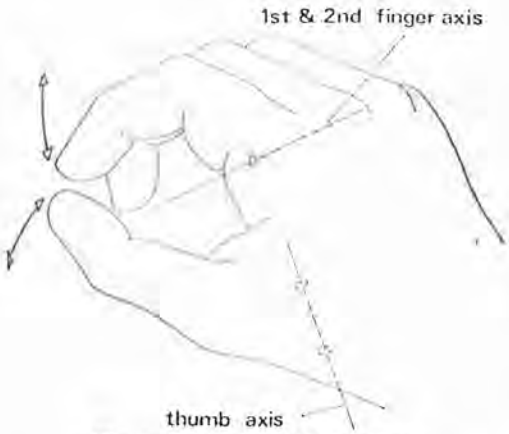

Fig. 4. Geometry of OBEU hand.

The basic geometry is shown in Figure 4. It is, in a sense, a compromise between the "pincer" type and the Kenworthy hand in trying to achieve the wide opening of the former and the good visibility of the latter. The rigid first and second fingers move together about an axis corresponding to the positions of the metacarpal phalangeal joints of the natural hand, the second finger being flexed slightly more than the first. The thumb moves about an axis approximately midway between the positions of the carpal metacarpal and metacarpal phalangeal joints and inclined at an angle of about 60 degrees to the first/second finger axis when viewed along the wrist centre line. This arrangement allows the loci of the tips of the thumb and first and second fingers to move approximately in a horizontal plane when the wrist axis is at about 25 degrees to the horizontal. In other words they will "sweep" the surface. Figure 5 shows the new hand in this situation and illustrates the reduction in upper arm abduction required compared to the "pincer" hand shown in the same situation in Figure 3.

To increase the stability of grip, "powder grip" conformable padding has been included in the gripping surfaces. This consists of tiny spherical plastic beads, enclosed by an inextensible bag, that conform to the shape of an

Fig. 5. Above-elbow amputee using OBEU hand.

object thus increasing the contact area. At the same time they do not store any elastic energy which would otherwise contribute to an unstable equilibrium situation. The overall result is that a stable grip can often be attained with significantly lower gripping force, an asset in a body powered device where operating forces are often low.

Hand mechanism

The method of construction of the hand mechanism had to fulfill several requirements. Firstly, since for cosmetic reasons it was to be made to fit the inside of a specific cosmetic glove, the external shape of the mechanism had to be made using this glove as a pattern. Secondly, it had to be capable of coping with the type of gripping geometry adopted, the axes of which make fabrication techniques using cartesian or polar co-ordinates difficult. Thirdly, as this was a development project it had to lend itself to quick production of small numbers of prototypes with the capacity for allowing changes to be made at short notice, while at the same time having the potential for being produced in relatively large numbers (in prosthetic terms). Finally, it had to have

a good strength to weight ratio bearing in mind that the silicone cosmetic glove is slightly heavier than its PVC counterpart.

The technique finally employed consists essentially of a brazed skeleton of steel rods constructed using brazing jigs originally derived from a moulding taken of the inside of the cosmetic glove. This moulding is also used to produce the moulds for the polyurethane foam padding. By this means the shape of the mechanism matches the cosmetic glove.

Fig. 6. Skeleton of OBEU hand.

The steel skeleton, shown in Figure 6 is mounted on an aluminium base plate which also incorporates the bayonet fixing for the wrist. The fingers and thumb are joined by a radius arm and rod linkage and operation of the hand is by a pushrod system operated through the centre of the bayonet (a pull cord version is also planned). For corrosion resistance the steel parts are nickel plated and those of aluminium are anodised.

The fingers and thumb are produced by moulding the polyurethane foam in place around the steel rods. The mould is sealed and the high pressure resulting produces a dense foam of good structural properties. The palm and back padding are produced separately and "clip" on to the skeleton, the texture of the foam for these being made softer and less dense by allowing controlled pressure relief from the mould.

Fig. 7. OBEU hand.

A completed adult male hand is shown in Figure 7. The weight of this hand is 285g (10 oz.).

Conclusion

A functional cosmetic hand prosthesis has been presented which shows improvements in cosmesis, weight, and function over those currently available. A clinical evaluation involving about 24 prostheses is currently being undertaken, following which it is intended to produce a range of sizes suitable for the majority of amputees.

Acknowledgements

The authors are grateful for the support and encouragement of Professor D. C. Simpson, Executive Dean, Faculty of Medicine, University of Edinburgh. Thanks are also due to Mr. A. C. Roberts of St. Luke's Hospital, Bradford for valuable advice regarding materials for the cosmetic gloves, and also to Mr. W. Barnett, Arm Training Instructor, Princess Margaret Rose Orthopaedic Hospital, for his willing co-operation as a "guinea pig". The development of both this hand prosthesis and the closely related modular arm system have been financed by a grant from the Scottish Home and Health Department.

REFERENCES

BARRACHINA, L. (1972). Research work conducted in France. Report of International Conference on Prosthetics and Orthotics, 144–179, S.O.P. Press, Cairo.

KENWORTHY, G. (1974). An artificial hand incorporating function and cosmesis. *Biomed. Eng.*, **9:12**, 559–562.

PEIZER, E., WRIGHT, D. W., MASON, C. and PIRELLO, T. (1969). Standards for externally powered hands. *Bull. Pros. Res.*, **10–12** Fall 1969, 118–155.

SIMPSON, D. C. (1971). Gripping surfaces for artificial hands. *The Hand*, **3:1**, 12–14.

SIMPSON, D. C. (1973). The control and supply of a multi-movement externally powered upper limb prosthesis. Proceedings 4th International Symposium on External Control of Human Extremities, Dubrovnik. Ed. Gavrilovic M. M. and Wilson, A. B. 247–254, Yugoslav Committee for Electronics and Automation, Belgrade.

SIMPSON, D. C. (1976). Some thoughts on upper limb prostheses for children with bilateral limb deficiency. *ISPO Bull.*, **17**, 5–6.

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Cerebral palsy

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The term "cerebral palsy" brings together a number of widely different syndromes, whose only common feature is a disorder of movement and posture. By definition, this is due to abnormality of the brain arising before it has reached maturity: abnormality of a transient or progressive nature is excluded. In a few children the motor disorder of cerebral palsy is the sole disability but more often it is associated with others such as mental subnormality, epilepsy, defective sight or hearing, learning disabilities of organic origin and personality disorders. Assessment of the total disability is thus a formidable task requiring the co-operation of many disciplines and the use of a wide variety of diagnostic procedures.

In the infant the major motor manifestations of cerebral palsy are usually absent because the deviant patterns emerge gradually as the result of maturation of an abnormal nervous system. Spasticity, for example, is often not apparent before the age of 1 year, while athetoid movements may not be seen before 1½ to 2 years and ataxia sometimes even later. The emergence of these major motor patterns is correlated with maturation of the brain, from primarily brain stem level at birth to higher levels of cortical function later. Signs of abnormal function may be recognized early, however, as abnormalities of muscle tone, delayed development, and persistence of infantile postural reflexes. The diagnosis of cerebral palsy should therefore be made before recognition of the major motor type is possible.

In the young infant, there may be feeding difficulties or other abnormal behaviour which alert the doctor to the possibility of cerebral palsy. Unusual degrees of floppiness or stiffness in certain positions, sudden changes in tone creating problems for the mother in dressing or bathing the baby and so on, may arouse suspicion early. Differential diagnosis at this stage may include cerebral tumour, hydrocephalus, craniosynostosis, spinal cord lesions, metabolic and endocrine defects, degenerative disease of the brain, muscle diseases, effects of poisons and, last but not least, variations of development in normal children. Since some of these conditions require urgent treatment and others may be made worse by injudicious interference, the child should be seen at a general paediatric clinic before the presumptive diagnosis of early cerebral palsy is made.

As time passes and the motor disability becomes more evident, its main characteristics can be recognized. In spasticity, the stretch reflexes are exaggerated, with lower than normal threshold, the tendon reflexes are increased, ankle clonus appears early (a useful clinical sign) and there is an increasing tendency to contractures. In athetoid forms of cerebral palsy, inco-ordinated and uncontrolled movements gradually appear and increase, at first as fine movement of extremities and ultimately as slow writhing movements of the limbs and trunk. Abnormal posturing and varying degrees of muscle tension commonly develop.

In ataxic cerebral palsy there is incoordination of muscle action. This of course is present to some degree in all forms of cerebral palsy, but to be called "ataxic" it must be of cerebellar type, with tremor, hypotonia, and other cerebellar signs. Once the major motor disorder has been identified, it may be used as a convenient label for classifying the patient's disability. It must be remembered, however, that mixed disorders are not at all uncommon and too great a degree of rigidity in classification is undesirable.

The multiplicity of other disabilities commonly associated with cerebral palsy and the great variety of possible combinations make the task of assessment a complex one demanding the resources of a multi-disciplinary team. The

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purpose of assessment is to identify and define the child's assets and liabilities, to consider his needs and to try to find the most practical and effective ways in which these needs can be met. Some are common to all children—the basic elements of nutrition and protection; an environment which encourages learning by graded experience; education suited to age and ability; and social contacts which will permit normal emotional maturation. These needs must be satisfied but, because the child is handicapped, provision may have to take special forms. In addition, the presence of a disability is likely to produce certain other needs. Some of these arise directly from the disability itself—for example, the need to devise a treatment programme specifically for the underlying condition. Others stem from the fact that the child is handicapped and are therefore less specific—for example, the provision of transport.

Remedial measures have to be considered early, because they offer the possibility of reducing the extent of the disability and consequently of modifying the child's needs in other areas. It is not so much a question of rapid and substantial reduction in disability as of planning a continuous programme of management which will require constant modification in the light of progress.

In infancy, the means of treatment must be appropriate to the child's and his family's total circumstances. The aims are to induce good patterns of movement and to influence any abnormal movement tendencies that have emerged. Home developmental guidance techniques should be introduced as early as possible. Patterned movements, both gross and fine, body control, and speech must all be encouraged. The parents must be given appropriate support and guidance and the infant provided with suitable sensory experiences. In the pre-school child, physical and occupational therapy helps the child to advance to higher levels of function and allows continuing social integration. Orthopaedic aids, such as bracing, splinting and special apparatus, and the use of drugs, may be helpful in a minority of children. From about the age of school entry, an educational programme is designed to suit the child's intellectual and physical abilities. Lower limb surgery to aid mobility and upper limb surgery to assist manual dexterity may be indicated at this stage. However, the usefulness of such operations as tenotomy or arthrodesis cannot be considered until it is known how far general management, physiotherapy and other techniques will prevent the development of conditions requiring surgery.

The primary reason for treatment is to improve and extend function and any decision for or against the more demanding or time-consuming methods should take account of whether the results will be worthwhile in the long run. Physical therapy must not be considered separately from all the other aspects of the child's upbringing. The overall aim is to make the best of his potentialities and therefore attention cannot be confined solely to his known abnormality. Moreover, we should remember that treatment of disabilities constantly reminds the child that he is disabled, whereas the aim is to try and make him forget. Management must include an evaluation of the consequences of therapy in terms of the child's total progress as well as of improvement in neuromuscular function. This may well show that a few extra degrees of movement in a joint are not worth the amount of school absence entailed, or that occasional epileptic seizures are preferable to blunting of intellectual function by drugs.

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The surgical management of cerebral palsy

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Cerebral palsy more than any other paralytic condition presents some of the most difficult and challenging problems in orthopaedic surgery. It is only relatively recently that surgery has come to play an important role in the treatment of this condition, but sufficient experience has now been gained to make possible an overall appraisal and statement of its value and indications.

Cerebral palsy is a complex and heterogeneous mixture of syndromes, but it can be conveniently defined as "a permanent motor disorder appearing before the age of three years due to a non-progressive interference with development of the brain". (MacKeith *et al.*, 1959).

In other words (Holt, 1965):

(1) It affects young children.

(2) It persists throughout life.

(3) There is always some disorder of muscle function.

(4) In all cases there has been interference with the developing nervous system.

The various manifestations of the condition combine with one another in many different ways, making assessment difficult and time consuming. The more important features are:

Ataxia—meaning inco-ordination and poor balance.

Athetosis—the occurrence of bizarre, purposeless movements.

Hypertonia or hypotonia—alterations of muscle tension.

Spasticity—meaning hyperactivity of the muscle stretch reflex.

Rigidity—persistent stiffness of muscles and movements.

Tremor—meaning rhythmical purposeless movements.

The disorder characteristically affects groups of muscles. It may affect a single limb, when it is described as monoplegia; arm and leg on one side, or hemiplegia; both legs—paraplegia; or all four limbs—quadriplegia. The term diplegia is used to refer to the latter condition when the paralysis of the legs predominates. In practice, however, in the majority of cases, careful examination will reveal abnormalities in limbs which at first sight appear to be normal. The motor problems are frequently complicated by other handicaps, such as defects of communication, blindness, and commonly mental abnormality, which in many cases is severe. This inevitably makes management a complex problem and a team approach is usually advisable. The team basically consists of a paediatrician, a mental health expert, a physiotherapist, and an orthopaedic surgeon. Such a team can attempt to build up a complete picture of mentality, specific handicaps, orthopaedic problems and social difficulties, and all these factors can be considered in making treatment decisions.

Although the contributions of orthopaedic surgery have been considerable, the actual operative techniques involved are for the most part relatively simple; nevertheless considerable judgement is necessary to derive the greatest benefit from them.

The basic aims can be defined in the simplest terms as being:

(1) To prevent the occurrence of serious deformity.

(2) To utilize to the best effect the resources which the child possesses.

It is in the first of these aims that the orthopaedic surgeon is likely to play the greatest part. In making orthopaedic decisions information will be required from the rest of the team about the child's overall capacity for function and the possibilities for rehabilitation and training. At best, however, these can only be rough guides and in practice it often pays dividends to aim high rather than low, because surprisingly often these children can achieve a remarkable level of function and independence

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when at first sight the situation might seem hopeless. The orthopaedic surgeon of course will himself be responsible for a large part of the functional assessment.

Overall function

This always starts with an assessment of the child's capabilities at the time of examination; for example, the ability to control head and limbs, to crawl, stand or walk, the ability to manipulate objects and to co-operate, and the presence of abnormal movement patterns, joint instability and so on. This necessitates a careful clinical record, wherever possible supplemented by photographs, and in some cases by cinephotography.

Deformities.

The measurement of deformities is carried out in a systematic manner, taking each joint in turn, not forgetting the spine. It is important at this stage to make a distinction wherever possible between fixed deformity and mobile deformity. Fixed deformities are those where it is not possible to put the joint into the anatomical position. Mobile deformities are those where the joint is continuously, or for most of the time, held in the deformed position, but can in fact, given sufficient relaxation, be placed in the anatomical position. It will frequently be possible to make a judgement about the relative importance on the one hand of soft tissue contractures, involving capsules, ligaments, tendons, and sometimes skin; and on the other hand the bony deformities which usually develop in longstanding cases. Both of these types of fixed deformity may arise together with, or independent of, spasticity. The distinction between spasticity and true joint contracture is of the greatest practical importance. Even when moving the joint gently, which should always be the case when examining these patients, it may not always be possible to estimate the amount of true contracture, and on occasion a decision about a corrective procedure may have to be made on the basis of an examination under anaesthesia.

There are a number of common patterns of deformity and it is therefore to some extent possible to standardize the indications for surgery.

Specific motor and sensory function.

Abnormalities of muscle function are of course the fundamental problems of cerebral palsy. Various defects of function are possible, indeed the phenomenon of muscle contraction and muscle integration can be disturbed in many ways. To give a few examples—the onset of a muscle contraction in relation to its stimulus may be delayed abnormally and the strength of contraction may increase relatively slowly. Or again the muscle may fail to relax at the correct time, antagonists may be out of phase with prime movers, and general muscle integration may be absent even though individual muscles may be capable of almost normal function. Sometimes stimulation causes too wide a response, and again, some children lack sensory awareness of muscle action, so obviously find difficulty in learning skills. It is important to consider the power of contraction. There is naturally a tendency to concentrate on spasticity and tightness of muscles, but careful examination will frequently reveal differences in relative power of muscle groups (Tachdjian and Minear, 1956), and occasionally weakness may be the sole sign of cerebral palsy. It seems likely that weakness is an important factor in the development of deformities as in other paralytic conditions (Sharrard, 1961).

Sometimes a muscle group is consistently weak but occasionally only certain movements are involved, so that a muscle may appear weak in one movement and not in another. I have already mentioned the difficulty of co-ordination in some patients, and of course there is often the problem of the child not understanding what is required. Frequently much time is necessary to gain the necessary co-operation. Given this co-operation, it is usually possible to arrive at some measure of muscle power, and indeed, it may sometimes be possible to use the Medical Research Council scale of grading. The situation, however, is much more complicated than in other paralytic conditions, and to see the problem as a simple one of rebalancing weak and strong muscles, is to invite many failures in treatment. The difficulty is that, although relative weakness may be demonstrable, the muscle or muscle group which appears to be weak may be capable of powerful contraction given the appropriate conditions. It is not uncommon to find that when the strong muscle group has been weakened by tendon section or denervation, the anta-

gonists develop a totally unexpected strength which may result in deformity occurring in the opposite direction. This suggests that much of the weakness was in fact inhibition from the strongly acting antagonists and it is therefore unwise to deduce too much from the apparent discrepancies in power. Undoubtedly spasticity in a group of muscles has this effect of inhibiting the antagonists and producing an apparent or indeed a real power discrepancy, with subsequent development of deformity. Theoretically the best treatment in these circumstances would be to diminish the spasticity whilst leaving the power intact. This would, however, require subtle interference with neurology and is hardly possible at the present time, although phenol nerve injection techniques suggest that such a differential block can be achieved in practice. (Braun *et al.*, 1972).

Other factors also come into play in producing relative muscle weakness. A stretched muscle may be weak because of mechanical disadvantage and if this disadvantage is rectified power may again be greater than expected. In practice of course an assessment of muscle power is of value in that it gives some idea of the speed at which deformities are likely to progress. The greater the difference in power, the more rapidly will the deformity occur, but even slight weakness can cause severe disability from simple functional loss long before the development of severe deformity. For example, relative weakness of the hip extensors or wrist extensors can produce severe interference with gait or hand function, even though deformity may develop relatively slowly.

Spasticity or hyperactivity of the stretch reflex is a difficult phenomenon to measure. It varies in degree and a simple clinical assessment can be made by moving the joint rapidly and noting where the 'catch' occurs. The presence of clonus may be a valuable physical sign in picking up milder degrees of spasticity. Again of course this is a manifestation of the hyperactive stretch reflex.

Co-ordination problems such as ataxia and athetosis are important defects of motor function and their assessment is important, although they are not usually amenable to surgical correction, and are not in themselves

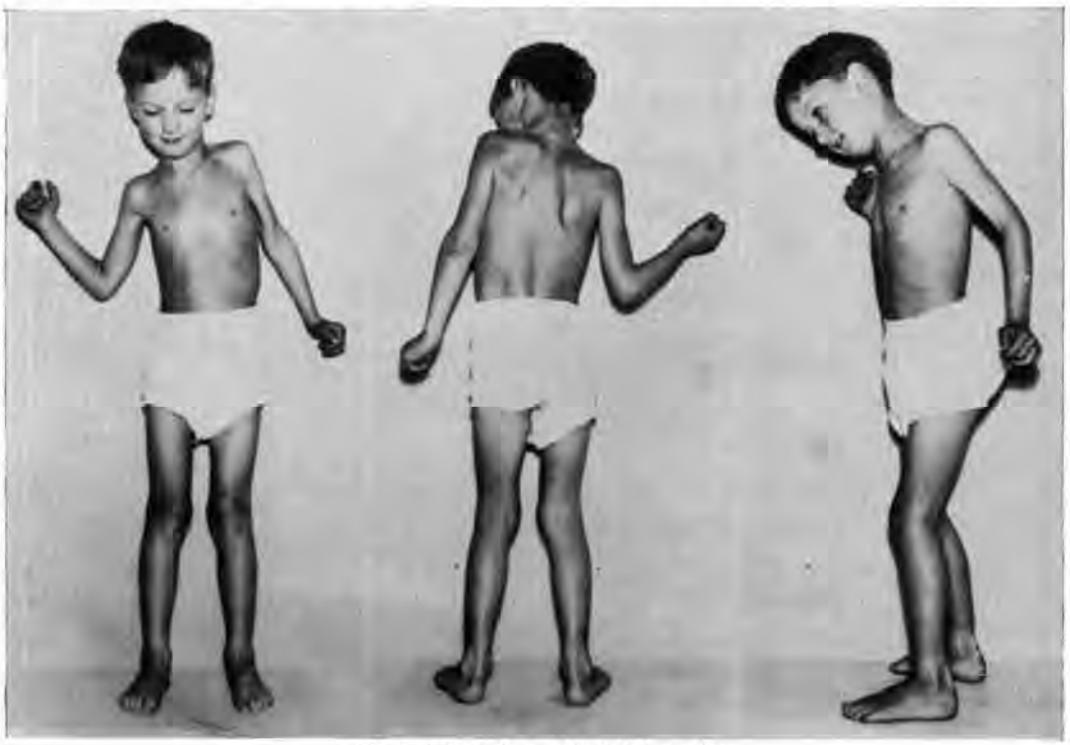

Fig. 1. Athetosis—no fixed deformities.

responsible for the development of deformity (Figure 1).

I have already mentioned the aims of surgery which are to prevent or correct deformity and to utilize resources to best functional effect. In practice these two aims tend to be complementary, in that procedures which are utilized to prevent deformity will also produce improvement in function. In deciding whether surgery is necessary, the assessment will normally have drawn attention to two main factors. Relative *muscle imbalance* usually associated with spasticity on the strong side, and either already associated with *deformity* or suggesting its potential development. It is rarely possible to detect potential deformity before it has already begun to occur, but the aim should always be to anticipate developing deformity and to deal with it before it becomes severe. Accepting that a deformity is present, the first question will usually be—*how can the deformity be corrected*?

Very mild deformities can sometimes be corrected by simple physiotherapeutic procedures such as stretching and serial plasters. More severe deformities will require elongation of tendons, capsules and ligaments, and sometimes skin. As in other paralytic conditions the more severe degrees of deformity in the older child may require bony surgery to produce adequate correction. Better results are always achieved by surgery at the soft tissue stage and, provided this is performed sufficiently early and adequately, it is usually possible to avoid the development of the worst bony deformities.

Having decided on the method of correction, the next question to be answered will be how to overcome the relative muscle imbalance. As already mentioned this is difficult to achieve because of the problems of spasticity and inhibition and the uncertain effects of mechanical disadvantage. In practice the methods which seem to work best usually combine well with the soft tissue correction procedures. For example, lengthening of the tendo-achilles at the ankle will often correct deformity and also will reduce the relative over-action of the calf. Whether it does this by simple reduction of mechanical power or by diminishing the apparent stretch inflow and therefore the corresponding inhibition of the ankle dorsiflexors is somewhat difficult to assess. The important point is that it does work and tendon elongation or even simple tendon section is a very valuable procedure in the surgery of cerebral palsy. Similarly, partial denervation of a muscle group may produce its effects in several different ways, but again experience shows that there are many situations where it can be conveniently and safely utilized to produce a re-balancing effect.

Because of the problem of assessing true muscle power the tendon transplantations which are useful in other paralytic conditions are on the whole less valuable in cerebral palsy. They are extremely variable in their effects, the commonest problem being overcompensation resulting in deformity in the opposite direction, and one can imagine that in disorders of stretch reflex arcs the effects of tendon transposition must be complex in the extreme. The situation is somewhat akin to the difficulties of tendon transplantation of reflexly innervated muscles in spina bifida. There are, however, a few situations where transplantation appears to be valuable—in deformities of the wrist particularly, and in certain deformities of the foot. In practice the most widely used re-balancing procedures are tendon lengthening and partial denervation.

Having decided, then, on the best method of achieving a balance, the next problem to be considered will, as usual in paralytic conditions, be how to achieve joint stability. Fortunately in cerebral palsy this is usually much less of a problem than in flaccid conditions, because although there may be true paralysis, there is usually a good deal of active musculature around the joints, and the corrective procedures and re-balancing operations are frequently sufficient to provide adequate joint stability.

Although splints and braces undoubtedly play a part in the overall management, it is often possible to avoid their use by judicious surgery. Modifications to footwear of course are frequently necessary but calipers are seldom needed. Again, as in other paralytic conditions, arthrodesis plays little part. One of the few widely used fusion procedures is that of triple arthrodesis in the older child to achieve a final stabilization of the foot. Arthrodesis of the wrist has been popular, but is losing some of this popularity in favour of re-balancing operations such as muscle slides and tendon transplantation.

Finally the question arises of restoring function in individual movements. Again the corrective procedures will often have the effect of achieving this end. Occasionally a specific procedure will be of value. For example, a particular hand or finger movement may be restored by an appropriate tendon transplantation. Opportunities for this are uncommon, however.

It is convenient next to consider the problems which arise with individual joints and then to discuss some of the patterns of deformity which occur and the way in which the various procedures can be utilized.

Deformities of the spine are fortunately rather uncommon in cerebral palsy, but all of the usual deformities do occur and can be formidably severe. Scoliosis may be associated with lordosis or kyphosis and one also occasionally sees curious torsional deformities, where the whole child appears to have been twisted round the vertebral axis, with torsion of the spine and pelvis, and the hips deformed in such a way that one is adducted and the other abducted. At the present time most of these spinal problems are nowhere near a solution, although the standard techniques for dealing with scoliosis are being utilized. There is usually no difficulty with sensation in these patients, so that external splintage may be used, and the Milwaukee brace and corrective spinal plasters and supports all have a place. The same applies to the tried and tested surgical techniques of fusion and internal fixation. Nevertheless the deforming forces are very difficult to overcome and it seems likely that until the exact forces involved can be better understood and rectified, this problem will remain a very difficult one.

The hip joint is often the site of trouble in cerebral palsy, the commonest deformities being flexion and adduction, together with internal rotation (Figure 2), although occasionally other patterns are seen—abduction and

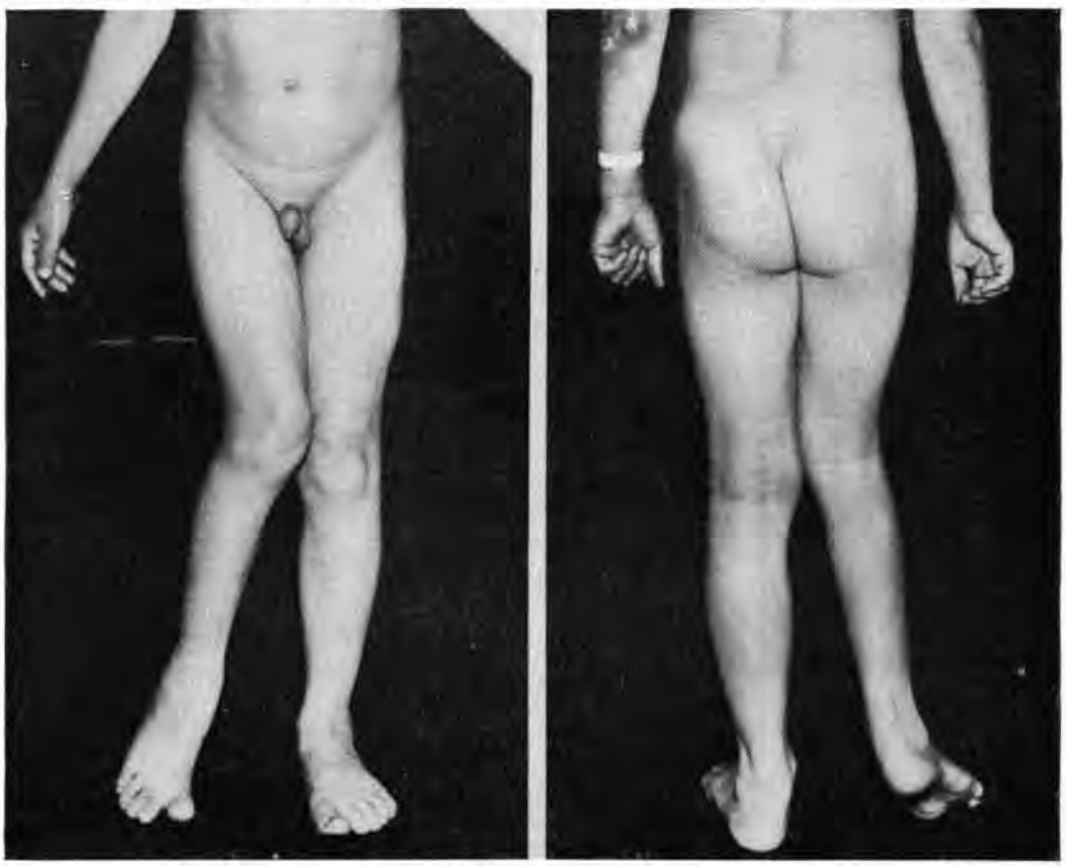

Fig. 2. Spastic hemiplegia.

external rotation being much less common. One of the commonest problems in cerebral palsy is a gradual diminution in the abduction range of the hip, and sometimes also in the range of extension, associated with tightness and usually spasticity of the abductors and flexors. This may, if left untreated, lead to gradual subluxation of the hip with eventual dislocation (Tachdjian and Minear, 1956, Sharrard *et al.*, 1975) and considerable increase in the disability (Figure 3). Careful and frequent orthopaedic examinations will detect this diminution in range and relatively simple surgical intervention will usually prevent it. It should be remembered that subluxation may occur before the abduction range diminishes to nil and is often associated with abnormalities in the shape of the femoral neck and its relationship to the shaft.

Adductor tenotomy is a simple and valuable procedure and it is a convenient guide to say that when abduction range has diminished to 30 degrees then surgery will normally be necessary. The adductor tenotomy is best performed by an open technique and consists of division of all tight structures, and where spasticity is severe, a section of the anterior branch of the obturator nerve. It is of the greatest importance to avoid dividing both branches of the nerve, as the disability from this is very severe. A short period of splintage in abduction after the operation is then usually followed by a period of physiotherapy to restore the original level of function.

At this point it is worth mentioning that in cerebral palsy the older the child, the more a surgical procedure temporarily interferes with function, and this may be a great disappointment to the parents who often feel that the child has been made worse by the procedures. This is particularly the case with hip surgery and it is therefore important to explain this point beforehand.

Occasionally section of the flexors, particularly the psoas, will be necessary to prevent progressive flexion deformity. Again if performed early and repeated this will usually avoid the development of the very severe flexion deformities seen in the untreated child. The dislocated spastic hip is a very difficult

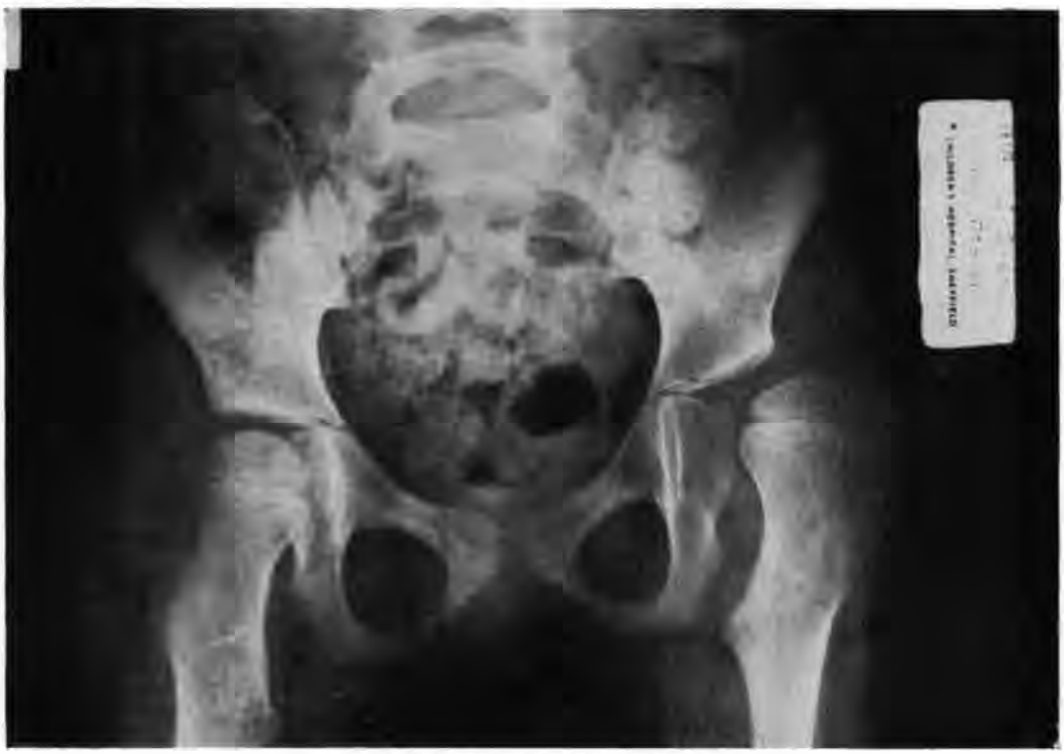

Fig. 3. Subluxating hip in cerebral palsy.

problem to deal with, and before embarking on the extensive surgery which is usually required to replace it, it is necessary to decide how much the dislocation is contributing to the overall disability and how likely one is to achieve permanent stability.

Rotational problems of the hip may be part of an overall pattern of deformity and are sometimes improved by more distal procedures. In persistent cases rotational osteotomy is usually a safe and simple procedure, but again in the older child its benefits must be set against the drawback of the considerable setback in function which usually occurs.

Although walking aids may be necessary to maintain the upright posture and to provide balance and stability it is rarely necessary to provide bracing to control the hips.

At the knees the commonest deformity is a flexion contracture, again usually associated with spasticity of the hamstrings and often forming part of a characteristic pattern of deformity of the limb (Figure 4). Less commonly hyperextension of the knee occurs, as occasionally does valgus or varus angulation. It should be possible to anticipate deformity and to carry out the necessary surgical procedures at an early stage. Hamstring elongation, or occasionally excision, is the most useful procedure (Figure 5). One of the difficulties about this procedure is the very strong tendency for the hamstrings to reform, or, even when they have been transplanted, to find their way back to their original insertions. Eggers' operation (Eggers, 1952), which is a transplant of the hamstrings into the lower femur, was designed to remove the flexion force at the knee and also to provide extra extension force at the hip. Its benefit however appears to stem mainly from the removal of the flexion force and its effects

Fig. 4. Flexion contracture of knees.

Fig. 5. Hamstring release for flexed knees.

as an active transfer have probably been overstated. It does have the slight advantage of making re-attachment of the tendons less likely.

If there is flexion contracture of the knee it is usual to elongate the distal hamstring tendons. It is convenient at this point to mention the curious condition of proximal hamstring tightness associated with difficulty in straight leg raising and in achieving an adequate length of stride, resulting in a rotating pelvis type of gait. This can be conveniently dealt with by proximal hamstring section (Sharrard and Seymour, 1968), a valuable procedure which may need to be repeated several times during the total period of growth.

At the ankle and foot a wide range of deformities are possible. The commonest by far is equinus deformity of the ankle associated with tightness of the tendo-achilles. Also common are cavus deformities of the foot with clawing of the toes and the valgus foot with a prominent head of talus on the medial side of the foot.

As already mentioned the various joint deformities tend to be associated together in patterns. The commonest one and the one which is typically associated with cerebral palsy of the hemiplegic type is that in which most of the joints are flexed; the elbow and wrist being flexed, fingers flexed into the palm, hip flexed, adducted and internally rotated, the knee flexed and the ankle in equinus. This pattern, more than any other, exemplifies the importance of tackling the problem step by step rather than embarking on an ambitious programme of surgery, much of which may not be necessary. It may be found, for example, that a simple elongation of the tendo-achilles will be enough to allow the heel to reach the ground and will remove much of the stretch stimulus from the calf muscles resulting in a general diminution of spasticity over the whole leg, and even occasionally in the arm. As a result the knee flexion and the hip flexion become less, and the internal rotation at the hip may diminish. In other words, one simple distal procedure has achieved at least partial correction of all the deformities. Having done this and allowed the child to recover it can then be decided if further procedures are necessary, usually proceeding from distal ones to more proximal.

Other patterns are also common. The scissoring of the diplegic due to adductor spasm and usually associated also with equinus of the ankles is very characteristic, (Figure 6) and can lead to great difficulties, even when sitting in a chair.

Fig. 6. Scissoring in spastic diplegia.

Also commonly seen in the diplegic is the combination of external rotation in the legs with the very difficult valgus foot (Figure 7); difficult usually because of the combination of a progressively valgus hindfoot with a supinated and abducted forefoot, and relative weakness of the invertor muscles. This is sometimes called a valgus-ex-equino deformity in the belief that the valgus arises secondarily to the tight tendo-achilles. In practice, however, lengthening of the tendo-achilles rarely improves the condition and can make it worse. The deformity tends to progress until it is very severe. It can be almost impossible to correct even by bony procedures such as triple arthrodesis and preventive surgery performed early is likely to give the best results. Unfortunately at present there is no general agreement on the best method of dealing with this problem. A wide variety of procedures have been used, one of the most popular being the Grice sub-

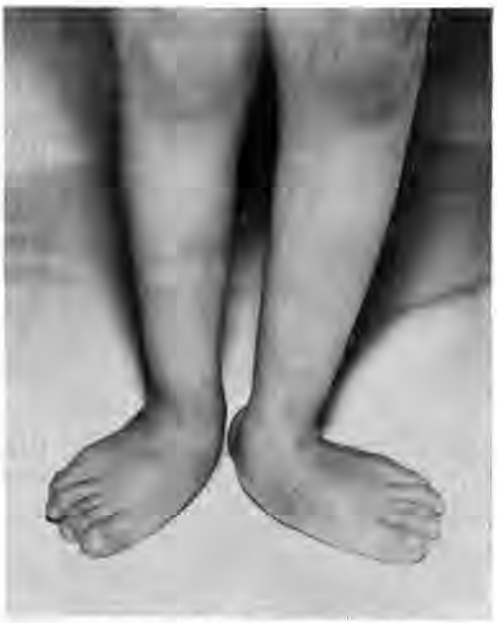

Fig. 7. Valgus foot in spastic diplegia.

talar arthrodesis (Grice, 1952), a procedure which, in cerebral palsy, frequently fails to prevent progression of deformity. In my experience, one of the most successful procedures, provided it is performed early, is to transfer one of the peroneal tendons to the medial side of the foot, usually into the tibialis posterior, and combine it with lengthening of the other peroneus tendon. Also useful in the carefully selected case is the medially based, closing wedge os calcis osteotomy which realigns the tendo-achilles so that it tends to pull the foot round into varus. However, both these procedures carry the disadvantage that they are somewhat unpredictable, and the end result may be a severe deformity in the opposite direction. Whatever method of correction is used, it is rarely possible to avoid the use of below-knee braces to control the tendency of the foot to sag into valgus. This is one of the few situations where bracing is necessary.

There has for a long time been a tendency to regard a triple fusion as being the ultimate answer to any foot deformity, but experience of this procedure suggests that it can be extremely difficult to perform in the badly deformed foot and an inadequate correction may result. It is therefore important to strive to obtain a well shaped plantigrade foot as early as possible and to maintain this by repeated surgery if necessary.

In summary then these constitute some thoughts on the principles of orthopaedic surgery in the treatment of cerebral palsy illustrated by their application to some of the more common problems. Nevertheless the variety of handicaps and deformities in these children is enormous and it must be appreciated that even when considering the lower limbs only, as I have tended to do in illustrating these principles, the range and scope of surgery is considerable. The results of treatment in these children are extremely gratifying and we must hope that, in well-run cerebral palsy clinics, the days have now gone when we see grotesquely deformed children with pressure sores and pain, and no hope of achieving their true potential level of function.

The author acknowledges his thanks to Blackwell Scientific Publications for permission to reproduce figures 1, 2 and 3 which are from 'Paediatric Orthopaedics and Fractures' by Mr. W. J. W. Sharrard and also to Mr. Sharrard for permission to reproduce figures 4 and 5.

REFERENCES

BRAUN, R., HOFFER, M. M., MOONEY, V. and MCKEEVER, J. (1972). Phenol nerve block in the treatment of acquired spastic hemiplegia in the upper limb. *J. Bone and Joint Surg.* **54A**, 4, 855.

EGGERS, G. W. N. (1952). Transplantation of the hamstring tendons to femoral condyles in order to improve hip extension and decrease knee flexion in cerebral spastic paralysis. *J. Bone and Joint Surg.* **34A**, 827.

GRICE, D. S. (1952). An extra-articular arthrodesis of the sub-astragalar joint for correction of paralytic flat feet in children. *J. Bone and Joint Surg.* **34A**, 927.

HOLT, K. S. (1965). Assessment of cerebral palsy. Vol. 1 Lloyd-Luke, London.

MACKEITH, R. C., MACKENZIE, I. C. K. and POLANI, P. E. (1959). Little Club Memorandum on classification and terminology of "cerebral palsy". *Cerebral Palsy Bulletin* **5**, 27–35.

SHARRARD, W. J. W. (1961). The origin and prevention of contractures in hemiplegic cerebral palsy. Little Club Clinics No. 4, 154. Spastics International Medical Publications and W. Heinemann Medical Books, London.

SHARRARD, W. J. W. and SEYMOUR, N. (1968). Bilateral proximal release of the hamstrings in cerebral palsy. *J. Bone and Joint Surg.* **50B**, 274.

SHARRARD, W. J. W., ALLEN, J. M. H., HEANEY, S. H. and PRENDERVILLE, G. R. G. (1975). Surgical prophylaxis of subluxation and dislocation of the hip in cerebral palsy. *J. Bone and Joint Surg.* **57B**, 2, 160.

TACHDJIAN, M. O. and MINEAR, W. L. (1956). Hip dislocation in cerebral palsy. *J. Bone and Joint Surg.* **38A**, 1358.

Prosthetics and Orthotics International, 1977, 1, 105–106

Spinal bracing for children with atonic cerebral palsy

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Some children with severe cerebral palsy have atonic spinal muscles that cannot support the trunk, consequently they cannot sit unaided. Kindly parents and staff prop them up but they slump forward or sideways. In time, the spine develops a fixed kyphosis or scoliosis with all the attendant complications.

The Department of Health and Social Services in Northern Ireland provides a Special Care Service for subnormal children including many with atonic cerebral palsy. A survey was carried out of all children within this category at Muckamore Abbey Hospital and it was found that many of them had "collapsing spines", could not sit unaided and had not developed a fixed spinal deformity. The survey indicated that about 70 children required some form of support. Initially this was intended as a preventive measure, but other, more pressing reasons emerged with experience. Previously, some children who had developed fixed spinal deformities had been fitted with Milwaukee braces, they could then sit and balance for the first time. However, the expertise and the production time required to fabricate and fit a Milwaukee brace precluded its use for so many children, and an alternative means of support had to be found.

Brace production

Due to the unsettled situation in Northern Ireland there was a shortage of orthotists and it was necessary to devise an effective spinal brace that could be produced easily, quickly and cheaply.

A cast of the trunk was made, with the spine straightened by head traction. This cast of plaster of Paris was made as thin as possible. The brace itself was of polyethylene, lined with Plastazote by heating them together at 120 degrees Centigrade. It was made in a front and a back half joined by Velcro straps, for this facilitated easy fitting by the parent or nurse. In order to eliminate the production of a positive cast, the hot plastic was moulded on the outer surface of the plaster of Paris body cast. The slightly increased circumference was eliminated by trimming the edge of the plastic where the front and back halves joined, this was done at the fitting stage. The brace reached to within 25 mm of the sternal notch above and to within 12 mm of the pubis below. The working time for producing the brace was approximately forty minutes (Figure 1).

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Results

Our experience is now based on some 80 children fitted over the last five years. The initial aim was that the support should prevent the onset of a fixed spinal deformity. Whilst none has occurred this remains to be proved.

Further reasons were found for providing polyethylene supports for these children. They could now sit up in a chair or wheelchair, this enlarged their horizons and increased their interest in the world about them. Child psychiatrists reported that they were more contented and that their mental state had improved. Some of the children learned to balance as a prelude to walking. Parents and nurses favoured the brace as it made the children easier to hold and to support when feeding.

Initially a flared base was tried so that the child could sit independently, but this caused some obstruction when the child was sitting in a hard-backed chair or was lying down.

For children with "floppy necks" the front and back panels of the support were extended up to the chin and the occiput. These extensions proved to be uncomfortable and it was found that the tone of the neck muscles appeared to improve if the trunk only was supported. The neck extensions were abandoned and, when necessary, a soft plastic collar was used.

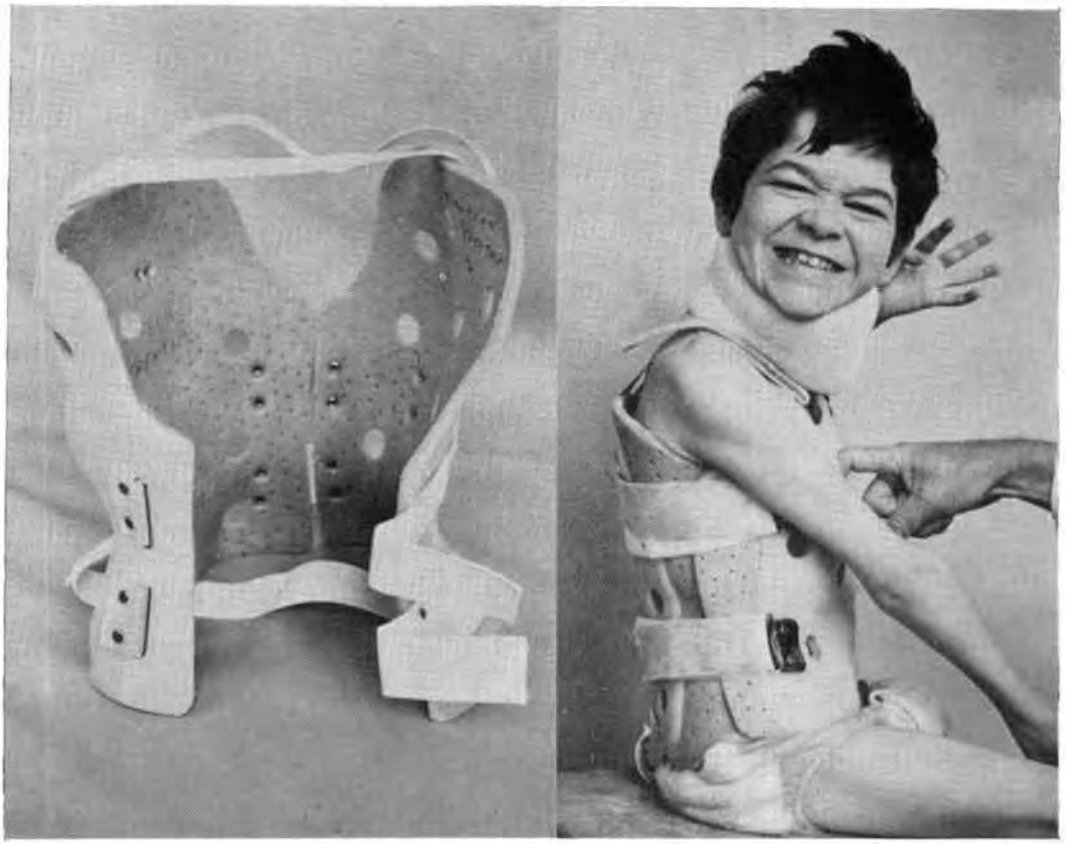

Fig. 1. Plastazote-lined polyethylene brace used at Musgrave Park Hospital.

We do not claim that this is the best support available, but it is quickly made, satisfactory, and cheap. It has permitted children with atonic cerebral palsy to sit up and, as a consequence of the increased stimulation, has improved their mental outlook. It has provided the opportunity for the children to learn to balance and in some it has permitted walking. None of the children has, as yet, developed any fixed spinal deformity, but further time is needed to see whether this will occur.

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Modern concepts in hand orthotics[1]

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This paper attempts to describe some of the principles and objectives in the orthotic treatment of hand disabilities. The author's experience over many years has been used in the design of a variety of orthotic devices while considering the following criteria:

Function

The device should place the hand in a functional position, thus permitting immediate use of any residual capability and also placing the hand in the optimal position to promote recovery.

Effectiveness

The device should be capable of effecting relief of the symptoms.

Adaptability

The device should be capable of adaptation to fit a reasonable range of patients.

Adjustability

It should be possible to adjust the device to compensate for the changing condition of the hand during treatment.

Comfort

The patient is more likely to co-operate in a comfortable splint.

Aesthetic Appearance

These points will be illustrated in the following series of figures.

Boutonnière injury orthosis (1)

This orthosis (Figure 1) may be formed by direct application using Prenyl. This material has the advantage of being easily adjusted after immersion in hot water and then setting in cold. The attitude of 40 degrees of flexion of the distal end portion prevents the orthosis from slipping.

Vitrathene and polypropylene may also be used; however, both require a former for the moulding process. Experience with this orthosis to date has proved it very effective in reducing the final deformity, but further evaluation is required.

Fig. 1. For Boutonnière injury (1) Type: passive. Material: Prenyl. Function: PIP joint in extension, DIP joint in flexion, 40 degrees approximately.

Boutonnière injury orthosis (2)

The distal and proximal volar plastic troughs are linked by parallel spring steel rods of 18 SWG wire. The dorsal trough is positioned distally for ease of application of the orthosis. Once the finger has been introduced the dorsal trough slides into position over the proximal interphalangeal joint, completing a three-point pressure system (Figure 2).

A full Celadex ring is required distally if a position of 40 degrees of flexion of the distal segment of the finger is required. When the orthosis is applied to the lateral aspect of the finger it corrects deviation. It has also been used in the treatment of a mallet finger.

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[1]Previously published in The Hand 7: 1, 58–62.

Fig. 2. For Boutonnière injury (2) Type: passive. Material: Celadex-spring steel. Description: slide-lock. Function: extends IP joints.

Ulnar deviation orthosis

This simple type of orthosis is easily fabricated. The orthosis functions by using the ring finger as a stabiliser, thus checking the ulnar drift of the little finger (Figure 3). The open-ended configuration is adopted to aid application and removal. The orthosis can be used for an ulnar nerve lesion or for an injury of the metacarpal joint, rather than in the rheumatoid arthritic.

Fig. 3. For ulnar deviation. Type: passive. Material: Celadex. Function: adducts to mid-line (positioned by adjacent finger).

Minor flexion contracture orthosis

The transparent Celadex plastic saddle is found to be cosmetically acceptable (Figure 4). For some patients, especially female, this factor is of great importance and, if it results in increased co-operation on the part of the patient, it will undoubtedly assist recovery from the injury. Once the patient's confidence has been gained, further treatment may be embarked upon if the contracture requires a stronger dynamic device. This orthosis can be used on social occasions and also during work to maintain some degree of extension when more active splintage is inconvenient or impracticable.

Fig. 4. For recovery phase of minor finger injury. Type: dynamic. Material: Celadex-spring steel. Function: resists flexion IP joints, assists extension IP joints.

Orthoses for thumb opposition

A three stage orthotic approach to the treatment of the hemiparetic child is demonstrated.

The long opposition orthosis (Figure 5 left).

The long opposition orthosis incorporates the wrist and metacarpals and can be fabricated in the clinic. The thumb portion may be omitted while the main wrist unit is positioned manually then immersed in cold water to set. A cap unit to abduct the thumb may be added later. If preferred the two components may be formed in the reverse order.

Alternatively, the orthosis may be fabricated on a positive cast and on some occasions a master cast may be used. The production of a plaster of Paris negative can present some difficulties with the small child.

The short opponens orthosis (Figure 5 centre).

This orthosis incorporates the metacarpals. It is important to maintain the seating on the entire lateral aspect of the distal palmar crease extending proximally. This provides increased comfort to the wearer. The Velcro fixation should be placed at the angle which provides the most effective fixation.

The thumb-cap opposition orthosis (Figure 5 right).

The thumb-cap opposition orthosis is the final stage of this orthotic treatment programme. An open-thumb unit can be used which gives

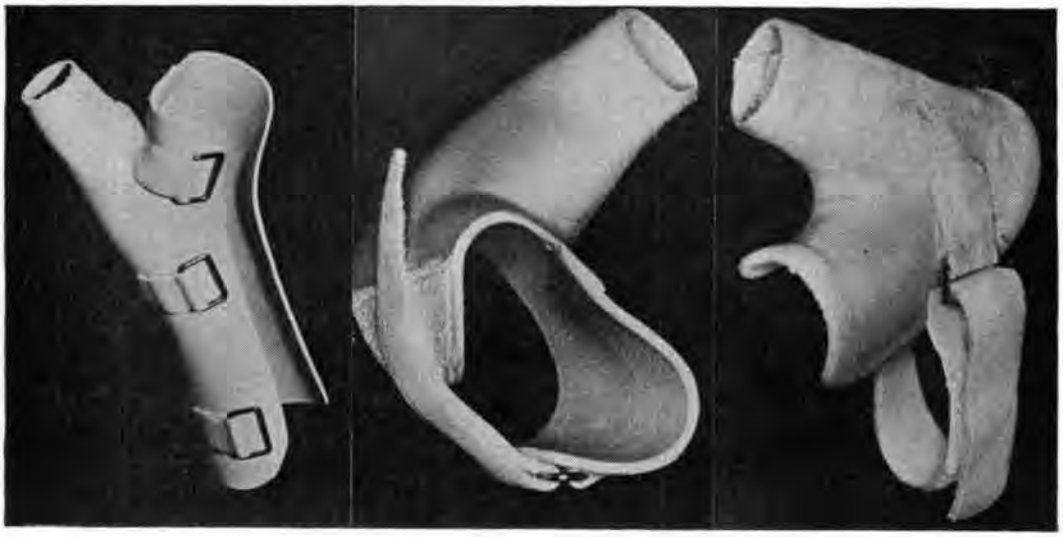

Fig. 5. For thumb opposition. Three stage orthotic approach. Left, long-incorporating wrist. Centre, short-incorporating metacarpals. Right, thumb cap. Type: passive. Material: Prenyl. Function: maintains opposition of thumb.

additional freedom; however, this can also cause difficulty with pressure. The choice will depend on the type of patient. This unit is normally acceptable to the patient as it is small and permits an increased range of movement.

Orthosis for injuries of ulnar nerve

In the production of this device (Figure 6) it is necessary to measure and cast the hand and to fabricate the orthosis on a former since the cemented joints require time to set. Once again the properties of Prenyl make it extremely easy to make adjustments in the clinic. If the orthosis is being used for an extended period, however, a more rigid plastic is used.

This piece of apparatus has been found aesthetically pleasing to the patient. It assists those who grasp objects, such as sacks, to perform their daily tasks. It has been used in

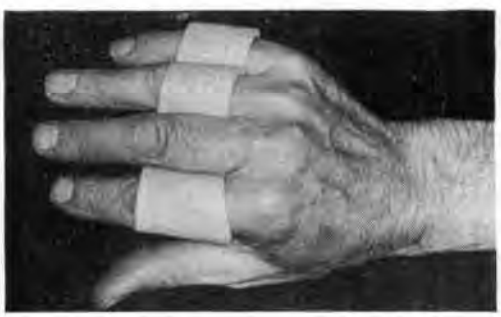

Fig. 6. For injuries of ulnar nerve. Type: passive. Material: Prenyl. Description: knuckle-duster. Function: prevents clawing, harmonises movement. Control by middle and index fingers.

Fig. 7. For injuries of ulnar nerve. Type: dynamic. Material: malleable metal—Plastazote—No. 20 SWG spring steel. Description: ulnar intrinsic. Function: assists flexion MP joints, resists extension IP joints. (Palmar bar adjustable).

the early stage of the treatment of ulnar nerve lesions to be followed by a lively type of orthosis (Figure 7) and also in the reverse sequence.

Orthoses for correction and prevention of flexion deformity

An example of the use of these orthoses is in the treatment of Dupuytren's contracture. The modular design of these orthoses is of considerable value when springs of varying tension are required. The chassis is malleable thus enabling precise fitting at the metacarpophalangeal joint and on the palmar aspect.

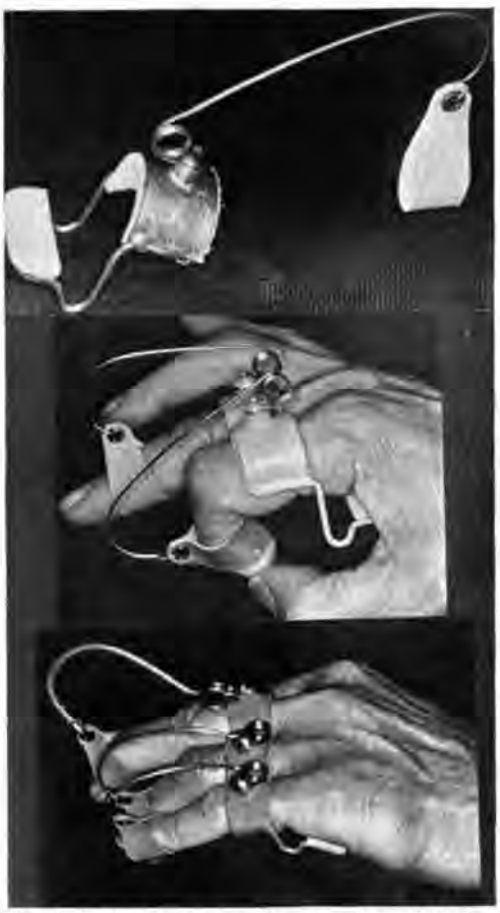

Fig. 8. For correction and prevention of flexion deformity. Top, single finger orthosis. Centre and bottom, multiple finger orthoses. Type: dynamic. Material: malleable metal-Plastazote-spring steel. Description: armchair (modified Exeter). Function: assists extension IP joints, resists flexion IP joints (spring adjustable).

The single-finger orthosis (Figure 8 top) is a modification of the Exeter armchair orthosis. This dynamic device is made in three sizes to cover the adult range. This means that the patient can be fitted in the clinic enabling treatment to commence immediately. A similar range is available for the treatment of children. When difficulty is experienced in maintaining the position of the chassis on the proximal segment it may be necessary to extend the saddle to enclose this segment more completely. This is most commonly encountered with the small finger. This type of device can be produced in multiples for application to two or more fingers (Figure 8 centre and bottom). Other orthoses of a similar design have utilised springs of a shorter length. The end of a spring with a short leg will move in the path of a circle generated by the coil of the spring alone. The natural path of the two distal phalanges moving from flexion into extension is that of an involute. (Figure 9).

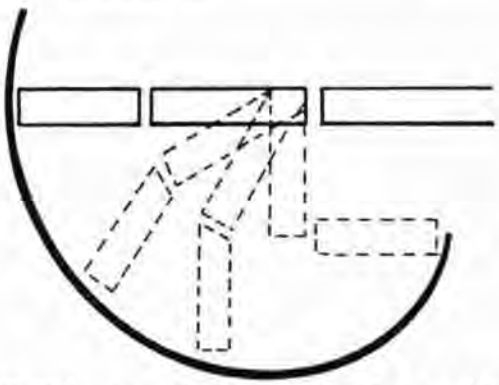

Fig. 9. Involute path of finger tip from flexion to full extension.

If a spring with a longer leg is utilised bending will take place in the leg as well as the spring coils. The combination of the motion occurring in the leg and in the coils of the spring results in a more accurate copy of the actual anatomical motion of the finger.

BIBLIOGRAPHY

BUNNELL, S. (1948). Surgery of the hand. 2nd ed. 122, 128, 131. J. P. Lippincott Co., Philadelphia.
WYNN PARRY, C. B. (1973). Rehabilitation of the hand. 3rd ed. 63, 240. Butterworths, London.
RANK, B. K., WAKEFIELD, A. R. and HUESTON, J. T. (1973). Surgery of repair as applied to hand injuries. 4th ed. 266. Churchill Livingstone, Edinburgh and London.

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The orthotic management of arthrogryphosis

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The arthrogryphotic child poses many problems for the orthotist who will need to be consulted for corrective splinting as early as a few weeks after birth.

These children are frequently born with gross flexion deformities and severe equinovarus club feet. The physiotherapist will give stretching exercises and strapping is applied to gain as much correction as possible.

Simple Denis Browne derotation splints can be applied first with strapping and, when the feet are large enough, open-toe bootees can be used. As the child grows it may be necessary to use the Denis Browne calcaneal splint. Lower-limb orthoses may be required for walking as early in life as one year as most of these children have a vast amount of energy and the will to progress.

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It is usual to provide the severely handicapped child with bilateral hip-knee-ankle-foot orthoses which may require a single pelvic band or both pelvic and thoracic bands with locking mechanisms at the hips. Corrective and accommodating footwear will also be necessary.

The orthoses will need to be reviewed constantly as most of these children progress fairly quickly when good physiotherapy is available. Aids for daily living will be a constant demand on the ingenuity of the occupational therapist and the orthotist.

The vastly differing needs of each individual case have to be considered in the light of limited movements in all anatomical joints.

Some patients will be completely independent and require nothing more than special footwear. Others will need specially constructed living accommodation with full accessories for even the simplest everyday tasks.

Fig. 1. Single steel KAFO with anterior patellar-tendon bar and knee locking mechanism.

Frames can be provided with adaptions for washing, hair brushing, cleaning teeth and dressing.

These children do not tolerate discomfort and no matter how good the intention of the medical staff may be regarding corrective splinting, most will find a loophole in the design to adapt to the most comfortable position of the limb.

Two examples of this can be clearly shown. First, in footwear there is frequently a desire to hold the foot in equinus and varus with the big toe completely flexed. Even though boots are provided with heel straps, varus "T" straps and varus tarsus straps, the child will always find a sympathetic member of the nursing staff to loosen the corrective straps, thus allowing the feet to become increasingly deformed.

A second example can be seen where there is increasing knee flexion deformity. A great deal of thought and time has been spent endeavouring to provide comfortable but corrective orthoses for knee flexion. Moulded Plastazote knee-caps can be used, or well shaped, soft leather knee-caps lined with lambs' wool, but, as mentioned earlier, there will always be someone around to loosen corrective straps and allow increasing deformities. This can be very serious and, if not checked, can lead to epiphyseal damage of a lasting nature.

A simple fairly foolproof method of making sure the knee is held in place is to use a single steel or double steel knee-ankle-foot orthosis with an anterior patellar-tendon bar and knee-locking mechanism. This will only lock in one position and will eliminate the loosening of straps as can be seen in Figure 1.

In spite of all our efforts it may be necessary for a number of serial plasters to be applied during growth.

When bone growth is complete, surgery may be performed to place the limbs in the best possible position for walking. The orthotist can then design effective and cosmetically acceptable orthoses which the young adults can assume themselves. Here, advanced techniques using good thermoplastics and laminates can be of enormous advantage.

It is possible to accommodate short, fixed equinus feet in ordinary shoes by extending foot pieces and adding false foreparts as toe fillers (Figures 2 and 3).

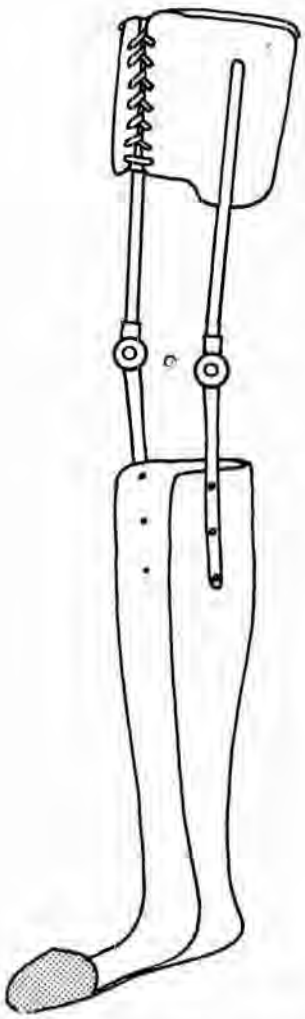

Fig. 2. KAFO with high density plastic below-knee leaf spring type shoe piece.

Good use can also be made of the extension prosthesis technique, combining the skills of both prosthetist and orthotist. Figure 4 shows how this can be applied, not only concealing the deformities of fixed equinovarus feet, but also bringing a child of diminutive height to normal stature.

There may be cases where severe limitation of joints will make it impossible for the subject to fasten any type of footwear. Unless something can be designed without fastenings, independence can never be achieved.

Figure 5 shows an extension prosthesis with patellar-tendon-bearing orthosis and automatic bilateral knee-locking joints. The foot enters the apparatus with the orthosis in a flexed position. When the foot is placed in the foot piece the knee joints can be locked by extending the knee. As the knee is fixed in flexion, no other fastenings are necessary.

In conclusion it would appear that the orthotic management of this very severe condition is primarily one of corrective splinting during growth with the object of enabling the arthrogryphotic patient to achieve a degree of independence.

Fig. 3. Cut-away section showing toe-piece to accommodate short equinus foot in normal size shoe.

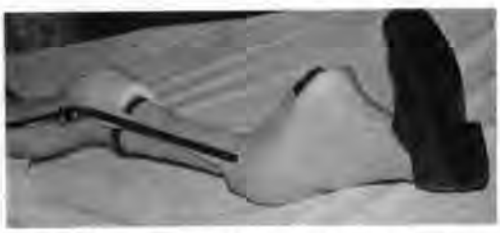

Fig. 4. Extension prosthesis technique applied to KAFO.

Fig. 5. Extension prosthesis with patellar-tendon-bearing orthosis and bilateral automatic knee locking joints.

Prosthetics and Orthotics International, 1977, 1, 114–118

Functional analysis of the UC-BL shank axial rotation device[1]

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Origins of concept

"Present indications are that transverse rotations of the various segments of the leg are an important factor in the ease and rhythm of walking of normal individuals. In order to improve function, reduce fatigue, and prevent more or less continual abrasion at critical points of the stump of the amputee, provision in the prosthesis for allowing transverse rotations of the same order of magnitude as present in normal legs has the possibility of being a major contribution to the improvement of artificial legs."

The above statement is a direct quote of the opening paragraph in the 1947 report on fundamental studies of human locomotion by the University of California Prosthetic Devices Research Project established at Berkeley in 1945. The goal of these studies was to provide a basis for improvements in prosthetics technology. From their results nothing stood out more clearly than the need for a device to allow passive axial rotation between socket and foot in lower-limb prostheses.

Design criteria

Design criteria for such a device were established on the basis of amputee tests of an experimental unit with adjustable stops and variable return spring characteristics. The final recommendation was that a lightweight unit be designed which would permit rotations of up to 20 degrees in either direction about the long axis of a prosthetic limb, with a centering spring torque of approximately 0.23 Nm (2 lb in) per degree of rotation. This range of motion was found to accommodate most locomotor activities without contact against the rigid rotation stops. The centering spring torque was a compromise: a stiffer spring would tend to negate the purpose of the device by allowing large torques to be applied to the residual limb; a softer spring would not return the foot consistently to centre during the swing phase.

In addition to providing these basic characteristics, any practical axial rotation unit must have bearings capable of supporting the amputee's weight and the severe bending moment that occurs during the latter part of stance phase when weight is supported on the forefoot. The friction torque in the bearings under load must be small compared to the centering spring torque if the unit is to perform its function of allowing axial rotation during stance phase. The return spring also should have adequate damping to prevent excessive vibration of the foot during swing phase. The axial rotation device should be compact to permit inclusion in the widest possible variety of prostheses, and it should be light in weight to minimize the increase in inertia of the distal part of the prosthesis. Finally, a truly practical device must be simple, reliable, and low in cost.

Previous designs

Since the need for an axial rotation device has been clearly recognized for 27 years, it is quite appropriate to ask why satisfactory devices have not been developed and made widely available to amputees. The reason seems to be that the requirements for high strength, low friction, soft but well-damped return spring, and light weight are difficult to achieve simultaneously. A number of designs have appeared, but all have lacked at least one of these essential features. The original University of California design was too large and heavy, and lacked adequate damping of the return spring (University of California, 1947). A subsequent design was compact but had excessive bearing friction which prevented rotation at the very time it was needed (Mullby and Radcliffe, 1960).

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[1] Previously published in Orthopadie-Technik, 1/75, 7–9.

Other designs have been unable to withstand the severe bending moment which occurs when weight is borne on the forefoot, or they have had excessively stiff return springs, or they have been excessively large and heavy (Staros and Peizer, 1972, 1973).

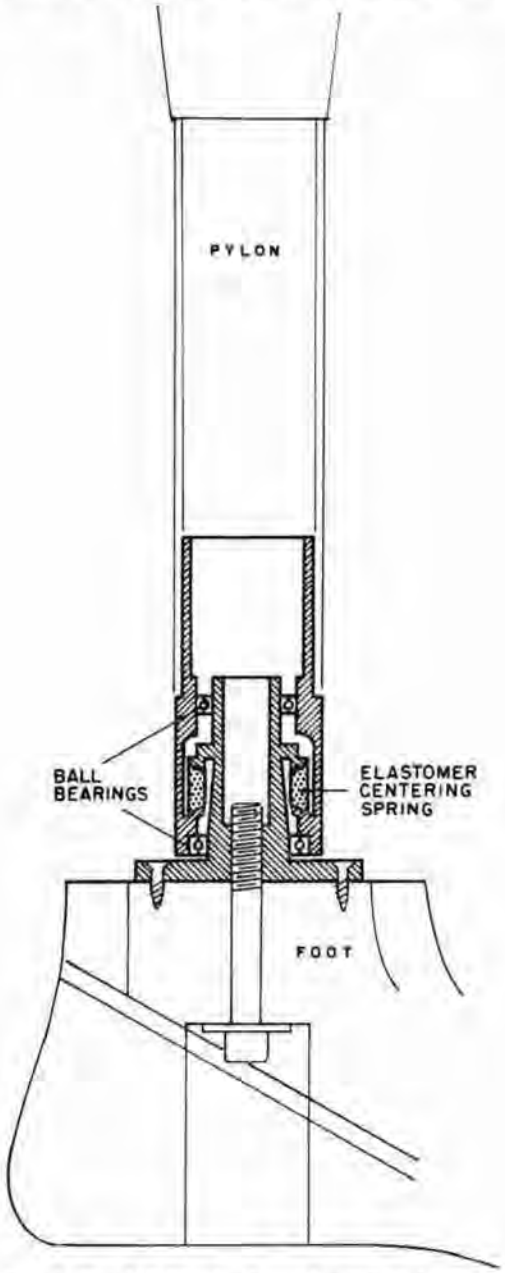

Fig. 1. The UC-BL shank axial rotation device in cross section. Although the unit is shown mounted on a foot, an alternative and preferred installation would invert the device and mount it as high as possible in the prosthetic shank. This preferred installation moves the mass of the unit proximally and minimizes bulk at the ankle.

The present design

The device described here has been conservatively designed to satisfy the original 1947 design criteria in the hope of providing increased opportunity for clinical evaluation of the concept of passive axial rotation in lower-limb prostheses. It consists of a pair of thin-section, full-ball-complement ball bearings which support axial loads and bending moments, and an elastomer torsion spring in a ring configuration as shown in Figure 1. The spring is shaped with conical end plates to allow uniform shear strains throughout the volume of the elastomer.

Amputee trials have been conducted primarily with above-knee (AK) amputees. Their response has been uniformly favourable with dramatic relief of skin abrasions and epidermoid cysts in some cases. The design criteria appear to be well suited to the needs of the AK amputee. Some questions remain whether the design is optimum for below-knee (BK) amputees, who, unlike the AK, can safely flex the knee during stance phase. Further clinical trials are needed to evaluate the specific requirements of the BK amputee. In any event, the need is less critical for the BK amputee because he generally has a normal hip joint which allows him much greater freedom of axial rotation.

Measurement procedure

The axial rotation device was installed in an above-knee prosthesis with a UC-BL polycentric knee and SACH foot. This prosthesis was then instrumented to allow measurement of axial rotation occurring within the device, axial torque in the shank, pelvis rotation about a vertical axis, and relative internal-external rotation between the socket and the pelvis. Measurements were obtained as the subject walked at a comfortable speed (100 steps/min) on a power-driven treadmill, both with the device operating and with its motion locked out.

Measurement results

With one exception, the measurements were much as expected. When the axial rotation device was operating, pelvic rotation about a vertical axis increased slightly to a total of 6 degrees, the shank rotated externally 8 degrees

over the foot during stance phase, and the step length increased slightly. What was not expected was that the relative internal-external rotation between pelvis and socket during stance phase *increased* from 3 to 8.5 degrees when the device was operating.

Because of the unexpected nature of this measurement, the measurements were repeated with another AK case wearing a single-axis hydraulic knee. The results of this second set of measurements were essentially the same as the first. It is the measurements of this second amputee which are shown in Figures 2 and 3.

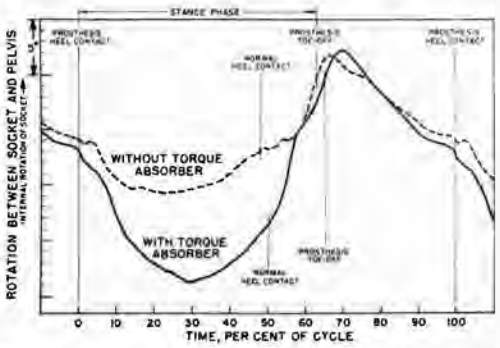

Fig. 2. A comparison of relative axial rotation between the pelvis and the socket of an above-knee prosthesis, with and without the axial rotation unit (torque absorber) operating. Note the unexpected increase in relative rotation which accompanies use of the device.

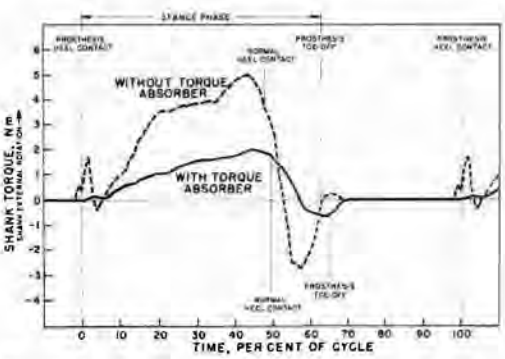

Fig. 3. A comparison of axial torques occurring in an above-knee prosthesis with and without the axial rotation unit operating. Note the decrease in torque which results from use of the device.

Discussion

Previously it had been tacitly assumed that the condition of minimum strain to the tissues around the brim of the socket would correspond to minimum relative rotation between the pelvis and the socket brim. The measurements do not support such an assumption.

When the axial rotation device is operating, axial torques are reduced, as shown in Figure 3. This reduction in torque, however, is accompanied by an increase in relative axial rotation between the pelvis and the AK socket during stance phase. This increased range of internal and external rotation can be attributed to the effect of muscle action within the confines of the quadrilateral AK socket.

At the instant of heel contact on his prosthesis, the amputee is actively extending the hip on the amputated side to assure stability of the prosthetic knee. This hip extension moment must be transmitted to the socket by means of increased contact pressures over the proximal-anterior and distal-posterior regions of the socket and stump. Since the gluteal muscles are largely responsible for the hip-extension moment there is a simultaneous generation of contact force in the gluteal region due to bulging of the contracting gluteal musculature.

The combination of these two effects gives rise to a contact pressure distribution similar to that shown in Figure 4. As illustrated, this pressure distribution generates an external rotation torque about the long axis of the socket.

When the prosthesis incorporates an axial rotation device, this net torque acting about the long axis of the socket is able to rotate the socket externally over the fixed foot, the only resistance to such rotation being the relatively weak return spring in the axial rotation device. This axial rotation tends to relieve the contact pressures which caused the torque and thereby reduces pressures in the critical antero-medial region of the brim.

When the prosthesis does not contain an axial rotation device, the hip extension moment still gives rise to the pressure distribution shown in Figure 4. Now, however, the prosthesis is very stiff in torsion and pressures cannot be relieved by external rotation of the socket. Consequently, the pressure pattern tends to rotate the stump internally within the fixed socket with little or no relief of pressure. For many amputees this combination of slight internal rotation and high contact pressure will give rise to skin trauma and the development of sebaceous cysts in the antero-medial region of the socket brim or chafing in the region of ischial contact.

As the stance phase continues and the centre of pressure moves forward to the ball of the foot, the hip action changes from active extension to active flexion as required to initiate knee flexion near the end of stance phase. This flexion moment tends to reduce the magnitude of the anterior force and increase the magnitude of the posterior force producing the socket-brim pressure pattern. At the same time the gluteal muscles relax their tension in the posterior region and the rectus femoris actively bulges against the anterior lateral brim area, allowing a posterior shift of the stump within the socket. The medially located hamstring tendons tend to resist this displacement and a pressure distribution similar to that shown in Figure 5 results. As illustrated, this pressure distribution which results from active hip flexion generates an internal rotation torque about the long axis of the socket.

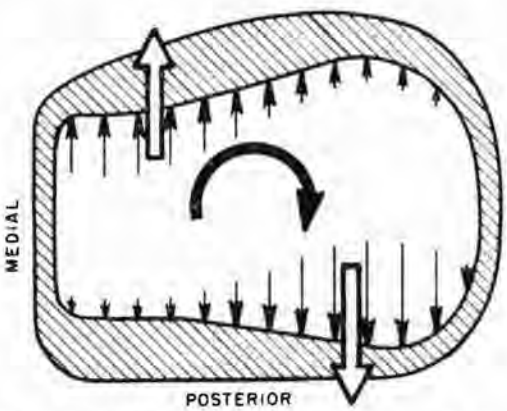

Fig. 4. Estimated pressure distribution around the brim of an AK socket at heel contact. Note the resultant external rotation moment.

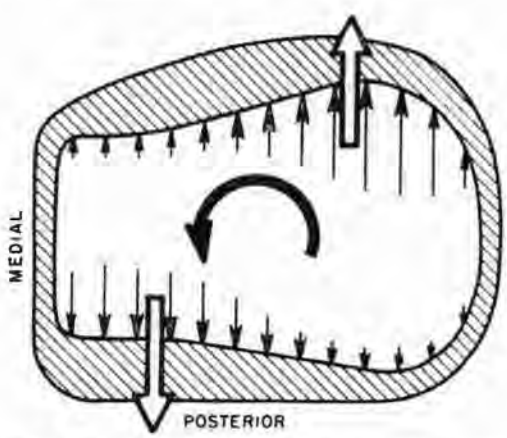

Fig. 5. Estimated pressure distribution around the brim of an AK socket just prior to toe-off. Note the resultant internal rotation moment.

Again, without an axial rotation device in the prosthesis, the socket cannot move to relieve these changing forces and the torques must be passed through the skin at the stump-socket interface, giving rise to the aforementioned skin problems which are familiar to limb fitters. With an axial rotation device the socket is free to respond to the demands of the stump and relieve the pressures and torques caused by cyclic action of the musculature.

Conclusions

The installation in an above-knee prosthesis of a device which allows rotation of the socket over the fixed foot has been shown to offer the amputee the following advantages:

1. Improved gait symmetry.
2. Reduction of axial torques between the stump and the socket.
3. Reduction of the frequency of occurrence, or elimination of, sebaceous cysts due to skin trauma at the socket brim.
4. Improved freedom of movement when changing direction of motion, working at a bench or counter, and in sports activities.

The usefulness of an axial rotation device for above-knee amputees has been demonstrated clinically with tests on research patients over a period of 30 years. The present design has been used successfully by several amputees for periods of up to 18 months without malfunction and it appears to have overcome the shortcomings of previous units. More extensive amputee trials will begin in the near future under the auspices of the Veterans Administration Prosthetics Center in New York City.

It is possible that experience may demonstrate that assymetrical spring rates, non-linear elasticity, or a change in rotation axis may improve future devices, particularly for the below-knee amputee.

Acknowledgement

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REFERENCES

MULBY, W. C. and RADCLIFFE, C. W. (1960). An ankle-rotation device for prostheses. Biomechanics Laboratory, University of California, San Francisco and Berkeley. *Tech. Rep.* **37.**

STAROS, A. and PEIZER, E. (1972). Veterans Administration Prosthetics Center Research Report, *Bull. Pros. Res.*, *BPR* **10-18,** 226.

STAROS, A. and PEIZER, E. (1973). Veterans Administration Prosthetics Center Research Report, *Bull. Pros. Res.*, *BPR* **10-19,** 148.

UNIVERSITY OF CALIFORNIA (1947). Fundamental studies of human locomotion and other information relating to design of artificial limbs. Report to National Research Council, Committee on Artificial Limbs. Vol. I, Part I, Sect. 1–1, and Vol. II, Part IV, Sect. 16.

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Planning prosthetic and orthotic programmes to aid developing countries

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At present there is a profusion of agencies and governments which send missions of prosthetics and orthotics experts into developing countries. Included are the UN, the World Rehabilitation Fund, the World Health Organization, the Social and Rehabilitation Service of HEW, Public Health Service, certain religious organizations, HOPE ship, and perhaps others. These agencies send experts to developing countries with the best intentions but sometimes without regard to each other's work. These efforts should avoid duplication, programmes should not overlap, one mission should not be critical of another, and agencies should not compete for the limited talent available to man the missions.

Co-ordination

The simplest solution is to employ a co-ordinating body to open effective channels of communication among these agencies and to advise and guide them on the best methods to pursue their goals. Their lines of interest and action cross where their programmes in support of prosthetic rehabilitation programmes extend into the same developing countries. A neutral agency, which does not conduct such programmes itself and which has extensive expertise in these matters, should be engaged to co-ordinate these functions.

The International Society for Prosthetics and Orthotics is an impartial international body which can draw upon expert talent the world over: it has established relationships with many international and national agencies. In recognition of these problems, the ISPO has a fully effective Committee on Education.

National and private agencies which sponsor overseas missions should contract with ISPO to co-ordinate their efforts. A very small investment will produce great returns in assuring more effective use of total project funds.

Planning

Three kinds of programmes are generally sponsored by agencies in the United States. One is the "research" programme in which advanced researchers and developers are aided by financial support, equipment and facilities, and by collaboration with counterpart experts from the United States. In this circumstance, a one- or two-phase effort is usually sufficient to achieve the rather limited purpose of supporting the development of a particular prosthetic component, system, or technique. Maintaining liaison between the sponsor and the developer is readily effected by a single person reinforced by the advice of other experts. A classic example of this type of programme is the Social and Rehabilitation Service support rendered Dr. Franjo Gracanin and Dr. Losze Vodovnik of Ljubljana, Yugoslavia who have carried through a project leading to the development of a neuro-stimulator designed for hemiplegics. Another example is the Veterans Administration support of Dr. Pierre Rabischong of the Unite de Recherches de Biomecanique, Montpellier, France. Dr. Rabischong is developing an advanced control system to enable quadriplegics to drive automotive vehicles, a goal which may have important impact on the treatment of paralysed persons.

A second type of programme involves the introduction of a device or a technique into an established prosthetics and orthotics rehabilitation programme in a particular country. An effort of this kind may require the sending of a team of prosthetists, therapists, engineers and physicians to transfer required medical/surgical procedures, prescription indications, training

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techniques, and prosthetic or orthotic skills. In this instance, a one-time effort will suffice since the task is essentially one of teaching the new techniques to an already skilled and knowledgeable counterpart group. A typical example is the training programme held at the Commission National de Rehabilitation del Lisiado in Buenos Aires in 1965. A seminar preceding the workshop was attended by doctors and other interested persons in allied fields from surrounding countries. The principles of total contact socket design and fitting were stressed as were the indications for prescription along with other technical and social aspects. However, the workshop which followed was restricted to the skilled technicians and medical persons on clinic teams to work out the environmental problems which arose. Subsequent surveys indicate that excellent total contact sockets were being routinely fabricated of a polyester resin obtained locally.

The third type of programme is aimed at developing countries in which there are no organized prosthetic and orthotic rehabilitation programmes or in which they are weak. The task in this case is quite different from the two mentioned above since it is not addressed to a well-organized prosthetics and orthotics rehabilitation community nor to skilled practitioners of all the participating disciplines. In this case a programme must be designed as a vehicle to carry the new knowledge and skills to the treatment teams and to the patient population. A programme of this nature cannot be effectively executed in one or two phases: it requires a long-range plan executed in several inter-related phases if the results are to be additive and to lead to a viable, effective local programme.

Effective long-range plans for such a programme cannot be made by the sponsoring agency and its own personnel. It is essential that appropriate representatives of the developing country participate in the initial planning in order to understand the prevailing conditions, to identify their goals, and to assess the available resources. Their own desires for the conduct and eventual results of the programme must be determined if a practical and effective plan is to be developed.

The *first* step in a programme of this nature is to bring representatives of the host country and sponsors together for planning meetings. The host group should come prepared to present their view of the best kind of aid which the planned programme could provide. Their proposal should include details on the areas in which training and education are required, the organization of the prosthetic rehabilitation community for exploiting the proposed training and education, their plan for measuring the effectiveness of the programme, their desires for follow-up phases after the initiation of the programme, and all the pertinent details on the availability of materials, facilities, equipment, and personnel in their own countries.

The planning session should then turn to the question of determining the extent to which the sponsoring agency has or can draw upon the means for carrying out the programme proposed by the host group. Even at this early stage the capabilities of ISPO are essential. Through ISPO those missions aimed principally at training can take advantage of already established facilities such as those in Teheran, Buenos Aires, Bogota, New York, Copenhagen, and those regional centres organized by the World Rehabilitation Fund.

In the *second* planning step the sponsoring agency, through ISPO, should designate a leader for the yet-to-be nominated team to visit the host country very shortly after the initial meeting. This trip is necessary to corroborate the information initially obtained, and to assess the capabilities of the region for support of the training and educational effort in terms of personnel, equipment, and facilities. He should also evaluate the capability of the existing rehabilitation service delivery system for transmitting the new methods.

The *third* planning step calls for the design of the programme with great detail on the first phase and the general outlines of second, third and subsequent phases as required. These three planning steps will obviate many common problems which otherwise must be solved *ad hoc* after the mission has arrived in the host country. Meetings with representatives of the host country and the information obtained by the representative of the sponsoring agency are essential to develop an adequate estimate of the real needs in the host country.

It is essential that the agency in the country sponsoring the mission develops an adequate estimate of the audience sector.

Of fundamental significance in this respect are:

a. *Facilities*

The physical facilities available including lecture rooms, production equipment, etc., work benches and hand tools, machinery, availability of supplies required for a course. This information is necessary for planning the kind and quantity of tools and materials to be shipped and whether it will be necessary to maintain the supply, a matter which may well colour the entire content of the course and programme.

b. *Organization*

It is essential to know the organization of the host group with respect to the relationships among various disciplines as, for example, medical/surgical, prosthetic/orthotic, occupational/physical therapy, and the administrative pattern from the local to the decision-making level. To achieve any real measure of success, the visiting mission must be fully aware of the status held by each of the groups in order to determine the extent to which they can independently carry out elements of the programme. The visiting mission must also know the lowest echelons of authority with which they must deal in order to institute procedures with reasonable assurance that they will be carried out. This means that the sponsoring agency must determine in advance the local team composition and the seats of authority, in order to secure the co-operation of those concerned.

c. *Language*

The sponsoring agency should recognize at the outset that differences in language and customs may be significant barriers to efficient operation. It is extremely rare, particularly in the United States, to find technically competent teachers who are fluent in a language other than English. In the past, sponsoring agencies have simply ignored this problem or have depended on the fact that members of the host group had a smattering of English. In our experience "a command" of English most frequently means reasonable fluency in ordinary conversational English and only an extremely tenuous grasp of the technical language of prosthetics and orthotics, let alone the medical and physical therapy jargons. Local interpreters, even those whose English is extensive, are often inadequate in that these people hear the technical language for the first time during the course. Furthermore, teaching through an interpreter is excessively time-consuming and even at best, reduces the feedback from the class to the vanishing point.

We recommend this problem be handled by arranging for the translation of all written material into the language of the host country by university medical faculties and engineering departments. The translated material should be checked out and distributed to the host group well in advance of the course to enable the partly fluent English speaking members to prepare to act as assistant instructors rather than interpreters. An advanced local prosthetist acting as an assistant instructor after he has prepared himself by reading the material in his native language is probably the most effective means of transmission. Extensive use of visual presentation is valuable.

d. *Social structure*

It is important to recognize that the culture of a country is reflected in a set of social attitudes. Included are concepts of the responsibility of society toward the handicapped, their place in society, and the attitudes of the handicapped toward themselves, and the non-handicapped population. In certain cultures, amputation or paralysis may bar an individual from meaningful employment, a reflection of the attitudes of both the handicapped and the non-handicapped. These differences may also be reflected in varying views of patients' needs and desires in the host country and in the country of the sponsoring agency.

The design of devices and the establishment of certain procedures may be rooted in concern for patients' psycho-social adjustment as well as functional regain. But in a culture where the handicapped are sequestered rather than brought back into the community, these matters are meaningless. Sophisticated devices with high cosmetic quality may be impractical. Prosthetic devices designed for use with western dress may be highly overdesigned or badly designed for cultures with vastly different dress patterns. In these situations it may be more fruitful to focus training on prosthetic principles, the use of local materials, and the adaptation of components to achieve greater versatility.

Consideration of tradition and local mores is also important in scheduling. Traditional

working hours, holidays and meal times in a particular cultural matrix must be observed in scheduling a training programme in order to avoid introducing unneccessary impediments.

There may also be a large gulf in the social status of professional and technical team members of the host country. The "clinic team" concept rests on the foundation of equally significant contributions of all the disciplines represented even though final responsibility for the patient's welfare rests with the team leader, the physician. In some developing countries, physical therapists represent a distinctly lower social stratum than physicians, and sometimes prosthetists and orthotists or technicians occupy an even lower prestige level.

The reality of such a situation must be faced by the mission members. They must realize that social pressure in such an environment may force a physician into a paternalistic and sometimes superficially arrogant attitude *despite his personal feelings to the contrary.* Legitimate and desirable ambitions of paramedical and technical personnel are often thwarted by these circumstances. The clinic team then appears weak with few or no significant contributions by its members. The visiting group can do little to change this picture since the mould of tradition may make both the physician and the others uncomfortable in the open give-and-take atmosphere of the classic clinic team. It is far more effective to recognize the realities and, by developing the knowledge and skill of the prosthetists and therapists, to enable them to elevate their status and make their positions more secure.

Selecting the expert team

Even in a fully developed country the teaching of technical prosthetics and orthotics skills is a difficult matter. It requires the organization of special programmes, facilities, and administrative support. It also demands competent, technical *educators*, which is to say, highly specialized personnel who are not only competent in a particular technical area but who are also competent to teach it. Missions consisting of one or two prosthetists or orthotists from the commercial community of the developed country are not likely to be the most effective group. We do not mean in any way to deprecate the contributions of such people who invariably are highly motivated to "do good" and often undertake these missions at great financial loss to themselves.

Individual members of the expert team should be selected mostly on the basis of their experience and effectiveness in teaching the specialized areas in prosthetics or orthotics which constitute the content of the programme. Composition of the team may vary in succeeding phases as emphases and subject matter change. Where possible, individual team members should be friendly to each other or have worked with each other to minimize the possibility of strained relationships within the team. They should be dedicated to the principles of the Samaritan because in the absence of financial or other personal gain, their underlying attitude strongly affects student motivation. Their professional status should be unquestioned to ensure sufficient stature to facilitate communication with the group in the host country. Broad experience enables them to vary basic procedures and techniques *knowledgeably* to meet local needs. To be avoided are personnel who look upon the programme as an opportunity for a junket.

Ideally, each discipline considered in the programme should be represented on the team. But this is sometimes unrealistic since physicians and therapists find it difficult to be away from their practices for lengthy periods. These problems can sometimes be overcome by the selection of an adequate team leader.

The team leader, regardless of his professional field, should be selected on the basis of broad experience in all aspects of the programme and particularly for his skills in administration of training and research programmes. He should certainly have a working, if not a completely fluent knowledge of the local language. He should be known to persons of the host country by reason of his professional reputation or writings. He should be a versatile person who is capable of improvisation, expediting procedures, and one not easily deterred by problems. He must keep the goal of the mission in sight throughout the programme, taking all the necessary steps to ensure its success. He should be reasonably poised and cultured so that he may communicate freely at all echelons of administration and operations—Embassy officials, the medical, and paramedical communities.

Team members should be selected from among universities and hospitals offering programmes in prosthetics and orthotics. For example, in collaboration with representatives of the rehabilitation community in Portugal, Dr. Sidney Fishman of New York University has developed a long-term and highly effective prosthetics education programme. The programme was developed by direct and lengthy collaboration between Dr. Fishman and key members of his staff and their counterparts in Portugal. The Portuguese authorities have made available appropriate facilities and equipment as well as English-speaking personnel who have been trained by Dr. Fishman and his group to act as instructors presenting the material to students in their native language. A two-platoon system was employed in which one team presented the first 2 or 2½ weeks of a 4 or 5 week programme, and the second team presented the second half with approximately a week of overlap to maintain continuity. This reduced the amount of time individual members spent away from their other duties. It also allowed Dr. Fishman to deploy a variety of specialized personnel in each technical area of the programme.

Preparation of the team

The members of the team should, during a reasonably formal training session, be made completely familiar with the administration and organizational matrix in which their programme is to be presented. They should be fully briefed on the individuals in the host country with whom they will interact and they should have a complete understanding of the position and authority of each person with whom they will deal in the host country. Members of a team must assure themselves, leaving as little to chance as possible, that all the materials and equipment that each will need to carry out his individual responsibilities will be available. Team members should be carefully indoctrinated on the customs of the country and particularly those traditions which must be considered during the progress of the course.

Each scheduled element in the programme must be assigned to a particular individual in the same fashion as any effective programme is developed. A certain amount of teaching depth should be insured to enable one individual to substitute for another in the event of illness. Team members should prepare their lesson plans as completely as possible to permit them to be reviewed prior to departure in order to ensure a similar level of content and presentation. Each team member should be informed of a particular person in the host country with whom he will work closely as a co-instructor. He should be fully informed on this individual's background, skills and experience.

Guide books or perhaps glossaries of appropriate phrases prepared by personnel in the host country should be made available to team members. Even for those with no command whatever of the local language, learning certain key words can be very useful, as for example, who, what, when, where, how, now, later, today, tomorrow, I, you, give, take, stop, come, go. Ten or fifteen carefully constructed phrases added to the words given above can provide an extremely useful working vocabulary which is quickly mastered in a few weeks preceding the visit.

Responsibilities of the host group

The representatives of the host country should be encouraged to take advantage of and to exploit to the fullest extent the efforts of the mission. Many problems can be circumvented be some of the steps described above. The host group should be asked to co-ordinate the receipt of supplies and equipment from outwith the host country and the procurement of other supplies and equipment within the host country in time to make them available for the course. The most significant contribution the host group can make is provision for continuing education after the initial course is given, and to integrate new knowledge and techniques into an effective, on-going service programme. It makes little sense to devote a great deal of effort to teaching prosthetic and orthotic treatment techniques which cannot be effectively integrated into the general health care service in the country. Techniques designed for application through a clinic team are lost in the absence of an organized programme with administrative, organizational, fiscal, and professional backup. It is, therefore, incumbent on the rehabilitation community in the host country to take steps to utilize and expand the application of what has been taught.

The planning stage must be co-ordinated in the host country at the lowest levels of authority which can guarantee follow-up measures. It is not enough to plan the technical materials; the planning must include discussions and conferences on the required administrative reinforcement, the appropriate organizational structure, adequate fiscal support, and supply functions. Questions on these matters must be brought up by the sponsoring agency through or with the participation of the team leader (to keep the entire team informed). The answers to these questions and the solutions to problems which they generate must come from the rehabilitation community of the host country but all must be managed if the programme is to be effective.

Summary

In essence, we are concerned with improving the effectiveness of training programmes presented in developing countries with weak or inadequate delivery of modern rehabilitation treatment services. We believe that great improvements can be made by more comprehensive and systematic planning. Sponsoring agencies should co-ordinate their efforts through the International Society for Prosthetics and Orthotics (ISPO) to avoid duplication and waste, and to take advantage of the world-wide scope of this agency. Plans will be more effectively executed if they are based on an accurate and reliable estimate of the complete situation to be found in the host country, including knowledge of the physical facilities, the organization of the host group, problems of language and of customs. Selecting a team of experts on the basis of criteria appropriate to the mission and preparing its personnel realistically will also lead to more effective programmes. In this connection the universities and teaching hospitals are the richest source of personnel although the team leader may be sought elsewhere. A key element in the whole picture is recognition of the responsibilities of concerned groups in the host country and enlisting their co-operation in preparation and exploitation of the overall effort.

We take pride in the technological advances which have produced instantaneous world-wide communication although the content of the communication is not always a source of pride. The rapid transmission of health and rehabilitation skills and advances is really a debt humans owe to each other regardless of national boundaries or other considerations. Sending missions without ulterior motives from one country, which has advanced in a particular sphere, to another country is to exercise a quintessentially human quality—the brotherhood of man. Let us do our share to reduce the impedances and make the work more effective.

Prosthetics and Orthotics International, 1977, 1, 125–126

Total rehabilitation for amputees in special conditions

T. STEINBACH

Orthopaedic Rehabilitation Department, Chaim Sheba Medical Centre, Tel-Aviv

War may be defined in military, economic, social or demographic terms. From the medical point of view war may be regarded as a sudden "epidemic" of wounds of varying degrees of severity. These injuries necessitate urgent, sustained, and diversified treatment.

The categories of wounded requiring treatment are dependent largely upon local conditions and the types of weapons employed. The experience of our Centre of Rehabilitation is based, unfortunately, on four successive wars in the last 25 years.

With the use of modern sophisticated weapons, a high percentage of casualties are the subject of multiple injuries and in variable psychological conditions. For these patients the treatment can be successful only in a hospital that is equipped to provide intensive care in a variety of specialities.

Whether an amputation occurs as a single injury or as part of multiple trauma, the best treatment can be offered only in a comprehensive Rehabilitation Centre. The rehabilitation of an amputee is not only a surgical or limb-fitting problem but a larger concept in which psychological, social, and professional aspects must be dealt with as quickly as possible by a well-trained team.

The task of our Centre was to perform in this framework the total rehabilitation of the amputees of the last war.

Of the casualties admitted 30 per cent were amputations of the upper limb (16 per cent above-elbow and 14 per cent below-elbow), and 70 per cent of amputations of the lower limb (2 per cent hip disarticulation, 27 per cent above-knee, 5 per cent through-knee, 30 per cent below-knee, 6 per cent Syme's). Eight per cent of all amputees were double (among them one double below-elbow and one double above-elbow). Two soldiers were triple amputees (below-knee, above-knee, above-elbow). In 50 per cent of the cases the amputation was not the sole injury, for example, among amputations of the upper limb 23 per cent also had eye injuries and diminution of visual feedback.

In 25 per cent of the cases admitted to the Centre, it was necessary to revise the stump to provide a good primary fitting. In all these revisions a myoplastic technique was used. The stump was judged to be in good condition when it healed "per primam", was not abnormally sensitive and was without scars on the weight-bearing areas. It was important that the proximal joint moved freely and that the length of the stump was sufficient to serve as a functional lever.

Upper-limb amputees were fitted with an "Orthoplast" socket and hook. Training in the use of the prosthesis began as soon as local and general conditions permitted and was conducted by an occupational therapist. On completion of the training programme a cosmetic hand was provided and several patients also received special tools to meet their specific vocational needs.

For the lower-limb amputees the Otto Bock modular prosthesis was used in all cases except through-knee and Syme's. Assembled on a plaster of Paris cast it met the necessities of an early fitting in the first week after amputation in all cases where supplementary injury permitted ambulation. The same modular unit was transferred to a plastic or wood socket when conditions of stump healing were satisfactory. No special problems arose in alignment of the prosthesis. Individual training followed by group training was given by qualified physiotherapists.

At admission every patient was examined by a psychologist who provided special care in all cases in which emotional impact or post-traumatic reactions appeared. A third of all cases received counselling, another third psycho-

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therapy either as individuals or in a group. For the remainder, no special care was necessary.

Manifestations of shock and depression in the first phase were found in 10 per cent of cases, aggression and impulsivity in about 15 per cent, neurotic reactions and somatic preoccupations, in later phases, were discovered in 20 per cent of cases. Only 5 per cent with sociopathic tendencies had difficulties in adjustment. The "phantom pains" (10 per cent), found at the beginning, disappeared slowly after the fitting of prostheses.

The aims of vocational rehabilitation are:

(1) Introduction of functional activity of the patient with every possible part of his body.

(2) In upper-limb amputations, transferral of the function of the dominant hand to the nondominant one while training for dexterity, co-ordination and gross movement. Fifty three per cent of amputees lost the dominant hand and 23 per cent had other injuries in the remaining hand.

(3) Activities and daily living training by use of the prosthesis.

(4) Training for work tolerance and endurance.

(5) Vocational evaluation.

(6) Motivation towards a vocational goal.

It was our policy to introduce vocational counselling as soon as possible after the injury. We found it to be of utmost importance in motivating the patient to think and plan his future, and to evaluate and assess realistically his abilities, potential, aptitudes and interests. In this way, we helped him to prepare a complete rehabilitation plan while he was still in the Centre. For this goal we used not only all the counselling techniques of evaluation, information, interpretation and manipulation of environment, but also had a complete tutoring programme in most high-school and specific vocational subjects. The individual lessons were taught by 26 professional teachers who volunteered their services.

We tried to bridge the gap between the rehabilitation centre and the outside world. Social workers played an important role in dealing with personal, familial, social and living problems. After a period of instruction and training, all the amputees, except those with severe diminution of visual acuity, received driving licences and were independent in transport.

Subsequently most of the amputees were discharged and four months after the beginning of the war the following figures show the vocational rehabilitation plans of our patients.

Vocational Plan	Total	Upper Limb	Lower Limb
	%	%	%
Returning to same job	28	6	22
Returning to same studies	19	10	9
Changing job	18	5	13
Changing studies	31	6	25
Transferred or without precise programme	4	3	1

Contact is maintained with our patients after they are discharged from the Centre. A number of patients may change their plans under the influence of family, friends and other advisers and it is important that the rehabilitation programme retains a degree of flexibility.

A comprehensive rehabilitation programme must be prepared and applied to each patient as soon as possible after they are admitted to the rehabilitation centre.

Acknowledgements

The psychologist was S. Gur; the team of limbfitters was headed by H. Bar Goren; the physiotherapy group was led by N. Elinson; the occupational therapists by R. Goldman and social workers by N. Rosman.

To them I express my deep acknowledgements.

Prosthetics and Orthotics International, 1977, 1, 127–128

Designer's Prize for ISPO Member

HRH The Duke of Edinburgh presented a clock to Brian G. Blatchford MBE, winner of the 1976 Duke of Edinburgh's Designer's Prize, at a special ceremony for the 1977 Design Council Award winners at the Eden Court Theatre, Inverness on 27 May. Mr. Blatchford was awarded the 1976 Duke of Edinburgh's Designer's Prize for the design of the British Modular Assembly Prosthesis.

Unlike Design Council Awards which go to the manufacturer, the Duke of Edinburgh's Designer's Prize is given to the designer of the product considered to be the most outstanding of all the Design Council Awards in any one year. Winners of the prize are invited to design or commission a product of their own choosing. Mr. Blatchford commissioned the design of his clock with a mechanism based on the principle of the "Mysterious Circulator" devised by Johann Andreas Schmidt, a Master Clockmaker captured by Lord Nelson at the Battle of Copenhagen.

Mounted in an elegant black chrome plated brass case, the single hand hard gold plated circulator pivots on a pair of ball races fitted to a pierced titanium dial. A blue oxidised titanium strip separating the clock base from the main body contrasts pleasantly with the deep lustre of the clock body.

Aptly described as the Mysterious Circulator, there is no visible mechanism to move the single hand. In fact, well known horologist David Evans of Birmingham Polytechnic Horology Department, has adapted a production watch mechanism to motivate the hand. Powered by a tiny mercury long life

Brian G. Blatchford MBE with Gerald C. Whiles, Head of School of Jewellery and Silversmithing at Birmingham Polytechnic. Mr. Whiles designed the case of the 'Mysterious Circulator' which Mr. Batchford commissioned as his Duke of Edinburgh's Designer's Prize 1976. Mr. Blatchford's company, C. A. Blatchford & Sons Ltd. of Basingstoke, Hampshire also won a Queens Award to complete the treble in 1976. (Photograph by courtesy of the Design Council).

battery, the standard clockwork mechanism has been modified to conserve electrical energy and double gearing has been introduced to eliminate any backlash in the mechanism. The clockwork movement and battery are contained in a case measuring only 28 mm in diameter by 8 mm deep.

The case containing the clock movement is balanced by a counterweight at the opposite end of the single hand. The equilibrium of the system is continually upset by the clockwork movement and through the action of the counterweight attempting to restore the balance, the hour of the day can be read off on the dial. An interesting feature of this system lies in the fact that the single hand can be spun freely and will always come to rest to indicate the correct time.

Because the single hand of the clock which is also known as a Chronological Equilibrium indicates the hour only, a liquid crystal display is incorporated in the clock base to indicate hours and minutes. This mechanism is quite separate from the hour movement.

Although the Schmidt principle has been used in a number of clocks throughout the world, the clock which Mr. Blatchford has received is unique. It is distinguished by an inscription which reads: "The Duke of Edinburgh's Designer's Prize 1976 presented to Mr. B. G. Blatchford by HRH The Prince Philip, Duke of Edinburgh, in Jubilee Year".

Prosthetics and Orthotics International, 1977, 1, 129–131

Calendar of events

5–10 September, 1977

Course in Orthopaedic Medicine for Doctors and Physiotherapists, London.
Infomation: Dr. J. Cyriax, M.D., M.R.C.P., Course Secretary, 32 Wimpole Street, London, W.1.

8–10 September, 1977

Chartered Society of Physiotherapy Annual Congress, Churchill College, Cambridge.
Information: Miss G. Hodge, M.C.S.P., Superintendent Physiotherapist, Newmarket General Hospital, Newmarket, Suffolk.

21–24 September, 1977

Autumn Meeting, British Orthopaedic Association, Eastbourne.
Information: Miss M. Bennett, Honorary Secretary, B.O.A., Royal College of Surgeons, Lincoln's Inn Fields, London WC2A 3PN.

28–30 September, 1977

Conference on Orthopaedic Engineering, Oxford Orthopaedic Engineering Centre, Oxford.
Information: Derek Harris, Oxford Orthopaedic Engineering Centre, Nuffield Orthopaedic Centre, Headington, Oxford OX3 7LD, or Keith Copeland, Honorary Secretary, Biological Engineering Society, Biophysics Department, Faculty of Medical Sciences, University College of London, Gower Street, London WC1E 6BT.

1–5 October, 1977

Western Orthopaedic Association, Annual Meeting, Colorado Springs, Colorado.
Information: H. Jacqueline Martin, Executive Secretary, 1970 Broadway, Suite 1235, Oakland, California 94612.

3–7 October, 1977

NC 201 Course on Ankle-Foot Orthotics for Orthotists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

5–8 October, 1977

American Academy for Cerebral Palsy, Annual Meeting, Atlanta, Georgia.
Information: James E. Bryan, Executive Secretary, 1255 New Hampshire Avenue, Northwest, Washington, DC 20036.

10–14 October, 1977

NC 101A Course in Lower Limb Prosthetics for Physicians and Surgeons.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

12–14 October, 1977

Clinical Orthopaedic Society, Annual Meeting, Cincinnati, Ohio.
Information: Mack L. Clayton, M.D., Secretary-Treasurer, 2045 Franklin Street, Denver, Colorado 80205.

17–21 October, 1977

American College of Surgeons, Annual Clinical Congress, Dallas, Texas.
Information: C. Rollins Hanlon, M.D., Director, 55 East Erie Street, Chicago, Illinois 60611.

24–28 October, 1977

NC 301 Course in Lower Limb Orthotics for Occupational and Physiotherapists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

24–28 October, 1977

4th Conference and Exhibition on Bio-Engineering, Budapest, Hungary.
Information: Scientific Society of Measurement and Automation, 1372 Budapest V, Kossuth Lajoster 6–8, Hungary.

25–29 October, 1977

American Orthotic and Prosthetic Association, National Assembly, San Francisco.
Information: W. McCulloch, American Orthotic and Prosthetic Association, 1444 N. Street, NW, Washington, D.C. 20005.

31 October–11 November, 1977

NC 204 Course in Patellar-Tendon-Bearing Prosthetics for Prosthetists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

6–10 November, 1977

Engineering in Medicine and Biology (AEMB), Annual Meeting, Los Angeles Hilton, Los Angeles, California.
Information: A.S.M.E., 345 East 47th Street, New York, N.Y. 10017.

21–24 November, 1977

NC 202 Course in Ankle-Foot Orthotics for Orthotists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

27 November–2 December, 1977

American Society of Mechanical Engineers (A.S.M.E.), Winter Annual Meeting, Hyatt Regency and Atlanta Hilton Hotels, Atlanta, Georgia.
Information: Bioengineering Programme, Dr. Ed Grood, Department of Orthopaedic Surgery, University of Cincinnati Medical Center, 231 Bethesda Avenue, Cincinnati, Ohio 45267.

28 November–2 December, 1977

NC 302 Course in Lower Limb Prosthetics for Occupational and Physiotherapists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

12–16 December, 1977

NC 102A Course in Lower Limb Orthotics for Physicians and Surgeons.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

January 1978

Second International Conference on Legislation Concerning the Disabled, Manila, Philippines.
Information: Rehabilitation International, 122 East 23rd St., New York, N.Y. 10010.

9–20 January, 1978

NC 203 Course in Knee-Ankle-Foot and Hip-Knee-Ankle-Foot Orthotics for Orthotists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

23 January–3 February, 1978

NC 205 Course in Above-Knee Prosthetics for Prosthetists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

13–17 February, 1978

NC 206 Course in Upper Limb Orthotics for Orthotists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

20–24 February, 1978

NC 101B Course in Lower Limb Prosthetics for Physicians and Surgeons.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

6–10 March, 1978

NC 102B Course in Lower Limb Orthotics for Physicians and Surgeons.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

13–17 March, 1978

7th Congress of the World Federation of Occupational Therapists, Tel Aviv, Israel.
Information: (President of the Organizing Committee) Mrs. M. Clyman, 65 Aloof David Street, Ramat-Gan, Israel.

13–23 March, 1978

NC 207 Course in Spinal Orthotics for Orthotists.
Information: J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, 73 Rottenrow, Glasgow G4 0NG.

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.

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.

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.

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(2) Authors' names, initials and title. The present address of any author if different from the place where the work was done, may be shown as a footnote.

(3) Department(s) in which the work was done.

(4) The name and full postal address of the author to whom correspondence and requests for reprints should be directed. This will appear as a footnote.

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References

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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