The Journal of the International Society
for Prosthetics and Orthotics

Prosthetics and Orthotics International

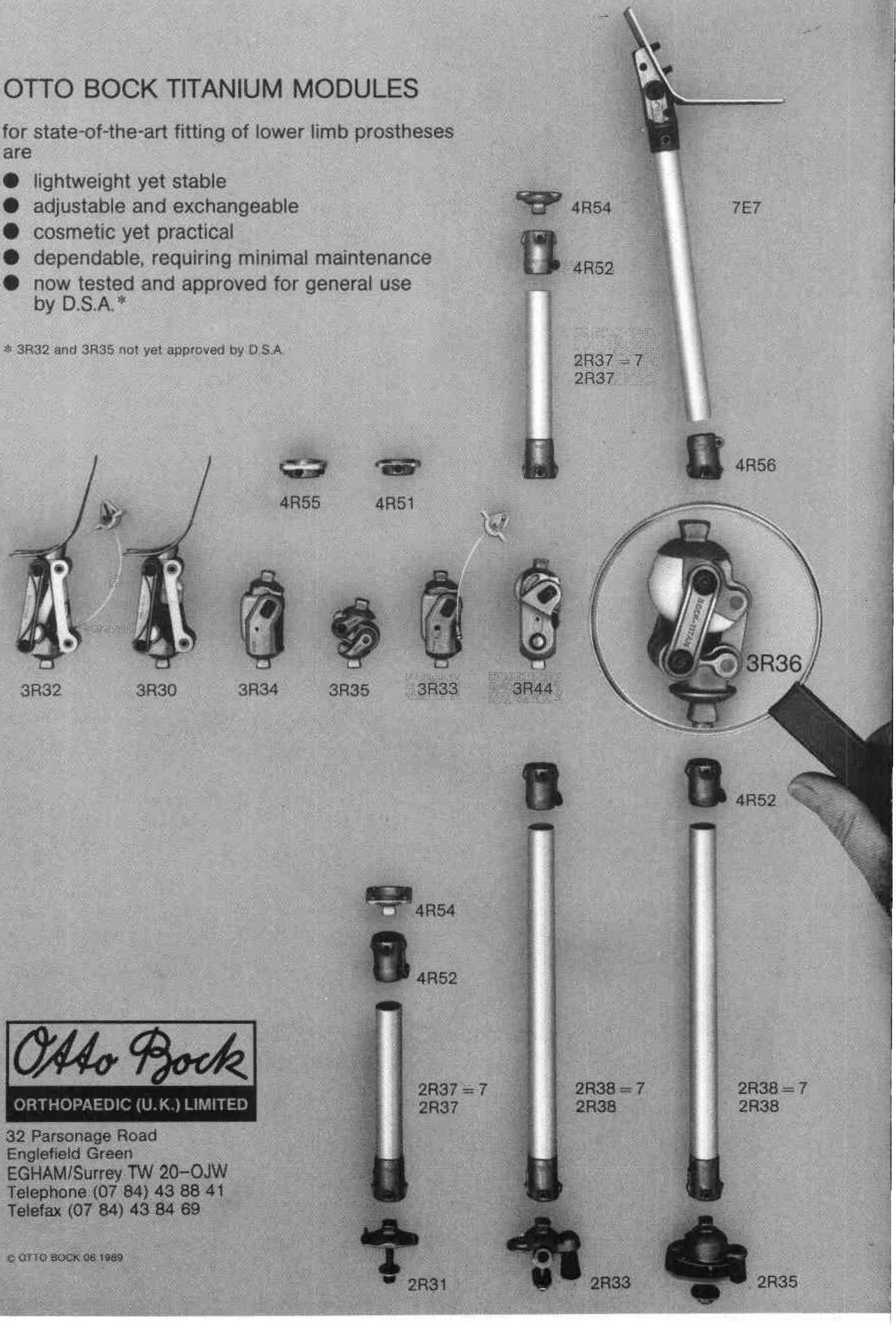
August 1989, Vol. 13, No. 2

OTTO BOCK TITANIUM MODULES

for state-of-the-art fitting of lower limb prostheses are

- lightweight yet stable
- adjustable and exchangeable
- cosmetic yet practical
- dependable, requiring minimal maintenance
- now tested and approved for general use by D.S.A.*

* 3R32 and 3R35 not yet approved by D.S.A.



Otto Bock
ORTHOPAEDIC (U.K.) LIMITED
32 Parsonage Road
Englefield Green
EGHAM/Surrey TW 20-OJW
Telephone (07 84) 43 88 41
Telefax (07 84) 43 84 69

Prosthetics and Orthotics International

Prosthetics and Orthotics International is published three times yearly by the International Society for Prosthetics and Orthotics (ISPO), Borgervaenget 5,2100 Copenhagen Ø, Denmark, (Tel. (01) 20 72 60). Subscription rate is £45 per annum, single numbers £16. The journal is provided free to Members of ISPO. Remittances should be made payable to ISPO.

Editorial correspondence, advertisement bookings and enquiries should be directed to Prosthetics and Orthotics International, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, Curran Building, 131 St. James' Road, Glasgow G4 0LS, Scotland (Tel. 041-552 4049).

ISSN 0309-3646

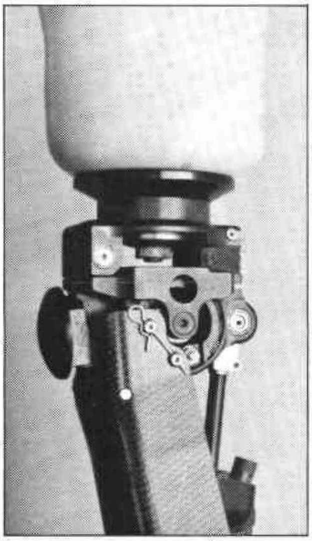
Produced by the National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, Glasgow

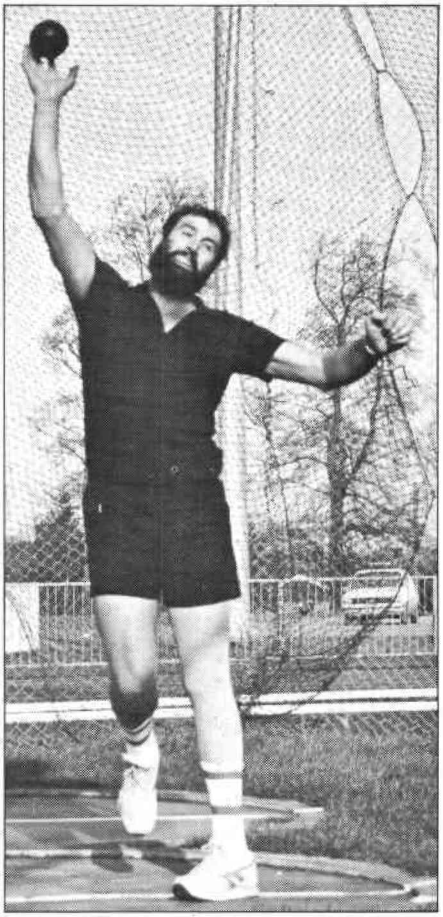
Printed by David J. Clark Limited, Glasgow

ENDOLITE

The High Technology Prosthesis

-at 6'7" and 236 lbs!





The company is pleased to announce, that a new knee control mechanism has been added to the range available within the light weight ENDOLITE™ system.

This new mechanism allows for a limited degree of knee flexion during the stance phase of walking whilst the knee is safely locked under the patient's weight. It helps to give a more natural gait when walking – cushioning the knee, so limiting shock loads transmitted through the socket, it also assists the patient's movement by releasing stored energy at the appropriate time.

In combination with the MULTIFLEX™ ankle the 'Stance-flex' stabilised knee has advantages to all patients, especially those participating in sporting activities.

Blatchford

Lister Road Basingstoke Hampshire RG22 4AH England
Telephone: 0256 465771

The Journal of the International Society for Prosthetics and Orthotics

August 1989, Vol. 13, No. 2

Contents

ISPO

Prosthetics and Orthotics International, 1989, 13, 57

Editorial

It is sometimes suggested that the ordinary member of our Society knows very little of what the Society is achieving. And in a sense this must be true. We do have a mechanism whereby Executive Board Minutes are sent to all National Member Societies — so National Committee Members should be fully informed — and we do publish, as in this issue of the Journal, a summary of each Board meeting for the benefit of the membership at large. However, both of these documents describe in rather stilted prose the detail of each individual meeting without tracing the development of any of our activities or philosophies.

In education, for example, a whole series of meetings leading on from the so-called Holte meeting, held in 1968 by our predecessor ICPO and the United Nations, has evolved a philosophy which defines two levels of operator — the full professional prosthetist/orthotist who works in the industrial world and the orthopaedic technologist, trained to a somewhat lower level, who works in the developing world, hopefully under the supervision of a prosthetist/orthotist. We have detailed appropriate education and training programmes for both these levels and our philosophy and curricula are widely accepted by most of the international governmental and non-governmental agencies in this field.

We have also developed a system of inspection and "recognition" of educational establishments. So far this has been applied only to schools in Africa producing orthopaedic technologists. Such recognition, however, is enormously important. It gives prestige to the school and confidence to its funding agency. It helps to maintain and raise standards. It improves the standing of the trainee and thus of the new profession in that country.

We have also studied the problem of the many grossly under-trained technicians working in many parts of the non-industrial world who are, nevertheless, the only providers of service. We held a meeting devoted solely to this topic and have developed strategies to tackle the problem. Further progress will not be achieved until we manage to attract funding, but we continue to seek that.

At regional level we are also actively tackling a special problem which looms large. Many will know that in the European Economic Community the year 1992 heralds the removal of all trade barriers in the Community. It will also bring, however, a system of reciprocal recognition of professional qualifications. In our field the variation of level of prosthetist/orthotist training in Europe is simply enormous — from the honours degree level of Scotland down to countries where virtually no training exists at all. This could give rise to a very serious situation where the higher standards would be threatened unless the Community is convinced of the need for special regulations. ISPO and INTERBOR are tackling this problem in a Joint Education Commission.

The above example of our activities in education was selected simply to demonstrate that there are many areas where we are extremely productive and effective but which may not be readily apparent to the membership.

We are investigating ways of improving communication. We might, for example, commission a regular series of reports, to be published in the journal, from Board members and Task officers on specific aspects of the Society's work. Communication, however, is a two-way process and we would welcome members' views. Are you content to see the Society continue with its work using the existing mechanisms and only learn of progress through reports and publications? Or, would you wish to have more information on the Society's activities than is currently provided in this way and through the Board reports, our Newsletter and, of course, feed-back from your National Committee. We would very much welcome your views and your ideas.

John Hughes
President

VI World Congress

12th–17th November, 1989, Kobe

Congress site and Kobe Portopia Hotel

Full details of the Congress programme and Registration Forms were included in the December 1988 issue of this journal.

Prosthetics and Orthotics International, 1989, 13, 59–62

Executive Board Meeting

23rd and 24th February, 1989
Copenhagen, Denmark

The following paragraphs summarize the major discussions and conclusions of the Executive Board Meeting held in Copenhagen in February. They are based on the draft minutes of that meeting which have yet to be approved by the Executive Board.

Chairman and Task Officer Reports

The Honorary Treasurer reported on the final accounts for 1988 which have already been published in the April edition of the Journal. The Honorary Treasurer presented a revised budget for 1989 which anticipated a deficit of approximately 220,000 Danish Crowns due to the high costs related to the Kobe Conference and also activities related to other international organizations. The Executive Board noted the increase in the contribution from SAHVA (Society and Home for the Disabled) to 100,000 Danish Crowns per annum and also recognised their continued support through the use of their accommodation and certain other facilities free of charge. The Board approved the budget for 1989. The Executive Board discussed the level of fees for 1990. Due to the fact that the costs for administering the Society were steadily increasing with inflation, and that no increase had been made for a number of years, it was unanimously agreed that the fee for 1990 should be raised to 450 Danish Crowns and for Developing Countries to 175 Danish Crowns. The annual subscription to 'Prosthetics and Orthotics International' for 1990 should be increased to £50 and the advertising rates for the Journal should be raised pro rata.

The protocol Committee discussed submissions for the Brian Blatchford Prize and the Forchheimer Prize. Final decisions would be taken on these prizes in consultation with the Blatchford family and the Forchheimer family and the prizes would be awarded at the forthcoming Congress in Japan. The President reported to the Protocol Committee that Professor Sethi had been invited to give the Knud Jansen Lecture and had subsequently accepted this honour.

The Honorary Secretary reported that there had been a steady increase in the Society's membership for the year 1988 to approximately 2,000. He also reported that there were now 19 National Member Societies, new Societies having been formed in Austria and Korea. He was also in contact with France, Jordan, Taiwan, Dutch Antilles and Indonesia with regard to the formation of National Member Societies in those countries. The Executive Board discussed the difficulties in creating National Member Societies and retaining members in the African Continent and it was suggested that the possibilities of developing an African Regional Society should be explored. The Executive Board also encouraged National Member Societies to consider twinning arrangements with countries in the developing world.

A number of reports on various ISPO activities were nearing publication. The proceedings of the CAT/CAM meeting held in Miami were being edited and it was anticipated that they would be published before the World Congress in Japan. The proceedings from the CAD/CAM meeting held in Seattle were also currently being edited and it was also anticipated that these would be published before the Congress. Since the Executive Board meeting, the report on the ISPO Workshop on Upgrading in Prosthetics and Orthotics for Technicians from Developing Countries Trained on Short Courses has now been published and it is anticipated that the report from the International Symposium of Prosthetic Orthotic Educators held in Toronto will also be published before the Congress. Ernst Marquardt (FRG) and H.G.B. Day (UK) were preparing a publication based on the recent Symposium on the Limb Deficient Child held in Heidelberg. It was hoped that publication will take place in 1990. French translations of the report of the ISPO Workshop (held in Moshi) on Prosthetics and Orthotics in the Developing World with Respect to Training and Education and Clinical Services, and the report on the Planning and Installation of Orthopaedic Workshops in Developing Countries had been organized by Sepp Heim and had been subsequently used at a meeting organized by the United Nations Centre for Social Development and Humanitarian Affairs, and held in Guinea. The costs of printing a limited number of these reports in French was not considered justified. However, copies could be made as the need arose. The Dundee '85 proceedings have now been published by Blackwell under the title, 'Amputation Surgery and Lower Limb Prosthetics'. The possibilities of publishing a new publicity brochure to help recruit new members to the Society is currently being explored.

Work is continuing in the International Standards Organization TC168 'Prosthetics and Orthotics'. A working Group meeting of the Committee was held in Bologna in October 1988, and a further meeting was to be held in Scotland in March, 1989.

The President reported that H.G.B. Day (UK) had accepted the position of Task Officer for the Limb Deficient Child. He had put forward a three point proposal with regard work in this area:

a) to investigate numbers and types of congenital limb deficiencies occurring in various countries.
b) to implement collaboration and correspondence between children's clinics on an international basis, in much the same way as exists at present in U.S.A.
c) to explore the needs of those with congenital limb deficiencies, and those of their families and determine the differences in these needs in various cultures.

The Executive Board agreed to these proposals in principle, however, the budgetary implications would have to be explored before implementing the proposals. Dr Day would report to the next Board meeting on this matter.

The questionnaire related to the Professional Register has been circulated and completed forms were now being returned to Copenhagen for the information to be computerized for use when ready. Should you not have already done so, please complete your form and have it returned to Copenhagen.

The Executive Board agreed to appoint Joan Edelstein (U.S.A.) as Task Officer for Journal Promotion.

The Task Officer for Cineplasty reported on the interest in this field mainly from the Federal Republic of Germany and the German Democratic Republic. A further meeting of the Task Force would be held in April, 1989 at the Congress of the German Orthopaedic Society.

International Organizations

Collaboration between ISPO and INTERBOR was continuing in the field of education and a meeting of the joint Education Commission will be arranged in the near future to discuss the European Economic Community directive on reciprocal recognition of Higher Education Diplomas and its effects on the field of prosthetics and orthotics.

The Society has been invited to participate in the World Health Organization (W.H.O.) Regional Seminar on Orthopaedic Technology in Developing Countries to be held in Senegal. It was agreed that George Murdoch and Sepp Heim should attend that meeting on behalf of ISPO. (Due to unfortunate circumstances, it was not possible for either George Murdoch of Sepp Heim to attend, and Jaak Van Rolleghem (Belgium) and Wieland Kaphingst (F.R.G.) represented the Society there.) The President also indicated that he had been in contact with W.H.O. with regard to establishing official relationships with them. It was agreed that the President and the Honorary Secretary would visit W.H.O. in order to prepare a programme of activities which would help establish official relations. The Board was informed that it was the intention of W.H.O. to establish a Reference Centre in Sweden. Kurt Oberg (Sweden) would be involved in the establishment of this centre and it was anticipated that there would be effective collaboration between the Reference Centre and ISPO.

The President reported that both he and the President Elect had taken part in the Rehabilitation International Congress held in Tokyo. The results were good publicity for the coming ISPO Congress in Japan.

The African Rehabilitation Institute (A.R.I.) had held a Seminar in Zimbabwe in February which focused on the African Continent and in particular sought to identify materials and components appropriate to Africa. George Murdoch had been involved in preparing and running the programme for this meeting and he was helped by four ISPO resource persons: Kurt Oberg (Sweden), Andries de Bont (Netherlands/Egypt), Harold Shangali (Tanzania) and Norman Govan (UK). Expenses for these resource persons had been paid for by A.R.I. It was anticipated that a report of this meeting would be available in the near future.

The President reported that ISPO had been invited to participate in an International Labour Office (I.L.O.) Conference for Arab speaking countries on Vocational Rehabilitation of Persons with Artificial Appliances. This meeting was originally arranged for May, 1989 but has now been postponed until December 1989. The Executive Board agreed that the Society should take part in this meeting and should offer to help with the planning of the programme.

The representative of Internationaler Verband der Orthopadie-Schutechniker (I.V.O.), Rolf Henze, reported that their next Congress would be held in Versailles from the 1st to the 3rd of September 1989.

Collaboration between World Orthopaedic Concern (W.O.C.) and ISPO continues to improve and it is hoped that future collaboration on specific projects would materialize.

The Honorary Secretary reported that the Society had been involved in the meetings held in Tanzania and Guinea by the Service for Technical Cooperation Support for Rehabilitation of Disabled Persons, Yugoslavia, in collaboration with the United Nations Centre for Social Development and Humanitarian Affairs. It was suggested that further collaboration with the Centre in Yugoslavia and with the United Nations office in Vienna should be explored at the VI World Congress in Japan.

The Honorary Secretary reported that he had been invited to the International Committee of the Red Cross (I.C.R.C.) project in Nicaragua to act as an external examiner for the prosthetics/orthotics course there. The course had been of three years duration and standards were relatively high and overseen by the Ministry of Education. The prostheses being fabricated were made from locally produced components and laminated plastic sockets. George Murdoch told the Board that he had observed the practice of the I.C.R.C. project in Bulawayo. He felt that the standards related to socket shape and alignment were rather disappointing. In general, it would appear that the standard of work in the I.C.R.C. projects was variable, but it was felt that their philosophy was to improve the professional content of their projects, and in general this was being achieved.

The Armenian Situation

The President reported that following the earthquake in Armenia, he had written to a number of agencies offering the assistance of the Society but to date had received no response. He informed the Board that Bo Klasson (Sweden) visited Armenia as a representative of the Swedish Red Cross and had agreed to represent ISPO there as far as he was able. It was agreed that Bo Klasson should continue to serve as a link between ISPO and the League of the Red Cross and Red Crescent Societies' project in Armenia and he agreed to explore the need for closer collaboration between ISPO and the League of Red Cross Societies.

Congresses

The organization of the VI World Congress continues. There has been a good response to the call for papers, posters and audio-visual presentations. The programme is now being finalized and it is anticipated that the Congress will be well attended. The Executive Board re-examined the invitation to host the VII World Congress in Chicago, U.S.A. and it was agreed to recommend to the International Committee that this invitation be accepted.

Conferences and Meetings

The President reported that Thamrongrat Keokarn attended the Third International Conference on Musculoskeletal Accidents and Injuries in the Workplace, held in Bangkok in November 1988. Unfortunately, the prosthetics and orthotics session had to be cancelled due to lack of interest.

The President Elect informed the Board that arrangements were underway to hold a European Conference on Rehabilitation Technology in November, 1990 and that he was a member of the steering committee. As part of that meeting would be related to prosthetics and orthotics, the Executive Board agreed that the Society should be involved as far as possible in the organizing and running of that part of the meeting.

Bo Klasson and Acke Jernberger presented suggestions for a meeting on the Deformed Foot to be held in 1990 in Sweden. It was agreed that they should present a more detailed programme and budget to the next Board meeting.

Prosthetics and Orthotics in Developing Countries (Americas)

The President informed the Board on developments in the U.S.A. with regard to prosthetics and orthotics and the developing world. A meeting had been held in Washington of the different agencies involved in prosthetics and orthotics in the Americas and the President had attended together with the Honorary Secretary. As an outcome of this meeting, it was suggested that ISPO and the American Academy of Orthotists and Prosthetists attempt to act as a focal point for requests for help and/or advice received from countries in Central America.

Rehabilitation Engineering

The Executive Board discussed the suggestion of the UK National Member Society that in order to encourage Rehabilitation Engineers to join ISPO, the Society should consider a change in its title. The Executive Board discussed this matter and agreed that ISPO should not change its name. However, it was agreed that a by-line should be printed on the Society's letterhead which accentuated the fact that ISPO covered rehabilitation engineering as well as prosthetics and orthotics.

Executive Board Nominations

The Honorary Secretary informed the Board that the Executive Board nominees for the next triennium had all accepted their nominations. The slate of nominations had been circulated to members of the International Committee seeking their agreement or additional nominations. The Executive Board's nominations are as follows:

President	Willem Eisma	Netherlands
President Elect	Melvin Stills	U.S.A.
Vice Presidents	Sepp Heim	F.R.G.
	Acke Jernberger	Sweden
Members	Valma Angliss	Australia
	Per Christiansen	Denmark
	Thamrongrat Keokarn	Thailand
	Jean Vaucher	Switzerland
Honorary Treasurer	J. Steen Jensen	Denmark
Honorary Secretary	Norman A. Jacobs	U.K.

Should any additional nominations be received a postal ballot will be conducted to elect the new Executive Board.

Proposed Amendments

The Executive Board discussed the proposed amendments to the Constitution submitted by four Fellows of the UK NMS, but decided it could not act upon them because of the implications in respect of the Society and its continued activity and existence. It was, however, indicated to National Member Societies that it is the Executive Board's intention to have a review of the constitution and their comments were sought so that the matter can be thoroughly discussed at the time of the International Committee meeting in Kobe. Then, if necessary, any constitutional changes could be made at an interim meeting of the International Committee some time between the Kobe and Chicago Congresses.

Fellowships

Fellowship of the Society has been awarded to Thamrongrat Keokarn (Thailand).

World Assembly

The World Assembly of the Society shall take place in conjunction with the VI World Congress in the Kobe Convention Centre and is programmed for Friday, 17th November.

Norman A. Jacobs
Honorary Secretary

Prosthetics and Orthotics International, 1989, 13, 63–69

Primary survival and prosthetic fitting of lower limb amputees

T. POHJOLAINEN, H. ALARANTA and J. WIKSTRÖM*

Invalid Foundation Orthopaedic Hospital, Helsinki

**Rehabilitation Research Unit, Helsinki University Central Hospital*

Abstract

During the period 1984-1985 amputation of the lower limb at a level potentially requiring a prosthesis was performed on 577 patients in 16 operative units. The mean age was 75.7 years for females and 68.1 for males. The most common site of the amputation was above the knee (49.9%). The majority of amputations (93.8%) were performed for vascular diseases and diabetes. Survival figures showed that 25.5% of amputees died within 2 months of amputation, 60.7% were alive after one year and 43.2% after two years. Out of a total of 577 patients, 26.9% were fitted with a prosthesis. Out of below-knee and above-knee amputees surviving over 2 months, 61.5% and 27.2% respectively were fitted with a prosthesis. There were markedly fewer prosthetic fittings in the over-60 age group. Diabetic patients of both sexes were fitted with a prosthesis more often than arterio-sclerotic patients. Among tumour patients 82.4% received a prosthesis. In the study area more emphasis must be put on the concept of preserving the knee joint and preoperative assessment of vascular patients for selection of amputation level. Every effort must be made to avoid delay in the postoperative mobilization and rehabilitation. Prosthetic fitting of amputees could be improved by better liaison between surgical unit and specialized rehabilitation unit and by closer team approach of amputee care.

Introduction

In Finland about 1,500 lower limb amputations are performed annually (Pohjolainen and Alaranta, 1988). Most of these amputations are performed on geriatric patients with peripheral vascular disease. It is predicted that the number of amputations will increase as the age structure of the Finnish population advances, producing a higher proportion of elderly age groups (data supplied by the Central Statistical Office of Finland).

The disability following limb amputation is permanent and it can also be enormous: in many cases amputation makes the patient heavily dependent on other people. The amputee requires considerable in-patient and out-patient care and frequently makes heavy demands upon the social services and welfare workers of the hospital and the community. Every attempt must be made to return the individual to as near normal a functional status as possible and to his original environment, or to an improved environment if previous living conditions were poor. Moreover, elderly patients often have changes in organs other than the limbs: they may have heart trouble, brain disorders and, especially in diabetics, eye, kidney and neurological disorders. However, it is possible for a high percentage of elderly amputees to make a successful return to society, either ambulant or in a wheelchair (Weaver and Marshall, 1973; Steinberg et al., 1985). The services which plan and organize the provision of prostheses and rehabilitation for amputee patients would benefit from information concerning the extent of the problems mentioned above which obviously differ from one country to another. In Finland, there are at present no earlier epidemiological figures relating to survival or to prosthetic fittings among lower limb amputees.

Methods

To assess the current situation regarding the rehabilitation of amputees in Southern Finland, data were collected on all lower limb amputations carried out by all 16 operative

All correspondence to be addressed to Dr. T. Pohjolainen, Invalid Foundation Orthopaedic Hospital, Tenholantie 10,00280, Helsinki, Finland.

units of the catchment area of the Helsinki University Central Hospital during the period 1984-1985, as well as data from every prosthetic workshop and rehabilitation unit in the same area. Statistics concerning minor amputations no higher than the foot were eliminated. Data on prosthetic fittings were obtained for the one-year period following amputation.

During the two-year period, amputation of the lower limb at a level potentially requiring a prosthesis was performed on 577 patients, of which 326 were females (56.5%) and 251 males (43.5%). The mean age was 75.7 years for females and 68.1 years for males. Table 1 shows the underlying diagnoses for which the amputations were carried out in patients of different age groups. The majority, 93.8%, were performed for vascular diseases; 3.2% were for tumour and 1.7% followed trauma. Of the 577 amputees, 88.2% were over 60 years old.

The largest group of amputees (49.9%) underwent unilateral above-knee amputation, with below-knee amputees forming the next largest group (27.0%). Bilateral amputation was performed on 109 patients (18.9%) (Table 2).

The chi-square test was used for the statistical calculations.

Results

Survival

About 73% of the patients with amputations due to vascular disease were alive two months after the operation, while 60% of these patients lived over one year and 41% over two years. Among the 245 diabetics 25% died within two months, about 62% lived for more than one year and nearly 46% more than two years. Among the 267 arteriosclerotics 27% died within two months, while 58% lived for more than one year and 38% more than two years. Among the 18 tumour patients 94% lived over

Table 1. Diagnostic groups according to age (yrs).

Diagnosis		Age groups					Age	
		0-59	60-79	80-	All	%	x	SD
Arteriosclerosis		19	147	101	267	46.4	75.7	9.9
Diabetes mellitus		20	155	70	245	42.4	73.3	10.6
Embolism		2	21	4	27	4.7	70.3	10.4
Tumour		15	2	1	18	3.2	34.4	25.1
Trauma		7	2	1	10	1.7	44.1	25.8
Frost bite		2	1	0	3	0.5	60.0	9.6
Buerger's disease		2	0	0	2	0.3	46.5	10.6
Osteomyelitis		1	0	1	2	0.3	59.0	39.6
Miscellaneous		0	3	0	3	0.5	72.5	0.7
Total	n	68	331	178	577			
	%	11.8	57.4	30.8		100.0		

Table 2. Amputation levels in different age and sex groups.

Amputation level	Women				Men				
	Age groups (yrs)				Age groups (yrs)				
	0-59	60-69	70-79	80-	0-59	60-69	70-79	80-	All
Lisfranc	3	1	1	2	1	0	0	0	8
Ankle[1]	0	0	3	2	0	0	2	1	8
Below-knee[2]	7	20	38	24	19	12	24	12	156
Above-knee[3]	6	20	59	82	18	29	48	26	288
Hip disarticulation	1	0	3	0	2	1	0	0	7
Hemipelvectomy	0	0	0	0	1	0	0	0	1
Foot/below-knee	1	1	3	2	3	4	2	0	16
BK/BK	2	2	2	7	2	6	3	1	25
BK/AK	0	0	10	0	2	5	3	3	23
AK/AK	0	2	9	10	0	4	12	5	42
Foot/AK	0	1	1	1	0	0	0	0	3
Total	20	47	129	130	48	61	94	48	577

[1] Includes Pirogoff, Boyd and Chopart amputations
[2] BK = Below-knee amputation
[3] AK = Above-knee amputation

two months, 78% over one year and 72% over two years. All patients amputated for trauma lived over two months and 90% lived over two years (Table 3).

Patients who underwent unilateral or bilateral below-knee amputation had a lower mortality than unilateral or bilateral above-knee amputees (Table 4).

The survival curve (Fig. 1) shows a sharp fall initially, especially in older age groups, but thereafter the slope is not very steep. At one year after operation, 61% of the entire group had survived and at two years, 43%. The postoperative mortality of patients under 60 years-old was 93% after two months, 84% after 12 months and 77% after 24 months. The corresponding figures for patients over 60 were 72%, 58% and 39% (Fig. 1).

Prosthetic fitting

Out of a total of 577 patients, 155 (26.9%) were fitted with a prosthesis. The average time between amputation and the fitting of a definitive prosthesis was 117 days. The time lag between surgery and fitting of the prosthesis was 111 days for unilateral below-knee, 125 for unilateral above-knee and 121 for bilateral below-knee amputees.

Figure 2 shows the prostheses fitted during the first postoperative year in different age groups among amputees surviving over two months from the time of amputation. The proportion of those fitted with a prosthesis decreased from 83% in patients aged 0-19 to 13% in patients aged over 80. There was a marked decrease in prosthetic fittings comparing the patients aged over 60 to the younger group ($p<0.001$).

Table 3. Survival following different diagnoses over two postoperative years and percentages of patients fitted with a prosthesis during the first postoperative year among amputees surviving over two months.

Diagnosis	Patients	Months of survival						Prosthesis fitted	
		2		12		24			
		n	%	n	%	n	%	n	%
Arteriosclerosis	267	194	72.7	156	58.4	101	37.8	55	28.4
Diabetes mellitus	245	185	75.5	152	62.0	112	45.7	74	40.0
Embolism	27	15	55.6	11	40.7	7	25.9	5	33.3
Buerger's disease	2	2	100.0	2	100.0	2	100.0	2	100.0
Tumour	18	17	94.4	14	77.8	13	72.2	14	82.4
Trauma	10	10	100.0	9	90.0	9	90.0	2	20.0
Frost bite	3	3	100.0	3	100.0	3	100.0	2	66.7
Miscellaneous	5	4	80.0	3	60.0	2	40.0	1	25.0
Total	577	430	74.5	350	60.7	249	43.2	155	36.0

Table 4. Survival of amputees at different amputation levels over two postoperative years and prosthetic fitting of amputees during the first postoperative year among the amputees surviving over 2 months.

Amputation level	Patients	Survival months						Prosthesis fitted	
		2		12		24			
		n	%	n	%	n	%	n	%
Ankle and foot[1]	16	14	87.5	12	75.0	12	75.0	2	14.3
Below-knee	156	130	83.3	109	69.9	87	55.8	80	61.5
Above-knee	288	195	67.7	155	53.8	98	34.0	53	27.2
Hip disarticulation	7	5	71.4	5	71.4	4	57.1	3	60.0
Hemipelvectomy	1	0	0.0	0	0.0	0	0.0	0	0.0
BK/BK[2]	25	21	84.0	18	72.0	15	60.0	8	38.1
AK/AK	42	30	71.4	22	52.4	9	21.4	2	6.7
BK/AK[3]	23	18	78.3	15	65.2	11	47.8	5	27.8
Foot/BK	16	14	87.5	13	81.3	12	75.0	2	14.3
Foot/AK	3	3	100.0	1	33.3	1	33.3	0	0.0
Total	577	430	74.5	350	60.7	249	43.2	155	36.0

[1] Includes Chopart, Pirogoff, Boyd and Lisfranc amputations
[2] BK = Below-knee amputation
[3] AK = Above-knee amputation

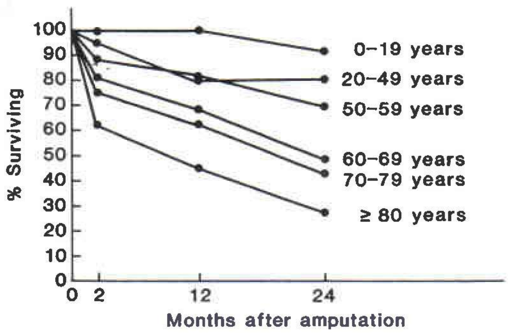


Fig. 1. Percentage surviving after amputation within different age groups.

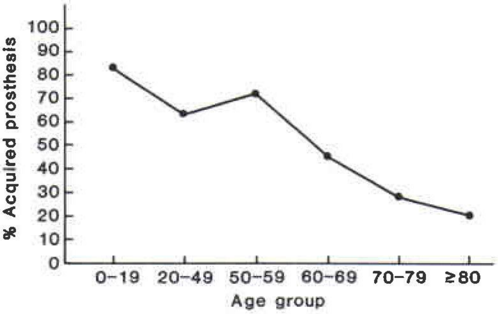


Fig. 2. Percentage of amputees within different age groups surviving over two months and fitted with a prosthesis during the first postoperative year.

Of the 326 females, 65 (19.9%) and of the 251 males, 90 (35.9%) received a prosthesis after amputation. Diabetic patients of both sexes were fitted with a prosthesis more often than arteriosclerotic patients. Of the 18 tumour patients and 10 trauma patients, 82.4% and 20% respectively received a prosthesis (Table 3).

Among all the patients undergoing unilateral amputation, 18.4% (53/288) of the above-knee group and 51.3% (80/156) of the below-knee group received a prosthesis. A prosthesis was fitted to 8 (32%) of the 25 bilateral below-knee amputees, but to only 2 (4.8%) of the bilateral above-knee amputees (Table 4).

Discussion

During the period under review the large majority of lower limb amputees were in the geriatric age group: 88% were over 60 years old and 31% were over 80 years old (Table 1). Most of the patients were amputated for complications of peripheral vascular disease and diabetes. The mortality rate was high in patients aged over 60 and in amputees suffering from vascular diseases. Lassila et al., (1986) have observed that the state of advanced lower limb ischaemia is associated with overall involvement of the arterial system and predict fatal cardiovascular events among these patients. A large proportion of elderly patients have a reduced physiological reserve and high mortality is partly associated with advanced cardiovascular problems and pulmonary diseases. Furthermore, advanced lower limb ischaemia may often be a manifestation of unbalanced homeostasis of patients in their terminal stages. The authors do not know what proportion of elderly, severely ill patients with arterial gangrene amputation should have been treated conservatively.

With regard to mortality over a longer period, Hansson (1964) reported 45%, 58%, 71% and 76% mortality 1, 2, 3 and 4 years postoperatively. According to the Danish Amputation Register (Ebskov and Josephsen, 1980) the percentages for 1 year to 4 years were 18.4%, 19.2%, 20.3% and 22.5%. In the series reported here the percentages for the first two years were similar to those in Hansson's study (Hansson, 1964).

The average age of vascular amputees in the authors' material was higher than in many other published studies (Harris et al., 1974, Finch et al., 1980, Lexier et al., 1987) and this may be one reason for the relatively high mortality rate. The mortality of above-knee amputees was greater than that of below-knee amputees. This is probably due to the severity of the ischaemia of the affected limb and associated generalized disease.

The relatively high mortality rate and the delay between surgery and prosthetic fitting may be due to the fact that the Finnish system of post-operative training and ambulation has been too passive. Early ambulation has been shown to be advantageous for geriatric patients since early gait training with a pneumatic walking aid in parallel bars diminishes complications and mortality (Pollack and Kernstein, 1985). By ambulating the patient as soon as possible it is possible to reduce complications such as pulmonary and urinary tract problems, stump oedema, stump infection and mortality, to inhibit loss of balance and psychological stress and to provide a definitive prosthesis (Redhead, 1983; Pollack and

Kernstein, 1985; Rausch and Khalili, 1985). Early ambulation is particularly important in patients aged over 60, as in the authors' experience their prosthetic fitting tends to be unsatisfactory and their mortality is fairly high.

In this series the prosthetic fitting in females was less satisfactory than in males. This is obviously due to the fact that the mean age of the males is lower. Patients who underwent a below-knee amputation showed the highest rate of prosthetic fitting, mainly because their disease was less advanced than in patients who had more proximal amputations.

The amputation level correlates with the diagnosis and the cause of amputation. In younger patients tumours are often associated with above-knee amputations (Pohjolainen and Alaranta, 1988). In trauma cases as much of the limb as possible must be saved. Of 10 trauma patients, six were amputated at ankle or foot level. The low percentage of prosthetic fitting in trauma (Table 3), ankle and foot level (Table 4) is explained because due to the distal amputation level most of these patients were adequately rehabilitated with orthopaedic shoes and did not require lower limb prostheses. This also partly explains the low percentage of prosthetic fitting of traumatic amputees.

When a major lower limb amputation is performed for ischaemia, the selection of the correct level is the primary problem. In this study there remains a disappointingly high rate of above-knee amputations in relation to below-knee amputations, although there has been a shift in emphasis towards preservation of the knee joint compared with the clinical series during the period 1950-1963 (Vankka, 1967). It has earlier been pointed out that the selection of amputation level and the operation itself should always be performed by experienced surgeons and the same amputating surgeon should take care of the whole rehabilitation (Romano and Burgess, 1971; Murdoch, 1977; Ham et al., 1986). In the authors' material, 89 per cent of patients were amputed in hospitals outside the vascular laboratory services and the low below-knee/above-knee (BK/AK) ratio 1:2 reflects the lack of resources in preoperative assessment of vascular patients. Amputation services in the study area were not generally centralized resulting in relatively low amputation numbers in some individual hospitals. Most of the amputations were performed by general surgeons without preoperative vascular consultation and few surgeons had access to ancillary methods to aid in the selection of the precise level of amputation. An analysis of individual surgical units in the study area revealed large differences, possibly reflecting different policies. Some hospitals for example, performed almost only above-knee amputations without considering the difficulties involved in the rehabilitation of the patients. The role of the vascular laboratory in the management of major lower limb amputations has been demonstrated also in another Finnish study (Lepäntalo, 1988). Preoperative assessment, employing methods such as segmental pressure studies (Pollack and Ernst, 1980; Barnes et al., 1981) and skin perfusion pressure studies (Holstein, 1985; Lepäntalo et al., 1987), thermography (Spence et al., 1981), skin blood flow measurements (McCollum et al., 1985), and transcutaneous oxygen measurement (Burgess et al., 1982; Ratcliff et al., 1984) has been found useful in the estimation of the level of limb viability.

Walking with an above-knee prosthesis is much more energy-consuming than with a below-knee prosthesis (Waters et al., 1976). This means that the more proximal the amputation, the greater the risk that the patient will never regain his ability to walk at all. Indeed many patients will never be capable of using their prosthesis after above-knee amputation (Romano and Burgess, 1971; Wagner, 1978; Stirnemann et al., 1987). In this series, unilateral and bilateral above-knee amputees displayed markedly poorer prosthetic rehabilitation than unilateral and bilateral below-knee amputees. The rehabilitation potential for above-knee amputees, especially in older age groups, is in fact often poor. The current problem for the geriatric amputee is not primarily one of prosthetic components, prosthetic design, fitting and alignment or gait training, but rather one of preservation of the knee joint. Compared with the figures reported by Burgess et al. (1971), Fleurant and Alexander (1980) and Netz et al. (1983), it seems that in Finland there are more above-knee amputations and a higher postoperative mortality. Thus in Finland, more emphasis must be placed on the concept that every effort should be made to preserve the knee joint.

The aim of the medical team, which includes a surgeon, physiatrist, physiotherapist, occupational therapist and prosthetist is to reduce in-patient stay, increase the proportion of patients discharged with a prosthesis and increase the effectiveness of long term rehabilitation (Jamieson and Hill, 1976; Ham et al., 1987). The social services can also play an important part in enabling the amputee to live within the community (Finch et al., 1980).

Despite the long tradition of medical statistics compiled by the National Board of Health in Finland, no general statistics are available on the etiological factors in amputations, the incidence of amputation, their complications, postoperative death, the duration of hospitalization, the number and type of prostheses fitted, the degree of mobility and other items of basic social information. In order to obtain information on these standard parameters the creation in Finland of an amputation register similar to the Danish Amputation Register (Ebskov, 1986) should be considered. Such a register would also permit the analysis of trends and the prediction of future needs in terms of staffing and financial resources.

Conclusions

The authors believe that the total problem of amputees, especially geriatric amputees, could be improved in Finland by: (1) more emphasis on preoperative assessment of vascular patients for the selection of amputation level and performance of the operation by surgeons with long experience; (2) better appreciation and application of preoperative and postoperative physiotherapy and early postoperative mobilization; (3) better integration of prosthetic fitting and the total rehabilitation of the patient by his admission from the surgical ward to a residential rehabilitation unit as soon as the stump is healed; (4) closer team approach of amputee care; (5) better liaison between the rehabilitation unit and the welfare services responsible for patient care in the home; (6) organized regular follow-up of amputees by the specialized rehabilitation unit.

A large and comprehensive rehabilitation programme to enhance the prosthetic fitting of lower limp amputees has been started in the study area and the results will be evaluated in forthcoming years.

Acknowledgements

This study was kindly supported by the Professor Langenskiöld Fund delivered by the Factory of Prosthetic Foundation, Helsinki. The authors are grateful for assistance received from the Factory of Prosthetic Foundation and the Prosthetic Factory of the Finnish Red Cross.

REFERENCES

Barnes, R. W., Thornhill, B., Nix, L., Rittgers, E., Turley, G. (1981). Prediction of amputation wound healing *Arch Surg* **116,** 80–83.

Burgess, E. M., Romano, R. L., Zettl, J. H., Schrock, R. D. (1971). Amputations of the leg for peripheral vascular insufficiency. *J Bone Joint Surg* **53A,** 874–890.

Burgess, E. M., Matsen, F. A., Wyss, C. R., Simmons, C. W. (1982). Segmental transcutaneous measurements of PO2 in patients requiring below the knee amputation for peripheral vascular insufficiency. *J Bone Joint Surg* **64A,** 378–382.

Ebskov, B., Josephsen, P. (1980). Incidence of reamputation and death after gangrene of the lower extremity. *Prosthet Orthot Int* **4,** 77–80.

Ebskov, B. (1986). The Danish Amputation Register 1972-1984. *Prosthet Orthot Int* **10,** 40–42.

Finch, D. R. A., Macdougal, M., Tibbs, D. J., Morris, P. J. (1980). Amputation for vascular disease: the experience of a peripheral vascular unit. *Br J Surg* **67,** 233–237.

Fleurant, F. W., Alexander, J. (1980). Below-knee amputation and rehabilitation of amputees. *Surg Gynecol Obstet* **151,** 41–44.

Ham, R., Roberts, V. C., Cotton, L. T. (1986). Postoperative management of the amputee. [Le Heu] *Br J Surg* **73,** 508.

Ham R., Regan, J. M., Roberts, V. C. (1987). Evaluation of introducing the team approach to the care of the amputee: the Dulwich study. *Prosthet Orthot Int* **11,** 25-30.

Hansson, J. (1964). The leg amputee: a clinical follow-up study. *Acta Orthop Scand,* [Suppl.] **35,** 104pp.

Harris, P. L., Read, F., Eardley, A., Charlesworth, D., Wakefield, J., Sellwood, R. A. (1974). The fate of elderly amputees. *Br J Surg* **61,** 665–668.

Holstein, P. (1985). Skin perfusion pressure measured by radioisotope washout for predicting wound healing in lower limb amputation for arterial occlusive disease. *Acta Orthop Scand,* [Suppl.] **213,** 1–47.

Jamieson, C. W., Hill, J. (1976). Amputation for vascular disease. *Br J Surg* **63,** 683–690.

LASSILA, R., LEPÄNTALO, M., LINDFORS, O. (1986). Peripheral arterial disease-natural outcome. *Acta Med Scand* **220**, 295-301.

LEPÄNTALO, M., ISONIEMI, H., KYLLÖNEN, L. (1987). Can the failure of a below-knee amputation be predicted? Predictability of below-knee amputation healing. *Ann Chir Gynaecol* **76**, 119–123.

LEPÄNTALO, M. (1988). The role of the vascular laboratory in the management of major lower limb amputations. *Ann Chir Gynaecol* **77**, 74–77.

LEXIER, R. R., HARRINGTON, I. J., WOODS, J. M. (1987). Lower extremity amputations: a 5-year review and comparative study. *Can J Surg* **30**, 374–376.

McCOLLUM, P. T., SPENCE, V. A., WALKER, W. F. (1985). Circumferential skin blood flow measurements in the ischaemic limb. *Br J Surg* **72**, 310–312.

MURDOCH, G. (1977). Amputation surgery in the lower extremity. *Prosthet Orthot Int* **1**, 72–83.

NETZ, P., STARK, A., RINGERTZ, H. (1983). Amputations for vascular insuffiency. *Prosthet Orthot Int* **7**, 9–14.

POHJOLAINEN, T., ALARANTA, H. (1988). Lower limb amputations in Southern Finland. *Prosthet Orthot Int* **12**, 9–18.

POLLACK, S. B., ERNST, C. B. (1980). Use of Doppler pressure measurements in predicting success in amputation of the leg. *Am J Surg* **139**, 303–306.

POLLACK, C. V., KERNSTEIN, M. D. (1985). Prevention of postoperative complications in the lower-extremity amputee. *J Cardiovasc Surg* **26**, 287–290.

RATCLIFF, D. A., CLYNE, C. A. C., CHANT, A. D. B., WEBSTER, J. H. H. (1984). Prediction of amputation wound healing: the role of transcutaneous PO2 assessment. *Br J Surg* **71**, 219–222.

RAUSCH, R. W., KHALILI, A. A. (1985). Air splint in preprosthetic rehabilitation of lower extremity amputated limbs. A clinical report. *Phys Ther* **65**, 912–914.

REDHEAD, R. G. (1983). The early rehabilitation of lower limb amputees using a pneumatic walking aid. *Prosthet Orthot Int* **7**, 88–90.

ROMANO, R. L., BURGESS, E. M. (1971). Level selection in lower extremity amputations. *Clin Orthop* **74**, 177–184.

SPENCE, V. A., WALKER, W. F., TROUP, I. M., MURDOCH, G. (1981). Amputation of the ischaemic limb: selection of the optimum site by thermography. *Angiology* **32**, 155–169.

STEINBERG, F. U., SUNWOO, I., ROETTGER, R. F. (1985). Prosthetic rehabilitation of geriatric amputee patients: a follow-up study. *Arch Phys Med Rehabil* **66**, 742–745.

STIRNEMANN, P., MLINARIC, Z., OESCH, A., KIRSCHHOF, B., ALTHAUS, A. (1987). Major lower extremity amputation in patients with peripheral arterial insufficiency with special reference to the transgenicular amputation. *J Cardiovasc Surg* **28**, 152–158.

VANKKA, E. (1967). Study on arteriosclerotics undergoing amputations. Including pre- and postoperative periods. *Acta Orthop Scand* [Suppl.] **140**.

WAGNER, F. W. (1978). Orthopaedic rehabilitation of the dysvascular lower limb. *Orthop Clin North Am* **9**, 325–350.

WATERS, R. L., PERRY, J., ANTONELLI, D., HISLOP H. (1976). Energy cost of walking of amputees: the influence of level of amputation. *J Bone Joint Surg* **58A**, 42–46.

WEAVER, P. C., MARSHALL, S. A. (1973). A functional and social review of lower-limb amputees. *Br J Surg* **60**, 732–737.

Prosthetics and Orthotics International, 1989, 13, 70–75

The role of orthotics in the rehabilitation of patients with fracture of the calcaneum

W. WINKLER

SUVA Rehabilitation Clinic, Bellikon, Switzerland

Introduction

Fractures of the calcaneum comprise about 1-2% of all fractures and as such are not common, yet in the author's experience they are surprisingly frequent.

Regrettably the various classifications offered by Essex-Lopresti (1952), Judet (1954), Rowe (1963), Böhler (1977), Vidal (1983), etc. do not lead to clear indications regarding final treatment, duration of disability or more indirectly the level of pension.

In the author's study there was a relationship between fractures involving the calcaneo-cuboid joint and protracted rehabilitation, an increased frequency of prescription of orthopaedic shoes and the size of the pension awarded. Although fractures with involvement of the midtarsal joint are usually mentioned in planning treatment, the late sequelae are barely discussed in the literature. Mattel's (1983) investigation on the treatment and rehabilitation of patients with fractures of the calcaneum consisted of a review of 111 cases which by the very nature of the clinic (Bellikon, Switzerland) was pre-selected. It is therefore clearly of interest to compare the results of this study with a randomly selected group of patients; specifically to compare the results in patients with a fracture of the calcaneum involving the midtarsal joint with those without involvement of the midtarsal joint. As an introduction to this topic the following statistical data is presented.

Statistical data

Various authors report a relatively high percentage of fractures without any involvement of the joint; Böhler (1977) reported 38.5%. In this series the percentage without subtalar involvement was 17.6%; in the author's view this incidence is still high and serves to support the view that the classifications of these fractures are not accurate with regard to prognosis.

About one third of the patients had involvement of the lateral midtarsal joint viz., the calcaneo-cuboid. This group of patients also most frequently needed rocker soles or orthopaedic shoes and ended up with the highest pensions (40 — 50% disability with unilateral calcaneal fracture involving the midtarsal joint; in contrast the average degree of disability in selected patients with unilateral calcaneal fractures is 20-25%).

More than half of the patients resumed work within 5 to 9 months after the accident. Yet the total average duration of incapacity was 9.5 months, which shows that a small number of cases with disproportionately great problems can worsen these numbers considerably.

Arthrodesis of the "lower ankle joint" was required by 28% of all patients (lower ankle joint: the composite of the talo-navicular, talo-calcaneal and calcaneo-cuboid joints). Again, this very high percentage reflects the selection of patients.

Surgical treatment of their fracture was carried out on 15% of the inpatients. As this presumably reflects the general frequency of surgical treatment of fractures in Switzerland no conclusions can be drawn regarding any special tendency.

Pathology

Orthotic management may also have its place in the acute treatment of fractures. The splint shoe with rocker bar (Fig. 1) was originally intended to replace a walking cast. Two or three different models of patellar-tendon-bearing orthoses could also be used: the rather unpopular Allgower orthosis with a stirrup as the only bearing area, the Sarmiento orthosis made of thermoplastics, or a rigid orthosis made of resin with a complete sole for footrest and heel-relief.

All correspondence to be addressed to Dr. W. Winkler, SUVA Rehabilitation Clinic, CH-5454 Bellikon, Switzerland.

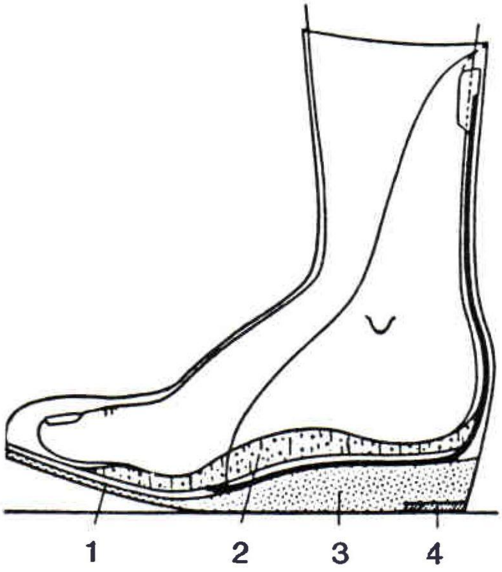


Fig. 1. Splint shoe with rocker bar by R. H. Rabl (1975). 1, bottom filler and insole; 2, inside cork insole; 3, Airolux; 4, rigid plate.

Instead of discussing these attention should be focussed on orthopaedic measures intended to alleviate the sequelae of fractures that have already healed. Therefore in discussing the damage suffered the final condition after treatment will be considered and not the mechanisms or classifications of fractures.

Morphological changes found subsequent to healing of fractures

1. Calcaneal spur : due to displacement of bone fragments a single piece of sharp bone may present as the lowest point of the heel (Fig. 2, 1).
2. Incongruity of the subtalar joint: according to Böhler (1977) 62% of all heel fractures produce distortion within the subtalar joint. It is very rarely possible to completely correct displacement; in fact, if visible involvement of the subtalar joint is at all present incongruity must be expected as a rule. Furthermore, well preserved mobility despite incongruity of the subtalar joint may cause more pain than complete loss of mobility.
3. Reduced height of the whole foot: it is important not to consider the reduction of height as only a matter of the calcaneus. Although phylogenetically the first to third metatarsal rays belong to the talus and the fourth and fifth to the calcaneum, in terms of function it is more useful to view all the bones of the foot with exception of the talus as a single unit, which is styled the "subtalar plate". A better understanding of displacements of the whole foot, not just the heel, can be derived from this concept.
4. Dorsal tilt of the talus: this is a consequence of the collapsed "angle of Böhler" (Böhler, 1977). Frequently the author observes a changed "mid-position" of the talus which has been forced to adapt to the altered condition of the subtalar plate (Fig. 2, 4).
5. Widening of the calcaneum: since the heel is usually slightly supinated at heel strike widening is generally towards the lateral side as a result of the progression of primary and secondary fracture lines under axial stress causing outward shift of the lateral wall (Fig. 2, 6).
6. Varus or valgus deformities: they also are due to the varus position of the heel upon impact, and in most cases a varus deflection does result. Other types of fractures or severely compounded fractures may cause such a

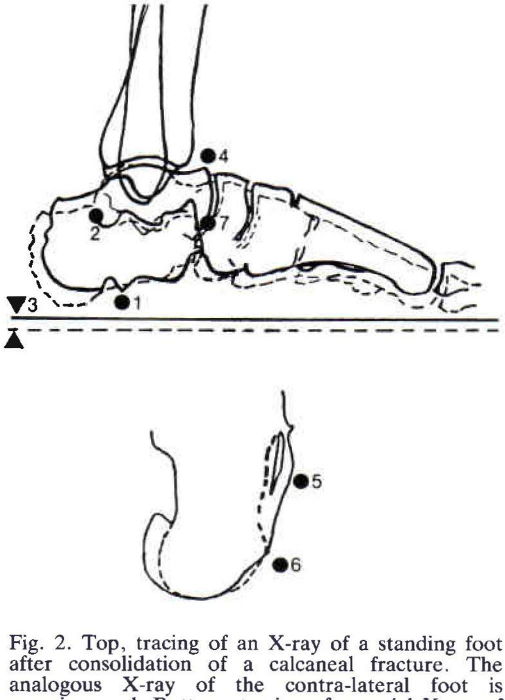


Fig. 2. Top, tracing of an X-ray of a standing foot after consolidation of a calcaneal fracture. The analogous X-ray of the contra-lateral foot is superimposed. Bottom, tracing of an axial X-ray of the hindfoot after consolidation of a calcaneal fracture. The numbers correspond with the possible permanent sequelae mentioned in the text.

massive lateral shift of bone that a valgus deformity results secondary to floor reaction forces (Fig. 2, 6).

7. Axial deviation in the midtarsal joint: this can have its greatest consequences in the talonavicular joint despite only slight displacement in the calcaneocuboid joint, or deviation may be confined mainly to the calcaneocuboid joint. The subtalar plate is weakened at this point. (Fig. 2, 7).

Functional changes subsequent to healed fractures

1. Impaired muscular balance on the movements of the ankle joint proper: positional changes of the muscular attachments have taken place. The tuber calcanei has moved considerably higher and the insertion of the Achilles tendon is closer to the belly of triceps surae. The tibialis anterior, a powerful dorsiflexor of the foot, fares similarly because of the increased dorsiflexed attitude of the talus compressed as it is into the deformed calcaneum. The effective lengthening of both tendons results in weakening of the contractile forces. In particular "push off" is affected, often severely so. The author's observations here are unequivocal: even after years the muscles fail to shorten enough to re-establish normal tension. This requires particular emphasis as the triceps surae is a tonic muscle that does tend to shorten, yet apparently it cannot shorten to a significant extent without having suffered injury itself. The effects on tibialis anterior are less serious. However these muscles should not be viewed separately. What is essential is the proprioceptive control of actions by antagonistic contraction. This is frequently impaired in sequelae of calcaneal fractures and in the author's observations represents by far the most important impairment.

2. Impaired muscular function on the "lower ankle joint": this is caused in part by incongruity and therefore by morphological factors and in part by dysfunction of the peroneal tendons. Widening of the calcaneum frequently causes, by impingement, marked distortion of the common sheath for peroneus longus and brevis. The pain upon tensing of these tendons leads to reflexive release. Thus the foot, which normally proceeds through pronation and resupination during unwinding of the step (Subotnik, 1975), cannot be actively stabilized.

Secondary to the new morphological features, mobility of the "lower ankle joint" may be markedly or even almost completely limited. Instability of the "lower ankle joint" during the stance phase causes pain: active muscular stabilization could control it. Hence dysfunction of the peroneal tendons is a double hindrance: adequate adaptation of the foot to the ground surface is prevented, and sufficient stabilization of the foot to prevent painful movements becomes impossible.

3. Weakening of the subtalar plate: in normal locomotion during toe-off the subtalar plate acts as the long arm of a lever as during resupination with tensing of the plantar aponeurosis, the individual bony links of the plate become interlocked, thus preventing bending forces. Following calcaneal fractures this can be impaired in two ways. On the one hand the resultant force in the subtalar joint upon interlocking of the subtalar plate causes pain by acting on incongruent joint surfaces. On the other hand the subtalar plate may not be able to interlock and in turn is subjected to bending forces at its weakest point viz., the midtarsal joint. One can imagine the severity of impairment should this joint also have incongruent surfaces secondary to the fracture.

Mechanical orthopaedic aids and their effects

In planning technical aids it is important to keep in mind the morphological as well as the functional changes. For instance elevation of the heel with cushioning of a calcaneal spur may prevent the creation of a sufficiently flat bedding for the foot because of insufficient contractility of the crural muscles. With some experience this can be anticipated but ultimately these unintentional reciprocal effects can never be fully avoided. This must be discussed with the patient, preferably before the first fitting, for he will not readily understand why he first gets his heel elevated and later lowered again. Consequently it is necessary to emphasize discussion with the patient as the cornerstone of technical orthopaedic management.

A further important aspect is that the desired effect on the foot cannot be achieved with a loose insole or with a modified shoe on its own but usually requires an insole as well as a modification of the shoe. A painful midtarsal joint generally requires a rigid support. This may be attained with a removable rigid insole or with a cork and leather insole secured to the shank of a shoe which has a rigid sole or resting directly on a full thickness cradle in a custom-built shoe.

Insole (support):

Its purpose is to distribute weight and to bridge points of weakness (Fig. 3). It is frequently employed after calcaneal fractures and is indispensable when varus deformity of the hindfoot is present and when the midtarsal joint is involved. Rather than correct a deformity the insole must be adapted to the existing shape of the foot when weightbearing. There is no exception to this rule even when a pronating correction is attempted. A support that is higher on the lateral aspect than on the medial will cause pain. However there is some justification for supinating corrections if relief of the peroneal tendons is desired as supination of the heel will give the tendons a bit more room; the support should be elevated about 2mm medially above the "mid-position" of the foot.

The first metatarsal ray is more yielding to pressure from the floor than the fifth. If mobility of the "lower ankle joint" is limited, even a plantigrade metatarsus and forefoot fails to distribute the load evenly between the first and fifth metatarsal heads, and the fifth metatarsal ray becomes overloaded. This should be taken into consideration while

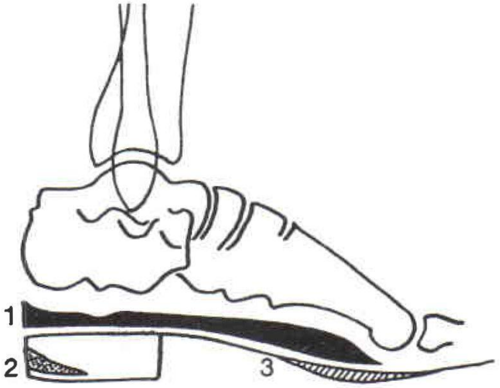


Fig. 3. Schematic representation of an orthopaedic aid for fracture of the calcaneum. 1. Insole with recess for calcaneal spur. 2. Buffer heel for shock absorption and to improve roll-over of the heel. 3. Rocker sole: in this case it is placed behind the first metatarsal head tapering off towards the forefoot.

manufacturing the insole by bedding the medial metatarsal-phalangeal joint a bit higher. Should a supination deformity of the hindfoot already be present it may even be advantageous to extend the support under the big toe, since an elevation of the first metatarsal head without simultaneous elevation of the big toe will result in a hallux flexus.

The insole is usually made from material of medium firmness or of a combination of materials. Especially rigid or hard material is recommended for pain in the midtarsal joint. Especially soft material is recommended for calcaneal spurs, but at the same time it must be taken into account that unintentional rocking on bouncy materials can cause pain in the "lower ankle joint".

Buffer heel

This works by shock absorption and by anterior displacement of the roll-over point of the heel (Figs. 3 and 4, top). With varus deformity present the buffer should be set at the middle or slightly medial to the middle of the heel. If it is applied at the usual roll-over point slightly lateral of the middle the varus deformity will be increased.

Heel raise

This affects the position of the talus and in certain cases will facilitate walking on uneven ground, especially uphill walking.

Lowering of the heel

This increases tension in the Achilles tendon and usually feels comfortable to the patient. Often patients appear in the clinic already wearing ready-made shoes with particularly low heels.

Rocker sole

By moving the roll-over point back a smaller range of motion is required in the true ankle joint and less load is transferred to the forefoot during toe-off (Figs. 3 and 4, centre and bottom). Rocker soles or roller bars additionally have a similar effect to lowering the heel. Thus if the position of the foot becomes too dorsiflexed the rocker must be accompanied by an elevation of the heel.

In addition to the height of the rocker at its crest and the position of the crest in relation to the foot it is possible to vary the position in relation to the direction of roll-over. Usually the crest is exactly at right angles to the

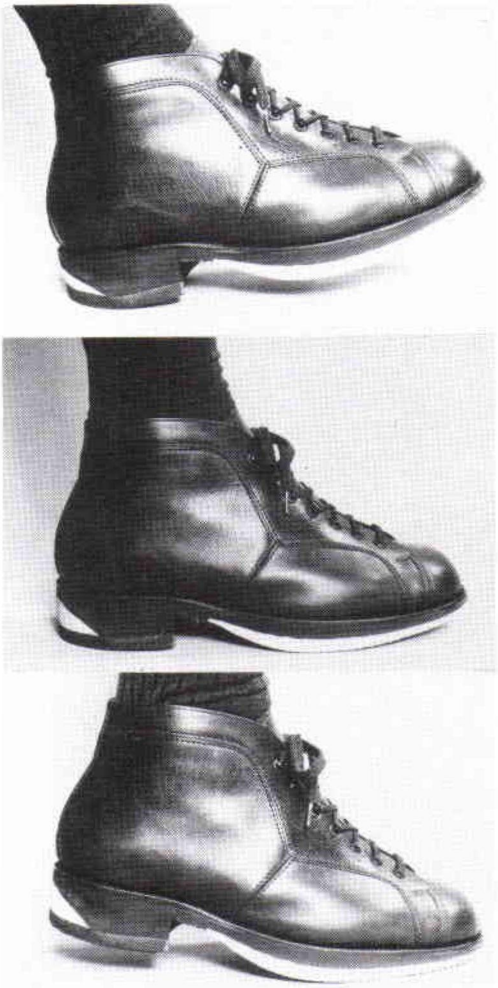


Fig. 4. Example of shoe modification (shown in white). Top, effect of buffer heel on heel-strike. Centre, the rocker sole lifts the forefoot during mid-stance. Bottom, because of the posteriorly positioned crest of the rocker, less force is exerted during toe-off.

direction of roll-over. However it is also possible to place the crest of the roller on a slant with the lateral side in front of and the medial side behind the metatarsal break. In most cases this arrangement is felt to be more comfortable. Furthermore it is an arrangement which is favoured in the manufacture of insoles. Thus both the insole and the rocker cause increased external rotation of the foot during the roll-over.

The bevel of the insole or the crest of the rocker can also be placed towards the other diagonal if internal rotation of the foot during roll-over is desired. However it must be pointed out that this form of rocker or insole is rarely felt to be comfortable and one must be prepared to quickly change the design if it fails to be successful.

High upper

A high upper is effective in diminishing instability in the "lower ankle joint", thus reducing pain, and enabling the patient to exert greater force. Patients are frequently advised to wear shoes with high uppers. Ready-made sports shoes featuring supplementary reinforcements are especially convenient and can replace expensive custom orthopaedic boots, however good setting of the foot in both frontal and sagittal planes must be achieved; should this not be the case, modifications of these shoes as described above are advised.

Inner shoe

An inner shoe more effectively immobilizes the "lower ankle joint" but unfortunately strongly inhibits movement at the ankle joint proper (Fig. 5). In the author's opinion short inner shoes with cambered stiffeners barely reaching the ankle are less effective than the ready-made shoes referred to above.

Custom orthopaedic shoe

This is used for complex sequelae and works basically in the same way as the previously described methods. An orthopaedic shoe can be ordered with e.g. a high stiffener around the heel, horizontal setting of the foot in the sagittal plane, even distribution of weight in the frontal plane, heel buffer and built in rocker. Indeed, it is necessary to require all of these modifications to warrant the manufacture of an orthopaedic shoe. However with bilateral calcaneal fractures it would be sensible to opt for orthopaedic shoes at an earlier stage.

Procedure for mechanical orthopaedic measures after calcaneal fractures

The initial prescription will include a buffer heel, lowering of the heel, rocker sole and fitting of an insole. Quite possibly these modifications can be applied to low shoes. Primarily the intention is to find out just how severe is the result of the calcaneal fracture. As previously mentioned it is not always possible to anticipate the precise prescription from the type of fracture. Two or three weeks after the

Fig. 5. Example of an inner shoe with full length sole and 20cm high upper because of very painful condition. A modified ready-made shoe may be worn over this.

initial fitting the patient returns to the clinic to discuss his complaints.

If severe problems persist shoes with high uppers are strongly recommended. In these, insoles are fitted to gain control of the roll-over as before.

If the symptoms are extremely severe or if immobilization with a high shoe is insufficient, an orthopaedic shoe or inner shoe remains as the last resort. At this point however a surgical procedure such as triple arthrodesis of the talocalcaneal, talonavicular and calcaneo-cuboid joints should be considered as an alternative. Caution must be exercised as results from this procedure after calcaneal fracture are variable. Hence one will generally continue with mechanical orthopaedic measures and during follow-up with more information available a decision can be made with more confidence.

Conclusion

In the treatment of calcaneal fractures mechanical orthopaedic measures not only help the patient but also the physician. The patient's concerns are clear: he needs more security and a stronger push-off and must be relieved of pain. The physician can discern significant functional or morphological problems by trial and error. For example he will be in a better position to decide whether a classic triple arthrodesis of the subtalar, talonavicular and calcaneocuboid joints is necessary or if a simpler talocalcanean arthrodesis would suffice. Discussion with the patient and his reaction to the modifications and aids provides information as to how the patient is responding to the injury and the degree of motivation. Thus technical orthopaedic measures are exceedingly valuable elements of comprehensive patient care.

REFERENCES

Böhler L. (1977). Die Technik der Knochenbruchbehandlung. 12. Auflage, II. Band, 1. und 2. Teil Wien; Mandrich.

Essex-Lopresti, P. (1952). The mechanism, reduction technique, and results in fractures of the os calcis. *Br. J. Surg.*, **39**, 395–419.

Judet, J., Judet, R. (1954). Traitement des fractures du calcanéum avec disjonction astragalo-calcanéenne, *Acta Orthop. Belg.*, **20(3)**, 284–291.

Mattel, R. (1983). Behandlung und Nachbehandlung von Calcaneusfrakturen, Inaugural-Dissertation zur Erlangung der Doktorwürde der Medizinischen Fakultät der Universität Zürich — Zürich: Universitat Zürich.

Rabl, C. R. H. (1975). Orthopädie des Fusses — Stuttgart: Ferdinand Enke Verlag.

Rowe, C. R., Sakellarides, H. T., Freeman, P. A., Sorbie, C. (1963). Fractures of the os calcis: a long-term follow-up study of 146 patients. *JAMA*, **184**, 920–923.

Subotnik, St. I. (1975). Pediatric Sports Medicine. Future Publishing Company.

Vidal, J., Orst, G., Lamolineric, G., Reboul, C. (1983). Traitement des fractures articulaires recentes du calcaneum. La place du traitement chirurgical et l'interet de l'osteosynthese par agrafe-tabouret. *Acta Orthop. Belg.*, **49(6)**, 711–724.

Prosthetics and Orthotics International, 1989, 13, 76–81

Prosthetic limb use in Australia 1981–1985 under the Free Limb Scheme

L. E. JONES

Department of Rehabilitation Medicine, Royal South Sidney Hospital, Zetland 2017, New South Wales

Abstract

A study has been made of data on 19,421 prosthetic limbs prescribed for 12,143 Australians under the Free Limb Scheme in the years 1981–1985. These prostheses consisted of 18,119 legs and 1,302 arms. The mean age of the lower limb prosthesis user was 52.8 and the upper limb prosthesis user 31.3 years. Males outnumbered females by 3 to 1 in the upper limb prosthesis users, and 2.8 to 1 with lower limb prosthesis users. Below-knee prostheses, patellar-tendon-bearing and thigh-lacing prostheses, made up 58.7% of all prostheses prescribed in the time span. Below-elbow prostheses were the commonest upper limb prostheses with children being the most frequent users. Comparisons with other studies of large number of prosthesis users show an older mean age in Australia and more below-knee prosthesis users than in American studies.

Introduction

The Free Limb Scheme was introduced into Australia in 1973. This scheme provides prosthetic limbs at no cost to Australian residents except for those people who are covered by insurance for industrial or motor-vehicle accidents. No major study has previously been carried out on the Australian population of prosthesis users. Large studies of amputees and their fitting with prostheses have been made in the USA by Glattly (1964), and Kay and Newman (1975). Glattly found a predominance of above-knee amputees among the lower limb prosthesis users. Twelve years later Kay found that the number of below-knee amputees presenting for prosthetic fitting had increased to 53.9%. The experience of Australian staff running prosthetic clinics is described by R. Jones (1977) who stated that in Australia, most amputees who have lost their lower limbs have suffered this amputation due to peripheral vascular disease. In another paper it was shown that below-knee amputation was more common than above-knee amputation. Katrak and Baggott (1980).

The current study looks at data in a five year period from 1981–1985 on individuals and the prostheses prescribed through the Free Limb Scheme administered by the Department of Veterans Affairs.

Method

To receive a prosthesis under the Free Limb Scheme, an amputee is seen by a medical specialist recognized by the Department of Veterans Affairs who gives the patient an official prescription for the prosthesis. Data from this prescription is processed and entered into a mainframe computer. Data for the years 1981–1985 was made available for analysis by the Veterans Affairs Department. Parameters which were available for sorting were the individual file number, date of birth, postcode, date of prescription, prescribing clinic, sex, limb and type of prosthesis. Causes of amputation were not coded in the data.

Results

In the years 1981–1985 there were 19,421 prostheses prescribed for 12,143 people: 18,119 lower limb and 1,302 upper limb prostheses. The age and sex distribution of these two groups is shown in Figures 1 and 2. The mean age of the lower limb prosthesis user was 52.77 years. (S.D.22): the mean age of upper limb prosthesis users was 31.3 years. (S.D.20.2). Males outnumbered females in each age group of prosthetic users except in the 80+ group

All correspondence to be addressed to Dr. L. Jones, Rehabilitation Centre, Joynton Avenue, Zetland 2017, New South Wales, Australia.

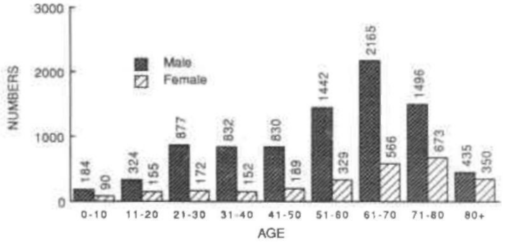


Fig. 1. Lower limb prosthesis users (1981–1985).

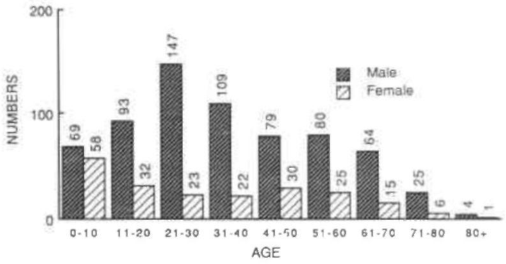


Fig. 2 Upper limb prosthesis users (1981–1985).

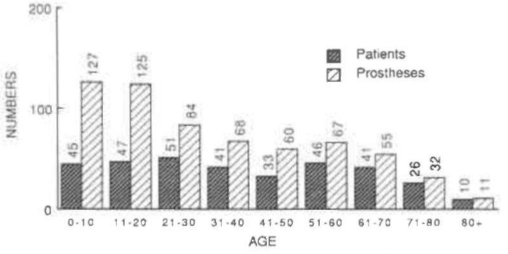


Fig. 3. Syme's prosthesis users (1981–1985).

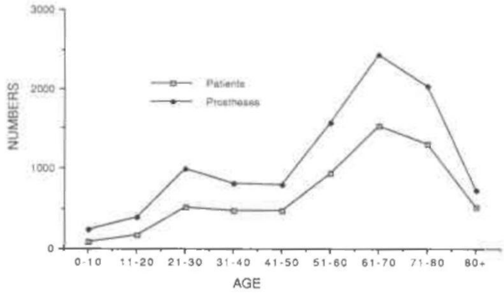


Fig. 4. PTB prosthesis users (1981–1985).

where females were almost as numerous as males (1.2 males to 1 female). The prevalence of prosthesis use in Australia in this time span was 80 per 100,000.

Lower limb prosthesis use

The Veterans Affairs coding for prosthesis type distinguishes between hip-and knee-disarticulation prostheses, the various above- and below-knee prostheses and Syme's prostheses. The category 'other', contains prostheses which are unusual, such as partial foot prostheses, special sockets or anomalous prostheses. Details of the foot used or of knee joints are not included. Figure 1 shows that in the years 1981 to 1985 there were 8,585 male and 2,676 female lower limb prosthesis users—a ratio of 3.2 males to 1 female. The distribution of people and the types of prostheses are shown in Table 1. In looking at the different types of prostheses it can be seen that Syme's prostheses are prescribed most frequently for actively growing children in the 0–10 year age group, (Fig. 3). The greatest number of patients receiving Syme's prostheses is in the 11–20 year age group. This difference is because the small child grows and needs a new prosthesis more frequently than an older person. The child with a Syme's may grow to become a PTB prosthesis user as the limb undergoes relative shortening. This is shown by the decline in numbers of Syme's users after the age group 11–20.

Table 1. Lower limb patients and prostheses

Prosthesis	n People	n Prostheses	Use in 5 years
Syme's	340	629	1.85
P.T.B.	5,982	9,961	1.67
Thigh lacer	861	1,448	1.68
Knee disartic	243	348	1.43
AK suction	1,078	1,605	1.49
AK non-suction	1,690	2,225	1.32
Hip disartic.	108	140	1.30
Other	822	1,522	1.85
Temporary	137	241	1.76
Total	11,261	18,119	1.61

The total of below-knee amputees can be calculated by combining those people using patellar-tendon-bearing prostheses and those using thigh lacing prostheses. This gives a total of 6,843 people or 60.8% of all lower extremity amputees. The number and age distribution of the users of patellar-tendon-bearing prostheses and the number of prostheses supplied are shown in Figure 4. They are used by all age groups. The mean age of the PTB prosthesis users was 58.1 years.

There were 861 people who received 1,448 thigh-lacing prostheses. Figure 5 shows the age distribution of the users and the prostheses supplied. The number of recipients steadily increased with age to reach a peak of 203 in the 61–70 age group. The 243 people who received

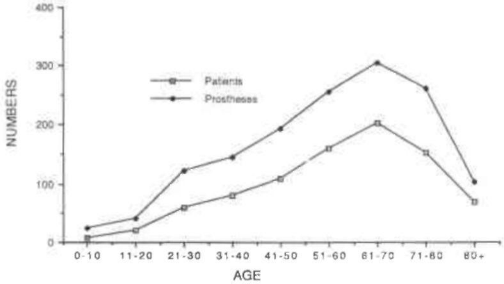


Fig. 5. Thigh lacing prosthesis users (1981–1985).

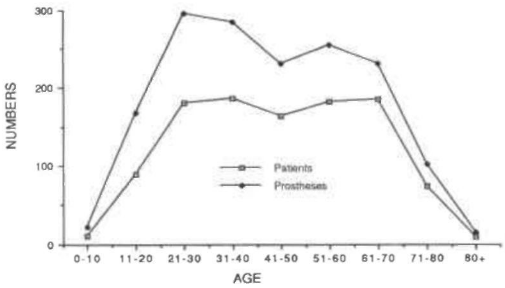


Fig. 7. AK suction socket prosthesis users (1981–1985).

348 knee-disarticulation prostheses were 2% of all lower extremity prosthesis users. With above-knee prostheses there are two variants of socket design; suction and non-suction sockets. The distribution by age and number of patients and prostheses are shown in Figures 6 and 7. The distribution of the AK suction socket prosthesis users is quite different from that of the non-suction socket. The mean age of suction socket users is 45 years, and non-suction socket users 59.2 years. Although the non-suction socket users use less prostheses in a five year period (1.32) than suction socket users (1.49), this difference is not statistically significant.

The coding for hip-disarticulation prostheses includes both Canadian, bucket, diagonal sockets and hemipelvectomy prostheses. The infrequent use of this prosthesis can be seen from Table 1.

The 241 temporary prostheses were used for initial gait training to obtain stump shrinkage prior to fitting with a definitive limb. They are mostly made by the physiotherapy staff and not usually shown in the Free Limb Scheme.

Unclassified lower limb prostheses include all those prostheses which are not easily amenable to classification e.g. partial feet prostheses, and the extension boot prostheses used in children. Because this group contains unspecified prostheses, no valid comments can be made regarding it.

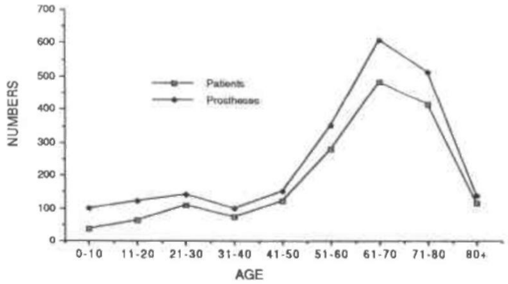


Fig. 6. AK non-suction socket prosthesis users (1981–1985).

Upper limb prosthesis use

During the five year period, 882 patients, 670 males and 212 females used 1,302 prostheses. These data give a ratio of 1.5 prostheses per patient and a male/female ratio of 3.2 to 1. In contrast to the lower extremity prosthesis user the person who uses an upper limb prosthesis is young. The mean age is 34.3 years, and the mode falls in the age group 21–30. The usage and numbers of individuals then falls steeply, until at the age of 80+ years only five people are identified who used six prostheses in a five year period.

The distribution of people and types of prostheses is shown in Table 2. Below-elbow prosthesis users are the largest single group, comprising 52.4% of all upper limb users. Figure 8 contains the details of below-elbow prosthetic prescriptions. Children aged 0–10 years were the most frequent recipients of this prosthesis (175 prescribed).

Above-elbow prostheses users are the next most frequent group. They formed 26.6% of upper extremity users, with a mean age of 34.7 years. Figure 9 shows that most above-elbow prosthesis users are children and adults under 30 years of age. There were 1.4 prostheses

Table 2. Upper limb prosthesis use

Prosthesis	n People	n Prostheses	n/person
Shoulder disartic.	48	58	1.2
Above-elbow	235	337	1.4
Elbow-disartic.	5	6	1.2
Below-elbow	462	713	1.5
Wrist-disartic.	108	145	1.3
Other	24	43	1.8
Total	882	1,302	1.5

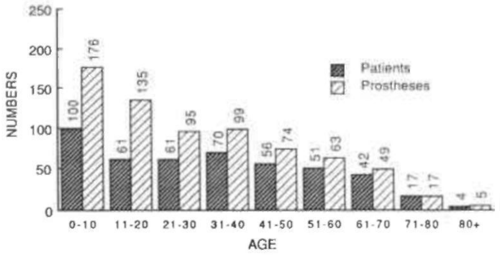


Fig. 8. Below-elbow prosthesis users (1981–1985).

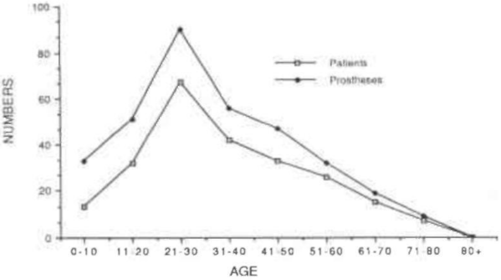


Fig. 9. Below-elbow prosthesis users (1981–1985).

prescribed per individual in the five year period. Shoulder-disarticulation prostheses formed 5.4% of upper limb prosthesis users. Wrist-disarticulation/partial hand prostheses were used by 108 people. Greatest usage occurred in the age groups 11–20 and 21–30. Only 43 limbs prescribed for 24 patients were not specifically classified in the five year period. The lack of specific limb classification appeared to occur when the limb classification system had been modified.

Discussion

No study has previously been published on the overall supply of artificial limbs in Australia. Studies of large numbers of prosthesis users in the USA have been made by Glattly (1962), Davies et al (1970), and Kay and Newman (1975). Outside of USA, major studies have been published from India by Narang and Jape (1982) and Hong Kong by Chan et al., (1984). The studies by Davies, Narang and Chan are prevalence studies which are similar to the present study. The American studies would be expected to have greater similarities to Australian studies as disease incidence (McGrath and Hill, 1982) and trauma occur in similar patterns, whereas both are different in Asia.

The mean ages of upper limb users, 33 years, and lower limb users 55.4 years, are older than the earlier reported American studies (Glattly, Davies and Kay). It reflects ageing of the Australian population with an increased incidence of vascular disease. Because this is a prevalence study, the traumatic amputees would be expected to lower the mean age of the study as they live a normal life span and continue to use lower limb prostheses. However the largest cohort of traumatic amputees, the World War I and World War II veterans, are now at least sixty years old and so increase the mean age. Young traumatic amputees whose limb replacements are paid for by work or motor vehicle insurance are not part of this study, and there is no central data bank for this group of people.

The sex distribution of upper and lower limb prosthesis users are the same, being 3.2 males to 1 female. The differing causes of amputation, trauma in young males and malignancy in both sexes of the young increase the number of male prosthesis users, both in lower and in upper limb.

Of the 19,421 prostheses supplied in the five year period, 93.3% were lower limb prostheses. Below-knee prostheses, either patellar-tendon-bearing or thigh-lacing prostheses comprised 58.7% of all prostheses prescribed. Above-knee prostheses were 19.7% of all prostheses prescribed.

The ratio of below-knee to above-knee users was 2.5 to 1. This is because vascular amputations are now more likely to be below-knee amputations in all states of Australia, except in Western Australia. Above-knee amputees who are elderly may not have the fitness to learn to use a prosthesis. Those who have learned to use a prosthesis may not necessarily continue to use it because it is easier to use crutches or a wheelchair (Katrak and Baggott, 1980). All these factors decrease the prevalence of above-knee prosthetic users.

Syme's prostheses are commonest in childhood where they are used for the congenitally limb deficient child. The Syme amputation is performed as a treatment method for certain congenital abnormalities. As the child grows the amputated limb grows less. It was noted from examining the data on individual children that frequently the child who was initially prescribed a Syme's prosthesis, later received a patellar-tendon-bearing prosthesis. This may explain some of the decline in prescription numbers and individuals after the age of twenty. In adults, the Syme amputation is used mostly after trauma (Herring, 1986). The decline in the occurrence of this amputation with age shown in Figure 9 concurs with the age decline in traumatic amputations.

Patellar-tendon-bearing prostheses are the preferred prostheses for 87.4% of below-knee amputees. Thigh-lacing prostheses are used by only 12.6% of below-knee users. The decline in numbers of PTB users in the young adult age group may have two explanations. The young adult who has had a below-knee amputation from malignancy may well die from that cause and so reduce the prevalence of people in this age group. The person who has lost a limb through trauma at work or motor vehicle accident is covered by insurance and so the prosthetic prescription often, but not always, does not show up in the Free Limb Scheme. In Australia the average life of a prosthesis is three years. Davies et al (1970) in their study found an average prosthesis lasted seven years.

Knee-disarticulation prostheses are an infrequent prosthetic prescription in Australia. Knee disarticulations are performed either to correct a congenital anomaly or for trauma. The peak occurrence at 31–40 demonstrates the non-vascular cause of this amputation.

With above-knee-prostheses, suction sockets are used most commonly by young fit people. This is confirmed by the finding that people in the 21–30 year age bracket are the commonest users. It is surprising that suction limbs continued to be prescribed and used in moderate numbers until the age of 80. This occasional use of a suction limb in an old person reflects its prescription initially when they were very much younger. The life of a suction limb is shown as three to four years. The non-suction above-knee prosthesis is prescribed relatively infrequently until after the age of 50.

Hip disarticulation prostheses are very energy costly to use (Fischer and Gullickson, 1978). This is one factor leading to these prostheses having the lowest usage for lower limb prostheses.

Upper limb prostheses have been shown to be infrequently used in Australia. This may relate to either the infrequency of upper limb amputation or to the dissatisfaction experienced with upper limb prostheses. It has been shown that below-elbow prosthesis use is commonest in children. This is because below-elbow limb deficiency is the commonest congenital upper limb defect in children (Krebs and Fishman, 1984). The number of individuals using prostheses declines steadily thereafter, except for a very small rise in the age group 31–40. Above-elbow prostheses and users are the second largest group of upper limb users. This prosthesis is used most by people in the age group 21–30—the peak period for trauma. There are also a few congenital limb deficient children. Shoulder disarticulation prostheses are so hot to wear and so hard to use, that they are very infrequently prescribed. If prescribed, they are often used only once and then discarded. This can be seen from the fact that in five years, 48 people received 58 prostheses. Wrist disarticulation/partial-hand prosthesis users form 12% of upper limb users. People who have suffered this loss will frequently receive a prosthesis initially, try it and discard it; not using a second one. Some however, will find a prosthesis valuable and continue to use it.

Conclusion

An analysis has been made of data on 19,421 prostheses prescribed for 12,143 Australians under the Free Limb Scheme. The mean age of prosthesis users is older than is shown from studies of large numbers of prosthesis users in the U.S.A., Hong Kong or India. A predominance of males of 3.2 to 1 in both lower and upper limb prosthesis users has been shown. The prostheses prescribed were for the lower limb in 93.3% of cases. There are more below-knee users in this study than in other studies of large numbers of prosthesis users. Patellar-tendon-bearing prostheses were the commonest below-knee prosthesis. Young above-knee adults use suction prostheses most frequently. Children were the predominant users of Syme's and below-elbow prostheses. In the five year period the patients in the study were on average prescribed 1.5 lower limb prostheses, and 1.6 upper limb prostheses. The Free Limb Scheme provides an important service to Australian citizens.

REFERENCES

CHAN K. M., CHEUNG D., SHER A., LEUNG P. C., FU K. T., LEE J. (1984). A 24 year survey of amputees in Hong Kong. *Prosthet. Orthot. Int.* **8,** 155–158.

DAVIES E. J., FRIZ B. R. Clippinger F. W. (1970). Amputees and their prostheses. *Art. Limbs.* **14** (2) 19–48.

FISHER S., GULLICKSON G. (1978). Energy cost of ambulation in health and disability: a literature review. *Arch Phys. Med. Rehab.* **59,** 124–133.

GLATTLY H. W. (1964). A statistical study of 12,000 new amputees. *South. Med. J.* **57,** 1373–1378.

HERRING J. A., BARNHILL B., GAFFNEY C. (1986). Syme amputation *J. Bone Joint Surg.* **68A,** 573–578.

HIERTON T., JAMES U. (1973). Lower extremity amputation in Uppsala County 1947–1969: incidence and prosthetic rehabilitation. *Acta Orthop. Scand.* **44,** 573–582.

JONES R. F. (1977). Amputee rehabilitation: basic principles in prosthetic assessment and fitting—Part 1. *Med J. Aust.* **2,** 290–293.

KATRACK P. H., BAGGOTT J. B. (1980). Rehabilitation of elderly lower extremity amputees. *Med. J. Aust.* **1,** 651–653.

KAY H. W., NEWMAN J. D. (1975). Relative incidence of new amputations: Statistical comparisons of 6,000 new amputees. *Orthot. Prosthet.* **29:(2)** 3–16.

KREBS D. E., FISHMAN S. (1984). Characteristics of the child amputee population. *J. Paediatr. Orthop.* **4,** 89–95.

MCGRATH M. A., HILL, D. A. (1981). The epidemiology of lower limb ischaemia in a New South Wales rural community. *Aust. N. Z., J. Surg.* **51,** 157–160.

NARANG I. C., JAPE V. S. (1982). Retrospective study of 14,400 civilian disabled (new) treated over 25 years at an artificial limb centre. *Prosthet. Orthot. Int.* **6,** 10–16.

Prosthetics and Orthotics International, 1989, 13, 82–85

Tumour related lower limb amputation: a 23 year experience

A. S. JAIN and C.P.U. STEWART

Abstract
This paper records the Dundee experience over 23 years and reports on 42 cases of tumour related lower limb amputations. There were 27 males and 15 females with 37 malignant and 5 benign tumours. Four of the 'benign' tumours proved to be osteoclastoma which were locally malignant. Prosthetic rehabilitation was achieved in all but one case. All patients fitted were able to use their prostheses.

Introduction

Amputations performed in the course of treatment for neoplasm represent only 1-2% of lower limb amputation in contrast to those (85%) performed as a result of peripheral vascular disease. Ebskov (1988) demonstrates the prevalence in Denmark from 1978 to 1983 inclusive of both causal conditions, the percentage due to tumour varying from 1.5 to 2.2%. The experience in Dundee reflects an almost exactly similar picture over the period from 1965-1988 (Murdoch et al., 1988). The population at risk is some 500,000, all amputations are performed by one of two teams of surgeons and all patients referred for prothetic rehabilitation are admitted to Dundee Limb Fitting Centre, where a computerized data base has been established.

The management of malignant tumours e.g., osteosarcoma has changed considerably since Jaffe's paper (1972) on chemotherapy and the increasing number of cases treated by wide excision and internal prosthetic replacement (Scales, 1988). Cases are still treated by radiotherapy but markedly fewer. When amputation is part of the management virtually all authorities believe prosthetic fitting should proceed whatever the presumed prognosis (Aitken, 1987). Inevitably only those patients who receive amputation as part of their management were admitted to the Limb Fitting Centre. A few, three, suffering from osteosarcoma and presenting in the past ten years were treated by wide excision, chemotherapy and internal prostheses. Of these, one subsequently required amputation and is included in this study.

This paper records the experience in Dundee over the past 23 full years and reports on 42 patients with lower limb tumour related amputations. The numbers are small but the experience is important as the population is reasonably static and the surgery and prosthetic rehabilitation concentrated on one clinic team. It is believed that these clinical problems are representative of similar thinly populated areas with no great city conurbations.

All correspondence to be addressed to Mr A. S. Jain, Consultant Orthopaedic Surgeon, Dundee Limb Fitting Centre, 133 Queen Street, Broughty Ferry, Dundee DD5 1AG, Scotland.

Clinical material

There were 27 male patients and 15 female in the 42 cases who represented an admission rate of 1.8 per year. The levels of amputation were as follows:

1 Hindquarter
11 Hip disarticulation (26.4%)
22 Above-knee amputation (52.4%)
1 Knee disarticulation
6 Below-knee amputation (14.2%)
1 Syme's amputation.

The distribution of the tumours affecting these patients and their outcome is displayed in Figure 1.

There proved to be 15 different types of pathology. The tumours may be classified in relation to the tissue involved, thus:

Bone	50%
Soft tissue	24%
Skin	21%
Secondary deposit	5%

Aetiology:	No. of cases:	% of total:	Av. age:	Sex: Male	Female	Level: Sy	BK	TK	AK	TH	HQ	RT/CT* Yes	No	Survival: Alive	Dead	Fitted: Yes	No
Osteosarcoma	13	30.9%	24.8	9	4	—	1	—	7	5	—	12	1	7	6	13	—
Melanosarcoma	5	11.9%	70.5	1	4	—	3	—	2	—	—	2	3	2	3	4	1
Sq. cell carcin.	5	11.9%	77.7	3	2	—	1	1	2	1	—	1	4	—	5	5	—
Chondrosarcoma	2	4.7%	65.0	1	1	—	—	—	1	1	—	—	2	1	1	2	
Rhabdomyosarc.	1	2.4%	71.1	—	1	—	—	—	—	1	—	—	1	—	1	1	—
2° Nephroma	1	2.4%	63.4	1	—	—	—	—	—	1	—	—	1	—	1	1	—
Fibrosarcoma	4	9.5%	47.4	4	—	—	—	—	3	1	—	1	3	1	3	4	—
Osteochondro.	1	2.4%	52.4	1	—	—	—	—	1	—	—	—	1	1	—	1	—
Osteoclastoma	4	9.5%	39.5	3	1	—	—	—	4	—	—	—	4	4	—	4	—
Neurofibrosar.	1	.2.4%	22.5	1	—	—	—	—	1	—	—	1	—	1	—	1	—
Liomyosarcoma	1	2.4%	66.8	1	—	—	—	—	—	—	1	1	—	—	1	1	—
2° Bladder	1	2.4%	88.1	—	1	1	—	—	—	—	—	1	—	—	1	1	—
Synovial ca.	1	2.4%	63.1	1	—	—	—	—	—	1	—	—	1	1	—	1	—
Lymphosarcoma	1	2.4%	80.0	1	—	—	—	—	1	—	—	—	1	1	—	1	—
Con. tis. sarc.	1	2.4%	58.0	—	1	—	1	—	—	—	—	1	—	1	—	1	—
	42	100%	50.1	27	15	1	6	1	22	11	1	20	22	20	22	41	1

*RT/CT = Radiotherapy/Chemotherapy

Sy = Syme's
BK = Below-knee
TK = Through hip

AK = Above-knee
TH = Through hip
HQ = Hindquarter

Fig. 1. Tumour distribution and outcome.

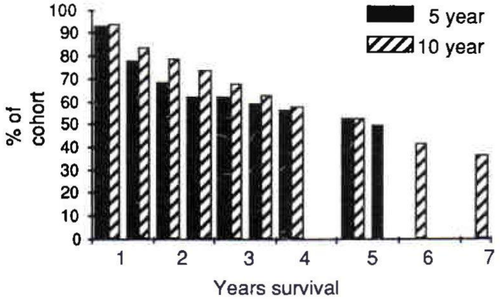


Fig. 2. Survival curves for malignant tumour related lower limb amputees.

Of the 42 cases, 37 (88%) proved to be malignant and five benign.

The five year survival rate for the 37 patients with malignant tumours was 50% (Fig. 2). The ages of the patients with osteosarcoma ranged from 11 years to 63 years 1 month. In two of the 13 cases of osteosarcoma the tumour followed longstanding osteomyelitis, one from a gun shot wound sustained in the 1914-18 war and the other originating in a longstanding varicose ulcer. If these two, aged 66 and 53 respectively, are excluded the average age for the remainder is 15 years 6 months. The levels of amputation employed for this group of patients were five at the hip, seven above the knee and one below the knee.

All but one of the osteosarcoma patients had radiotherapy, chemotherapy or both with survivals ranging from 16 years 1 month to 1 year 1 month. The single patient not having any adjuvant treatment was 66 years old with a long history of chronic osteomyelitis; a below-knee amputation was performed and prosthetic fitting completed but the patient only survived some seven months.

All five of the benign tumour amputees were alive and well at the end of the study (range from 2 years 9 months to 19 years 10 months post-amputation). However, four of the "benign" tumours proved to be osteoclastoma — tumours which are locally destructive with each individual example lying in a unique location in a spectrum of malignancy. One patient suffering from an osteoclastoma was treated by local extirpation and the residual space filled with bone tubes on no less than three occasions. It may be that the local surgery was inadequate each time, or conceivably the nature of the tumour itself changed and became more aggressive. In any case amputation became necessary thirteen years after the first biopsy and the patient is still alive twenty-three years later. Osteoclastoma requires to be treated with great respect and certainly justifies its appearance in this study.

Prosthetic rehabilitation was achieved in all but one case: that patient was an 85 year old lady with a melanocarcinoma treated by an above-knee amputation and in whom prosthetic fitting was deemed inappropriate because of severe mental confusion. At below-knee level the patients were fitted with patellar-tendon-bearing prostheses of one variety or another. At above-knee level conventional prostheses were used until the advent of modular limbs in the 1970's. All patients remained under review until they died or to date and all contrived to use their prostheses.

Discussion

In keeping with other studies a wide range of tumour types was found. In this study 15 different pathologies were identified. Troup and Bickel (1960) described 21 different neoplastic types. Taft (1966) found 26 diagnoses in 350 cases and Pack (1964) described 18. The authors experience concerns a smaller group of patients but remains roughly in keeping with a distribution, already related, divided between bone, soft tissues and skin. In two cases secondary deposits respectively from kidney and bladder were responsible for amputation.

With the numbers available it is not possible to comment on the significance or otherwise of sex, level of amputation or, more importantly, adjuvant therapy such as chemotherapy.

In Dundee Limb Fitting Centre and associated hospitals there is an experience in amputation surgery which has been very carefully documented. The Centre's management of the dysvascular patient has also been carefully recorded in the literature. It is believed that this testifies to a carefully planned and skilfully executed management of the amputee, which concerns primarily 87% of the vascular amputees.

The experience recorded here was gained against the same disciplined background with concentration of the operative experience and a trained and integrated clinic team performance. But the small numbers, the variety of pathologies and sometimes the demanding surgical operations required point up the real problem for patient, surgeon and clinic team. There is clearly a case to be made to concentrate the experience in one centre comprehensively housed, equipped, staffed and funded. On this basis Scotland with a population of five and a half million might possibly justify such a centre. The reality of course, is that big city and university rivalries, the social problems for patients and families alike and the difficulties of persuading funding authorities to collaborate all militate against such an ideal solution.

In Dundee the first consideration was to develop a loosely formed "tumour" team consisting of the surgeon, the pathologist, a radiotherapist, a radiologist and an oncologist with expertise in chemotherapy. The deliberations of this team largely determine the management for any given patient. Fortunately in Scotland, the Bone Tumour Registry established in Glasgow soon after the Second World War provides a concentration of expertise in identifying tumour types and their likely behaviour. Moreover the free association of pathologists throughout the United Kingdom also contributes in identification in very unusual or difficult cases.

The "local" team having discussed the situation and examined all the evidence including radiographs, angiograms and a range of blood tests will then determine the course of action. The pathologist is always available to offer advice regarding the surgical procedure of any individual biopsy. The surgeon should be the one identified with this work and able to call on an, albeit limited, experience. Excepting the hindquarter procedure where the proximity of the tumour may enforce modifications on the surgical procedure, the amputation will normally be conducted at a site where all the tissues are normal and entitle the surgeon to envisage an "ideal" stump and no problems with wound healing. It is believed strongly that prosthetic fitting should proceed as speedily as the patient's condition permits.

The Dundee experience has been small, 42 cases, but the authors think that the philosophical and organizational approach is justified and reflected in the results.

Acknowledgements

We gratefully acknowledge the typing carried out by Mrs M. Copland and the graphic work carried out by Mr. S. Scott.

REFERENCES

Aitken, G. T. (1987). Prosthetic fitting following amputation for bone tumour. A preliminary report. *ICIB* **3, (5),** 1-2, 10.

Ebskov, B. (1988). Trends in lower extremity amputation (Denmark, 1978-1983). In: Amputation surgery and lower limb prosthetics, Eds. G. Murdoch, R. Donovan Oxford: Blackwell Scientific Publications, 3-8.

Jaffe, N. (1972). Recent advances in the chemotherapy of metastic osteogenic sarcoma. *Cancer,* **30,** 1627-1631.

Murdoch, G., Condie, D. N., Gardner, D., Ramsay, E., Smith, A., Stewart, C. P. U., Swanson, A. J. G. Troup, I. M. (1988). The Dundee Experience. In: Amputation surgery and lower limb prosthetics, Eds. G. Murdoch, R. Donovan, Oxford: Blackwell Scientific Publications, 440-457.

Pack, G. T. (1956). Major exarticulations for malignant neoplasms of the extremities; interscapulothoracic amputation, hip-joint disarticulation and interilio-abdominal input; a report of results in 228 cases. *J. Bone Joint Surg.* **38A,** 249-262.

Scales, J. T. (1988). Design of prosthetic implants (in relation to the hip) In: Amputation surgery and lower limb prosthetics, Eds. G. Murdoch, R. Donovan, Oxford: Blackwell Scientific Publications, 222-235.

Taft, C. B. (1966). Survival and prosthetic fitting of children amputated for malignancy. *ICIB,* **5, (5),** 9-28.

Troup, J. B., Bickel, W. H. (1960). Malignant disease of the extremities treated by exarticulation: Analysis of two hundred and sixty-four consecutive cases with survival rates. *J. Bone Joint Surg.,* **42A,** 1041-1050.

Prosthetics and Orthotics International, 1989, 13, 86–89

Temporary prosthetic fitting for below-knee amputation

H. OZYALCIN and E. SESLI

Department of Orthopaedic Surgery and Traumatology, Ege University Medical Faculty, Bornova, Izmir, Turkey

Abstract

The problems encountered in fitting and using the permanent below-knee prosthesis in developing countries are the high price of the prosthesis, inadequate fitting and lack of proper rehabilitation. In Turkey, the preferred treatment of the stump post-operatively is by the soft dressing method with bandaging for maturation and shrinkage. Generally, the application of the permanent prosthesis is in the sixth month post-operatively.

Since in patellar-tendon-bearing (PTB) sockets, stumps have to withstand high pressures in limited areas, the PTB socket can only tolerate small volume changes in the stump. For this reason bandaging over a long period may be insufficient for adequate stump shrinkage and amputees will need another below-knee prosthesis, which most of them cannot afford after only a few weeks use.

In the authors' clinic, 19 amputees were fitted with simple, effective and inexpensive temporary prostheses following either conventional immediate post-operative dressing or the soft dressing method. The temporary prosthesis is worn for two months. It produces fast stump shrinkage, helps maturation and permits ambulatory discharge even in bilateral amputees. For economical reasons, only eight of nineteen patients were fitted with permanent prostheses, all wearing them successfully without the necessity of further rehabilitation.

Introduction

The major goals of lower extremity amputation are to obtain a well-healed stump and permit mobilization of the patient with a properly fitted permanent prosthesis. Immediate post-operative rigid dressing and pylon fitting provide good primary wound healing, facilitate stump shrinkage and prevent formation of oedema and contractures of the knee, while allowing early mobilization of the patient (Sarmiento et al., 1970; Vitali et al., 1978).

The concept of rigid dressing was first advocated by Muirhed Little during the First World War; it was re-introduced by Berlemont in 1961 and greatly stimulated by Weiss in 1963 (Lien et al., 1973; Kerstein, 1974; Kerstein and Dugdale, 1975; Vitali et al., 1978).

However, conventional immediate rigid dressing also has some disadvantages (Wu et al., 1979). It requires experienced technicians and as the oedema subsides the dressing has to be changed many times before the application of the permanent prosthesis. Since it immobilizes the knee, it also prevents the rehabilitation of the knee joint. It does not permit observation of the stump and wound.

The other method of rehabilitation with elastic stump bandaging may postpone the fitting of the permanent prosthesis by at least six months (Laforest and Regon, 1973; Baker et al., 1977; Manella, 1981).

The wearing of a temporary prosthesis is beneficial in obtaining proper stump maturation (Laforest and Regon, 1973; Kerstein and Dugdale, 1975). It facilitates the management of the permanent prosthesis and avoids the alternative of the fitting of a second permanent prosthesis. Consequently it is suggested that in developing countries, simple, inexpensive temporary prostheses are essential.

The authors' apply removable rigid dressing technique with a simple dynamic alignment unit and a SACH foot for two months following wound healing which takes place either with immediate post-operative conventional rigid dressing or soft dressing (Sarmiento et al., 1970; Lien et al., 1973).

All correspondence to be addressed to Dr. H. Ozyalcin, Department of Orthopaedic Surgery and Traumatology, Ege University Medical Faculty, Bornova, Izmir, Turkey.

Rigid dressing prevents the formation of oedema and extremity contractures efficiently. It facilitates stump maturation, maintenance of postural reflex, and permits more simplified rehabilitation with good psychological effects (Kerstein and Dugdale 1974; Wu et al., 1979).

Materials and method

In the Department of Orthopaedic Surgery and Traumatology in Ege University, between 1984-1988, 19 patients with below-knee amputation have been managed with the procedure of removable rigid dressing and temporary prosthesis. The etiology for amputations was vascular in seven patients and trauma in 12 patients. Average age of the patients was 44 (max. 65, min. 20). Sixteen were male and three were female.

If the patients were suitable, a rigid dressing and pylon with dynamic alignment unit were applied immediately after the operation. In nine patients, two weeks following surgery the stitches were removed and the temporary prosthesis applied. For the rest of the patients, temporary prostheses were applied following soft dressing. A plaster PTB socket was applied with dynamic unit and SACH foot. For socket preparation, a stockinette was applied to the healed stump or on a sterile dressing, if the wound was not completely healed. Three felt pads were applied to protect the sensitive pressure areas (Fig. 1). A normal plaster cast was applied over the stump. The cast trim line was supra-patellar level anteriorly and patellar-tendon level posteriorly to allow 90 degrees of comfortable knee flexion (Wu et al., 1979). Before the cast dried, pressure was applied over the patellar-tendon with both thumbs and the popliteal area with fingers of both hands. The upper part of the simple dynamic alignment unit was fixed to the socket with a plaster cast. To provide easy adaptation of the stump to the socket in the initial days, a hole 2 cm diameter was made in the bottom of the socket. If the stump was comfortable, the socket was removed for fixing of the pylon and application of the elastic bandaging. The straps were attached to the socket with plaster and incorporated to the waist belt through a supracondylar band (Fig. 2).

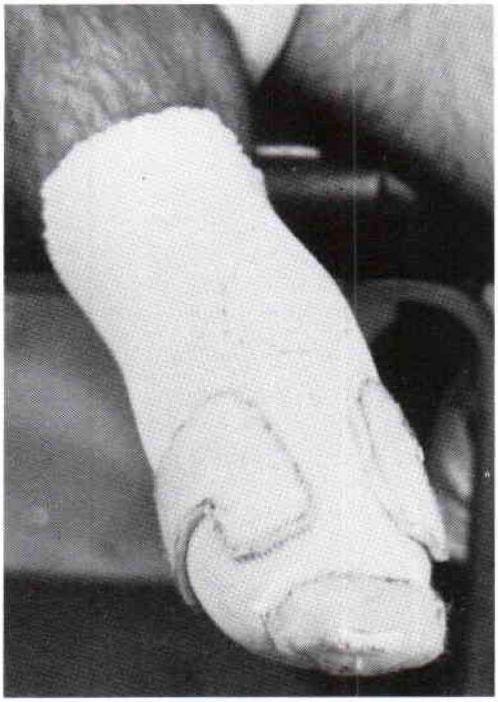


Fig. 1. Felt pads placed on the pressure sensitive areas.

On the first day the patient was permitted to exercise in the parallel bars for a short time only. On the second day if the patient tolerated the stresses and the stump condition was good, the weightbearing period was increased depending on the comfort of the patient. If the patient complained of pain in the stump end or piston action of the stump, it was checked by inspection through the end-hole. The temporary prosthesis was removed every evening and as the stump shrunk more stockinettes were added. If the stump had shrunk very rapidly in a few days the cast socket was changed.

Results

During the four years of the study, 19 patients with 20 stumps were fitted with a temporary cast socket prosthesis. Post-operatively nine patients managed conventional immediate rigid dressing with dynamic alignment unit, pylon and SACH foot prior to the temporary prosthesis. Ten patients were treated with soft dressing and temporary prosthesis as soon as wound healing had been controlled.

Eight patients were finally fitted with permanent prostheses. One patient was fitted with a permanent prosthesis after wearing the temporary prosthesis for one month, but developed severe stump shrinkage for which

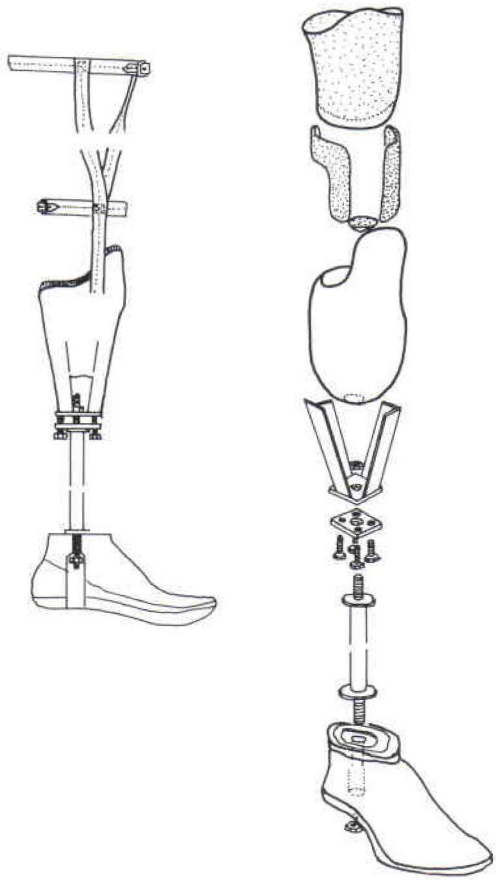


Fig. 2. Temporary PTB prosthesis with SACH foot, simple dynamic alignment unit and cast socket.

even the addition of six socks was insufficient thus necessitating the provision of a new permanent prosthesis. Two patients were still using their temporary prosthesis six months after the operation.

Three patients removed their prostheses for the weekend and applied elastic bandage but were not able to re-apply their prostheses, because of oedema of the stump. New plaster sockets were then made for these patients and one week later, oedema had subsided and they were able to put on their old sockets again. The reason may be either misuse of bandages or the ineffectiveness of bandage compared to "socket pumping" action in the rigid dressing (Manella, 1981).

The average period of time for rehabilitation from amputation to final ambulatory discharge using the temporary prosthesis was 62 days (max. 133, min. 21). All the wounds were already healed at the time of discharge. The permanent prosthesis was ordered after the temporary prosthesis had been worn for two months. By this time, most of the patients were wearing eight or nine stump socks.

Discussion

The primary purpose of amputation is the treatment of the disease of the patient. Especially for the below-knee level it is hoped that a high degree of restoration of function will be achieved particularly with the use of the PTB prosthesis (Kerstein and Dugdale, 1974).

The rate of success decreased rapidly with inadequate control of shrinkage of the stump and poor rehabilitation with an improperly fitted permanent prosthesis (Rajeswaramma et al., 1973). To estimate the benefits which might be attained using a temporary prosthesis 68 patients with below-knee amputations performed between 1977-1981 in the authors' clinic were reviewed retrospectively and it was found that only one patient was able to walk with a prosthesis. The major problem was the provision of a well-fitted prosthesis, mainly because of socket problems and the expense of components.

Ready-made temporary prostheses can also be used in the initial stages of rehabilitation (Kerstein, Dugdale, 1974), but these are also quite expensive and may produce stump problems because they do not have custom-made sockets.

These points are very important for the developing countries since most people can afford only one prosthesis. In the method described here a "removable cast socket temporary prosthesis" is used after conventional post-operative rigid dressing or soft dressing and prior to the provision of a permanent prosthesis. All the components except the SACH foot are hand made with ordinary tools and machinery. The dynamic alignment unit used provides full rotation, thirty degrees of angulation and 1½ cm of length adjustment. The same SACH foot is used in the permanent prosthesis. All patients are mobilized with the temporary prosthesis including one bilateral amputee. Standing position is stable as for other well-fitted below-knee amputees (Vittas, 1986) (Fig. 3).

If the stump is long (3 cases) the end-hole helps to place the stump into the socket and

Fig. 3. Weightbearing training.

also gives the opportunity to examine the stump end during weightbearing.

Reduction of oedema occurs on the first or second days of wearing the prosthesis. Stump shrinkage was so rapid in three patients that new plaster sockets had to be made.

At the beginning all patients had the fear of breakdown of the wound or sutures, but weightbearing was not a problem for most patients. Only in three geriatric patients could the wound not stand weightbearing. In one of these three patients who had Buerger's diesease an above-knee amputation was performed. The other two patients were diabetic and their unhealed wounds presented a minor problem and healed after the wearing of the prosthesis was delayed for one week. On stump shrinkage, a sufficient number of socks was added until eight or ten ply. Stump socks are not readily available and are expensive (Wu et al., 1979), so end sutured stockinettes have been used. A nylon sock is preferred for the last ply for ease of fitting.

Psychologically all patients accepted the temporary prosthesis. No serious objection was encountered against the prosthesis. Balance patterns were satisfactory in all patients in accordance with their age.

REFERENCES

Baker, W. H., Barnes, R. W., Shurr, D. G. (1977). The healing of below-knee amputations: a comparison of soft and plaster dressings. *Am. J. Surg.*, **133**, 716–718.

Berlemont, M. (1961). Notre expérience de l'appareillage précoce des amputés des membres inférieurs aux éstablisments. Helio-Marins de Berck. *Ann. Méd. Phys.*, **4**, 213.

Kerstein, M. D. (1974). A rigid dressing with a pneumatic prosthesis for below-knee amputees. *Am. Surg.*, **40**, 373–374.

Kerstein, M. D., Dugdale, F. (1974). Ambulation with a temporary prosthesis two weeks after below-knee amputation. *Am. Surg.*, **40**, 221–223.

Kerstein, M. D., Dugdale, F. (1975). Early ambulation after below-knee amputation. *Conn. Med.*, **39**, 360–362.

Laforest, N. T., Reagon, L. W. (1973). The physical therapy program after an immediate semirigid dressing and temporary below-knee prosthesis, *Phys. Ther.*, **53**, 497–501.

Lien, I. N., Wu, C. F., Hand, C. Z. (1973). Immediate postoperative pylon fitting for lower extremity amputation. *J. Formosan Med. Assoc.*, **72**, 224–233.

Manella, K. J. (1981). Comparing the effectiveness of elastic bandages and shrinker socks for lower extremity amputees. *Phys. Ther.*, **61**, 234–237.

Rajeswaramma, V., Green, R. F., Silber, M., Hinterbuchner, C. (1973). Pressure-sensitive stump sock. *Arch. Phys. Med. Rehabil.*, **54**, 142–150.

Sarmiento, A., May, B., Sinclair, W. F., McCollough, N. C., Williams, E. M. (1970). Lower extremity amputation. The impact of immediate postsurgical prosthetic fitting. *Clin. Orthop.*, **68**, 22–31.

Vitali, M., Robinson, K. P., Andrews, B. G., Harris, E. E. (1978). Amputations and prostheses. London: Bailliere-Tindall, pp 22–27.

Vittas, D., Larsen, T. K., Jansen, E. C. (1986). Body sway in below-knee amputees. *Prosthet. Orthot. Int.*, **10**, 139–146.

Wu, Y., Keagy, R. D., Krick, H. J., Stratigos, J. S., Betts, H. B. (1979). An innovative removable rigid dressing technique for below-knee amputation. *J. Bone Joint Surg.*, **61A**, 724–729.

Prosthetics and Orthotics International, 1989, 13, 90–96

Biomechanics of orthoses for the subluxed shoulder

J. C. COOL

Laboratory for Control, Faculty of Mechanical Engineering, University of Technology, Delft

Abstract

Based on biomechanics several operational principles for the neutralization of a shoulder subluxation are described. The pros and cons of the operational principles are discussed. A detailed analysis of the forces acting on the upper and lower arm indicates a preference for only one of the operational principles and explains why the arm sling and hemisling fail in the elimination of subluxation. With the operational principle selected a shoulder orthosis has been developed. Clinical results are given.

Introduction

As a consequence of a brachial plexus lesion or a hemiplegia a subluxation of the shoulder frequently occurs. Smith and Okamoto (1981) have described several designs of orthoses for the subluxed shoulder, together with a checklist for hemiplegic slings. However, the orthoses described are difficult to evaluate because no operational principles are provided. Furthermore the checklist contains no information to evaluate control functions.

Often a new orthosis is described by the moulding techniques applied and the materials used. This is valuable, but cannot replace an indication of the operational principle. It must be doubted whether all the prescribed orthoses give the results expected.

The proper functioning of an orthosis requires that the laws of biomechanics are obeyed. In a well designed anti-luxation shoulder orthosis the correct forces must be exerted at the right action point. Otherwise the luxation is either uncorrected or only partially corrected.

All correspondence to be addressed to Prof.IR J. Cool, Laboratory for Control, Faculty of Mechanical Engineering, University of Technology, Leeghwaterstraat 1-3, 2626 CE Delft, Netherlands.

Biomechanics

The theory of biomechanics comprises the mechanical laws of movement and equilibrium of forces, together with the visco-elastic behaviour of biomaterials.

In the case of a shoulder orthosis for the neutralization of subluxation it is sufficient to consider only static forces acting on the paralysed arm.

The analysis is simplified to the two dimensional situation. Only the forces and movements acting in the plane through the upper and lower arm are considered. It is assumed that this is a vertical plane containing the gravity forces. The contact forces between arm and trunk are omitted.

For a comfortable orthosis the contact forces between the orthosis and the skin of the arm need careful control, both in direction and magnitude. The direction of these contact forces must be perpendicular to the skin surface. Components of the contact force in line with the skin surface give rise to excessive skin displacements, and have a bad effect on the correct operation of the orthosis. The resulting friction forces on the skin are intolerable unless very small and intermittent. The reaction of the skin to friction is to creep in a direction opposite to the external friction force thereby trying to restore normal skin position. This has an adverse effect on the function of the orthosis.

Experience has shown that skin pressures up to 0.5 N/cm^2 are tolerable even on atrophied skin. The orthosis developed as a result of these studies is designed in accordance with this value. The occurrence of skin friction is prevented.

Operational principles

The neutralization of a subluxation requires that the paralysed arm is elevated. After that

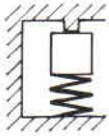
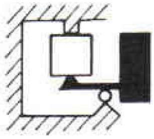
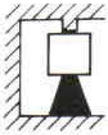
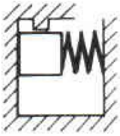
	Description	Advantages	Disadvantages
a 	Elevation force applied by spring	Controlled subluxation	Variable shoulder force
b 	Elevation force applied by counterweight	Controlled subluxation constant shoulder force	Heavy and voluminous because of counterweight
c 	Elevation held by clamping	Insensitive to disturbing (dynamic) forces	Sensitive to movements of fixation point
d 	Elevation held by friction		Sensitive to disturbing forces High normal forces

Fig. 1. Different operational principles for the elevation of a mass. The mass is indicated by a white square. The elevation force application is shown black.

the arm must be held in the elevated position. This means that a force equal to the weight of the arm and acting upwards, must be continually present. For the generation of that force different solutions exist. Each solution represents an operational principle.

In Figure 1 different operational principles for the elevation of a mass m are indicated. The mass m can be elevated by the action of a spring (a) or a counterweight (b). In the elevated position no clamping is necessary. The restoring force caused by spring or counterweight is always present and corrects immediately any deviation from the elevated position.

Once the mass is elevated by some external force, it can be held in the elevated position by the action of a clamp (c) or by friction (d). These operational principles are less favourable than (a) or (b), because no restoring force is present. The influence of a disturbing force or movement is not conrolled. Displacement of the fixation point of the clamp (c) or overcoming of the friction force (d) reintroduces subluxation. Application of the operational principles (c) or (d) cannot guarantee that subluxation is neutralized.

Each working principle has its own advantages and disadvantages. These are indicated in Figure 1. On disturbance the spring of principle (a) causes a variable pressure force. Principle (b) has a favourable constant pressure force, but the counterweight necessary is voluminous and heavy. As discussed the principles (c) and (d) are very sensitive to disturbing movements and forces. Principle (d) depends on friction forces, which always require very high normal forces. Many different designs can be developed to apply these principles.

Forces on the upper arm

To neutralize a subluxation the humerus must be elevated until in the gleno-humeral joint small or zero play is left. The upper arm has a weight Wu. For the elevation of the upper arm a vertical force Fu which exceeds the weight Wu must be applied. An upward force Fu that exceeds Wu results in a shoulder force.

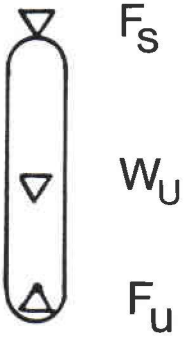


Fig. 2. Forces acting on the upper arm. The equilibrium condition is Fs + Wu = Fu. For a small force Fs the force Fu only slightly exceeds Wu.

Fs between humerus and scapula (Fig. 2). Any positive value of Fs will ensure the subluxation is neutralized. The value of Fs is not critical, but preferably should be small. High forces between humerus and scapula should be avoided. As an indication Fs should never exceed Wu. With that value the upward force Fu = 2 Wu.

With preference the upper arm rests in the vertical or nearly vertical position. This position is both comfortable and cosmetically acceptable. Hence the force Fu has to be axially exerted on the vertical upper arm. As it is undesirable for Fu to act on the outer area of the upper arm it has to act on the upper arm internally. The elbow joint is the only applicable point for the force Fu to act on the humerus.

In the elbow joint the vertical force Fu can act on the humerus without risk of damage to the joint. A sound elbow joint can transmit high magnitude forces in the extended as well as in the flexed mode.

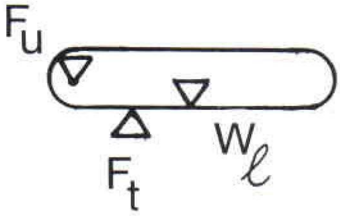


Fig. 3. Forces acting on the lower arm. The equilibrium condition is Fu + Wl = Ft. Considering also the equilibrium condition of the upper arm gives Ft = Fs + Wu + Wl. The minimum value for Ft is the weight force of the whole arm.

Forces on the lower arm

In the elbow joint a force Fu acts upwards on the humerus. This results in a downward reaction force Fu on the lower arm. The lower arm has weight Wl acting through its centre of gravity. For equilibrium of the lower arm at least a third force Ft is necessary. Both forces Fu and Wl act vertically downward; therefore Ft has to act vertically upward.

According to the laws of mechanics the action point of the force Ft is nearest to the biggest downwards force. In practical situations Fu roughly equals Wl. That means the action point of Ft is roughly centred between the elbow and the centre of gravity.

The lower arm is approximately cylindrical. As no friction forces are tolerable the lower arm has to be positioned perpendicular to the force Ft. Thus, the vertical force Ft requires a horizontally positioned lower arm.

In Fig. 3 the lower arm is shown schematically with the forces acting on it. Other force systems could also satisfy equilibrium conditions.

The lower arm as counterweight

In the preceding paragraphs the forces acting on the upper and lower arm are defined. Combination of Figures 2 and 3 produces Figure 4. Fu is an internal force and is therefore not indicated in Figure 4.

If the action point of force Ft is considered fixed the force system can be represented as shown in Figure 4. This figure resembles the counterweight system of Figure 1b. The weight of the lower arm elevates the upper arm. Thus the lower arm acts as the counterweight. With no additional counterweight necessary the disadvantage of this operational principle (heavy, voluminous) disappears.

In this circumstance the operational principle 1b is highly favourable because of:

- Controlled subluxation by the continuously present elevation force. No need for clamping of the arm.
- Small constant shoulder force only slightly influenced by dynamics.
- The lower arm acts as a counterweight. No additional masses required.

Illustration of the operational principle

In principle, neutralization of subluxation is obtained by the addition of a fixed point to the

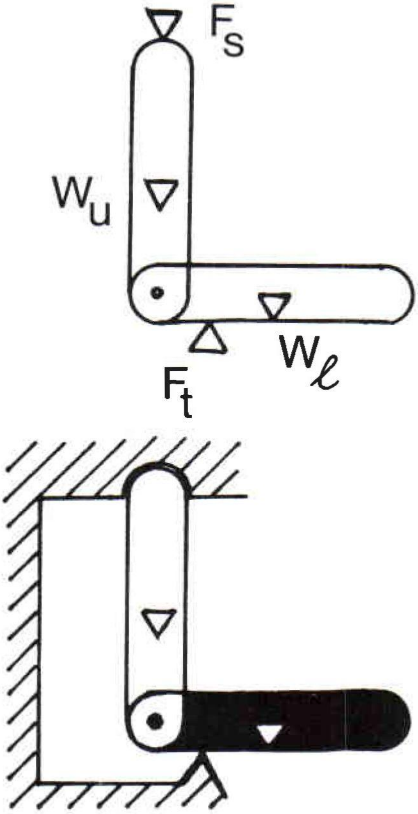


Fig. 4. Combining Figures 2 and 3 gives Figure 4, top. The resultant force Ft delivered by a fixed support produces Figure 4, bottom. The lower arm is shown black resembling. Figure 1b. The lower arm acting as a counterweight removes the disadvantage of operational principle 1b.

paralysed arm. However the position of that fixed point is of particular importance. The different possibilities are illustrated in Figure 5.

In Figure 5 the paralysed arm is represented by two pivoted bars. One bar represents the upper arm, the other bar represents the lower arm. In the centre of gravity of each bar the weight force acting is indicated by a white triangle. The pivot represents the elbow joint, which is indicated by a small circle in the figure. A black triangle indicates the position of the fixed point. It must be remembered that the fixed point represents the suspension point of the arm. It is fixed relative to the body, not to the environment.

The different possibilities displayed in Figure 5 are described below

5a — The paralysed arm is hanging down from the shoulder. A subluxation s exists, caused by the weight forces Wu and Wl of the upper and lower arm respectively.

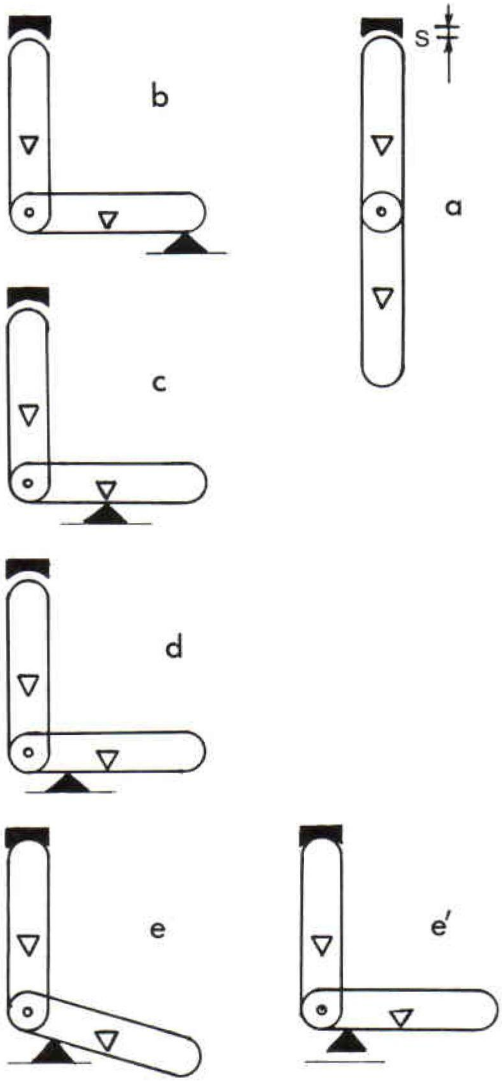


Fig. 5. The paralysed arm with acting forces (see text).

5b — The arm is suspended at the distal end of the lower arm. The weight of the lower arm is only partly supported. The subluxation s still exists.

5c — The lower arm is suspended just at the centre of gravity. The weight of the lower arm is counteracted. The subluxation is caused by the weight of the upper arm only.

5d — The fixed point of the lower arm is centred between the two centres of gravity.

Exact balance of both the upper and the lower arm is obtained. Although no subluxation force exists, the subluxation s is still present.

5e — The exact balance of 5d is disturbed by positioning the fixed point a small distance nearer to the elbow joint. Now the lower arm weight forces the upper arm upwards, thereby eliminating the subluxation.

5e' — The position on the lower arm of the fixed support point is decisive to neutralize subluxation. In 5e the lower arm inclines due to the displacement s of the elbow joint. The horizontal position of the lower arm can be restored by a small elevation of the fixed point.

Suspension

In static systems one single force never operates. Forces always are generated in pairs. The action of a force necessitates opposite force action elsewhere. A spring can deliver force only if the other end of the spring can react against a fixed point. The same is true for a rope, a rod and any arbitrary construction. The two forces always have the same action line.

The force Ft needs a reaction force to form a pair. Therefore two possibilities exist: the paralysed arm can be suspended from the shoulder or the hip can support the arm. In the situation of Fig. 6 (left) a tension band suspends the arm on the shoulder. A shoulder cap transmits the suspension force to the body. In the situation of Fig. 6 (right) a compressive rod supports the arm. A band around the hip transmits the supporting force to the body. In both situations the force pairs to the body have corresponding magnitudes and the same directions.

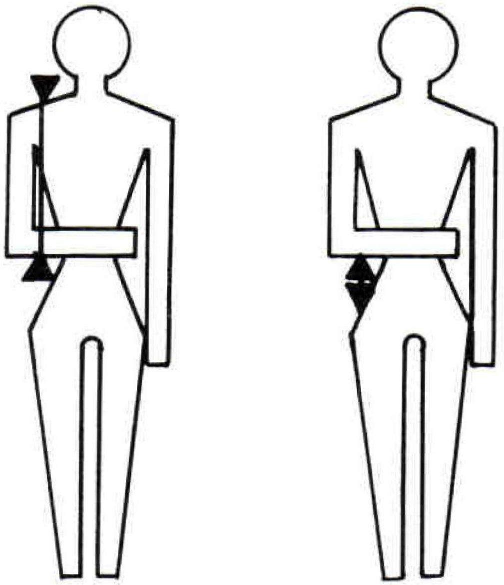


Fig. 6. By suspension of the arm the suspension force Ft combines with a reaction force on the shoulder (left) or on the hip (right)

External suspension of the arm weight from the shoulder localizes all body forces to the arm and shoulder, imitating the normal situation. This suspension system has been chosen for the orthosis developed. Support of the arm weight by the hip introduces eccentric forces to the body, but leaves the shoulder region unloaded. In some practical situations this solution can be advantageous.

Why arm sling and hemisling fail

With knowledge of the possible operational principles it is easy to understand why many solutions suggested in the literature do not give the results expected. This is illustrated below by an analysis of the hemisling and the arm sling.

A hemisling is a simple band resting on the sound shoulder; one end is looped around the paralysed lower arm near the elbow, the other end is looped around the hand on the injured side. Figure 7 shows schematically the arrangement with the two forces Fe and Fh acting on the lower arm near the elbow and the hand respectively. A subluxation could be neutralized if the resultant force of Fe and Fh acted in accordance with Figure 5e. Then Fe is required to be of much greater magnitude than Fh. However that is unachievable. Any difference between the two forces is caused by friction between band and skin at the shoulder. As previously discussed the skin does not accept friction over long periods. Therefore in the schematic drawing of the hemisling, rollers are introduced, equalizing the forces Fe and Fh. The resultant force is centred between them, near the middle of the lower arm. The force acting at that point is unable to neutralize subluxation. The situation is similar to figure 5c.

The same is true for an arm sling. The only difference from the hemisling is the distributed pressure along the lower arm. These pressures unite in two forces around the neck of the patient. Because the skin of the neck does also

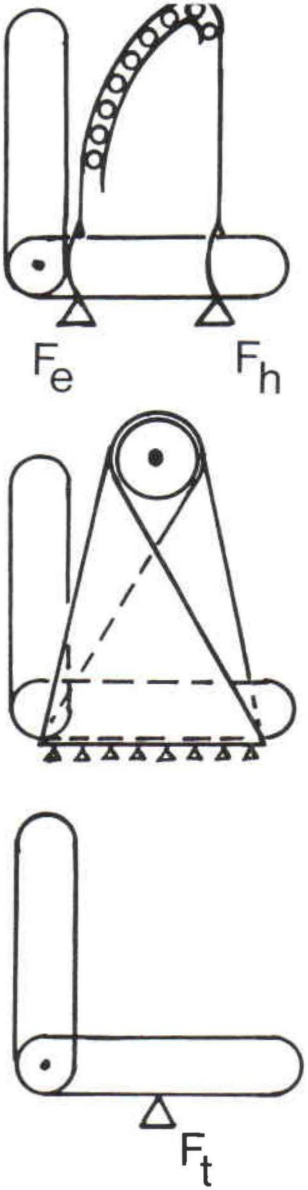


Fig. 7. The hemisling (top) as well as the arm sling (centre) give rise to midarm suspension forces Ft (bottom). In accordance with theory subluxation is not neutralized.

not accept friction these forces have equal magnitude, leaving a uniform pressure distribution on the lower arm with a midarm resultant. Therefore also the arm sling cannot neutralize subluxation of the shoulder.

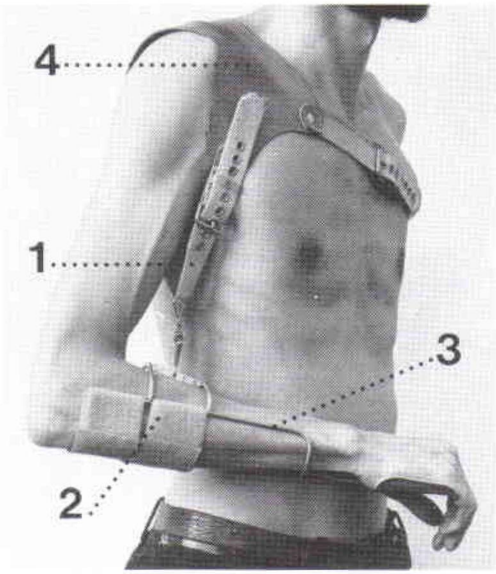


Fig. 8. Patient with orthosis, 1-textile tension band; 2-leather suspension strip; 3-stainless steel brace; 4-textile or leather shoulder cap.

The correct orthosis

The orthosis designed clearly demonstrates the operation principle selected. (Fig. 8). The tension band 1 suspends the paralysed arm at the shoulder. The shoulder cap 4 transmits the suspension force Ft to the body. At the other end the suspension force is transmitted to the lower arm by the brace 3. The brace 3 is constructed for various reasons.

- The suspension force Ft has the magnitude of the weight of the arm. To transmit this force to the skin the surface area is calculated using the maximum allowable pressure $0.5 N/cm^2$. The result is a required area roughly $50\ cm^2$. For reasons of comfort a strip of leather provides the contact. The strip dimensions are 5 by $10\ cm^2$. For a good pressure distribution to the small suspension band 1 the leather strip 2 ends in the metal parts of the brace.
- The leather strip 2 is mounted between two separated metal bars.
- In many practical situations the wrist is also paralysed and needs support. Of course a separate cock-up brace for the wrist could be used. For reasons of simplicity the cock-up brace is integrated in the orthosis.
- The integrated construction gives the possibility of positioning the leather strip

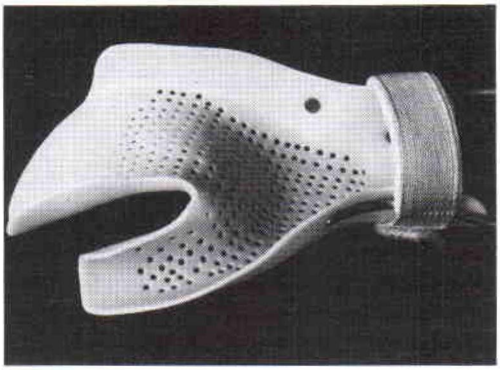


Fig. 9. Spasm supressing hand support for hemiplegic patient.

relative to the hand. This eases donning and doffing of the orthosis.

The cock-up part of the brace provides a hand support. Depending on the planned use of the orthosis completely different supports have been designed. Patients with a brachialis lesion often prefer a very small self-adaptive hand support. For patients with hemiplegia a spasm suppressing hand support can be made (Cool et al., 1984). Figure 9 shows a photograph of such a hand support.

The metal parts of the orthosis are constructed of stainless steel. This material offers some advantages.

- Very high strength/weight ratio. This gives the possibility of constructing extremely lightweight braces.
- High corrosion resistance. For orthopaedic applications stainless steel is one of the best materials available.
- Fairly machinable and weldable.
- Commercially available in a variety of profiles and many dimensions.

With the designed orthosis an accurate analysis of all forces acting can be made. The result is similar to the analysis above; however some forces deviate from the exact vertical direction. As a result the lower arm is preferably suspended in a slightly inclined position, perpendicular to the suspension-band.

Concluding remarks

Basic biomechanical principles and control qualifications lead to the design of an orthosis for the neutralization of shoulder subluxation. From an understanding of the inevitable force patterns the designed orthosis is the logical development.

Many patients favour the new orthosis because of:

- reduced pain
- light weight (total weight 150 g).
- easy donning and doffing
- comfortable wearing
- reduced arm sway
- invisible to wear (underneath clothing)

At the moment the orthoses are distributed in The Netherlands, Belgium and West Germany by Basko Camp B.V.; Postbox 8359, 1005 AJ Amsterdam. In the last years over 1600 orthoses were supplied.

REFERENCES

Cool, J. C. et al. (1984). Hemiplegic patients and their shoulder orthosis. (in Dutch). *Ned. Tijdschr Fysioterapie,* **94, (10)** 217-220; *and Ned. Tijdschr Ergoterapie,* **12, (6)** 123-128.

Smith, R. O., Okamoto, G. A. (1981). Checklist for the prescription of slings for the hemiplegic patients. *Am. J. Occup. Ther.* **35,** 91-95.

Prosthetics and Orthotics International, 1989, 13, 97–99

The Flek-shin: a composite material for use in flexible shank below-knee prostheses

A. J. THURSTON, J. RASTORFER*, H. BURIAN*, and A. W. BEASLEY*

Wellington School of Medicine, Wellington, New Zealand
**Wellington Artificial Limb Centre*

Introduction

Conventional below-knee prostheses are manufactured of rigid materials for durability and stability. The use of glass fibre and resin composite materials to form the rigid shank of the below-knee prosthesis is well established in many countries and forms part of the modern practice of cosmetic prosthesis manufacture.

While these materials are strong, durable, easily worked and cosmetically acceptable, there are a number of disadvantages. Mechanically they are essentially inert. The finished limb resists compressive and bending forces and as a consequence running, jumping and even vigorous walking are performed only with difficulty and certainly at high energy cost to the wearer.

A new material has been developed at the Wellington Artificial Limb Centre and the Wellington School of Medicine which is semirigid but sufficiently flexible to allow its energy storing properties to be utilized in amputee gait. No data on the suitability of this new composite material for use in artificial limbs exist. As part of the development of this material it was essential to determine its fatigue strength and durability before further development of this exciting new concept could proceed.

Method

A composite material was fabricated by laminating glass fibre, carbon fibre and Kevlar™ in a mould, without prestressing the tensile elements, and then incorporating a methyl methacrylate resin (70% rigid Orthocryl®, 30% flexible Orthocryl®). The laminate was compressed during curing of the resin. The resulting composite material was then aligned and mounted on a custom-made socket and a standard Otto Bock S.A.C.H. foot.

All correspondence to be addressed to Dr. A. J. Thurston, Senior Lecturer in Orthopaedic Surgery, Wellington School of Medicine, University of Otago, Wellington Hospital, Wellington, New Zealand, PO Box 7343 Wellington South.

a. Deformation tests The deformation of a shank during normal use was measured by fixing a foot plate in the shoe to which was attached a blade, orientated in the sagittal plane, and bearing a piece of white card. On to the proximal end of flexible shin segment of the prosthesis, a stylus was mounted and adjusted so as to record the displacement of the upper end of the composite shin on the white card. The subject then donned the prosthesis and executed a number of vigorous runs. This recorded the bending in the shin relative to the foot of the prosthesis.

b. Fatigue tests Base-line stress/strain data were recorded on an Instron before fatigue testing (Fig. 1, top).

Each shank was then mounted on a test rig comprising a pneumatic cylinder driven by compressed air and controlled by valves for cyclic loading (Fig. 1, bottom). The rig was capable of applying variable bending loads to the flexible shin at a variable frequency. The frequency of loading for these tests was one Hz as recommended by Wevers and Durance (1987). The number of cycles was recorded by an IVO (model H200) event counter. Failure of any of the prosthetic components resulted in the test material falling away from the test rig and the cessation of counting.

Each flexible component was tested initially for the equivalent of three months use. It was then retested on the Instron to determine if there had been change in the mechanical properties of the composite material. The cyclic loading was repeated in three months use equivalents and tested to the equivalent of two

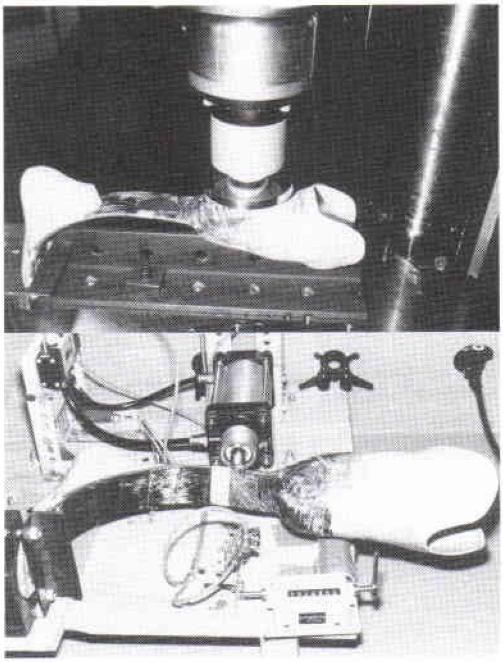


Fig. 1. Top, below-knee prosthesis with the flexible composite material of glass fibre, carbon fibre, Kevlar™ and synthetic resin with the cosmetic cover removed, mounted on the Instron for testing. Bottom, fatigue testing rig showing the Flek-shin mounted by the toe. The pneumatic cyclinder applies a cyclical bending force to the proximal end of the prosthesis. The counter records complete cycles.

and a half years of use or until fatigue failure of the composite material occurred.

From the stress/strain graphs for each "three months equivalent" stage, the degradation of the mechanical properties of the new composite shank material became evident and on the basis of these results the suitability of the material for incorporation into below-knee prostheses for selected patients was assessed.

Height and weight considerations for patients of different body habitus were not incorporated at this stage.

c. Field tests Prostheses each incorporating a flexible shin (Flek-shin) of this composite material were fitted on three patients for subjective assessment. Patients were asked to use the new Flek-shins regularly for a period and then to report back on their impressions of the new material.

Results

Fatigue testing of the material was continued until failure or to the equivalent of two and a half years of vigorous use. Of the samples tested none failed during testing and all endured for the equivalent of two and a half years.

The stress/strain characteristics of the samples showed no statistical change over the period of testing. Typical stress/strain graphs for one specimen tested at 0, and 30 months are shown in Figure 2. The apparent hysteresis effect is accounted for by movements in the test instrument between compressive and tensile modes.

The subjective tests carried out by the three patients all produced favourable reports. Each agreed that the new prosthesis felt "alive" and that running was almost a new experience. When each patient was being observed there was an obvious difference in running gait between using a standard, rigid shank prosthesis and the Flek shin.

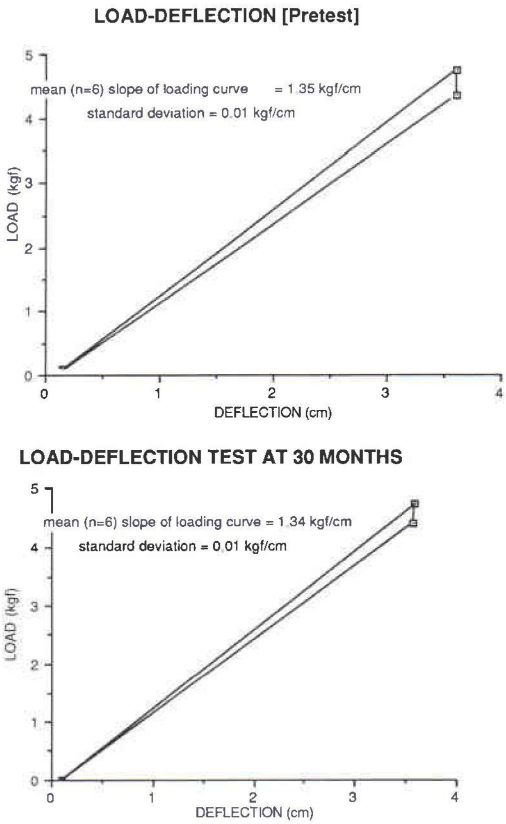


Fig. 2. Stress/strain graphs for one sample of the composite material tested after the equivalent of 0, and 30 months of vigorous use. No statistical difference exists between these recordings.

Discussion

Energy utilization in amputee gait is increased over that in non-amputee gait. In an attempt to gain a relative reduction in energy expenditure in vigorous physical activity in amputees the use of flexible components in below-knee prostheses has become widespread.

The inclusion of a semi-rigid, shank connecting the socket with the terminal device (foot) has been shown to improve greatly the functional abilities of the amputee as far as vigorous activity is concerned. The basis of the improved function is the bending of the shank during the flat foot to toe-off phase of the gait cycle. This stores potential energy within the shank which is released as kinetic energy as "active" plantar flexion of the prosthetic foot at toe-off. The effect is similar to the active plantar flexion of the foot brought about by the sural triceps and the long toe flexors during normal gait.

Various examples of flexible feet and shank components are available commercially. The authors have found that it is possible to fabricate, without sophisticated equipment, a laminated composite of glass fibre, carbon fibre, Kevlar™ and synthetic resin which fulfils the requirements of an energy storing component for use in below-knee prostheses. This material is easily modified to suit individual patients in that by changing the composition of the composite material the relative flexibility, and thus the energy storing capacity, can be tailored to each patient's needs.

The material has been fatigue tested using bending loads to an equivalent of two and a half years of vigorous use without significant deterioration in its elastic deformation properties. At this stage it would have outlasted many of the other components of a standard below-knee prosthesis. The material is recommended for the younger active patient committed to vigorous sporting activities.

Acknowledgements

This research was supported by a grant from the New Zealand War Pensions Medical Research Trust Fund. The assistance and advice of Mr T. Porritt of the New Zealand Department of Scientific and Industrial Research is also acknowledged.

REFERENCE

Wevers, H.W., Durance, J. P. (1987). Dynamic testing of below-knee prosthesis: assembly and components. *Prosthet Orthot Int* **11,** 117-123.

Prosthetics and Orthotics International, 1989, 13, 100–103

Limb salvage in diabetics with foot ulcers

K. LARSEN, P. HOLSTEIN and T. DECKERT

Steno Memorial Hospital, DK 2820 Gentofte, Denmark

Abstract

The healing results in 491 ulcers in 272 diabetic patients are reported. Soft moulded insoles and shoe corrections were the main part of the therapy. There were 329 (67%) neuropathic, 87 (17%) traumatic, 44 (9%) ischaemic and 31 (6%) ulcers of other various pathogenesis. Thirty seven per cent of the ulcers were complicated with invasive infection. Within the period of observation of 18 months (3–39 months) healing was obtained in 79% of the patients (88% of the ulcers) and major amputation was carried out in 8% (4% of the ulcers). There were 21 major amputations, which in 18 cases was due to ischaemia. Thus in only 3 cases (1% of the patients) neuropathy as complicated by invasive infection caused major amputation. Fifty nine ulcers (12%) were classified as relapsing ulcers or ulcers with new localizations and were caused by severe deformity of the foot (58 cases) often in combination with neglect of prophylaxis (7 cases). Only one recurrent ulcer was caused by ischaemia. The series shows that shoe corrections and insoles are effective in treating diabetic neuropathic ulcers. Recurrent ulcerations are caused by severe foot deformity and neglect of therapy. Loss of limbs is caused by ischaemia and invasive infection.

Introduction

The risk of amputation in the diabetic patient has been found to be increased 15 times as compared to the non-diabetic patient (Most and Sinnock 1983). Recent studies, however, suggest that the progressive destruction of the neuropathic or gangrenous foot can be stopped and the number of amputations substantially decreased (Holstein et al., 1976; Wagner, 1979; Brand, 1979; Lippmann, 1979; Runyan et al 1980; Larsen et al., 1982; Pollard and Le Quesne, 1983; Burden et al., 1983). The present study was undertaken to evaluate healing results and to identify high risk patients as regards recurrent ulceration and risk of amputation.

All correspondence to be addressed to Ms. K. Larsen, Kollelevbakken 14,DK 2830 Virum, Denmark.

Patients and methods

Patients

The series is consecutive consisting of 272 patients with 491 ulcers treated in Steno Memorial Hospital from 01.12.79 through 30.11.82. In 204 patients there was unilateral and in 68 bilateral ulcers. Figure 1 shows the age distribution and the treatment of diabetes. About one third were younger than 50 years, mostly insulin dependent and 48 per cent of the ulcers occurred in patients active in their jobs. Figure 2 shows the duration of diabetes mellitus, which in 24 per cent was of more than 30 years duration. Many of the patients were over-weight (Table 1), although being under-weight did not prevent ulceration.

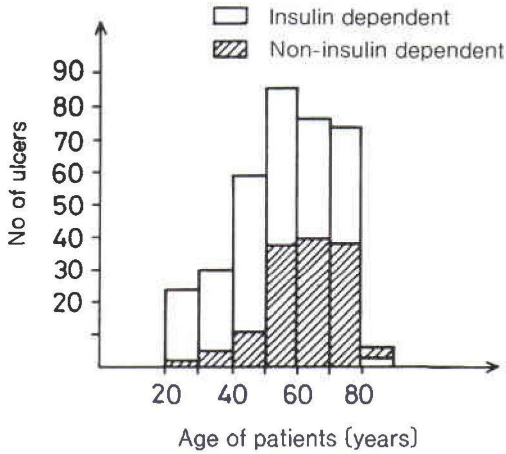


Figure 1: Treatment of diabetes and age distribution of patients.

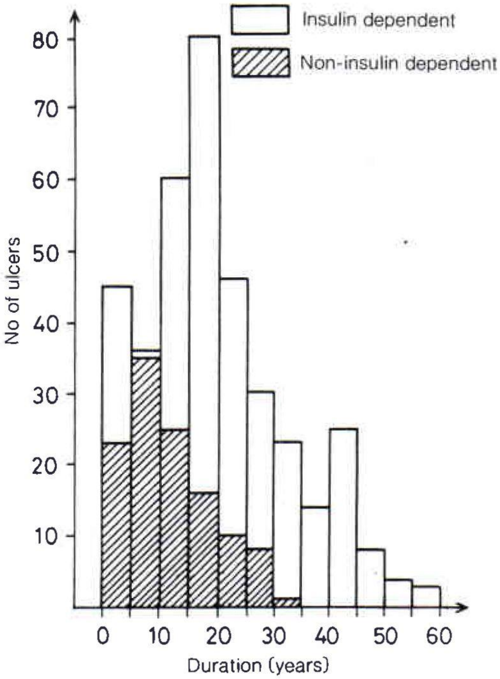


Figure 2: Treatment of diabetes and duration of the disease.

Previous amputations were recorded as follows: one above-knee, 20 below-knee and 22 on the toes or on the forefoot.

Ulcers

Table 2 shows the duration of the ulcers before treatment in the present hospital. The duration did not, however, correlate with the healing time. The localization of the foot ulcers is shown in Figure 3, highlighting the importance of proper footwear, insoles and protection of the heel. Table 3 shows the pathogenesis, most ulcers having been caused by repetitive stress (Brand, 1979). Ischaemic ulcers were defined by the finding of a digital blood pressure less than 40 mm Hg. Fifty nine ulcers were classified as relapses or new ulcers in previously healed feet. Invasive infection occurred in as many as 37 per cent of the ulcers.

Table 1. Bodyweight* and number of ulcers.

Normal	256
Over-weight	187
Under-weight	49

*According to weight table by Natvig (1956).
Normal weight: Ideal weight ± 10 per cent.

Table 2. Duration of ulcers

<1 month	318	65%
1≤3 months	109	22%
3 months≤1 year	44	9%
>1 year	20	4%

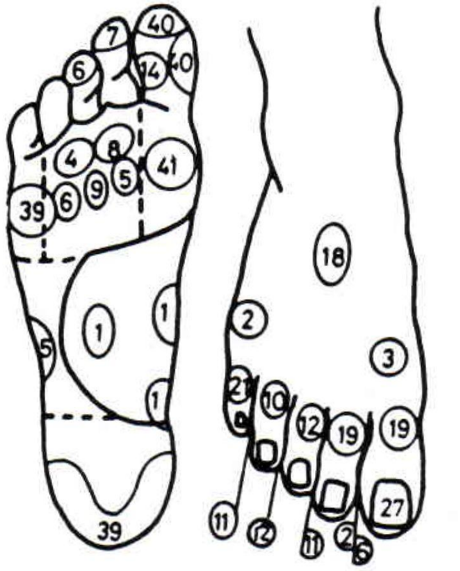


Figure 3: Localization of 439 ulcers. The drawing does not include ulcers around the malleoli and ulcers following digital amputations.

Methods

Two main principles in treating plantar foot ulcers were followed: 1) Abnormal varus or valgus load present in most cases was corrected with modules made from soft materials (3–5 mm Rubazote[R]) and adjusted to balance the foot. 2) Abnormal pressure points were compensated for by pads of the same material. This compound insole was corrected during the course of healing resulting in a final device for permanent use, eventually covered with thin leather. Moreover, prominent structures, e.g. claw toes were protected with silicone rubber pads. Venous ulcers were treated with zinc paste bandage followed by compression stockings. More spacious shoes were prescribed whenever necessary, possibly as orthopaedic

Table 3. Pathogenesis

Neuropathic	329	(67%)
Traumatic	87	(17%)
Ischaemic	44	(9%)
Venous	27	(5%)
Miscellaneous	4	(0.8%)

Table 4. Footwear and ulcers

Unsuitable footwear	205	(42%)
Suitable footwear	283	(57%)
No footwear	3	(0.6%)

footwear (Table 4). In cases of suspected ischaemia, digital and ankle blood pressures were measured with strain gauge plethysmography.

Minor necroses were excised often by repeated small revisions without anaesthesia. Digital amputations were done during local anaesthesia in Steno Memorial Hospital whereas major amputations were done in collaborating hospitals. Invasive infection in the form of osteitis or plantar abscess was treated with surgical drainage supported by antibiotics according to cultures. Great attention was always paid to blood sugar control. The vast majority of the series (83 per cent) were treated in the out-patient clinic.

Results

The series was evaluated 3 months after the end of the period studied yielding a mean time of observation of 18 months (3–39 months). Out of 491 ulcers 88 per cent healed, i.e. 79 per cent of the patients (Table 5). The healing rate was statistically significant correlated with digital as well as ankle blood pressures (Table 6). Healing of ulcers was not related to their localization.

Eight per cent of the patients had major amputation below the knee, i.e. in four per cent of the ulcers. Of these 21 amputations 18 were caused by ischaemia and three by infection originating from heel necrosis. Vascular reconstruction was only attempted in one ischaemic limb and was not successfull.

Table 7 demonstrates the pathogenesis of 59 cases of recurrent ulceration found in 46 patients. One was ischaemic and 58 were neuropathic, all of these occurring in severely deformed feet. Eight of the patients had neglected the prophylaxis.

Table 6. Healing in relation to distal blood pressure

Systolic digital blood pressure	Healing rate	
< 20 mm Hg	2/7 (29%)	$P < 0.001$
20 – 29 mm Hg	11/16 (69%)	
30 – 39 mm Hg	7/9 (78%)	
≥ 40 mm Hg	39/41 (95%)	
Systolic ankle blood pressure		
< 50 mm Hg	1/4 (25%)	$P < 0.05$
50 – 89 mm Hg	12/17 (71%)	
≥ 90 mm Hg	53/60 (88%)	

Table 7. Relapses and new ulcers

Neuropathic	58	plantar ulcer	26
		first toe	11
		digitus malleus	11
		misc.	10
Ischaemic	1		
	59		

Discussion

The localization of the ulcers in the present series is similar to that demonstrated in leprosy patients (Languillon, 1964) the common denominator being the insensitive feet.

In the treatment of diabetic neuropathic foot ulcers two different principles are currently used. In some centres healing is obtained by application of rigid casts (Brand, 1979; Wagner, 1979; Burden et al., 1983; Jernberger, 1986) and maintained by various shoe systems. In other centres the external pressure is relieved with the aid of soft materials which are adjusted during the healing phase (Holstein et al., 1976; Faris, 1982). The authors prefer the latter principle because pressure necrosis from rigid casts is avoided and the adjusted shoes and insoles provide a proper prophylaxis against new ulcers—with a shoe cosmesis acceptable to most patients.

The literature on diabetic foot lesions is growing, but it is at present difficult to compare the results from one centre to another and an

Table 5. Healing rate

	Death	Still under treatment	No follow-up	Major amputation	Healing
Neuropathy	2	5	18	3	301
Trauma	1	0	0	0	86
Ischaemia	8	1	0	18	17
Venous	0	2	1	0	24
Misc.	0	0	2	0	2
Total number of ulcers 491	11 (2%)	8 (2%)	21 (4%)	21 (4%)	430 (88%)

untreated control group is not available. However, the compensation for neuropathy and the aggressive treatment of invasive infection give healing rates, which are comparable to those obtained in ulceration and gangrene in non-diabetic patients (Holstein and Lassen, 1980), and these results are confirmed in the present study.

This series demonstrates that soft insoles and proper footwear are adequate in preventing major amputation in neuropathic lesions, but these measures were not adequate in preventing new ulcers, which occurred in the severely deformed feet possibly in connection with neglect of prophylaxis. It is possible that a wider use of surgical correction of the deformities and more extensive use of orthotic measures are justified in such cases.

Major amputations were almost exclusively performed in severe ischaemia where the patients were not suitable for vascular reconstruction. However, the femoro-crural in situ by-pass (Leather et al., 1981), had not yet been introduced in Denmark during the period studied. Today a number of diabetic patients with ischaemic ulcers are effectively treated by this procedure.

The annual number of major amputations in diabetics in Denmark is slowly but steadily decreasing. From 560 in 1980 to 300 in 1986 (Ebskov, 1988). This is probably due to an increasing interest in diabetic foot problems, economic support for regular foot control and reinforcement of education at all levels. Major attention is paid to the prophylaxis since "if an ulcer develops . . . the preventative measures have failed (Faris, 1982)".

REFERENCES

BRAND, P. W. (1979). Management of the insensitive limb. *Phys. Ther.* **59**, 8–12.

BURDEN, A. C., JONES, G. R., JONES, R. AND BLANDFORD, R. L. (1983). Use of the "Scotchcast" boot in treating diabetic foot ulcers. *Br. Med. J.* 14 May, 1555–1557.

EBSKOV, B. (1988). The dimension of the problem. Paper in "Rehabilitation and prosthetics after amputation on the lower limb". ISPO—symposium, May, Herlev, Denmark.

FARIS, I. (1982). The management of the diabetic foot. Churchill Livingstone, 65.

HOLSTEIN, P., LARSEN, K. AND SAGER, P. (1976). Decompression with the aid of insoles in the treatment of diabetic neuropathic ulcers. *Acta Orthop. Scand.* **47**, 463–68.

HOLSTEIN, P. AND LASSEN, N. A. (1980). Healing of ulcers on the feet correlated with distal blood pressure measurements in occlusive arterial disease. *Acta Orthop. Scand.* **51**, 995–1006.

JERNBERGER, A. (1986). Treatment of foot ulcers and gangrene. Presented at V World ISPO Congress.

LARSEN, K., CHRISTIANSEN, J. S. AND EBSKOV, B. (1982). Prevention and treatment of ulcerations of the foot in unilaterally amputated diabetic patients. *Acta Orthop. Scand.* **53**, 481–485.

LANGUILLON, J. (1964). Frequency and localization of plantar perforating ulcers of leprosy patients. *Lep. Rev.* **35**, 239–249.

LEATHER, R. P., SHAH, D. M. AND KARMODY, A. M. (1981). Infrapopliteal arterial by-pass for limb salvage. Increased patency and utilization of the saphenous vein used "in-situ". *Surgery* **190**, 1000–1008.

LIPPMANN, H. I. (1979). Must loss of limb be a consequence of diabetes mellitus? Diabetes Care **2**, 432–436.

MOST, R. S. AND SINNOCK, P. (1983). The epidemiology of lower extremity amputations in diabetic individuals. Diabetes Care **6**, 87–91.

NATVIG, H. (1956). Nye høyde-vekt tabeller for norske kvinner og menn. Landsforeningen for kosthold og helse. Oslo Universitet.

POLLARD, J. P. AND LE QUESNE, L. P. (1983). Method of healing diabetic forefoot ulcers. *Br. Med. J.* **286**, 436–437.

RUNYAN, J. W., ZWAAG, R. V., JOYNER, M. B., MILLER, S. T. (1980). The Memphis Continuing Care Program. *Diabetes Care* **3**, 382–386.

WAGNER, W. F. (1979). A classification and treatment program for diabetic, neuropathic and dysvascular foot problems. A.A.O.S. Instructional course lectures. **28**, 143–163.

Book Review

Amputation Surgery and
Lower Limb Prosthetics
Edited by George Murdoch, Ronald Donovan
Blackwell Scientific Publications Ltd. 1988
480pp £49.50.

The publication of extended conference proceedings as an "instant monograph" is increasingly common. All too often the results are disappointing with articles of very variable standard, often of doubtful relevance, showing evidence of hurried preparation. None of these criticisms can be levelled at this volume which is a masterly example of what can be achieved with this format given careful selection of contributors in the first place and good editing thereafter. The standard of production and the reproduction of the illustrations matches the quality of the text.

The conference concerned was held in July 1985 in Dundee, the principal sponsor being the International Society for Prosthetics and Orthotics. The underlying theme was the multi-disciplinary approach to the problem and there are over 66 contributors from every corner of the globe, representing inter alia surgeons, prosthetists, bio-engineers and nurses not forgetting the consumer.

The surgical topics covered include wound healing and stump care together with current views on level determination. There is a detailed account of the surgical technique at each amputation level and a particularly useful series of articles on congenital limb deficiency. In an extended article at the end there is an account of the experience in Dundee showing what the multi-disciplinary approach can achieve.

In the prosthetic sections the current state of design and prescription are set out together with the latest developments in prosthetic technology including computer aided design and manufacturing, but in spite of such "high-tech" emphasis the problems relevant to the developing world have not been forgotten.

One searches in vain for a topic which has been omitted and indeed, if there is to be a criticism it is perhaps that the net has been spread a little too wide. Articles on current management of bone tumours and endo-prosthetic replacement techniques while interesting in themselves are perhaps not strictly within the remit of the subject.

The appeal of the book will obviously be wide ranging. Not everyone will need to study the full level of detail in each of the topics dealt with but for anyone connected with amputations, whether it be in the field of surgery, prosthetics or rehabilitation and their associated basic sciences, this book will become required reading, not only for the up to date account of their own speciality but also for the insight it gives into the developments in the many associated specialities. To all of these it is unhesitatingly recommended as a major contribution in the field.

Prof. B. McKibbin,
University of Wales College of Medicine,
Department of Traumatic and Orthopaedic Surgery,
Royal Infirmary,
Cardiff.

ISPO Publications

V World Congress, July, 1986 Copenhagen
Programme and Abstracts $20 (US)

Standards for Lower Limb Prostheses
Report of a Conference, Philadelphia 1977
$10 (US)

The Deformed Foot and Orthopaedic Footwear
Report of the ISPO Workshop in Stockholm March 1977
Edited by Bo Klasson
Co-Editors A. Forchheimer, J. Hughes, G. Murdoch ISPO Members $15 (US)
Non-Members $18 (US)

Directory of Films in Prosthetics and Orthotics
Compiled and Edited by J. E. Edelstein and R. G. Donovan
Published 1980 $5 (US)

Prosthetics and Orthotics International
August 1983
Special Issue — Through-knee Amputation and Prosthetics
Edited by J. Steen Jensen $18.00 (US)

Prosthetics and Orthotics International
April 1985
Special Issue — CAD/CAM Computer Aided Design and Manufacture
Edited by Bo Klasson
Photocopy of papers $20.00 (US)

Prosthetics and Orthotics in the Developing World with Respect to Training and Education and Clinical Services
Report of an ISPO Workshop Moshi, Tanzania
Edited by N. A. Jacobs, G. Murdoch
Published 1985 ISPO Members $5 (US)
Non-Members $10 (US)

Planning and Installation of Orthopaedic Workshops in Developing Countries
Edited by S. Heim (Co-ordinator), W. Kaphingst, N. A. Jacobs
Published 1986 ISPO Members $5 (US)
Non-Members $10 (US)

Training and Education in Prosthetics and Orthotics for Developing Countries
Report of an ISPO Workshop Jönköping, Sweden
Edited by K. Öberg, G. Murdoch, N. A. Jacobs
Published 1987 ISPO Members $5 (US)
Non-Members $10 (US)

Up-Grading in Prosthetics and Orthotics for Technicians in Developing Countries Trained on Short Courses
Report of an ISPO Workshop, University of Strathclyde, Glasgow, Scotland
Edited by G. Murdoch, N.A. Jacobs
Published 1989 ISPO Members $10 (US)
Non-Members $20 (US)

Prices include surface mailing.
Orders which must be accompanied by the appropriate remittance (cheque or international bank draft made payable to ISPO), should be sent to:

ISPO Publications,
National Centre for Training and Education in Prosthetics and Orthotics,
The Curran Building,
University of Strathclyde,
131 St. James' Road,
Glasgow G4 0LS,
Scotland.

INTERNATIONAL SOCIETY FOR PROSTHETICS AND ORTHOTICS

FEE REDUCTION

FOR DEVELOPING COUNTRIES

The Executive Board has agreed that individuals from Developing Countries who wish to join the Society can do so at a reduced annual membership fee of DKK175. This reduced fee also applies to existing members. Those individuals who wish to take advantage of this reduced fee should apply in writing to:

The Secretariat,
ISPO,
Borgervaenget 5,
2100 Copenhagen Ø,
DENMARK.

Prosthetics and Orthotics International, 1989, 13, 106–108

Calendar of events

National Centre for Training and Education in Prosthetics and Orthotics
Short Term Courses 1989-90

Courses for Physicians, Surgeons and Therapists

NC503 Introductory Biomechanics; 23rd–27th October, 1989
NC504 Lower Limb Orthotics; 6th–10th November, 1989
NC508 Orthopaedic Footwear; 27th November–1st December, 1989
NC510 Wheelchairs; 11th–15th December, 1989
NC511 Clinical Gait Analysis; 17th–19th January, 1990
NC502 Upper Limb Prosthetics and Orthotics; 22nd–26th January, 1990
NC505 Lower Limb Prosthetics; 29th January–2nd February, 1990
NC506 Fracture Bracing; 3rd–7th September, 1990 (also suitable for orthotists and plaster technicians).

Course for Orthotists and Therapists

NC217 Ankle-Foot-Orthoses for the Management of the Cerebral Palsy Child; 26th February–2nd March, 1990.

Further information may be obtained by contacting Prof. J. Hughes, Director, National Centre for Training and Education in Prosthetics and Orthotics, University of Strathclyde, Curran Building, 131 St. James' Road, Glasgow G4 0LS, Scotland. Tel: 041-552 4400 ext. 3298.

3–6 September, 1989
11th Brazilian Conference on Biomedical Engineering, Sao Paulo, Brazil.
Information: Comite Organizador do XI CBEB, Caixa Postal 8091, 05403, Sao Paulo SP, Brazil.

3–6 September, 1989
Annual Scientific Meeting of the Biological Engineering Society, Bristol, England.
Information: Ms. J. Upton, BES, The Royal College of Surgeons, 35–43 Lincoln's Inn Fields, London WC2A 3PN, England.

13–15 September, 1989
British Orthopaedic Association Scientific Meeting, London, England.
Information: BOA, 35–43 Lincoln's Inn Fields, London WC2A 3PN, England.

17-23 September, 1989
Combined Meeting of Scoliosis Research Society and European Spinal Deformities Society, Amsterdam, The Netherlands.
Information: Scoliosis Research Society, 222 S. Prospect, Suite 127, Park Ridge, IL 60068, U.S.A.

20–22 September, 1989
Annual Congress of the Chartered Society of Physiotherapy, Harrogate, England.
Information: PR Dept., Chartered Society of Physiotherapy, 14 Bedford Row, London WC1R 4ED, England.

2–8 October, 1989
American Orthotic and Prosthetic Association Annual National Assembly, Reno, U.S.A.
Information: AOPA, 717 Pendleton Street, Alexandria, VA 22314, U.S.A.

11–15 October, 1989
Eastern Orthopaedic Association, Montreal, Canada.
Information: EOA, 301 8th St., Suite 3F, Philadelphia, PA 19106, U.S.A.

22–26 October, 1989
53rd Annual Meeting of the Western Orthopaedic Association, California, U.S.A.
Information: H. Jacqueline Martin, Executive Director, Western Orthopaedic Association, 2975 Treat Blvd., D-4 Concord, CA 94518, U.S.A.

25–29 October, 1989
43rd Annual Meeting of the American Academy for Cerebal Palsy and Developmental Medicine, San Francisco, U.S.A.
Information: John A. Hinckley, Executive Office, 1910 Byrd Ave., PO Box 11086, Richmond, VA 23230-1086, U.S.A.

27–28 October, 1989
Netherlands Society of Rehabilitation and Physical Medicine Scientific Meeting, Utrecht, Netherlands.
Information: Dr. J. De Vries, Rehabilitation Centre Het Roessingh, PO Box 310, 7500 AH Enschede, Netherlands.

November, 1989
3rd World Congress of Disabled People's International, Bogota, Colombia.
Information: DPI General Secretary, Box 36033, S-10071 Stockholm, Sweden.

7–10 November, 1989
2nd British Symposium on Total Knee Replacement, Harrogate, UK.
Information: Metaphor Conferences and Meetings, 21 Kirklees Close, Farsley, Pudsey, West Yorkshire LS28 5TF, England.

8–12 November, 1989
11th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Seattle, U.S.A.
Information: Dr. Francis A. Spelman, Regional Primate Research Centre, SJ-50, Centre for Bioengineering, Dept of Otolaryngology, Univ. of Washington, Seattle, WA 98195, U.S.A.

12–17 November, 1989
ISPO World Congress, Kobe, Japan.
Information: Secretariat, 6th ISPO World Congress, c/o International Conference Organisers Inc., 5A Calm Building, 4-7 Akasaka 8-chome, Minato-Ku, Tokyo 107, Japan.

13–17 November, 1989
6th Cuban Congress of Orthopaedics and Traumatology, Havana, Cuba.
Information: Convergence, 16 Rue Jean-Jacques Rousseau, 75001 Paris, France.

22-26 November, 1989
9th Meeting of the Western Pacific Orthopaedic Association, Singapore
Information: Dr. Satku, Secretary, Organising Committee, 9th WPOA/AOA/SOA Meeting, Dept. of Orthopaedic Surgery, National University Hospital, Lower Kent Ridge Rd., Singapore 0511.

10–15 December, 1989
Annual Meeting of the Bioengineering Division of the American Society of Mechanical Engineers, San Francisco, USA.
Information: Prof. Boris Rubinsky, Dept of Mechanical Engineering, University of California, Berkeley, CA 94720, USA.

1990

22–28 January, 1990
American Academy of Orthotists and Prothetists Annual Meeting and Scientific Symposium, Phoenix, USA.
Information: AAOP, 717 Pendelton St., Alexandria, VA 22314, USA.

1–4 February, 1990
Combined Sections Meeting of the American Physical Therapy Association, New Orleans, U.S.A.
Information: Information Dept., APTA, 1111 N. Fairfax St., Alexandria, Virginia 22314, U.S.A.

8–13 February, 1990
American Academy of Orthopaedic Surgeons Annual Meeting, New Orleans, U.S.A.
Information: AAOS, 222 South Prospect, Park Ridge, IL 60068, U.S.A.

10 March, 1990
Annual Scientific Meeting of the Association of Prosthetists and Orthotists, Stirling, Scotland.
Information: Gordon Watters, Orthotic Centre, Stracathro Hospital, Brechin, Angus, Scotland.

April, 1990
British Orthopaedic Association Scientific Meeting, Glasgow, Scotland.
Information: BOA, 35-43 Lincoln's Inn Fields, London WC2A 3PN, England.

1-6 April, 1990
6th World Congress on Pain, Adelaide, Australia.
Information: L. Jones, International Association for the Study of Pain, 909 NE 43rd St., Suite 306, Seattle, Washington 98105-6020, U.S.A.

2-6 April, 1990
W.F.O.T. 10th World Congress, Melbourne, Australia.
Information: W.F.O.T. 10th World Congress Secretariat, 1st Floor, 387 Malvern Rd., South Yarra, Victoria, 3141, Australia.

22–25 April, 1990
70th Annual Conference of the American Occupational Therapy Association, New Orleans, U.S.A.
Information: Division of Continuing Education, AOTA, 1383 Picard Drive, Rockville, MD 20850–4375, USA.

22–24 May, 1990
3rd S. M. Dinsdale International Conference on Rehabilitation, Ottawa, Canada.
Information: Education Dept., The Rehabilitation Centre, 505 Smyth Rd, Ottawa, Ontario K1H 8M2, Canada.

15-20 June, 1990
13th Annual RESNA Conference, Washington, U.S.A.
Information: Susan Leone, RESNA, 1101 Connecticut Ave. NW, Suite 700, Washington, DC 20036, U.S.A.