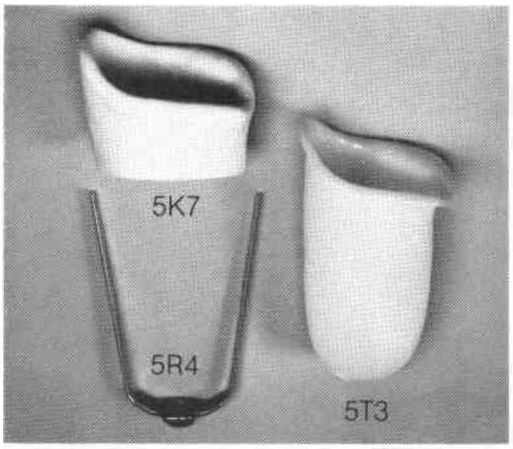
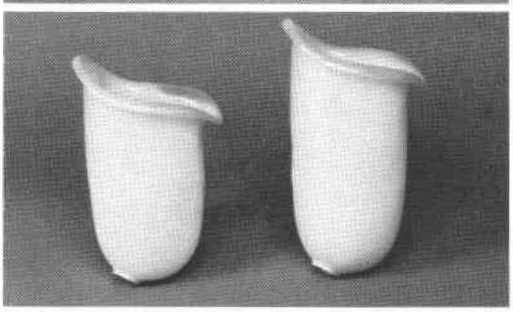
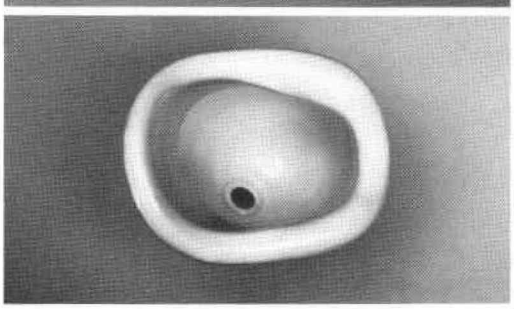
The Journal of the International Society for Prosthetics and Orthotics

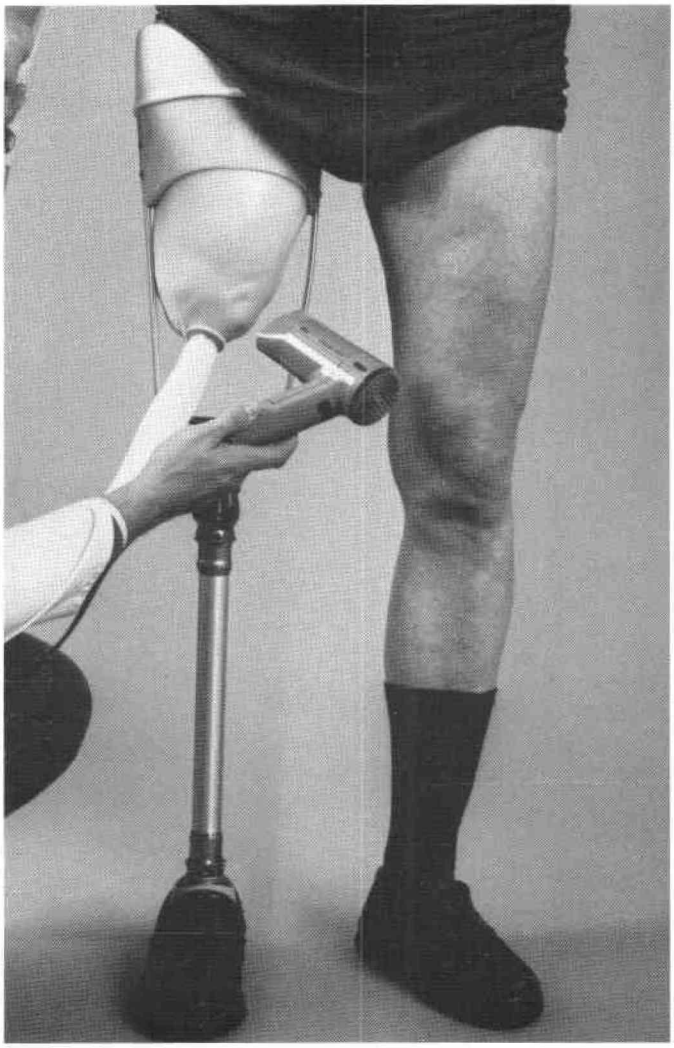
Prosthetics and Orthotics International

December 1986, Vol. 10, No. 3









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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 $50 (U.S.) per annum, single numbers $17 (U.S.). The journal is provided free to Members of ISPO. The subscription rate for Associate Members is $25 (U.S.) per annum. 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

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December 1986, Vol 10, No. 3

Contents

ISPO

Prosthetics and Orthotics International, 1986, 10, 111–113

Editorial

Two Executive Board meetings were held at the time of the World Congress in Copenhagen. The first was the final meeting of the retiring Executive Board and the second was the inaugural meeting of the new Board.

The following paragraphs attempt to summarize the major discussions and conclusions of these meetings. They are based on the approved Minute of the first meeting and the unconfirmed Minute of the second meeting.

Standing Committee and Task Officer Reports

The Chairman of the Finance Committee reported that the Society was in a sound financial position and presented the Budget for 1987. It was indicated that the Board of SAHVA (Society and Home for Disabled, Denmark) had indicated its intention to continue its financial support over the next three years at the rate of 75,000 DKK per annum and that the War Amputations of Canada had decided to continue with a yearly grant of $5,000 (Canadian). It was agreed that the International membership fee should remain at 400 DKK in 1987 and that the subscription rate of the Journal should be increased to $52.50 (US). The Honorary Treasurer was asked to re-examine the level of the Society's contingency fund which at present is 750,000 DKK. A small sub-group of the Board was appointed to examine the possibility of acquiring information processing equipment with regard to accounts, the creation of a professional register, labels etc.

The President reported on the formation of a Chinese National Member Society. Although approaches had been made to other countries regarding the establishment of National Member Societies, no positive results had been achieved over the past triennium. It would appear that strong motivation has to exist within a country in order to succeed in the establishment of a National Member Society. Membership of the Society now stands at 1,850 with, additionally, 400 subscribers to 'Prosthetics and Orthotics International'.

The Society had been involved in a number of activities related to education over the past Triennium which resulted in three meetings held in Moshi, Tanzania; Toronto, Canada and Jonkoping, Sweden. The Report of the Moshi meeting has been published and the Toronto and Jonkoping reports are being prepared for publication. As an outcome of the Jonkoping meeting, it is proposed to hold an ISPO Workshop to consider the requirements for the upgrading of technicians previously trained on short course programmes and at present working in the developing world. A small planning committee has been formed and a firm proposal will be put to the next Board meeting.

The Design and Layout Manual for Workshops in Developing Countries was completed and was in the process of being printed.

The Prosthetics Manual on the Direct Socket Lamination Technique had now been published by GATE (German Appropriate Technology Exchange).

It was agreed that the Editorial Committee should be re-named the Publications Committee. The committee examined the possibilities of producing a volume of selected articles from 'Prosthetics and Orthotics International' and a proposal will be put to the next Board meeting. The committee were also examining the possibility of producing an International Newsletter and would prepare a firm proposal with regard to editors, costs, printing, distribution etc. which it would bring to the next Executive Board meeting.

Sidney Fishman reported on the results of a survey of 90 prosthetists who had attended instructional courses on the ISNY Flexible Socket in New York University. This survey indicated a very favourable response from patients toward this type of fitting. He went on to indicate that promising results were now being achieved at below-knee level. The Executive Board would consider sponsoring courses at below-knee level following the receipt of a formal proposal.

International Organizations

The Executive Board continues to have reciprocal representation with the Board of Directors of INTERBOR and close collaboration was being established between the two Societies. INTERBOR was holding a Congress in June 1987 in Barcelona and the Board agreed to accept an invitation to ISPO to collaborate in this event. Collaboration with INTERBOR at ISPO's Japanese Congress was discussed and it was agreed that their President should represent INTERBOR on the International Congress Committee and that INTERBOR should be invited to nominate four of their members to participate on the International Scientific Committee. Further collaboration was being examined.

It was agreed that the President and Honorary Secretary should communicate with the International Committee of the Red Cross and the World Health Organization with regard future collaboration with these organisations.

The Executive Board is examining the possibility of ISPO participation in the Rehabilitation International Congress to be held in Japan in 1988 and have offered to run a session on "Changes in Prosthetics and Orthotics with regard New Technology". Seishi Sawamura was pursuing these plans with the organizers of the RI Congress on behalf of the Executive Board and would report developments to the next Executive Board meeting. It was agreed that the President and the Honorary Secretary would attend the RI Assembly, to be held in London in October 1986.

Approaches had been made by the Internationaler Verband der Orthopadie-Schuhtechniker (IVO) with regard establishing closer contacts between the two societies. It was agreed that this matter should be pursued.

The Executive Board discussed the proposal from the International Labour Office (ILO) to hold, in the near future, a Pan African Workshop for experts and policy makers in prosthetics and technical aids. It was agreed that the Society should respond in a positive manner indicating its willingness to collaborate in the development of a programme for the workshop by helping to identify experts who could make it a successful event.

The Executive Board had received a plan for prosthetics and orthotics services in Pakistan to be carried out under the auspices of a United Nations Development Programme (UNDP) project in Pakistan. As George Murdoch would be visiting Pakistan on behalf of the Pakistan Orthopaedic Association in the near future, it was agreed that he should use this opportunity to examine this plan in some detail and report back to the Executive Board.

The Society continues contact with other international organisations such as World Orthopaedic Concern (WOC) and the World Rehabilitation Fund (WRF).

World Congresses

The Secretary General of the Copenhagen Congress, J. Steen Jensen, indicated that the Congress had been well attended and that the commercial and scientific exhibition was well supported. A full report would be made at the next Executive Board meeting. The President thanked the Danish organizing committee on behalf of the Society and the Executive Board for the hard work members had put into the arrangements for the Congress.

Seishi Sawamura indicated that arrangements were well underway for the 1989 Congress which would be held in Kobe, Japan. The programme committee will start planning the detailed scientific programme by asking National Member Societies for nominations to the International Scientific Committee and also approaching the National Member Societies for comments on the proposed themes, and suggestions for speakers and instructional courses. In order to save money, it was agreed that the International Congress Committee would meet prior to Executive Board meetings. These would be attended by Seishi Sawamura who would be the link between the Japanese group and the Committee.

No formal invitations for the 1992 Congress had yet been received although some National Member Societies had expressed interest. Those National Member Societies wishing to host the 1992 Congress should be asked to submit formal offers by the end of March 1987.

Future Activities

a) An ISPO Symposium on Traumatic Amputation will be held in Herzilya, Israel from September 6–10 1987.

b) A joint meeting of the ISPO National Member Societies from the Netherlands, Belgium and the Federal Republic of Germany will be held in the University of Gronningen, Netherlands from 28th–30th October 1987. There shall be simultaneous translation into Dutch, English and German. Members from other National Member Societies will be welcomed.
c) A Symposium on the Limb Deficient Child will be held in Heidelberg, Federal Republic of Germany in October 1988.
d) The possibility is being investigated of holding a second workshop on the Deformed Foot in Sweden in 1988.
e) The possibility of the Society collaborating in a conference in the USSR in May 1988 is also being investigated.

Fellowships

The following members have been elected as Fellows of the Society:
William A. Doig (Australia)
Andrew E. Harding (Australia)
Hans Christian Thyregod (Denmark)
Oistein Johansen (Norway)
Penelope J. Anthony (Norway)

Developing Countries

The Honorary Secretary reported on the visit to the school in Lome, Togo following a request for an inspection by ISPO with regard their training of orthopaedic technologists. The Executive Board agreed that the Centre National D'Appareillage Orthopedique, Lome, Togo should be given the Society's recognition for a period of three years, for the training and education of Orthopaedic Technologists as defined within the Society's Education Policy. The Honorary Secretary also reported on a letter from Jordan with a similar request. The Board agreed that this school should be inspected at a suitable date and the possibility of the inspection team offering a seminar or course in the area at the same time should be investigated. A small committee was established which would examine the matter of reduced membership fees for professionals in developing countries. It should report to the next Executive Board meeting.

The Brian Blatchford Prize

The President informed the Board that the Blatchford family has indicated its intention of endowing a sum of £10,000 to ISPO to establish a Trust Fund for a "Brian Blatchford Prize" which would be awarded for the most important innovation in prosthetics and orthotics in the previous three years. Final arrangements have yet to be made with the family. The conditions for the Prize will be published as far in advance as possible of the Japan Congress.

Norman A. Jacobs
Honorary Secretary

Prosthetics and Orthotics International, 1986, 10, 114–116

Hexcelite(R) versus plaster of Paris: a controlled trial of the below-knee walking cast

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Abstract

Hexcelite(R) and plaster of Paris below-knee walking casts were compared in a controlled clinical trial, involving 82 patients.

Fewer bandage complications, problems and better comfort was found with Hexcelite compared to plaster of Paris ($P<0.05$). If all costs relating to materials, transportation, complications and extra visits due to these, were taken into account, plaster of Paris was found more expensive than Hexcelite(R). Based on the above an increased use of Hexcelite(R) is recommended.

Introduction

Over the years various types of plaster of Paris have been developed (Nielsen et al, 1973), as well as alternative bandage materials such as polyurethane and Hexcelite(R) (a thermo-plastic polyester). Of these, Hexcelite(R) has found favour in Danish orthopaedic departments but only as an alternative to plaster of Paris in those special cases where a lighter bandage is indicated, (Nielsen, and Lauritzen, 1981; Rosetzsky, 1982). The argument for not using Hexcelite(R) is mainly based on the work of Nielsen and Lauritzen (1981) who reported that Hexcelite(R) bandages were more expensive and more difficult to apply than plaster of Paris. The authors' experience however, is that there are more bandage complications and problems using plaster of Paris than with Hexcelite(R). As patients treated by using Hexcelite(R) seemed to be more satisfied, the authors' have questioned, whether it really is more profitable, in the long run, to avoid using Hexcelite(R).

A randomized trial was designed, with the aim of comparing Hexcelite(R) and plaster of Paris (Cellona), when used for the most frequently applied bandage in the out-patient clinic, the below-knee walking cast. This weight-bearing cast demands the optimum of material and comfort.

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Patients and methods

During the period 1st January to 31st December 1983, 82 patients in the out-patient clinic took part consecutively in the investigation, having given their informed consent. Excluded from the investigation were patients who were specifically prescribed Hexcelite(R), patients with limited mobility and patients with acute injuries of less than 24 hours—due to post-traumatic oedema. All bandages were applied by random sample by the same technician, who had wide previous experience with plaster of Paris and Hexcelite(R). All bandages were applied according to the manufacturer's instructions.

The number of bandages and application time was recorded, and the patient was given a form, so that technical changes or improvements could be recorded at any subsequent consultation due to complications, as could the appointed removal of the bandage at the clinic. After removal of the bandage, the patients were given a final examination for bandage problems or sequelae, and were interviewed about comfort and activity level.

Eleven out of the 82 patients were excluded, three because of incomplete information, and eight who were lost at follow up. Thus the final material consisted of 71 patients (87 per cent)—34 with plaster of Paris (10♀/24♂) and 37 with Hexcelite(R) (10♀/27♂), mean age 34.8 years, range: 15–70 years.

The 34 plaster of Paris and 37 Hexcelite(R) patients were comparable as far as sex, age, activity level, bandage wearing time (3.9 weeks for plaster of Paris and 4.0 weeks for Hexcelite(R)) and reasons for treatment were concerned. (malleolar fracture, ligamental rupture and rupture of the Achilles tendon).

The results have been prepared statistically with chi-square test and Fischer's exact test.

Results

The mean application time was 20 minutes for plaster of Paris, 21 minutes for Hexcelite(R).

Bandage complications

As seen in Table 1, 46 per cent (16) of the plaster of Paris patients and 19 per cent (7) of the Hexcelite(R) patients (P<0.05) had bandage complications, which were mainly broken plaster of Paris at malleolar level and loose foot plates (seen in both groups). With plaster of Paris, re-application of a complete new below-knee walking cast was often necessary, while most of the Hexcelite cases could be repaired by heating and remodelling.

No patients had thrombo-embolic complications or prolonged bandage time. Complications due to the bandage were seen in 20 per cent (14/71) (Table 2). These were significantly more frequent with plaster of Paris (P<0.05).

Bandage comfort with Hexcelite(R) was found to be significantly better (P<0.01) than with plaster of Paris (Table 3).

Bandage economy

The associated expenses can be divided into the following items:

1) Material costs.
2) Application time.
3) Transportation costs.
4) Costs of extra consultations due to problems/complications.

The average total material cost for Hexcelite(R) was found to be 2.6 times that of plaster of Paris (Table 4). There was no difference in the application time. The

Table 1. Bandage complications
Hexcelite(R) versus plaster of Paris.

Type (T)	Complications (% of T)	No Complications (% of T)	Total (%)
Plaster of Paris	16 (46)	18 (54)	34 (100)
Hexcelite	7 (19)	30 (81)	37 (100)
Total	23 (32)	48 (68)	71 (100)

(p<0.05, Chi square test)

Table 2. Bandage problems
Hexcelite(R) versus plaster of Paris.

	Swelling	Irritation	Abrasion	Sensory loss	Total	Problems (% of Total)
Plaster of Paris (Total=34)	5	3	3	1	12	(35)
Hexcelite (Total=37)	1	0	1	0	2	(5)
Total (nT=71)	6	3	4	1	14	(20)

(p<0.05, Fischer's exact test)

Table 3. Bandage comfort
Hexcelite(R) versus plaster of Paris.

Type (T)	Good (% of T)	Fair (% of T)	Pour (% of T)	Total (%)
Plaster of Paris	17 (53)	11 (34)	4 (13)	32 (100)
Hexcelite	35 (95)	2 (5)	0 (0)	37 (100)
Total	52 (75)	13 (19)	4 (6)	69 (100)

(p<0.05, Fischer's exact test)

Table 4. Bandage economy (DKK)
Hexcelite(R) versus plaster of Paris

	Material costs	Transportation costs	Extra visits	Total cost
Plaster of Paris	83	132	118	333
Hexcelite(R)	218	31	47	296
Ratio (P/H)	1:2.6	1:0.2	1:0.4	1:0.89

transportation costs varied from area to area, so the calculations in Table 4 are based on an average of 241 DKK for stretcher cases, 142 DKK for patients able to sit up in an ambulance and 126 DKK for transportation by taxi.

For extra visits to the clinic or emergency ward a previously calculated cost of 250 DKK (Sonne-Holm and Sørensen, 1977) has been used. When all costs are taken into consideration, Hexcelite(R) expenses were found to be 0.89 times that of plaster of Paris.

Discussion

The results reveal a great number of bandage complications and problems. The reliability of these figures is difficult to evaluate, since the only other reference is Rosetzsky (1982), who found bandage complications in 36 per cent (8/22) of his polyurethane forearm casts. In this trial an attempt has been made to reduce the application bias to a minimum, as all casts were applied by the same professional bandage technician, and the findings seem to confirm the hypothesis that initiated the study, namely that there are more complications and problems with the below-knee walking cast made of plaster of Paris than with Hexcelite(R).

Hexcelite(R) has previously been criticised (Bachmann, 1977; Nielsen and Lauritzen, 1981), because it was found more difficult to apply than plaster of Paris, especially due to the following: 1) It stiffens more quickly than plaster of Paris (after 1 to 2 minutes), which may cause problems in accurate anatomical application. 2) The temperature of the water, 65°C, in which Hexcelite(R) is kept, may cause problems during application. 3) The intermediate plaster tape in the Hexcelite(R) rolls delays application. In practice these criticisms were found to be justified, but experience with the material demonstrates that the disadvantages can be reduced, and the first can be used positively, if only one is aware of it; fast bandage stiffening can be employed for quick anatomical application, without pressure marks. The warm water problems can be reduced by using smooth gloves, careful squeezing out of excess water and covering the part of the patient closest to the bandage with a towel. The intermediate plastic tape can be removed by an assistant. In the new Hexcelite(R) it has been removed.

Another reason for Hexcelite being considered difficult to use, is lack of training and experience in its application. It appears from Nielsen and Lauritzen (1981), that only 18 Hexcelite below-knee walking casts had been applied in a year (and most probably not by the same person).

The material cost of Hexcelite(R) was found to be 2.6 times the price of plaster of Paris, but when expenses for transportation and complications were taken into account, plaster of Paris was found to be 1.13 times more expensive than Hexcelite(R). Furthermore the use of Hexcelite(R) must mean fewer days off work for the patients.

Conclusion

Based on the above results, the Hexcelite(R) below-knee walking cast was found to have significantly better bandage comfort, with fewer complications and problems, was less expensive than plaster of Paris, and thus serves the patient and society best. For these reasons an increased use of Hexcelite(R), is recommended together with research in the area of alternatives to plaster of Paris.

Acknowledgements

Special thanks to bandage technician Verner Rasmussen, without whom this project would not have been possible.

REFERENCES

Bachmann, O. (1977). Erfahrungen mit einem neuartigen Gipseratz-Fixationsmaterial zur Frakturbehandlung. *Ther. Umsch.* **34,** 744–747.

Nielsen, K., Lauritzen, J. (1981). A new thermoplastic casting material. A comparison between plaster of Paris and Hexcelite. *Acta Orthop. Scand.* **52,** 27–29.

Nielsen, J. B., Nielsen, M. L., Sneppen, O. (1973). Plaster of Paris bandages. An experimental investigation of the strengths of different types of plaster of Paris during the drying phase. *Ugeskr. Laeger.* **135,** 1365–1369.

Rosetzsky, A. (1982). Colles fractures treated by plaster of Paris and polyurethane braces: a controlled clinical study. *J. of Trauma.* **22,** 910–913.

Sonne-Holm, S, Sørensen, C. H. (1977). Social costs of sports injuries. *Ugeskr. Læger.* **139,** 2596–2598.

Prosthetics and Orthotics International, 1986, 10, 117–124

Prescription of above-knee and below-knee prostheses

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Abstract

New developments in socket design, materials and fabrication are briefly reviewed. A series of charts is presented which summarize the below-knee and above-knee prescription procedures followed at the Veterans Administration Prosthetics Center.

Introduction

It is the purpose of the authors to present one clinic team's approach to the prescription of above-knee and below-knee prostheses.

Prosthetic prescriptions have varied significantly under relatively similar circumstances from centre to centre, in the experience of the authors. There are many different knee components, prosthetic feet and socket designs available. Modifications of older concepts are continually being added to the armamentarium of the clinic team.

Although the prescription procedures acceptable to the authors appear to have worked well for them and the amputees they serve, they may not be as readily acceptable to others.

If the charted outline of prescription and component selection stimulates discussion and controversy, its purpose will have been accomplished.

Since no two amputees will have the same general physical status, individual stump characteristics, or vocational or occupational problems, a rigid approach is not possible. In some instances, climate, terrain and cultural differences will also affect the prescription. A basic concept, however, with an understanding of such individual restrictions, is presented in this paper.

It is challenging and of continuing importance that new techniques are being tested in various centres throughout the world. Many of these are logical and promising and will undoubtedly, after adequate testing, become firmly established tools of the prosthetist.

Until, however, they have been widely used by a sufficient number of prosthetists other than the developers, and the reports of their experience become available, a final judgement must be held in abeyance.

The newer developments which the authors have recently adopted have prompted them to revise an earlier presentation outlining their clinic team's approach to the selection of components for lower limb prostheses (Rubin and Fischer, 1982).

The format employed in the previous article has been used here with pertinent chart and text modifications to reflect changing attitudes in specific instances. The authors have been very conservative in developing the charts and have preferred to include in the text advances in prosthetics which are still not universally employed rather than in the charts, per se. These include such potentially significant developments as the "Scandinavian Flexible Socket" (Jendrzejczyk, 1985) the "Normal Shape-Normal Alignment" above-knee prosthesis (NSNA) (Long, 1985) and the "Contour Adducted Trochanteric Controlled Alignment Method" (CAT-CAM) (Sabolich, 1985), among others. The authors' experiences with the Scandinavian flexible socket have been quite positive. The amputee's response to the action and cosmesis of the Seattle foot (Burgess et al, 1984), also a recent development, has been generally favourable. There are problems, as with everything new, which will undoubtedly be eliminated by the developers. The very active amputee still experiences too frequent breakage. With the advent of the Seattle foot, other feet incorporating the stored energy concept are continually becoming commercially available. There is, incidentally, some similarity in this concept to the shoe with the addition of a long steel spring and rocker bar that is advisable in orthotics when a solid ankle orthosis is used.

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Another foot-ankle that has not yet had broad acceptance is the Mauch hydraulic ankle. This centre was involved in the initial testing of the Mauch ankle, in spite of which it has had limited experience with it. It does have capabilities that other feet do not have, such as adjustability to the terrain when walking up and down-hill. There had been a frequent malfunction problem with this device which limited the frequency of prescription. The authors look forward to gaining experience with the new, lighter, and, presumably sturdier version. It promises to be a very sophisticated ankle.

Xeroradiography(R) (Varnau et al, 1985), has been introduced to prosthetics, but the authors have viewed the routine use of this technique with caution, because the radiation dosage is nine times as high as with routine X-ray exposure and "Syme level as well as long above-knee residual limbs require two pictures merely to complete the image for one projection" (Varnau et al, 1985). If two projections each of an antero-posterior and a lateral view are employed, the basic dosage will be nine times the routine X-ray dosage, quadrupled. A good deal of useful similar information is obtainable with the clear socket method and the occasional use of routine X-ray when specifically indicated (and after consultation with the physician member of the Clinic Team). From the medical point of view excess exposure to radiation should be limited unless no other reasonable alternative exists. Varnau et al (1985) do indicate their concern for the juvenile patient and advise that the "benefits of Xeroradiography(R) must be weighed against the greater radiation dose". It is suggested that this cautionary approach be broadened to include adults as well.

Above-knee amputation socket design is undergoing dramatic evolutionary changes at this time. The reports of Lehneis (1985) Long (1985) and Sabolich (1985) are most significant in this regard. The CAT-CAM of Sabolich and the NSNA of Long have had extensive testing by the originators, and Lehneis, in cooperation with the U.S. Veterans Administration, is at present engaged in investigating the special design indications for the geriatric amputee's socket.

Currently, many other prosthetists are learning and using the CAT-CAM system. Their reports, when available, will make an important contribution to the acceptance of this method.

Similarly, below-knee sockets are being fabricated with flexible plastic at several centres and this concept also appears to have merit. Sidney Fishman and his group at NYU in conjunction with the U.S. Veterans Administration are also involved in exploring the use of a frame and socket configuration for the B/K.

CAD-CAM (Computer Aided Design — Computer Aided Manufacture), a sophisticated approach to the eventual increase in speed of production of prostheses has been under development by several prosthetic centres.

As Murdoch (1985) has indicated the "individual prosthetist will be able to fit more patients in a given time", but his clinical experience and expertise will be required to modify the CAD-CAM product.

The enthusiasm for acronymic description of prosthetic techniques has led to the identification of the "Icelandic Roll-On Suction Socket" as the Ice-Ross system (Kristinsson, 1985a) and the "Icelandic Pull-On Suction Socket" as the Ice-Poss system (Kristinsson, 1985b). Both of these systems employ injection moulded sockets to achieve B/K suction and both are not widely accepted by prosthetists. Because the designs referred to above are still undergoing changes (Sabolich is preparing a new report on a procedure he designates as SCAD-CAM) they have not been included in the basic charts which are part of this paper.

Summary

A series of charts has been presented summarizing the above-knee and below-knee prescription procedures which have been followed at the Veterans Administration Prosthetics Center. There is a very significant evolution in socket design, materials, and fabrication which everyone involved in prosthetics is observing carefully. However, new developments do require extensive trial before becoming universally accepted and these new developments are undergoing such a trial at present. "It would be a truism to point out that some of the devices categorized as research items at the time of this writing will no longer be considered to be such by the time this book *(sic)* is published. Some will be accepted and others discarded" (Rubin and Wilson, 1981).

BELOW–KNEE AMPUTATION

STUMP LENGTH (From medial tibial plateau)	MODIFYING FACTORS	PROSTHESIS	SUPENSION	FOOT/ANKLE UNIT
10 cm. to above Syme level	No stump problems	After stump has matured following use of temporary prosthesis, PTS is preferred–PTB is second choice	1. For PTB, cuff type (if snug suprapatellar suspension cannot be tolerated, or additional security needed, waist belt and auxiliary anterior suspension strap should be added) 2. Wedge, as below, for PTS	1. SAFE foot as first choice 2. SACH foot as second choice 3. See text concerning Seattle and Single Axis feet.
4 cm. to 10 cm.	No stump problems	PTS, or if 4 cm. to 7 cm. PTS-SP (Patellar Tendon Supracondylar, Suprapatellar)	1. Soft insert with built-in wedge, first choice 2. Removable wedge or removable medial wall, second choice	As above
Either of above	1. Unstable knee 2. Occupational considerations requiring maximum stability 3. Short BK stump and contralateral limb problem, such as AK amputation.	Thigh corset side joints prosthesis	Thigh corset Waist belt and fork strap if needed	1. SACH as first choice 2. Single axis, second choice
Any length	Extremely hypersensitive soft tissue unable to tolerate pressure (prior to removing a patient in this group from any of the above categories, a trial of a gel socket should be made)	Prosthesis should be fabricated with quadrilateral socket, freely suspended stump, double bars to distal shank segment and SACH foot. A knee lock or offset knee joints should be used. This will be an A/K prosthesis	Flexible plastic hip joint and pelvic band, with belt	Single axis
Any length	Stump problems which are not as severe as above (amputee can tolerate limited pressure, but trial of a PTB or PTS with gel socket has failed)	Gluteal or ischial bearing thigh corset, side joints at knee, and socket with soft insert.	Thigh corset Waist belt and fork strap if needed	1. SACH as first choice 2. Single axis second choice
4 cm. to 10 cm.	Flexion contracture up to 30° (a longer stump, or one with a greater contracture cannot be fitted with a BK prosthesis)	PTS	Supracondylar	SACH
4 cm. to 10 cm.	Flexion contracture greater than 30°,	Bent-knee Prosthesis (highly undesirable but may be only option)	Molded plastic laminate thigh socket with velcro closure, lacing, or distal anterior window, or medial window	1. SACH as first choice 2. Single axis second choice

ABOVE-KNEE AMPUTATION–PHYSIOLOGICAL AGE: ACTIVE						
STUMP LENGTH (From Ischial tub.)	SOCKET	SUPENSION	KNEE	KNEE STABILIZATION	STRUCTURAL TYPE	ANKLE-FOOT UNIT
From 5 cm. to above flare of femoral condyles	1. Total suction for the young, active, adult amputee 2. Partial suction for the older amputee if this is an initial fitting. If older amputee has previously used total suction then continue. 3. Non-suction if failure of 1. and 2. (For the amputee with a very short residual limb high lateral and anterior walls should be used, preferably with total suction and auxiliary suspension	1. Suction (see socket column) – total or partial 2. For partial suction, auxiliary support is needed: a. Rigid metal hip joint, waist band and belt for very short stump. b. plastic joint and waist band with belt if amputee has adequate hip control and stump is at least 12 cm. or longer. c. Silesian belt for longer stump. 3. Non-suction: –auxiliary support as above.	1. Fluid control preferred. 2. Single axis as second choice	1. If SNS is used, then stability achieved by the special stabilizing function and fluid flow characteristics of the unit, plus proper alignment. 2. If fluid control units other than SNS are used, stability is achieved by fluid flow characteristics of the unit, plus proper alignment 3. If a single axis unit is used, stability is achieved by alignment	1. Either Exoskeletal or Endoskeletal if knee unit selection not in doubt. (Subjective choice of amputee) 2. If knee unit selectior is in doubt then Universal, Knee-Shin Set-up, or multiplex, to allow trial of various units.	1. SAFE foot as first choice 2. SACH as second choice Single Axis foot as third choice Refer to comments in text concerning Seattle foot
Approximately 5 cm.	1. If stump soft tissue is bulky, assign to less than 5 cm. category, below, and treat as a hip disarticulation. 2. If stump soft tissue is lean and problem-free, assign to 5 cm.+ category, above, and treat as an above-knee amputation.					
Less than 5 cm.	Treat as hip disarticulation with molded socket	Socket contoured to achieve pelvic suspension	1. Low resistance hydraulic or pneumatic unit as first choice 2. Single axis as second choice	weight-activated knee preferred	Exoskeletal or Endoskeletal	Single axis
Trans-condylar (femoral)	Partial end-bearing without suction	1. Soft insert with supra condylar suspension as first choice 2. Waist belt as second choice a) plastic hip joint, waist band and belt if hip is stable b) metal hip joint, waist band and belt if hip control is inadequate	1. Four-bar linkage with fluid control as first choice 2. Single axis with outside joints only if amputee is habituated to this system and refuses change	1. The four-bar linkage unit's stability is based upon the geometry of the unit plus proper alignment. 2. The stability of the single axis knee is achieved by alignment (Single axis hydraulic if amp does not object to comesis)	Exoskeletal or Endoskeletal	Same choices as in 1st category, above

ABOVE-KNEE AMPUTATION– PHYSIOLOGICAL AGE: LIMITATION OF ACTIVITY						
STUMP LENGTH (From Ischial Tub.)	SOCKET	SUSPENSION	KNEE UNIT	KNEE STABILIZATION	STRUCTURAL TYPE	ANKLE-FOOT UNIT
From 5 cm. to above flare of femoral condyles	Partial suction (open end if above contra- indicated by stump problems or rigid habit pattern)	1. Rigid metal hip joint and waist band, with belt, for short stump or weak hip muscles. 2. Flexible plastic hip joint and waist band, with belt, for longer stump and stable hip.	1. Low resistance fluid control as first choice 2. Single axis knee as second choice	1. If fluid control is used then stabilization is achieved by fluid flow characteristics and alignment 2. If single axis is used then stabilization is achieved by alignment. (weight-activated lock may be added if needed)	Endoskeletal lightweight Titanium components as first choice Exoskeletal as second choice	1. If stump is short, single axis as first choice (SACH as second). 2. If stump is of intermediate length, or long, SACH as first choice (single axis as second) 3. Single axis for the blind amputee
Approximately 5 cm.	1. If stump soft tissue is bulky, assign to less than 5 cm. category, below, and treat as hip disarticulation. 2; If stump is lean and problem-free, assign to 5 cm.+ category, above, and treat as AK amputation.					
Less than 5 cm.	Treat as hip disarticulation with molded socket	Achieve by molding socket over the pelvis.	Single axis	Stabilization achieved by alignment	Endoskeletal See Above	Single axis
Trans-condylar (femoral)	Partial end-bearing. No suction.	1. If hip control is unimpaired, then flexible soft socket insert with supracondylar suspension 2. If rotational hip control needed, then Silesian belt. 3. If moderate hip control needed, but retention of limited motion is desirable, then flexible plastic hip joint and band, with belt. 4. If hip control is poor, (weak muscles) then metal hip joint and waist band with belt.	1. Four-bar linkage knee without hydraulic as first choice 2. Outside knee joints, single axis, as second choice	1. Stability of the four-bar linkage is dependent upon the geometry of the unit 2. Stability of the single axis is dependent upon alignment.	Endoskeletal See above	1. SACH as first choice 2. Single axis as second choice

ABOVE-KNEE AMPUTATION–PHYSIOLOGICAL AGE MARKED LIMITATION OF ACTIVITY Household Bathroom						
STUMP LENGTH (From ischial tub.)	SOCKETS	SUSPENSION	KNEE	STABILIZATION	STRUCTURAL TYPE	ANKLE-FOOT UNIT
From 5 cm. to above flare of femoral condyles	1. Partial Suction as first choice 2. Open end if partial suction contraindicated by status of stump, or if amputee is habituated to open end socket and refuses change	Metal hip joint and band, with belt	Single axis	Stability of knee achieved by alignment, and, if needed, a weight-activated lock; or a manual lock may be added to provide adequate stability	Endoskeletal Titanium 1st choice. Exoskeletal. 2nd choice	Lightweight SACH or single axis
Approximately 5 cm.	1. If stump soft tissue is bulky and amputee is considered to have the potential for utilizing the prosthesis for household or bathroom ambulation, or limited exercise purposes, then assign to less than 5 cm. category, below, and treat as hip disarticulation. 2. If stump soft tissue is lean and problem-free, assign to 5 cm.+ category, above, treat as AK amputee and consider addition of hip lock, as well.					
Less than 5 cm.	Molded pelvic socket as for hip disarticulation (see 1. immediately above)	Achieved by molding socket over pelvis	Single axis	1. Knee stability achieved with manual knee lock. 2. Hip stability achieved with stride control hip lock.	Titanium, 1st choice, Exoskeletal 2nd choice	Single axis or Sach See above
Transcondylar (femoral)	Partial end-bearing. No suction	Metal hip joint and band, with belt	Single axis	1. Weight-activated lock preferred 2. A manual knee lock should be used if indicated by the clinical status of the amputee	Either endoskeletal or exoskeletal (patient preference)	Single axis or Sach See above

KNEE DISARTICULATION					
MODIFYING FACTORS	SOCKET	KNEE	SUSPENSION	STRUCTURAL TYPE	ANKLE–FOOT
1. Unmodified stump with or without retention of retracted patella, and no stump problems 2. Gritti-Stokes amputation	End-bearing, as well as support provided at all aspects of the stump-socket interface by well-contoured fit.	1. Single axis hydraulic knee preferred if amputee does not object to cosmesis. 2. Four bar linkage hydraulic 2nd choice 3. If amputee refuses change then outside joints	1. Soft socket insert fabricated to achieve supracondylar suspension as first choice. 2. Flexible plastic hip joint and band, with belt, as second choice, or Silesian belt.	Either Endoskeletal or Exoskeletal	1. Safe foot 1st. choice 2 Sach foot as second choice 3. Single axis as third choice
Stump modified by removal of medial and lateral condylar prominences	As above. If potential for end-bearing is limited, then include quadrilateral socket with proximal support.	As above	1. Supracondylar suspension not adequate Use flexible plastic hip joint and band, with belt, or Silesian belt (see above)	As above	As above
As above but cannot tolerate end-bearing	As above	As above	As above	As above	As above
Bilateral knee disarticulation	As in the appropriate category, above	1. SNS knees preferred. 2. Single axis with outside knee joints only if amputee will not accept fluid control (*bilateral* four-bar linkage knees difficult to manipulate since knees must be un-weighted to allow sitting).	As above	As above	As above

REFERENCES

Burgess, E., Hittenberger, D. A., Carpenter, K. L. (1984). The VA Seattle foot. In: Veterans Administration Rehabilitation R & D Progress Report, p5.

Jendrzejczyk, D. J. (1985). Flexible socket systems. *Clin. Prosthet. Orthot.* **9(4),** 27–31.

Kristinsson, O. (1985a). The Ice-Ross System (abstract) *AOPA Almanac* **33(10),** 50.

Kristinsson, O. (1985b). The Ice-Poss System (abstract) *AOPA Almanac* **33(10),** 57.

Long, I., A. (1985). Normal shape-normal alignment (NSNA) above-knee prosthesis. *Clin. Prosthet. Orthot.* **9(1),** 9–14.

Lehneis, H. R. (1985). Beyond the quadrilateral. *Clin. Prosthet. Orthot.* **9(4),** 6–8.

Murdoch, G. (1985). Editorial *Prosthet. Orthot. Int.* **9,** 1–2.

Rubin, G., Fischer E. (1982). Selection of components for lower limb amputation prostheses. *Bull. Hosp. Joint. Dis. Orthop. Inst.* **42,** 39–67.

Rubin, G., Wilson, A. B. (1981). Research trends in lower limb prosthetics. In: American Academy of Orthopedic Surgeons. Atlas of Limb Prosthetics. St. Louis, MO: C.V. Mosby, p 435–439.

Sabolich, J., (1985). Contoured Adducted Trochanteric — Controlled Alignment Method (CAT-CAM): Introduction and basic principles. *Clin. Prosthet. Orthot.* **9(4),** 15–26.

Varnau, D., Vinnecour, K. E., Luth, M., Cooney, D. F. (1985). The enhancement of prosthetics through Xeroradiography[R]. *Orthot. Prosthet.* **39(1),** 14–28.

Prosthetics and Orthotics International, 1986, 10, 125–128

Below-knee amputation in patients with vascular disease and prosthetic fitting problems

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Abstract

A study was made of 544 cases with lower limb deficiencies caused by obliterative diseases; 262 cases were below-knee amputees. Of these, 106 (40%) were amputees transferred from other clinics for prosthetic fitting; in 156 cases (60%) the amputations were performed in the Institute.

Amputations were carried out using one of two techniques according to the state of arterial and collateral circulation. The posterior flap below-knee amputation (Burgess, 1969) was employed in 94 cases, the other 62 amputations were carried out using a modification of that technique which was characterized by the formation of a musculo-fascia-cutaneous flap.

The stump wound healed by first intention in 127 patients (81.4%), by second intention in 18 (11.5%) and in 11 cases (7.1%) the wounds failed to heal.

Successful prosthetic fitting and walking training was achieved in 91.3% of amputees and 67.2% were returned to productive work.

Introduction

This paper presents the results of treatment and prosthetic fitting of below-knee amputees with limb deficiencies resulting from obliterative vascular diseases.

A study was made of 544 cases with lower limb deficiences caused by obliterative diseases; 262 cases were below-knee amputees: of these 106 amputees (40%) were transferred from other clinics for prosthetic fitting and in 156 cases (60%) the amputations were performed in the Ukurainian Research Institute.

Most of below-knee amputees in the group with obliterative enderteritis ranged from 30 to 40 years old and in the group with atherosclerotic occlusions and diabetic angiopathy from 60 to 70 years old.

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Gangrene often combined with secondary infection; acute intoxication with developing limb ischaemia; established rest pain together with demonstrable progressive ischaemia; ineffective conservative treatment or reconstructive surgery were considered as indications for amputation (Fig. 1).

Patient examination

Pre-operatively patients were thoroughly examined by means of both clinical and ancillary techniques. The results showed that patients with obliterative vascular diseases exhibit considerable changes in the blood coagulant system leading towards increasing coagulability and depression of fibrinolysis.

On the first post-operative day hypercoagulation increased in the said category of patients. By the fifth day the decrease of coagulability and the increased fibrinolysis activity could be observed although the main

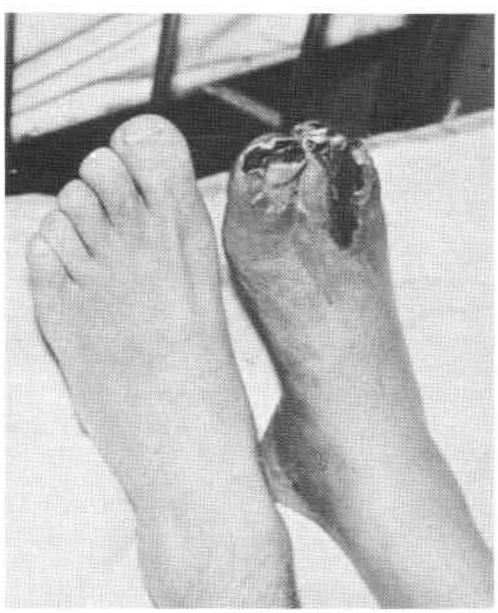

Fig. 1. Indications for amputation-gangrene of the distal portion of the foot.

characteristics shown in the coagulogram still tended towards hypercoagulation. By the tenth day after the operation the coagulogram tended to be normal.

The results of medical examination indicated that the degree of the above mentioned changes were coincident with the severity of clinical manifestations and the tendency to hypercoagulation increased with the age of the patients.

When comparing coagulogram dynamics of different nosologic types it was observed that the most severe coagulation system disorders occurred in those patients with obliterative atherosclerosis in the older age groups.

Furthermore, the exhaustive clinical examination indicated significant immunological changes in most patients; they exhibited considerable immune reaction deficiency. To increase their resistance, passive and active immunization were carried out by means of staphylococcal gamma globulin and anatoxin injections. Patients received general care along with detoxicating, desensibilizing, sedative and vitamin treatment.

Amputation technique

Special attention was paid to level selection and amputation technique. The level of limb amputation was selected with respect to objective results of angiography, thermography, reovasography, capillaroscopy which were assessed together with the clinical evidence.

For selection of the amputation level consideration was given to both the location of the artery occlusion and the degree of collateral circulation development. Having considered the results of a comprehensive examination amputation was performed at the level showing sufficiently developed collaterals, e.g. in case of developed collateral circulation at knee joint level amputation was carried out in the upper third or quarter of the shank and the post-operative wound healed by first intention. Amputations were carried out by one of two techniques according to the state of arterial and collateral circulation. The first technique employed was the posterior flap below-knee amputation as described by Burgess (1969) and 94 (60.2%) below-knee amputations were performed using this technique. The remaining 62 (39.8%) amputations were carried out using a modification of that technique, developed at the

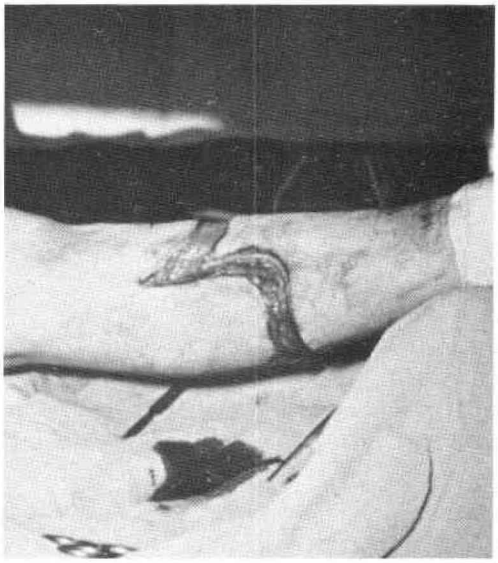

Fig. 2. Formation of posterior musculo-fascia-cutaneous flap; incision of the cutaneous and fascial tissues.

Institute, which was characterized by forming a musculo-fascia-cutaneous flap (Fig. 2).

It was observed that the surface layer of the below-knee posterior muscle group suffered less. Accordingly dissection was carried out up

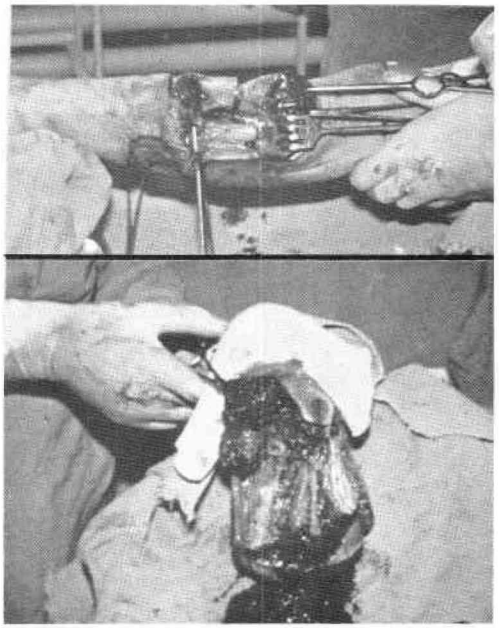

Fig. 3. Top, cutting of muscles, tibia and fibula. Bottom, shaped posterior musculo-fascia-cutaneous flap.

to the level of the residual bone in the case of both anterior and lateral muscle groups, the deep layer of the posterior group and the soleus muscle from the surface layers (Fig. 3). In a number of cases with insufficient circulation the major portion of the anterior and lateral shank muscle groups were excised and a thin musculo-fascial flap with viable circulation was formed. The fibula was frequently eliminated. Only the better vascularized inner portion of the musculus soleus was saved. The shaped, cut and thinned posterior musculo-fascial flap was sutured under slight tension to the thinned antero-lateral musculo-fascial flap fully covering the residual bones (Fig. 4). The subcutaneous cellular tissues and skin were secured with interrupted sutures. The wound was drained. Amputation was performed without tourniquet to spare the tissues. This technique makes it possible to construct a short below-knee stump, preserve knee joint function and increase the range of prosthetic functions.

In the post-operative period much attention was paid to prevention of post surgical complications, improvement of the general condition of a patient and the stump circulation.

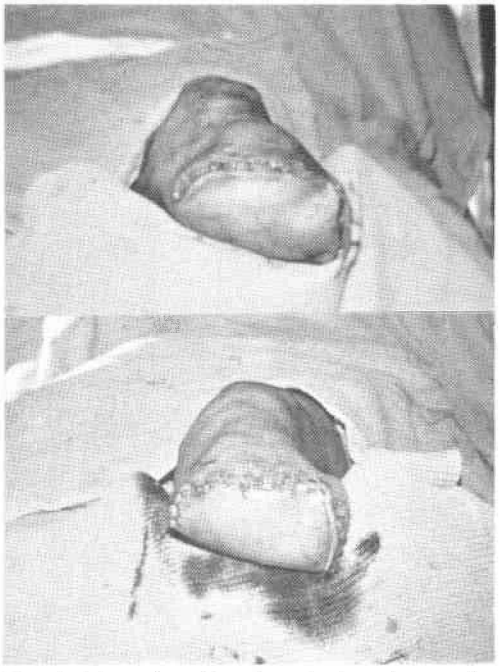

Fig. 4. Top, the thinned and shaped posterior musculo-fascial flap is sutured to the thinned antero-lateral musculo-fascial flap. Bottom, cutaneous sutures.

Post-operative treatment results indicated that the stump wound healed by first intention in 127 patients (81.4%), by second intention in 18 (11.5%) and in 11 cases (7.1%) wounds failed to heal.

This method of below-knee amputation permits preservation of the knee joint in those ischaemic cases when it is otherwise usually recommended to amputate at the above-knee level.

Prosthetic fitting

Prosthetic fitting is started within one or two weeks after taking out the stitches. To speed up the process of stump shaping physiotherapy techniques as well as exercise therapy and phantom pulse gymnastics are applied.

Temporary prostheses are employed and to manufacture these prostheses the same standard units and pre-fabricated parts as in permanent prostheses are used. Only the socket, which is changed as required with changing stump volume, is temporary. Once walking skills are mastered, stump volume stabilized and the gait pattern optimized fitting of a permanent prosthesis is then started.

In most cases (78.2%) below-knee PTB-type prostheses with a rigid receptacle socket are prescribed. The sockets are fabricated of gauze and polyamide lacquer, and metal-polymer

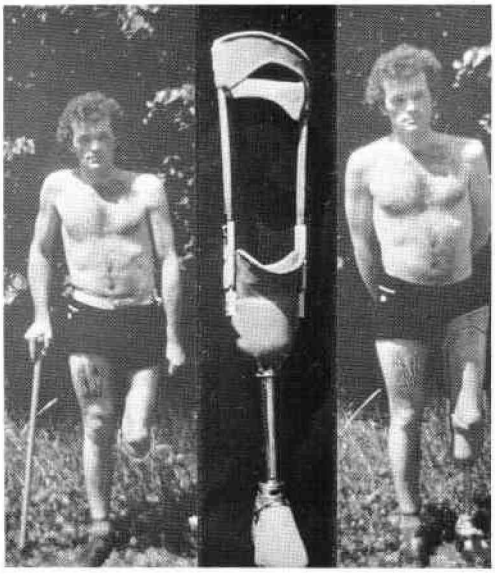

Fig. 5. Left, patient with short below-knee stump. Centre, prosthesis with thigh piece and ischial tuberosity bearing. Right, patient wearing prosthesis.

sockets are made of reinforced polyethylene and fitted into a modular prosthesis.

For the below-knee stump in the upper third the socket has to encompass the patella. In short painful stumps with trophic disorders the below-knee prostheses with a thigh piece and ischial tuberosity bearing is prescribed (Fig. 5). In certain cases a suspended leather socket for the below-knee stump may be used. In short below-knee stumps with persistent permanent flexion contracture shin prostheses for flexed knee are fabricated.

Special attention was paid to the receptacle socket fabricated individually by means of the negative plaster mould. The area of the patellar ligament, the patella, the head of the fibula, the condyles of the femur and the tibia, and the tibial tuberosity were all carefully highlighted. Total contact sockets which could be cushioned if necessary by a layer of foamed polyethylene were employed.

Results

In spite of the many problems so often encountered with this category of patients, amputation at the below-knee level was achieved in 58.9% of patients. Successful prosthetic fitting and walking training was achieved in 91.3% of amputees and 67.2% were returned to productive work. The results obtained in the above mentioned patients depend not only upon the quality of prosthetics but to a considerable extent are dependent on the general condition of the patient, the rate of progress of the disease process, the extent of circulation disorders both in the stump and in the contralateral limb as well as on the energy demands on the body in the use of the prosthesis and the level of function achieved.

REFERENCES

BURGESS, E. M. (1969). The below-knee amputation. *Inter. Clin. Inf. Bull.* **8(4),** 1–21.

Prosthetics and Orthotics International, 1986, 10, 129–134

Running patterns of transfemoral amputees: a clinical analysis

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Abstract

The challenge of rehabilitating young, healthy transfemoral amputees may extend beyond the boundaries of teaching them to adapt to functional activities of daily living. The goal for several of these amputees is to participate and sometimes even compete in recreational activities, including running. These amputee runners require prosthetic adaptations as well as a comprehensive individualized training programme to ensure that their running is as safe and energy efficient as possible. To help amputees achieve this, clinicians must understand normal and prosthetic locomotion. This paper compares the biomechanical differences between walking and running in normal locomotion and analyses the running modes used by transfemoral amputees. The modified running mode achieved with the Terry Fox Running Prosthesis subjectively "looks" more energy efficient to the observer and "feels" more energy efficient to the user. These assumptions have yet to be confirmed or refuted by a rigorous scientific research study. An outline of the proposed physiotherapy protocol includes the familiarization, treatment, and training phases. Physiotherapists involved in amputation rehabilitation may not be commonly confronted with this level of patient expectation. It is their responsibility to give realistic guidance to these amputees so that they can safely and independently pursue their recreational running activities. This need can best be fulfilled by providing sound clinical advice which has been validated by research findings.

Introduction

The performance of athletic skills is enhanced by the development of an individualized training programme which will condition the body and minimize the possibility of sports injuries, and by the selection of appropriate prosthetic components. These considerations will assist the amputee in accomplishing the specific physical requirements unique to each chosen sport.

Many sports, such as volleyball and basketball, require running, stride-jumping or hopping on one leg. Mastering these skills presents problems for many amputees because of the sudden ground impact which causes stump discomfort. Some transtibial amputees compensate by cushioning the forceful impact, using excessive hip and knee flexion. However, transfemoral amputees are unable to do this. During running, they must deviate from the normal running pattern by using a hop-skip running cycle (Mensch and Ellis, 1984). When using the hop-skip method an extra hop with the sound leg is introduced into the running cycle.

To facilitate more natural, safe and energy efficient prosthetic running for these higher level amputees, one must understand the differences between the running and walking cycles, assess amputees running modes and relate these findings to the prosthetic and physical training requirements.

The characteristics of walking and running

In the normal, the main difference between walking and running is the leg support pattern.

Walking

Walking involves a period of double support, when the swing leg has reached ground contact and the support leg has not yet advanced into swing (Fig. 1, top). The stance phase entails 60% of the cycle and the swing phase 40% (Perry, 1967); Hughes and Jacobs, 1979; Inman et al, 1981; Vaughan, 1984). On the average, energy requirements are moderate, as most persons utilize a walking speed which is comfortable for their cardio-vascular system (English, 1981; Inman et al, 1981).

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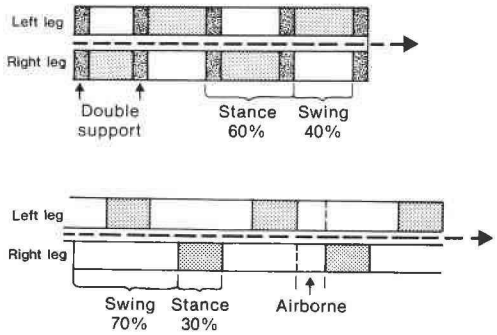

Fig. 1. Schematic representation of walking cycle (top) and running cycle (bottom).

Running

Running records an instant where both legs are simultaneously off the ground (Wells, 1971; Hughes and Jacobs 1979; Brody, 1980). This is the "airborne" phase which occurs following push off and ends with heel contact of the opposite leg. The increase in velocity during running results in a change in the distribution of time for stance and swing during the cycle. The running cycle then consists of about 30% stance phase and 70% swing phase (Fig. 1, bottom), and as well, the duration of the running cycle is shorter compared to the walking cycle (Brody, 1980; Vaughan 1984).

During running, step length, joint angulation and axial rotations increase. Joint angulations and axial rotations serve several functions during running. They—

cushion the ground impact

help to make running smooth and rhythmic

decrease the vertical displacement of the centre of gravity thus contributing to energy efficiency (Inman et al, 1981; Man and Hagy, 1980)

provide a balanced muscle length-tension and force-velocity relationship (Soderberg, 1983) thus assisting the forward acceleration of the body in the pushoff phase

increase momentum.

Foot functions are enormously intensified during running, compared to walking. Heel contact occurs with forceful impact. Brody (1980) states that the runner "collides" with the ground. During mid stance the foot must hold the body over flexed joints and must provide a powerful pushoff to produce the main acceleration thrust. The intensified muscle work, needed for running, increases energy requirements (Inman et al, 1981).

The characteristics of walking and running—transfemoral amputees

Transfemoral amputees must adapt to—

the functional loss of the knee, ankle and foot

the unequal body weight distribution which results from the unilateral weight loss

the initial disturbance in coordination and proprioception which affects balance (Mensch and Ellis, 1986).

When walking with a prosthesis they experience limitations in movement control and are acutely aware of the weight of the prosthesis. All of these factors affect the gait pattern.

Walking

Transfemoral amputees walk with an unnatural and stiff gait. This occurs because the natural axial rotation of tibia and fibula in relation to the knee and the foot is absent and because prolonged, active stump hip extension is required to maintain prosthetic stance stability (full knee extension) (Mensch, 1983). When compared to the position of the natural knee during the same phase within the gait cycle (slight knee flexion), the biomechanical difference and the effect on gait synchronization is evident.

Transfemoral amputees may adapt by demonstrating a variety of gait deviations and by keeping their energy output at a comfortable level by walking at a slower pace (English, 1981).

Running

For several reasons, amputees fitted with a standard transfemoral prosthesis are unable to use a normal running pattern—

prosthetic heel contact is forceful and occurs without the support of the sound leg

the ground reaction force responds with equal intensity to the impact and thus creates a strong prosthetic knee flexion moment (Fig. 2).

the prosthetic knee is further forced into flexion by forward momentum

the hip is unable to exert a sufficient extension moment to counteract prosthetic knee flexion

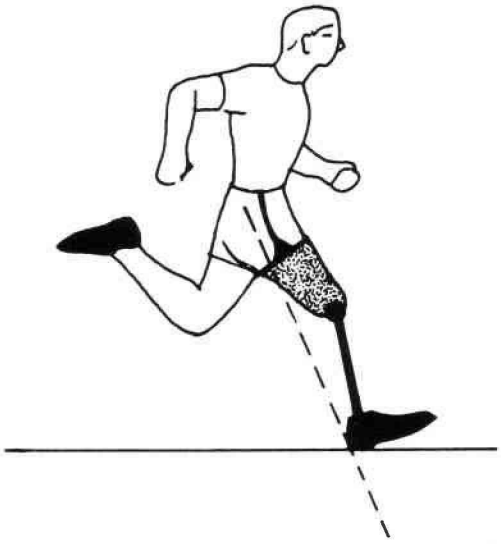

Fig. 2. Prosthetic knee flexion moment using 'normal' running pattern.

Fig. 4. Position of prosthesis at heel contact using hop-skip method.

Transfemoral amputees adapt by running with a hop-skip style. This cycle (Fig. 3) records a double stance phase (with the sound leg taking on an extra hop) and a prosthetic swing phase. The "airborne" phase occurs during the hop. There is a short period of double support when the legs alternate from stance to swing. The extra hop makes modified running possible. The hop occurs as a result of forward momentum and provides time to complete the prosthetic swing phase. This prosthetic swing may not be fast enough for running because forceful prosthetic pushoff can cause excessive heel rise which then results in a delay in swing completion.

The hop also decreases the distance between both legs when heel contact occurs (Fig. 4). The short period of leg double support, combined with the less acute angle of the limb at heel contact and the decreased impact at heel contact, permits controlled weight transfer to the prosthesis and reduces the intensity of the prosthetic knee flexion moment. The amputee is, thus, able to use stump hip extension functionally to continue running.

Running speed is produced by intense muscle work which is mainly generated by the sound leg and facilitated by excessive arm and trunk work. The running pattern is arrhythmic, abrupt and highly energy consuming (Inman, et al, 1981).

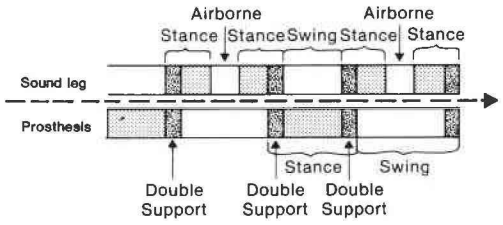

Fig. 3. Schematic representation of hop-skip cycle.

Running with a Terry Fox Running Prosthesis*

The components of the prototype of the Terry Fox Running Prosthesis (Fig. 5, left) include—

a flexible or a conventional quadrilateral suction socket with the addition of a Silesian band. This auxiliary suspension is necessary to reduce stump tissue rotation which, if present, can hinder running

a polycentric knee mechanism which provides stance and swing phase control

a precompressed heavy duty spring mechanism which, fitted into the shank section, absorbs ground impact and, temporarily, stores energy

a Greissinger foot, with, in addition to dorsiflexion, plantar flexion, inversion and

*Terry Fox, the first Canadian amputee cross-country runner, had the idea of fitting a telescoping mechanism into the shank of his prosthesis but, due to his untimely death, was unable to develop this idea further.

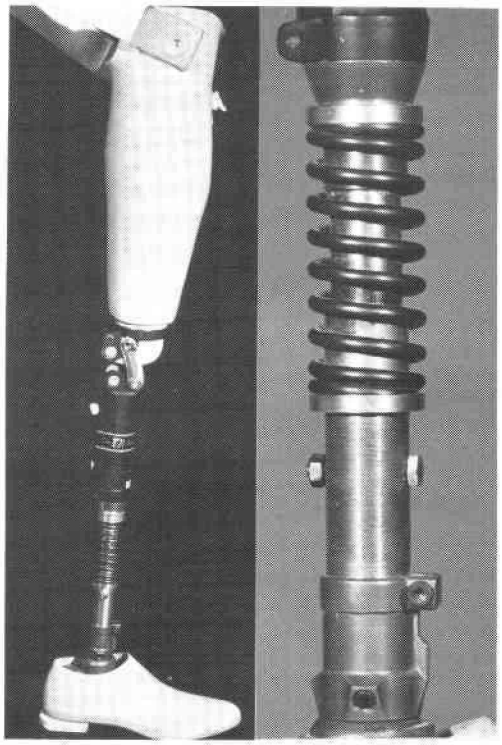

Fig. 5. Left, Terry Fox Running Prosthesis. Right, spring mechanism.

eversion, absorbs some axial rotation on weight-bearing.

The precompressed spring mechanism (Fig. 5, right), designed and developed by a team under the guidance of Guy Martel, a Canadian prosthetist, is the key prosthetic modification which allows transfemoral amputees to run with a near normal step pattern. The precompression of the spring mechanism is adjusted to the body weight so that during walking, it is inactive and only becomes operational during running.

When running, the spring mechanism compresses on heel contact. This cushions the ground impact and slightly shortens the prosthesis, providing stump comfort. Spring compression, maintained by weight-bearing as the support phase advances to mid stance, keeps the centre of gravity low. Stump hip extension is accomplished with more ease and the body is able to accelerate smoothly over the prosthesis. At the end of prosthetic stance, as weight-bearing decreases, the stored energy is released, propelling the prosthesis, at pushoff, into swing (Mensch and Ellis, 1984).

With this spring mechanism, transfemoral amputees are also able to hop on their prosthesis and to stride-jump. These two additional functional advantages give amputees a tremendous potential to participate in and enjoy many sports activities which previously were "off limits" to them. One distinct disadvantage, which has been identified, is the additional weight of the running prosthesis. Unfortunately the spring mechanism weighs 663 g.

One can hypothesize that the more normal running pattern, made possible with the Terry Fox Running Prosthesis, will reduce the amputee's energy requirements when compared to the hop-skip method. However the added weight of the spring component may adversely affect the amputee's energy requirements while running.

Although the subjective feedback from users has been very positive, it is felt that only a rigorous, scientific research study would demonstrate and validate the effectiveness of the precompressed spring mechanism on energy conservation during running.

Research considerations

The expectation was that this prosthetic design would permit transfemoral amputees to run in a more normal symmetrical step pattern.

During the analysis of running with this new prosthesis, several observations were made, leading to the following hypotheses.

1. The potential energy resulting from spring compression on weight-bearing is converted to kinetic energy as weight-bearing is decreased during the latter phase of stance. This released energy will intensify prosthetic pushoff, assisting the forward projection of the prosthesis into swing. This may possibly also help to raise the centre of gravity on the sound side.
2. The resultant normalization of the running pattern would decrease energy expenditure during running for transfemoral amputees compared to the hop-skip technique.

Physical therapy in the clinical trial (Fig. 6)

The physiotherapy component of the randomized cross-over clinical trial of the Terry Fox Running Prosthesis outlines the following possible hypotheses and protocols for the familiarization, treatment and training phases of the research study.

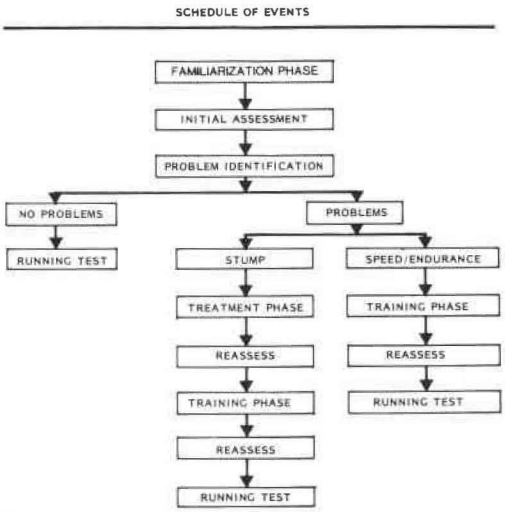

Fig. 6. Research project-physiotherapy schedule of events.

Familiarization

Although the subjects are prosthetic users, they will require an adjustment or familiarization period after being fitted with the test unit. The test unit consists of a transfemoral suction socket prosthesis with a Teh Lin* knee unit. The socket and knee unit remain constant but the shank sections, with and without the spring mechanism, are interchangeable. Both shank sections are equal in weight.

This phase will permit the subjects to adjust to the weight differential between the prosthesis that they are accustomed to wearing and the test unit. Problems may include tissue pistoning, altered proprioceptive feedback to the stump and difficulty converting to the functioning of the Teh Lin knee mechanism. The team will deal with any problems which may occur at the stump socket interface or with dynamic alignment to minimize, as much as possible, prosthetic factors which might hinder training.

The subjects will wear the test unit without the spring mechanism for three days, as this limb most closely resembles their existing prosthesis. They will then wear the unit with the spring for four days. The subjects will not run during this phase.

Treatment phase

The study subjects may have stump problems related to decreased strength, decreased range of movement, or problems related to skin conditions which may hinder training and consequently their ability to perform the running test.

The purpose of this phase is to minimize, as much as possible, these physical factors which might influence training. After specific assessment, appropriate physiotherapeutic intervention will be given until the subjects have optimal strength, range of motion and problem free skin. When this is achieved, the subjects will progress to the training phase. The treatment phase will be eliminated if none of the listed problems are identified during the assessment.

Training phase

Although the study subjects may not have any stump problems, they may lack the speed or the endurance to perform the running test. The test requires that each subject maintain fast walking or running at speeds 2, 3, 4, 5, 6 and 7 km per hour for three minutes each.

This phase will consist of supervised sessions progressing from walking to fast walking to jogging and, finally, to running. The ability to achieve and maintain the required speeds will be monitored weekly.

Each amputee's training will include equal time spent using—

the test unit without the spring
the test unit with the spring
the test unit without the spring with weight adjustment (to compensate for the weight of the spring).

This will ensure that the subjects are fully prepared to perform the running test.

Using this schedule of events the subjects potentially could be training at different times but this should not pose a problem because once the required speed and endurance are achieved, the running test will be performed.

Training considerations

All amputee runners, like nonamputee runners require an individualized graded training programme (Fig. 7). Some common running injuries such as chondromalacia patella, (also called the runner's knee), tendinitis, shin splints and hamstring injuries may occur when athletes use incorrect running techniques, have poor postural habits, wear incorrect running shoes, omit warm-up and stretching exercises before running or are not properly conditioned (Brody, 1980).

*Trade name

Fig. 7. Running training.

Since all amputees rely heavily on the sound leg for balancing, standing and walking, it is vital to condition this limb.

Physical therapists must provide guidance regarding the type, intensity, duration and frequency of activity (Gibson et al, 1983) and must include resisted stump motion exercises in the conditioning programme.

Conclusion

The participation of many healthy adult amputees in recreational activities, including running, has increased the demands on the physiotherapeutic aspects of amputation rehabilitation. Physiotherapists must be able to provide realistic guidance to these athletes by continuing to observe and analyse the biomechanics of movement, participate in and incorporate research findings into the development and evaluation of prosthetic components for sports activities and formulate and evaluate comprehensive training programmes.

By meeting these requirements, physiotherapists will be able to continue to develop and maximize the potential of these amputee runners.

REFERENCES

BRODY, D. M. (1980). Running injuries *Clin. Symp. (CIBA),* **32 (4),** 2–36.

ENGLISH, E. (1981). The energy cost of walking for the lower extremity amputee. In: J. R. Kostuik and R. Gillespie (eds.), Amputation surgery and rehabilitation: the Toronto experience. New York: Churchill Livingstone, 311–314.

GIBSON, S. B. GERBERICH, S. G., LEON, A. S. (1983). Writing the exercise prescription: an individualized approach. *Phys. Sports. Med.* **11 (7),** 87–110.

HUGHES, J., JACOBS, N. (1979). Normal human locomotion. *Prosthet. Orthot. Int.* **3,** 4–12.

INMAN, V. T., RALSTON, H. J., TODD, F. (1981). Kinematics. In: Human walking. Baltimore: Williams and Wilkins, 22–77.

MANN, R. A., HAGY, J. (1980). Biomechanics of walking, running, and sprinting. *Am. J. Sports. Med.* **8 (7),** 345–350.

MENSCH, G. (1983). Physiotherapy following through-knee amputation. *Prosthet. Orthot. Int.* **7,** 79–87.

MENSCH, G., ELLIS, P. (1984). The Terry Fox running prosthesis. *Physiotherapy Canada,* **36 (6),** 245–246.

MENSCH, G., ELLIS, P. (1986). Amputation levels.—stump characteristics and treatment considerations related to gait. In: Physical Therapy Management of Lower Extremity Amputations. Rockville: Aspen Systems Corporation.

PERRY, J. (1967). The mechanics of walking: a clinical interpretation. *Phys. Ther.* **47,** 778–801.

SODERBERG, G. L. (1983). Muscle mechanics and pathomechanics. *Phys. Ther.* **63,** 216–220.

VAUGHAN, C. L. (1984). Biomechanics of running gait. *CRC Critical Reviews in Biomed. Eng.* **12,** 1–48.

WELLS, K. F. (1971). Locomotion: Walking and running. In: Wells, K. F., Luttgens, K. Kinesiology — The scientific basis of human motion (5th Ed.) Philadelphia: W. B. Saunders Company, 410–429.

FURTHER READING

KUMAR, V. N. (1982). Normal locomotion and prosthetic gait deviation. In: Banerjee, S. N., (ed.), Rehabilitation management of amputees. Baltimore: Williams and Wilkins, 237–254.

MENSCH, G., ELLIS, P. (1982). Analysis of common gait deviations. In: Banerjee, S. N., (ed.), Rehabilitation management of amputees. Baltimore: Williams and Wilkins, 221–226.

Prosthetics and Orthotics International, 1986, 10, 135–138

A comparison of shoe insole materials in plantar pressure relief

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Abstract

A clinical study was performed to evaluate the effectiveness of seven shoe insole materials and their ability to relieve areas of high plantar pressure. The following materials were tested: Latex foam, Plastazote^R, Dynafoam^R, Ortho felt, PPT^R, Spenco^R, and Molo^R. Twenty-six patients with areas of high plantar pressure were tested using each of these materials. The Harris and Beath footprinting technique was used to measure plantar pressure. It was found that the average pressure of a clinically painful plantar area was 398.15kN/m^2. All insole materials tested decreased this pressure, with averages ranging from 186.33kN/m^2 to 286.35kN/m^2. PPT, Plastazote and Spenco were the most effective products tested.

Introduction

Areas of increased plantar pressure have been clearly linked to foot pain and discomfort (Godfrey et al, 1967; Silvino et al, 1980). Increased pressure is also responsible for skin breakdown in the denervated foot such as in Hansen's disease and diabetic neuropathy (Bauman et al, 1963; McDowell and Enna, 1974). Attempts to reduce this high plantar pressure have produced a wide variety of shoe insoles which can be inserted into footwear between the shoe sole and the plantar surface of the foot.

Because of the great number of products clinically available, there is a need for experimental data to determine which products are most effective. This study was undertaken to compare seven materials commonly used to reduce plantar pressure. The study measures maximum plantar pressures using the Harris and Beath (1947) footprint technique which enabled both quantitative and qualitative results to be compiled.

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Materials and methods

Description of materials tested

Seven products were evaluated and are briefly described below.

Plastazote^R is a foamed polyethylene of closed cell construction. It is mouldable, bouyant and non-toxic. Plastazote is widely used in orthopaedics as a foot orthosis for protection against pressure points. It can be laminated to other materials for increased reinforcement. Three densities are available. The medium density was tested.

Latex foam is a cellular rubber of open cell construction (absorbs water). It is washable, odourless and can be cemented to other materials. Latex foam has a long history of use in orthopaedics as a footwear insole and cast padding.

Dynafoam^R is a polyvinyl chloride foam compound. It is odourless and water resistant, and quickly forms an impression of the foot.

Ortho felt is a resilient fabric composed of a blend of cotton and wool, with a relatively low tensile strength. Felt is widely used for cast padding and pressure relief pads in shoes.

Spenco^R is a neoprene sponge product with nitrogen-induced closed cells which is covered with a multistretch nylon fabric on one side. It is resistant to decay and odour. Spenco is said to absorb vertical forces, torque, and fore, aft, and lateral shear. It is designed to prevent neuropathic and rheumatoid ulcerations and is marketed for athletes to prevent blisters and callosities (Spence and Shields, 1968).

Molo^R is a combination of latex, jels, leather, cork and other products which are incorporated into a rubbery sheet. Under continued pressure Molo forms an impression of the foot. It is resistant to moisture and can be joined to another substance.

PPT^R is an open cell, porous, firm foam material which relieves local pressure. It is marketed as a "high-energy absorbing substance" that will not "bottom out" under the forces of pressure, shock and shear.

All materials tested were one-eighth inch thick and can usually be added to a shoe without making it too tight to wear comfortably.*

Measurement of plantar pressures

Plantar pressures were recorded using the version of the Harris and Beath footprinting mat manufactured by Berkemann Laboratories and available through Apex Foot Products Corporation, Englewood, N. J. For details of its use and quantification of the recorded pressure, see Harris and Beath (1947) and Silvino et al (1980).

Twenty-six patients were studied, 16 male and 10 female, ranging in age from 25 to 71 years. All patients complained of forefoot pain on weight-bearing and all showed areas of increased pressure under one or more metatarsal heads when tested with the Harris and Beath technique.

Footprints of the 26 patients were initially recorded without orthotic material. Subsequent footprints were recorded for each patient testing each of the materials described above.

The material to be tested was placed underneath the recording paper which was under the Harris mat. When a subject stepped on the mat the pressure recorded represented the interface between the foot and the insole material which is where plantar pressure redistribution occurs.

Footprints using each insole material were compared to the patient's control footprint, and a general category of effectiveness was assigned to each product by the overall improvement observed. The following three categories were used: most reduction in plantar pressure, some reduction, least reduction.

* All products, except PPT, were purchased from the Eneslow-Apex Shoe Corporation, 200 Forest Avenue, Englewood, N.J. 07630. PPT was obtained from Professional Protective Technology, Inc., 21 East Industry Court, Deer Park, N.Y. 11729.

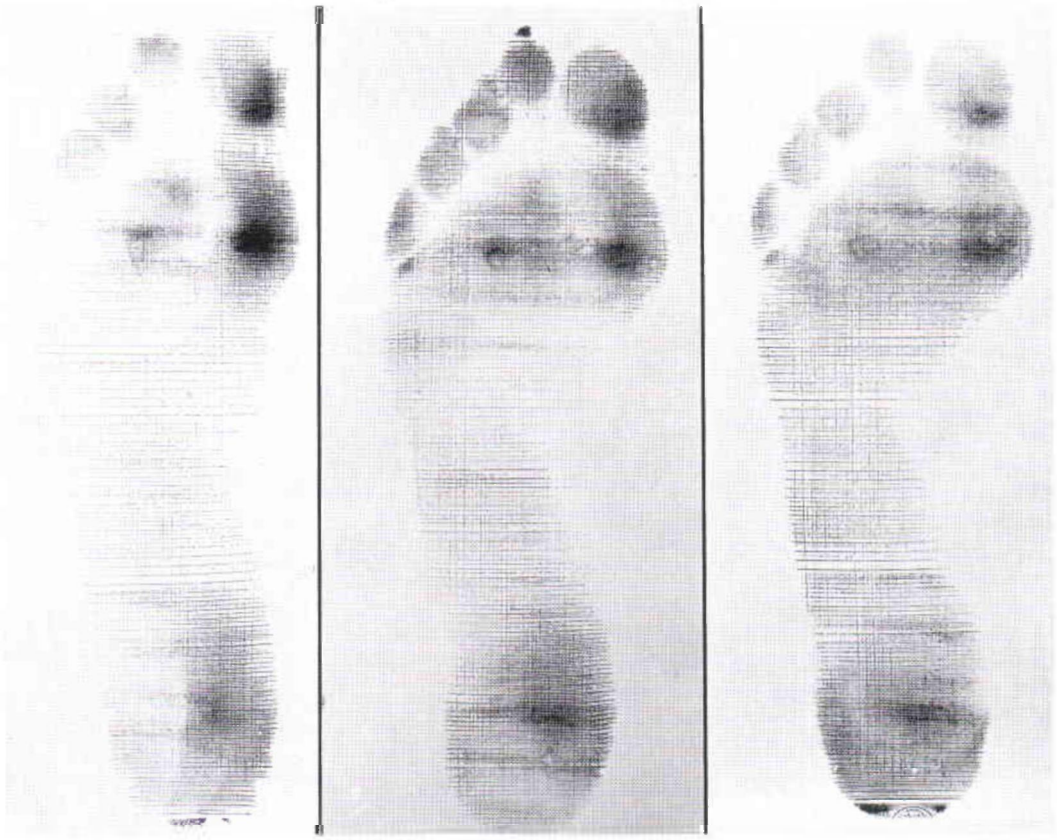

Fig. 1. Footprints recorded using the Harris and Beath footprinting mat and various orthotic materials demonstrate an area of increased pressure under the first metatarsal head; left, with least effective material, centre, with more effective material, and right, with most effective material.

Table I. Comparison of insole products and their effectiveness in reducing plantar pressure. P=26.

Product	Mean pressure under painful matatarsal head (kN/m^2)	Percent decrease in pressure (%)	Category of effectiveness
PPT	186.33	53	most
Plastazote	188.29	53	most
Spenco	193.19	51	most
Dynafoam	230.46	42	some
Molo	232.42	42	some
Ortho felt	266.74	33	least
Latex foam	286.35	28	least
Control	398.15	—	—

Estimation of pressure was made for each footprint using a calibration curve (Silvino et al, 1980). Mean pressure values were then calculated for each product and for the control. Numerical data was evaluated for significance by a two-way analysis of variance.

Results

The seven materials were divided into general categories of effectiveness by the overall appearance of the footprints. Those that showed the most reduction in plantar pressure were Plastazote, Spenco, and PPT. Those that showed some reduction were Dynafoam and Molo. Those that showed the least reduction were Ortho felt and Latex foam.

Figure 1 demonstrates an example of the three categories of effectiveness. The estimated foot pressures appear in Table I. The mean value of pressure under the clinically painful metatarsal head was $398.15 kN/m^2$ without any insole material. When the various products were used the mean pressure at the painful site ranged from $286.35 kN/m^2$ with Latex foam to $186.33 kN/m^2$ with PPT. This represented a decrease in pressure of 28 percent and 53 percent respectively.

Two-way analysis of variance disclosed that all seven products were significantly different from control at the $p<0.01$ confidence level. PPT, Plastazote and Spenco, while not significantly different among themselves, were significantly different from the other products ($p<0.01$). Ortho felt was significantly different from all other products as was Latex foam ($p<0.01$).

Discussion

This clinical study compared the effectiveness of seven shoe insole materials using the Harris and Beath footprinting technique. By observing the general appearance of the footprints, it was found that PPT, Spenco, and Plastazote relieved plantar pressure most effectively. Quantitative data obtained from the footprints agreed with the general categories of effectiveness. Statistical analysis confirmed that PPT, Plastazote and Spenco were significantly more effective in reducing plantar pressure than the other products tested. This conclusion is in agreement with laboratory compression testing of orthotic materials performed by Campbell et al (1982) which included Plastazote and Spenco in the optimal category based on load-deformation curve characteristics.

Utilizing the most effective orthotic material for relief of pressure is important in the prevention of trophic ulceration in the anaesthetic foot as well as in providing relief of pain in such common conditions as metatarsalgia. Past research has shown that clinically painful plantar areas tend to occur at pressures exceeding $254.97 kN/m^2$ (Bauman and Br and, 1963; Bauman et al, 1963; Silvino et al, 1980). All 26 patients studied complained of forefoot pain on weight-bearing and all showed plantar pressures above $254.97 kN/m^2$ at the site of pain (mean $398.15 kN/m^2$, range $260.86 kN/m^2$ to $474.64 kN/m^2$). When insole materials were introduced, the pressure at the painful area was reduced to below $254.97 kN/m^2$ for all the products except Latex foam and Ortho felt.

The study did not consider long-term use of different products by symptomatic patients since that would be difficult to do accurately with so many products. However, this would be an interesting area for a follow-up study now that the materials are categorized as to general effectiveness.

The products that are less effective in relieving high plantar pressure still may have important uses in orthopaedics. For example, Dynafoam, because of its creep properties, forms an impression of the foot or other high pressure area and is useful in covering braces and orthoses. Many of the products tested can be bonded to other compounds for increased

strength or special uses. The relief of pressure by these compound materials has not been studied and is an area where more research is needed.

It has been demonstrated that differences exist between commercially available products in their ability to relieve high plantar pressure and this information can be of great value in prescribing footwear insoles for the many patients suffering from pain or pressure-induced lesions of the feet.

Acknowledgements

The authors wish to acknowledge the editorial assistance of Beatrice Pasternak.

REFERENCES

BAUMAN, J. H., BRAND, P. W. (1963). Measurement of pressure between foot and shoe. *Lancet* **23** March, 629–632.

BAUMAN, J. H., GIRLING, J. P., BRAND, P. W. (1963). Plantar pressures and trophic ulceration: an evaluation of footwear. *J. Bone Joint Surg.* **45B,** 652–673.

CAMPBELL, G., NEWELL, E., MCLURE, M. (1982). Compression testing of foamed plastics and rubbers for use as orthotic shoe insoles. *Prosthet. Orthot. Int.* **6,** 48–52.

GODFREY, C. M., LAWSON, G. A., STEWART, W. A. (1967). A method for determination of pedal pressure changes during weight-bearing: preliminary observations in normal and arthritic feet. *Arthritis Rheum.* **10(2),** 135–140.

HARRIS, R. I., BEATH, T. (1947). Army foot survey—an investigation of foot ailments in Canadian soldiers. Ottawa, Canada: National Research Council of Canada. (N.R.C. #1574).

MCDOWELL, F., ENNA, C. D. (1974). Surgical rehabilitation in leprosy. Baltimore MD: Williams & Wilkins.

SILVINO, N., EVANSKI, P. M., WAUGH, T. R. (1980). The Harris and Beath footprinting mat: diagnostic validity and clinical use. *Clin. Orthop.* **151,** 265–269.

SPENCE, W. R., SHIELDS, M. N. (1968). Prevention of blisters, callosities and ulcers by absorption of shear forces. *J. Am. Podiatry Assoc.* **58,** 428–434.

Prosthetics and Orthotics International, 1986, 10, 139–141

Body sway in below-knee amputees

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Abstract

The purpose of the present study was to test the hypothesis that below-knee amputees have less standing stability than normal persons. Twenty below-knee amputees were tested with the quantified Romberg test.

All amputees below 59 years and all women above 59 years had a decreased sway compared with matched control groups of normal persons.

Amputated men above 59 years did not show any difference in sway compared with the matched control group.

Presuming that small sway excursions can be interpreted as a stable standing position, the study shows that a well fitted PTB-amputee stands at least as safely as a normal person.

Introduction

A safe standing position is essential both for normal persons and for amputees. Below-knee amputees may have an altered ability to stand safely on their prosthesis. Since Romberg in 1851 introduced his visual test for assessment of postural sway, few authors have described advanced methods of measuring the sway of normal individuals as well as of lower limb amputees.

It is known that sway increases significantly with age (Sheldon, 1963; Overstal et al, 1977; Brynskov et al, 1979) and that old men sway significantly more than old women (Brynskov et al, 1979).

In a previous study, Fernie and Holliday (1978) found that leg amputees had an increased speed of sway when compared to normal persons.

The present study aimed at the basic question: Do below-knee amputees have figures of standing stability different from those of normal persons?

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Patients and methods

Twenty patients, eighteen men and two women, fitted with patellar-tendon-bearing (PTB) prostheses after below-knee amputations, were included in the trial.

The median age was 61 years (range 16–76 years). Seven patients had a right-leg amputation and 13 were amputated on the left side.

The reasons for amputation were in eight cases traumatic, in seven arteriosclerotic and in five diabetic.

The patients were examined clinically and their history was taken. The patients admitted to the study had to meet the following criteria:

1. A well-functioning PTB prosthesis. All patients could walk without a stick.
2. No disease of the central nervous system.
3. No disease of the spine.
4. No other abnormalities of the lower extremities, except the amputation.
5. No signs of cardiopulmonary insufficiency.
6. No intake of alcohol during the last 12 hours before the test.
7. Well regulated diabetes (for the five diabetic patients).

All amputations were performed by the same technique: sagittal flaps as described by Persson (1974). All patients had well healed scars, without neuroma formation or any other complications.

The measurements of body sway were performed with the patient standing on a force plate (Jansen et al, 1982). The patient was asked to stand relaxed with closed eyes, arms hanging at the sides and the medial sides of the feet separated by an interspace of 1cm. The test lasted for three minutes and the time from the 15th to the 75th second was the period of measurement.

The force plate is placed horizontally, level with the surrounding floor of the room. The size of the plate is 45×30cm. The force plate is

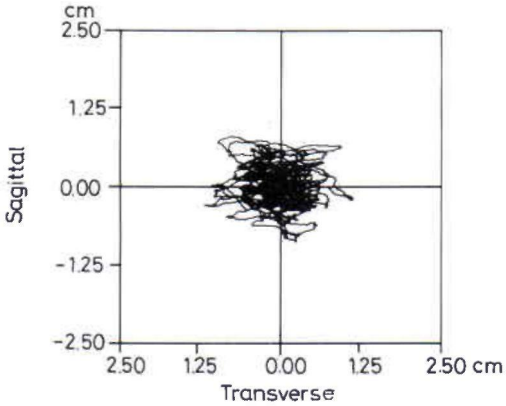

Fig. 1. The movements of the centre of pressure of the feet during 60 seconds of standing position. The patient had a PTB prosthesis on the left side.

mounted on resistive strain gauge transducers one in each corner of the plate. Thus the vertical force applied to each corner of the plate is measured (Fig. 1).

The measurements are transferred to a computer (PDP 11/10) and the values of the sway in the sagittal and transverse directions are determined during the 60 seconds of measured sway; the mean values of the sway excursions are also determined in the two directions (Fig. 2). The area between the mean value and the sway curves is found and is divided by the time of measurement. Thereby the average distance between the sway curve and the mean value is found. This calculation is made in the sagittal and transverse directions. By vectorial summation a common sway figure can be calculated. The unit of measurement is length (cm).

Due to previous findings in studies of normal persons (Thyssen et al, 1982) the material was divided into two groups:

Group I: All women and men below 59 years of age (10 patients), and

Group II: All men above 59 years of age (10 patients).

As body sway was uniform in men aged 20 to 59 years and women aged 20 to 69 years, the values of Group I of the present study were compared to the sway values of the whole age corresponding normal material. In Group II the men older than 59 years were compared with normal men of matching age.

The comparison was made by use of the Mann-Whitney (rangsum) test. Level of significance $p<0.05$.

Results

In Group I there was significantly less sway in the two directions, transverse and sagittal, as well as in total sway than in the corresponding control group. (median: transverse 38%, sagittal 34%, sum 46%).

In Group II there was no significant difference in sway in the transverse direction, but there was significantly less sway (median 24%) in the sagittal direction.

The smaller sway in the sagittal direction did not cause significant differences in the total sway ($p>0.05$).

The results of the two groups are shown in Figures 1. and 2.

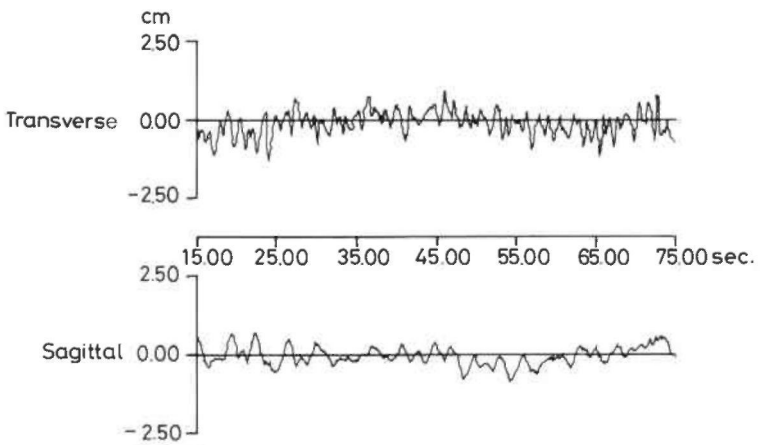

Fig. 2. Sway curves in the sagittal and transverse directions. The curves are calculations for the plot in Figure 1.

Discussion

The findings differed from those of Fernie and Holliday (1978) as their findings indicated that amputees had a less stable standing position than normal control persons. However Fernie and Holliday permitted a position of the feet which the patient felt as most comfortable, while in this study a fairly narrow base was used for the standing position. It is therefore remarkable that a more stable standing position was found. A mathematical comparison between the Fernie and Holliday analysis of speed of sway and those calculated for length of average sway is not possible.

The findings of a more stable standing position in amputated women and younger men and the limited sway in the sagittal direction in the elder amputated men is interesting.

The explanation of the reduced sway when compared to normal persons may be the relatively stiff ankle of the prosthesis and the fact that the normal lower leg only needs slight muscle movements to maintain balance.

If small sway excursions can be interpreted as a stable standing position, the study shows that a well-fitted PTB amputee stands at least as safely as a normal person.

REFERENCES

Brynskov, J., Thyssen, H. H., Jansen, E. C., Munster-Svendsen, J. (1979). Postural stabilitet hos yngre og ældre normale personer malt med kraftmaleplade – – force plate. *Ugeskr. Læger* **141,** 367–368.

Fernie, G. R., Holliday P. J. (1978). Postural sway in amputees and normal subjects. *J. Bone Joint Surg.* **60–A,** 895–898.

Jansen, E. C., Larsen, R. E., Olesen, M. B. (1982). Quantitative Romberg's test: Measurement and computer calculation of postural stability. *Acta Neurol. Scand.* **66,** 93–99.

Overstall, P. W., Exton-Smith, A. N. Imms, F. J. Johnson, A. L. (1977). Falls in the elderly related to postural imbalance. *Brit. Med. J.* **1,** 261–264.

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

Sheldon, J. H. (1963). The effects of age on the control of sway. *Gerontol. Clin.* **5,** 129–138.

Thyssen, H. H., Brynskov, J., Jansen, E. C., Munster-Swendsen, J. (1982). Normal ranges and reproducibility for the quantitive Romberg's test. *Acta Neurol. Scand.* **66,** 100–104.

Prosthetics and Orthotics International, 1986, 10, 142–148

Results of the pilot phase of a clinical evaluation of computer aided design of trans-tibial prosthesis sockets

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Abstract

This study served as a pilot to develop the methodology for a larger number of clinical trials. Ten trans-tibial amputees compared sockets made by conventional methods with sockets made using computer aided socket design (CASD). Prosthetists, paired for experience, fitted each subject with one prosthesis using each method. A preferred socket was selected by the subject on the basis of comfort without knowledge of the method by which the socket was designed. Prosthetists also evaluated the sockets. Three subjects preferred sockets built using CASD and one subject preferred the conventional socket only slightly more than the CASD socket. Six subjects clearly preferred the conventional fitting.

Introduction

A method of computer aided design of trans-tibial prosthesis sockets was developed by the Medical Engineering Resource Unit (MERU) in Vancouver, Canada (Saunders et al, 1985). This paper reports the results of a pilot study of clinical trials conducted at an independent centre. The purpose of this study was to develop a protocol and to determine the sample size required to execute a full series of clinical trials. This larger study will be conducted during the next two years to determine whether computer aided socket design (CASD) is worthy of further investigation and development. The pilot study results are reported at this time, firstly because of a perceived interest in the prosthetics community and secondly to relate experience with the protocol to other research groups planning evaluations of CAD/CAM systems.

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Method

CASD socket

The CASD system consisted of an interactive software package operated on an IBM PC/XT microcomputer with a VECTRIX* graphics unit and monitor. The following limb measurements were entered into the computer: length of the residual limb, length of the sound limb, mediolateral diameter at the tibial plateau, anteroposterior diameter at mid patellar tendon level and at one inch intervals below. The program used these initial data to generate a primary modified shape. The prosthetist then examined the shape and had the opportunity to change it using an interactive modification software package. Graphical representations of the modified socket were examined and approved before the data were transferred to a floppy disc.

The disc was then sent to Vancouver where the MERU team used their numerically controlled milling machine to carve the shape from a solid polyurethane foam plug. The plug was returned to Toronto where a socket was vacuum moulded using acrylic orthoglass**. This plug was not smoothed or otherwise altered. The orthoglass was selected because its rigidity and transparency enhanced the quality of the evaluation. The socket was trimmed and attached to temporary alignment apparatus using Seglehartz adhesive**. All legs were set up using a SACH foot fitted with the subject's own shoe.

Conventional socket

Standard measurements and a plaster cast were taken. A plaster positive was developed and modified. This was used to vacuum mould

*Manufactured by Vectrix Corporation, North Carolina, U.S.A.

**Distributed by Otto Bock Orthopedic Industry of Canada, Winnipeg, Canada.

an acrylic socket in the same manner as the CASD socket. After trimming and attachment to an alignment rig the conventional socket limb appeared to be the same as the CASD socket limb.

Subjects

Ten volunteers with trans-tibial amputations were fitted in this pilot phase. Subjects were mentally alert, physically well and had no major problems with their residual limbs. All amputees were active wearers of patellar-tendon-bearing prostheses.

Surgery had occurred at least 18 months previous to the study. Amputations had been caused by peripheral vascular occlusive disease in seven subjects and trauma in the remaining three subjects. Subjects included eight males and two females aged 54 to 72 years (mean 64.6 years).

Prosthetists

Six prosthetists from three centres in the Toronto area volunteered for participation. Prosthetists were paired according to low, medium and high experience levels. They were provided with background material and a CASD study manual before attending a two day, hands-on training course. One subject was measured and fitted with a CASD socket during the course.

Design of study and procedure

Subjects were assigned randomly to one pair of prosthetists. Each prosthetist was then assigned randomly to make either a conventional socket or a CASD socket for the subject. Prosthetists within a pair fitted an equal number of subjects with the two types of sockets. The four more experienced prosthetists fitted two subjects with CASD sockets and two subjects with conventional sockets each, while the two least experienced prosthetists fitted one CASD and one conventional socket each.

Measurements and a plaster cast were taken with both prosthetists present. Within one week the subject returned to be fitted with the conventional and the CASD sockets. Both fittings were done at the same session with both prosthetists present. Every effort was made to conceal the origin of the sockets from the subject in order to eliminate bias. If the socket fitted well enough to permit weight-bearing a routine dynamic alignment was performed. If the socket fitted well enough to permit continued walking the subject was allowed to walk for a period of up to twenty minutes. Prosthetists evaluated the limb using a prepared questionnaire and the subject selected the preferred socket, using a continuous scale (Table 1). The subject's response was not made known to the prosthetists.

Three possible subject choices led to different procedures.

1. If the subject chose the CASD socket the trials ended.
2. If the subject was unable to decide he was asked to take the limbs home for further use to facilitate choosing a socket. In that case the limbs would have been fitted with a footstep monitor to measure the number of steps taken with each limb.
3. If the conventional limb was preferred the trials continued.

If the trials continued the CASD socket was modified on the computer screen and a second limb manufactured in the same manner as the first. The limb was dynamically aligned and compared to the original, unmodified conventional limb using the same method as the first comparison.

On the basis of the subject's choice the procedure was repeated once more if the conventional socket was preferred. Thus, a second modification to the CASD socket was allowed. The trials stopped after the second CASD modified socket was compared to the conventional socket.

All sockets were fitted with a one-ply cotton residual limb sock and a standard patellar-tendon-bearing socket design was used for all limbs. Either hip belt or neoprene sleeve suspension was used depending on which was closest to the subject's accustomed suspension.

Results

All subjects were able to decide which socket they preferred without taking the legs home for extended walking. Only one trial was stopped early because the subject chose the CASD socket after the first socket modification.

Table 1 summarizes the results of the subject evaluation of sockets. Sockets were identified as follows: a=conventional, b=first CASD socket, c=first CASD modification and d=second CASD modification. The first three

Table 1. Subject responses

least exper pros			med. experience pros			most experience pros		
subj	socket	choice	subj	socket	choice	subj	socket	choice
1	a/b	conv: 3	7	a/b	conv: 4	3	a/b	conv: 4.8
	a/c	conv: 3		a/c	CASD: 3		a/c	conv: 5
	a/d	conv: 2					a/d	conv: 4
	b/d	d: 4		b/c	c: 4		b/d	d: 2
2	a/b	conv: 4.4	8	a/b	conv: 4	4	a/b	conv: 3.9
	a/c	conv: 3.7		a/c	conv: 4		a/c	conv: 5
	a/d	CASD: 1.7		a/d	conv: 4		a/d	conv: 5
	b/d	d: 4.3		b/d	d: 4		b/d	d: 2
			9	a/b	conv: 4	5	a/b	conv: 5
				a/c	conv: 3.3		a/c	conv: 4.9
				a/d	conv: 2.7		a/d	CASD: 4
				b/d	d: 3.4		b/d	d: 5
			10	a/b	conv: 4	6	a/b	conv: 4
				a/c	conv: 1.1		a/c	conv: 5
				a/d	conv: 2.0		a/d	conv: 1
				b/d	d: 2		b/d	d: 4

legend: socket a=conventional
b=first CASD socket
c=first CASD modification
d=second CASD modification

Scale for subject evaluation:
For each socket comparison a subject was asked to place an × anywhere on a horizontal scale numbered as follows:

Socket # Socket #

5———4———3———2———1———0———1———2———3———4———5

The numbers were labelled as follows:
0=neutral;
1=slightly better;
2=somewhat better;
3=moderately better;
4=much better;
5=very much better.

comparisons were between the conventional socket and each of three CASD sockets. The last comparison was between the first and last CASD sockets.

One subject preferred the CASD socket on the first modification while a further two subjects chose the CASD socket on the second CASD modification. One subject found the conventional socket to be only slightly better than the second CASD modification and another three found the conventional socket to be somewhat better to moderately better than the second CASD modification. The remaining four subjects found the conventional socket to be much better to very much better than the second CASD modification.

All CASD sockets that were preferred were chosen on the first attempt for each of three different prosthetists. One prosthetist from each of the three experience level groups had a CASD socket chosen by a subject. There did not appear to be a strong relationship between the level of experience and the success of the individual prosthetist.

The prosthetists were asked to state whether the sockets they made were medically safe to wear at home for one week. They were also asked to outline any problems with the socket that were interfering with comfort and safety. Table 2 summarizes their responses. Six of the

Table 2. Prosthetist evaluation

Was the prosthesis safe to wear at home for one week?

	Socket			
Subject	a	b	c	d
1.	No*	No*	No*	No*
2.	No*	No*	No*	Yes*
3.	Yes	No*	No*	No*
4.	Yes	No*	No*	No*
5.	Yes	No*	No*	Yes*
6.	Yes	No*	No*	Yes*
7.	Yes*	No*	No+*	
8.	Yes*	No*	No*	No*
9.	No*	No*	No*	Yes+*
10.	No*	No*	No*	No*

legend: *modifications would improve the fit
+prosthetist unsure, would require longer walking session to be positive
socket a=conventional
b=first CASD socket
c=first CASD modification
d=second CASD modification

ten conventional sockets were considered safe for one week's use, although two of these might have been improved with modifications. Four of the second modifications of the CASD sockets were considered safe to use for one week, with modifications recommended in all cases. CASD sockets fitted to subjects 2 and 5 were preferred by the subject and were also rated as safe for one week's use by the prosthetists. Subject 9 did not prefer the CASD socket and the prosthetist suggested that it might be safe for use, although he requested further walking before making a decision. Subject 7 preferred the CASD socket although the prosthetist was not confident that the socket was medically safe on the basis of the allotted walking. Subject 6 considered the conventional socket to be only slightly better than the CASD socket when both conventional and CASD sockets were considered by the prosthetists to be safe for use for one week.

All four sockets fitted using conventional methods by the most experienced prosthetists required no modifications. All conventional sockets made by the least and medium experienced prosthetists required modifications, with only two considered to be safe for use for one week.

The times required for designing the socket, building the socket and setting up a leg for trial fit are presented in Table 3. The mean time required for making the conventional leg and the first CASD leg was similar. Successive modifications of the CASD legs took less time and there was considerable variability in the amount of time required by each prosthetist. There was no apparent relationship between the amount of time taken on the computer and the success of the CASD fit. Prosthetist A took 9.33 hours for subject 5, prosthetist B took 2.25 hours for subject 2 and prosthetist D took 1 hour for subject 7. Subjects 5, 2 and 7 preferred the CASD over the conventional socket. The other major reason for variation in time was the amount of time taken to break the polyurethane plug out of the socket. This factor depended on the shape of the socket.

Prosthetists were asked a series of questions after the completion of the trials, the responses to which are summarized in Tables 4 and 5. All prosthetists enjoyed using the computer to some extent. Two believed that CASD has a good future, two felt that it has a moderate future and the remaining two felt that CASD has very limited to no future. Five prosthetists felt that

Table 3. Time taken to make prosthesis

	Socket				
	a	b	c	d	b+c+d
Total time (hours)					
mean	3.71	3.61	3.17	3.16	9.55
standard deviation	.56	.92	1.37	.97	3.26
CASD computer time (hours)					
mean		.86	1.18	1.16	3.07
standard deviation		.80	1.08	.69	2.38

Table 4. Prosthetist responses to questionnaire on CASD

	Prosthetist					
Topic	A	B	C	D	E	F
Enjoyed using computer	mod+	mod	mod+	mod+	mod+	mod+
CASD has future	lim	mod	none	good	good	mod
Years to clinical usefulness	7.5	10	infin	5	7.5	4
Frustration making conventional	none	little	little	little	none	little
Frustration making CASD socket	little	strong	strong	little	mod	mod
# Subjects to learn CASD well	30	30	na	2	75–100	3–4
# Modifications needed to get good fit	infin	infin	20–25	2–4	4	4

legend: lim= limited
mod= moderate
infin= infinite
na= no answer

CASD would be clinically useful in four to 10 years. Little frustration in making the CASD sockets was felt by two prosthetists, while two were moderately frustrated and two had strong feelings of frustration. The number of subject fittings prosthetists suggested might be required to learn CASD well varied considerably from two to 100. Three prosthetists felt that four modifications might be required to get a good CASD fit while others felt it would take 20 to an infinite number.

It was believed that several factors might have been related to a prosthetist's success in using CASD. These included experience as a prosthetist, education, experience with computers, ability/experience in translating two dimensional images into three dimensional images. Table 5 summarizes responses to questions related to these factors.

Prosthetists provided a full evaluation of the fit of each socket. The following is a summary of some of the more common shape problems:

1. The posterior shelf was not perpendicular to the anteroposterior plane. It was tighter on the medial border and therefore interfered with the hamstrings tendon.
2. There was too much relief over the tibial tubercle and proximal two-thirds of the tibial crest.
3. There was too little relief in some sockets in the distal posterior and distal anterior regions.
4. There was insufficient convexity of shape to accommodate the patella in some sockets.
5. The socket was too small mediolaterally proximal to and at the femoral condyles.
6. Sometimes the socket was too small anteroposteriorly at the patellar tendon level.
7. There were some areas of non-contact just distal and lateral to the patellar tendon bar.
8. It was extremely difficult to accommodate unusual boney shapes at the fibular head and near the tibial tubercle.
9. The software did not deal well with a cylindrically shaped residuum.
10. Ridges appeared after modification of the posterior aspect.
11. All prosthetists found it necessary to add length to the socket.

Prosthetists had several recommendations to improve their ease of use of the CASD system. These included the following.

1. Use of shape sensor or some other method to provide more accurate and complete input data.

Table 5. Experience and ability

Experience/ability	Prosthetist					
	A	B	C	D	E	F
College/university	y	y		y	y	y
Computer used for:						
games	y	y		y	y	y
wordprocessing				y	y	
programming		y			y	
graphics		y				
Took drafting course	y	y		y	y	y
Art sculpture experience	y			y	y	
Used topographical maps	y	y		y	y	y
Self rated ability to translate 2d cross sections to 3d image	***½	½	*	**	0	*½
Subject preferred CASD	+	+		+		
Prosthetist rated CASD ok for one week	#	#				#
# legs fitted	10,000	960	1880×	1500	350	1680

legend:
0 not good at all
* slightly good
** moderately good
*** very good
**** excellent
+ plus 10 years technical experience

2. Provide more options for the initial modifications done by the computer software before the prosthetist is permitted to alter the shape.
3. Provide more flexibility in modifying sockets, ie. more choices of patch shapes and easier blending of changes into an existing shape.
4. Improve the quality of the graphics; label cross section orientation.
5. Provide the ability to manipulate the perspective of viewing in three dimensions.

Discussion

The use of a one-ply cotton sock and a rigid acrylic socket represented a very rigorous test of socket fit. Prosthetists usually have the option of varying the thicknesses of socks and the rigidity of the socket. In fact, many elderly amputees are fitted with a soft liner in the socket. The level of difficulty encountered in obtaining a good fitting socket for this study was demonstrated by the inability of four of the six prosthetists to make on the first attempt a conventional socket that did not require modifications to improve its fit. However, the most experienced prosthetists had no difficulty achieving a good fit with all their conventional sockets.

One possible advantage of the CAD/CAM approach (Klasson, 1985) is that a permanent record of the socket shape is retained on computer disc. Thus, the opportunity is afforded to use trial sockets and to work toward an optimal fitting by successive modifications. The practicality of this approach will depend on the time taken for each trial and the number of trials needed. The objective of the developers is to reduce the prosthetist's time to a few minutes. This study protocol simulated this suggested process by permitting up to three attempts. A total of 29 CASD sockets were made for the 10 subjects.

One problem with the protocol used in this pilot study was that the conventional socket is not always an excellent fit as a basis for comparison, however, the use of such a rigid test reveals the inadequacies in expertise in both systems. Two of the three CASD sockets that were preferred by the subjects were compared to conventional sockets rated favourably by the prosthetists. The third CASD socket that was preferred by the subject was compared to a socket not rated favourably by the prosthetist. The third CASD socket was, however, rated well by the prosthetist and therefore it can be considered to be a reasonably good fit.

In addition to providing a rigorous test of socket fit the acrylic socket facilitated evaluation of fit because of its transparency. The extent and location of areas of excessive contact and non-contact were more easily identified. However, the process required a considerable expenditure of time. The time required for the vacuum forming technique is similar to that required for making a more flexible polypropylene socket using the techniques outlined by Davies et al, 1985. However, because of its rigidity and brittleness, the acrylic socket took longer to trim and a considerable length of time was needed to dig the foam plug out of the socket.

The validity of the subjective evaluation of the socket fit by both prosthetists and subjects is difficult to assess. There was, however, reasonable agreement on the quality of the socket fit between the prosthetists and subjects. Of the four CASD sockets that were rated better by the prosthetists two of them were preferred by the subjects, one subject preferred the conventional socket only slightly and the last subject found the conventional socket to be moderately better than the CASD socket.

The prosthetists who had greater success with the CASD were not consistently from any one prosthetist pair (experience level). Prosthetist A, who had a reasonable level of success in both CASD sockets he fitted was the most experienced of all six. However, prosthetist C, who had more difficulty with CASD, was also in the most experienced pair. Prosthetist C had no experience with a computer. Prosthetist A, however, had used a computer for games, had done both drafting and artistic sculpture, had used topographical maps, had college education and rated himself as very good to excellent at translating two-dimensional cross sections to three-dimensional images. On the basis of the questions asked regarding experience and ability, there appears to be no clear explanation for the differences in CASD success among the remaining four prosthetists.

Ideally, subjects would be asked to walk with the experimental and conventional limbs for a longer period of time in order to assess comfort and fit. In this pilot phase however all subjects felt that they were able to make a clear choice

between the sockets. Whenever the choice between the sockets was close to neutral the subject was asked if he had sufficient walking to make a choice. No subject requested additional walking. Some prosthetists believe that subjects should be asked to use the limbs for a longer time before choosing a socket. This would require close supervision of subjects over a lengthy period and therefore a considerably greater expenditure. It is unknown whether such measures would have changed the outcome of this study.

It is worthy of note that the method of storing shapes on a computer disc, shipping it to Vancouver and shipping the shapes back for vacuum moulding was very successful. Occasionally, in order to accommodate a subject's schedule the data was transferred by telephone to Vancouver. It was possible to receive the carved plug within 18 hours. This success demonstrates the ease with which such a system could be used to facilitate limb fitting in remote areas. The distance from Toronto to Vancouver is approximately 5,000 kilometres.

Conclusions

Three subjects out of 10 chose CASD fittings in preference to conventional fittings. Therefore, the CASD system, at its present state of development, was not found to be an improvement over conventional fitting methods. However, the results of this pilot study demonstrated that some success has been achieved. Many of the deficiencies encountered were systematic rather than random errors and might be expected to be corrected in future revisions of the system. The results of the larger study with more subjects must be awaited before definitive and statistically valid statements can be made concerning the rate of successful fittings. It will be of particular interest to observe if there are any trends toward improved fittings and reduction in time taken as the prosthetists gain more experience with CASD during the longer trial.

Acknowledgements

This project was funded by:
Health and Welfare Canada (NHRDP);
West Park Prosthetics Manufacturing Limited.

We would also like to acknowledge the assistance of: subject volunteers and prosthetists from West Park Prosthetics Manufacturing, the Sunnybrooke Medical Centre and the Hugh MacMillan Medical Centre.

The Medical Engineering Resource Unit in Vancouver, particularly Margaret Bannon and Carl Saunders, are to be commended for their high level of cooperation and expertise in running the training course and delivering the carved plugs promptly.

REFERENCES

Davies, R. M., Lawrence, R. E., Routledge, P. E., Knox, W. (1985.). The Rapidform process for automated thermoplastic socket production. *Prosthet. Orthot. Int.* **9**, 27–30.

Klasson, B. (1985). Computer aided design, computer aided manufacture and other computer aids in prosthetics and orthotics. *Prosthet. Orthot. Int.* **9**, 3–11.

Saunders, C. G., Foort, J., Bannon, M., Dean, D., Panych, L. (1985). Computer aided design of prosthetic sockets for below-knee amputees. *Prosthet. Orthot. Int.* **9**, 17–22.

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Calendar of events

National Centre for Training and Education in Prosthetics and Orthotics
Short-Term Courses and Seminars 1986/1987

Courses for Physicians, Surgeons and Therapists

NC505 Lower Limb Prosthetics; 19th–23rd January, 1987.
NC502 Upper Limb Prosthetics and Orthotics; 26th–30th January, 1987.
NC510 Wheelchairs; 9th–10th March, 1987.
NC511 Clinical Gait Analysis; 23rd–25th March, 1987.
NC506 Fracture Bracing; 30th March–3rd April, 1987.
NC501 Functional Electrical Stimulation; 6th–9th April, 1987.

Courses for Prosthetists

NC205 Above-Knee Prosthetics; 16th–27th February, 1987.
NC214 Flexible Above-Knee Sockets; 16th–18th March, 1987.

Courses for Orthotists

NC216 Contemporary Orthotic Management of the Spine; 2nd–6th February, 1987.
NC217 Ankle-Foot-Orthoses for the Management of the Cerebral Palsy Child; 2nd–5th March, 1987.

Courses for Prosthetics Technicians

NC605 Contemporary Prosthetic Construction Techniques; 9th–13th February, 1987.

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.

North Western University Medical School
Short Term Courses

Courses for Physicians, Surgeons and Therapists

702–B Spinal, Lower and Upper Limb Orthotics; 27 April–1 May, 1987.
703–B

Courses for Physicians and Surgeons

603–D Lower and Upper Limb Prosthetics; 16–20 March, 1987.
603–E Lower and Upper Limb Prosthetics; 20–24 April, 1987.
603–F Lower and Upper Limb Prosthetics; 11–15 May, 1987.

Courses for Therapists

622–A Lower and Upper Limb Prosthetics; 16–20 February, 1987.
622–B Lower Limb Prosthetics; 18–22 May, 1987

Courses for Rehabilitation Personnel

640 Orientation to Prosthetics for Rehabilitation Personnel; 23–24 March, 1987.

Courses for Pedorthists and Orthotists

801 Pedorthic Management of the Foot; 8–12 June, 1987.

Requests for further information should be addressed to Charles M. Fryer, Director, Prosthetic-Orthotic Center, 345 East Superior Street, Room 1723, Chicago, Illinois 60611, USA.

New York University Medical School
Short Term Courses
Courses for Physicians and Surgeons

741B Lower Limb Prosthetics; 2–6 March, 1987.
751B Lower Limb and Spinal Orthotics; 16–20 March, 1987.
741C Lower Limb Prosthetics; 4–8 May, 1987.
751C Lower Limb and Spinal Orthotics; 11–15 May, 1987.
744A Upper Limb Prosthetics and Orthotics; 8–12 June, 1987.

Courses for Therapists

752B Lower Limb and Spinal Orthotics; 16–20 March, 1987.
742A Lower Limb Prosthetics; 27 April–1 May, 1987.
752C Lower Limb and Spinal Orthotics; 11–15 May, 1987.
745A Upper Limb Prosthetics and Orthotics; 8–12 June, 1987.

Interdisciplinary Course

754A Foot Orthotics; 6–7 April, 1987.

Courses for Prosthetists

7431A The ISNY Above-knee Flexible Socket; 8–9 January, 1987.
7461A The ISNY Upper Limb Flexible Socket; 10 January, 1987.
7432B The Narrow ML Above-knee Socket; 22–24 January, 1987.
7433C The ISNY Below-knee Flexible Socket: 25–27 March, 1987.
7433D The ISNY Below-knee Flexible Socket; 21–23 May, 1987.
7432C The Narrow ML Above-knee Socket; 27–29 May, 1987.
7433E The ISNY Below-knee Flexible Socket; 3–5 June, 1987.

Additional information and application forms may be obtained by contacting Ms. Sandy Kern, Registrar, Prosthetics and Orthotics, New York University Post-Graduate Medical School, 317 East 34th Street, New York, NY 10016. Telephone (212) 340–6686.

16–18 January, 1987
Rehabilitation symposium on locomotor systems, Singapore.
Information: Dr. Lee Eng Hin, Chairman, Rehabilitation Symposium 1987, c/o Department of Orthopaedic Surgery, National University Hospital, Lower Kent Ridge Road, Singapore 0511.

19–20 January, 1987
3rd International Symposium on Sports Injuries, Jerusalem, Israel.
Information: Sports Medicine Unit, Howard Cosell Center for Physical Education, Hebrew University, Givat Ram, Jerusalem 91904, Israel.

22–27 January, 1987
American Academy of Orthopaedic Surgeons Annual Meeting, San Francisco, California.
Information: American Academy of Orthotists and Prosthetists, 717 Pendleton St., Alexandria, VA 22314.

26–30 January, 1987
Western Australian Orthopaedic Summer Meeting, Perth, Australia.
Information: Mr. Barrie Slinger, Chairman, Organizing Committee, PO Box 40, West Perth, Western Australia 6005.

15–22 February, 1987
American Academy of Orthotists and Prosthetists Annual Meeting and Scientific Symposium, Tampa, Florida.
Information: American Academy of Orthotists and Prosthetists, 717 Pendleton St., Alexandria, VA 22314.

20–21 February, 1987
Course on "The management of unicompartmental osteoarthritis of the knee", London, England.
Information: Miss Julie Trigwell, British Orthopaedic Association, 35–43 Lincoln's Inn Fields, London WC2A 3PN, England.

24–26 February, 1987
4th European Conference of Rehabilitation International on "Vocational Rehabilitation: Essential for Equality and Full Participation", Berlin, GDR.
Information: Organizationsburo, 4 Europaische Regional Konferenz von R. I., DDR–1040 Berlin, Albrechtstrusse 22, GDR.

25–27 February, 1987
Course on "Advances in the management of spinal disorders", Mansfield, England.
Information: Mr. R. C. Mulholland, Harlow Wood Orthopaedic Hospital, Nr. Mansfield, Nottingham NG18 4TH, England.

26–28 February, 1987
3rd International Seating Symposium, Memphis, Tennessee.
Information: Mr. James Farris, Rehabilitation Engineering, University of Tennessee, 682 Court Av., Memphis, Tennessee 38163, U.S.A.

2–6 March, 1987
International Symposium on Sexuality and Disability, Eilat, Israel.
Information: Israel Rehabilitation Society, 18 David Elazar St., Hakirya, Tel Aviv, 61909 Israel.

12–13 March, 1987
13th Annual Northeast Bioengineering Conference, Philadelphia, PA.
Information: Kenneth R. Foster, Dept. of Bioengineering, University of Pennsylvania, 220 S. 33rd St., Philadelphia, PA 19104–6392, U.S.A.

18–19 March, 1987
Course on "The science of scoliosis", Leeds, England.
Information: Prof. R. Dickson, Clinical Sciences Building, Room 8.8, St James University Hospital, Leeds LS9 7TF, England.

26–28 March, 1987
USOC Conference on Sports Medicine/Science for the Disabled Athlete, Mt. Washington Valley, New Hampshire.
Information: Mary Magaret Newsom, U.S. Olympic Committee, Dept. of Education Services, 1750 East Boulder St, Colorado Springs, Colorado 80909–5760, U.S.A.

1–3 April, 1987
International Conference on Gait Analysis and Medical Photogrammetry, Oxford, England.
Information: Conference Secretariat, Oxford Orthopaedic Engineering Centre, Nuffield Orthopaedic Centre, Headington, Oxford OX3 7LD, England.

27–28 April, 1987
24th Annual Rocky Mountain Bioengineering Symposium, Fargo, North Dakota.
Information: Dr. John D. Enderle, Division of Bioengineering, Dept. of Electrical and Electronics Engineering, North Dakota State University, Fargo, ND 58105, U.S.A.

3–8 May, 1987
American Orthopaedic Association Annual Meeting, Washington, DC.
Information: AOA, 444 N. Michigan Av., Chicago, IL 60611.

10–13 May, 1987
ESSR–87; 22nd Congress of the European Society for Surgical Research, Aarhus, Denmark.
Information: ESSR–87, Institute for Experimental Clinical Research, c/o Aarhus Municipal Hospital, DK–8000 Aarhus C, Denmark.

13–15 May, 1987
Annual Scientific Meeting of the International Medical Society of Paraplegia, Aylesbury, England.
Information: Dr. Hans L. Frankel, The National Spinal Injuries Centre, Stoke Mandeville Hospital, Aylesbury, Bucks HP21 8AL, England.

15–18 May, 1987
Spine Study Group 5th Symposium, Charleston, South Carolina.
Information: Pat Curl, Course Coordinator, PO Box 33185, San Diego, CA 92103, U.S.A.

17–20 May, 1987
Pediatric Orthopaedic Society, Toronto, Canada.
Information: POS, PO Box 11083, Richmond, VA 23230, U.S.A.

18–20 May, 1987
"Toward 2000" The World Confederation for Physical Therapy — 10th International Congress, Sydney, Australia.
Information: Frank Allander APTA, 1111 N Fairfax St., Alexandria, VA 22314, U.S.A.

21–24 May, 1987
1st International Wheelchair Trials and Exposition, Jackson, Mississippi.
Information: 1st International Wheelchair Trials, PO Box 4268, Jackson, MS 39216–4268, U.S.A.

24–28 May, 1987
14th Annual Meeting of the International Society for the Study of the Lumbar Spine, Rome, Italy.
Information: Dr. Sam Wiesel, Secretary, The International Society for the Study of the Lumbar Spine, Sunnybrook Medical Centre, Room 5505, 2075 Bayview Av., Toronto, Canada M4N 3M5.

3–5 June, 1987
3rd Canadian Congress on Rehabilitation, Quebec, Canada.
Information: Secretariat, Canadian Rehabilitation Council for the Disabled, One Yonge Street, Suite 2110, Toronto, Ontario M5E 1E5, Canada.

4–6 June, 1987
Annual Meeting of the Association of Children's Prosthetic Orthotic Clinics, Vancouver, British Columbia.
Information: Sidney Fishmen M.D., c/o NYU PGMS, 317 E.34th St., New York, New York 10016, U.S.A.

Prosthetics and Orthotics International, 1986, 10, 157–160

Prosthetics and Orthotics International Index to Volume 10, 1986

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Subject Index

INTERBOR
X WORLD CONGRESS
JUNE 24–27, 1987, BARCELONA

Interbor has decided to hold its 1987 World Congress in Barcelona, Spain. This Congress aims to bring together orthopaedic specialists from all over the world in order to trade experiences and knowledge about the new techniques and materials that are the future of our profession. It is our hope and desire that the orthopaedic technicians will be joined at the Congress by all those specialists who work to make patients' recovery possible: orthopaedic surgeons, specialists in rehabilitation, engineers, specialists in biomechanics, electronics, microcomputers etc.

The Programme will include sessions on:

New materials in Below-Knee and Above-Knee Prosthetics and Orthotics Sports Orthotics/ Sports and Trauma
Orthotic/Prosthetic Treatment of Geriatric Patients
CAD/CAM
New Technology in Prosthetic Design
New Orthotic Systems for the Trunk
Orthopaedic Insoles.

There will also be practical courses on the following subjects:

Cosmetic restoration, moulded one-piece seating, hand orthotics, fracture orthoses, above-knee plaster casting, St Etienne orthosis, Rainey jacket, below-knee plaster casting, bandages/orthoses for burn patients, Boston overlap brace, insoles for foot relief, training prostheses.

Simultaneous translation will be available in Spanish, French, English, German and Italian.

There will be an exhibition in conjunction with the Congress.

Fees	**Before March 30, 1987**	**After March 30, 1987**
INTERBOR+ISPO members	16,000 Pts	18,000 Pts
Non-member	17,500 Pts	19,200 Pts
Accompanying person	8,500 Pts	8,500 Pts
Saturday only	6,000 Pts	6,000 Pts
Students (with Student ID)	9,000 Pts	9,000 Pts
Closing dinner	5,000 Pts	5,000 Pts

Organizing Committee
President: J. van Rolleghem
Vice-Presidents: M. Cañamares
J. Segarta

Scientific Committee
A. Bähler
O Cohí
W. H. Eisma
J. B. Noblejas

Scientific Exhibition
G. H. D. Rutz

Secretary
J. Mª Camós

Further information from:

BRP—Barcelona Relaciones Públicas
c/. Pau Claris, No 138, 7º 4ª

Asunto: Xº Congreso Internacional de la Unión Internacional de Técnicas Ortopédicas

Call for papers

All papers should be sent to the organizers before February 1987 and should contain the following information:

Author's name, address, employer and a brief abstract (no more than 200 words). Any material must be typewritten. The Scientific Committee will notify authors of acceptance.

ANNUAL SCIENTIFIC MEETING on PROSTHETICS and ORTHOTICS
presented by
THE AUSTRALIAN NATIONAL MEMBER SOCIETY
of the
INTERNATIONAL SOCIETY FOR
PROSTHETICS AND ORTHOTICS (ISPO)
conjointly with
THE DEPARTMENT OF VETERANS' AFFAIRS

The meeting will be of interest to Orthopaedic Surgeons, Vascular Surgeons, Rehabilitation Specialists and all medical and paramedical personnel in the treatment of musculo-skeletal deficiences.

This meeting is designed to immediately follow the World Congress of Physiotherapy being held in Sydney, in order that overseas speakers and delegates may participate.

CONTENT:	Overseas guest lecturers from Canada and U.S.A. The following subjects will be covered:— Training: Prosthetic Gait Training, General Training, Specialized Training; Scoliosis; Evaluation; Systems of Patient Care; Management of Cerebral Palsy; Wheel Chairs; Brachial Plexus Injury and Management; Switches; Driving for Amputees and Free Papers.
SPEAKERS:	Will be drawn from those involved in this work overseas and in several States.
VENUE:	Royal Children's Hospital, Flemington Road, Parkville, Victoria 3052.
DATES & TIMES:	Monday, 25 May 1987 8.30 am—5.00 pm Tuesday, 26 May 1987 9.00 am—4.00 pm
REGISTRATION:	6 April 1987 Deadline
REGISTRATION FEE:	$100.00
STUDENT REGISTRATION FEE:	$20.00
ISPO MEMBERS REGISTRATION FEE:	$20.00
LATE REGISTRATION FEE:	$125.00, *Late Registration fee for ISPO Members is $20.00.*
FURTHER INFORMATION FROM:	ISPO Chairman, Mr W. G. Doig, FRCS, FRACS (03) 63 4688 or at the Royal Children's Hospital.

INTERNATIONAL SEMINAR ON PROSTHETICS AND ORTHOTICS
THEME: TRAUMATIC AMPUTATIONS
HERZLIYA, ISRAEL. SEPTEMBER 6 – 10 1987

TOPICS will include:

Multiple trauma; management of the traumatized limb with specific reference to the decision to be made with regard to limb salvage or limb abiation; reimplantation; amputation following limb salvage procedures; stump reconstruction; early amputation; late assessment of the post-traumatic patient; traumatic amputations in children and the elderly; multiple amputations; rehabilitation goals of the upper limb and the lower limb amputee; new developments in prosthetics and orthotics; following limb salvage, bracing of limbs—function or support; foot disorders in post-traumatic patients; surgical and/or orthotic solutions. Indications for partial foot amputations.

Venue:	The Dan Accadia Hotel, Herzliya, Israel.	
Fees:	Before July 1, 1987	After July 1, 1987
Physicians	US $ 180.00	US $ 220.00
Para-medical participants	US $ 140.00	US $ 170.00
Accompanying persons	US $ 80.00	US $ 80.00

Further information from the Secretariat, ISPO 1987, PO Box 50006, Tel Aviv 61500, Israel. Telephone (03) 654571.

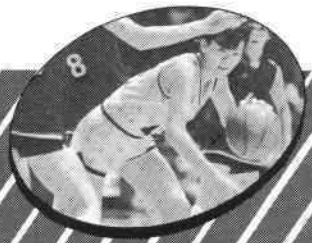
CALL FOR PAPERS

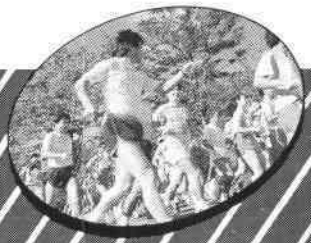
Those wishing to present a paper are requested to submit an abstract no later than January 31, 1987.

Dynamic Knee-Brace **New Product**

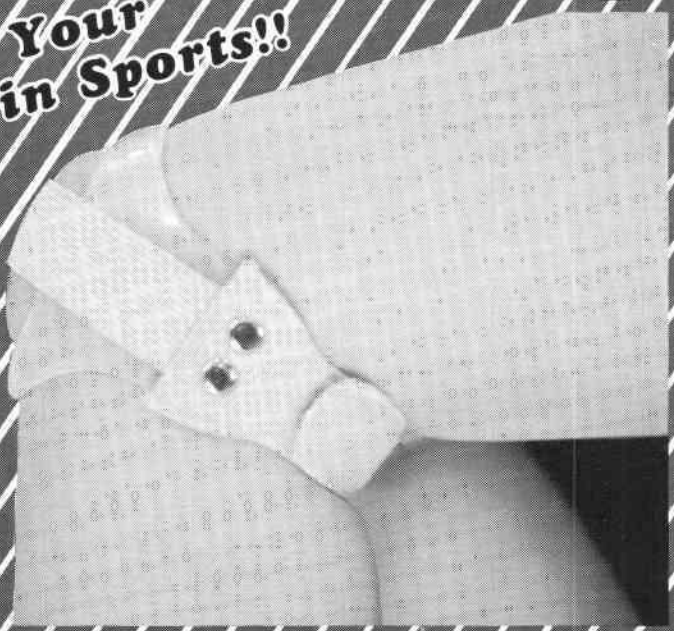
Patellar Band

703N





Protects Your Knees in Sports!!



— Japanese Patent, Design Registration, Trademark Registration and U·S·A Patent — Being Applied for.

(Product Name) **Patellar Band**

(Model No.) **703N (P.B.-R.L.)**

Size	S	M	L
Peripheral Dia. of Knee Joint (cm)	30—34	35—39	40—44

(Applicable to both left and right knees)

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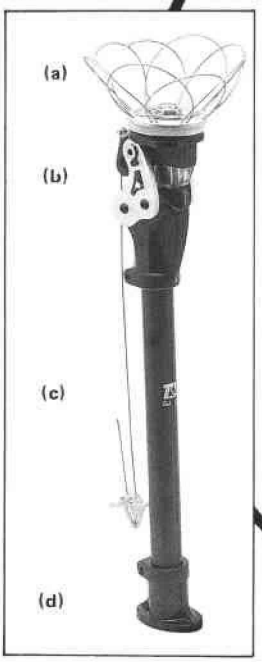
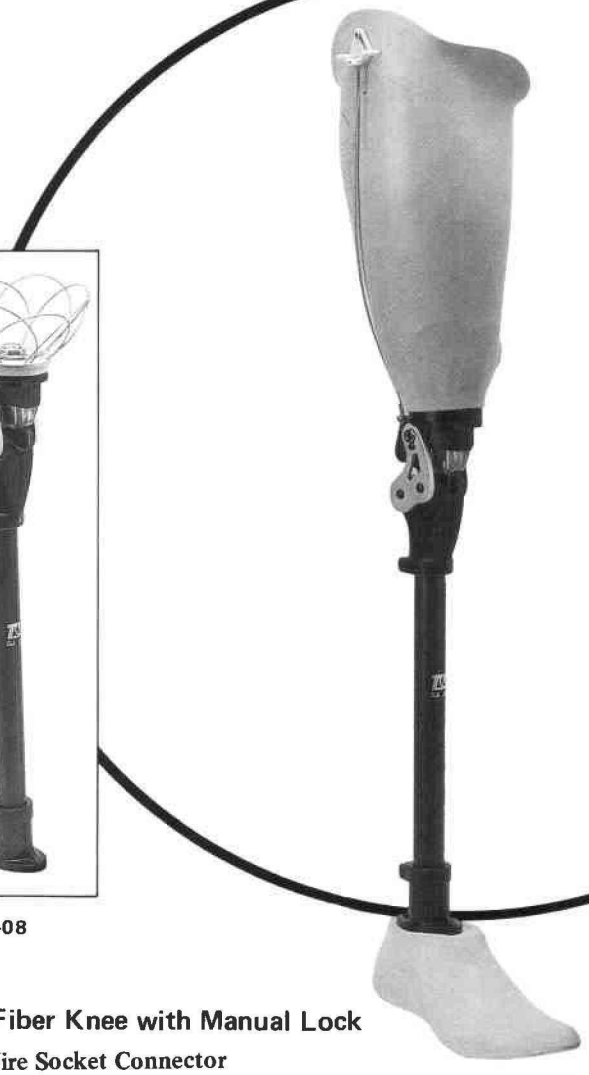
TEH LIN CARBON FIBER PROSTHESIS

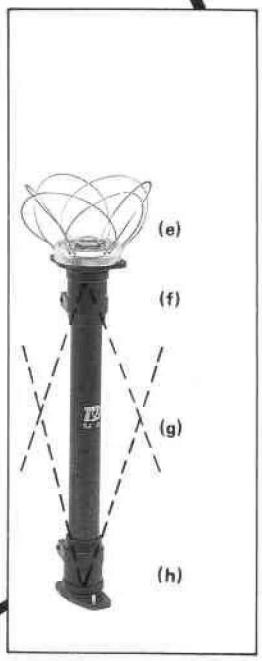
A.



CFSAKM-08



B.



CFSBKA-09

A. Carbon Fiber Knee with Manual Lock

(a) AK Wire Socket Connector
(b) Carbon Fiber Knee with Manual Lock Unit
(c) Carbon Fiber Tubing
(d) Carbon Fiber SACH Ankle

Weight: 0.9 Kgs.

B. Carbon Fiber Adjustable Below Knee

(e) BK Wire Socket Connector
(f) Carbon Fiber BK Adaptor
(g) Carbon Fiber Tubing
(h) Carbon Fiber Adjustable SACH Ankle

Weight: 0.35 Kgs.

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THE PROSTHESIS HAS BEEN WELL RECEIVED IN THE U.S.A.
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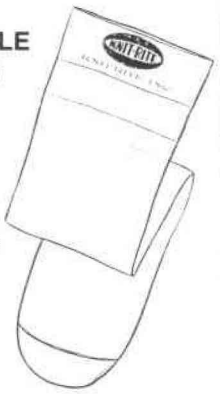
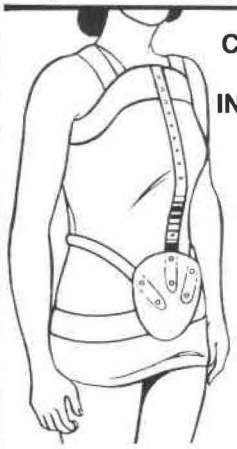
Compressogrip STUMP SHRINKERS

Tubular elastic compression material for control or prevention of edema following amputation surgery.

NEW STYLE SHEATHS



Sheath sizes correspond to prosthetic sock sizes



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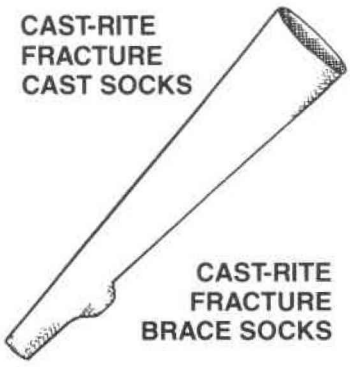
For wear under body jackets, girdles, plaster casts, etc.

Compressogrip TUBULAR ELASTIC BANDAGE

CAST-RITE FRACTURE CAST SOCKS



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The patented S.O.M.I.® Brace has been used for a number of years to provide stability and support for a variety of injuries associated with the cervical spine. Now, the respected S.O.M.I. suspension system is available with a halo type body jacket to provide even more support for a variety of post-surgical applications as well as acute sprains, strains and subluxations.

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Stabilization of the cervical spine is achieved by immobilizing the skull relative to the chest with a S.O.M.I. type superstructure connected to a halo type body jacket. Occipital and mandible pads are completely adjustable to provide maximum support and control anterior/posterior motion, lateral flexion and axial rotation. In addition, an improved over-the-shoulder suspension system is used for positive body jacket support and positioning.

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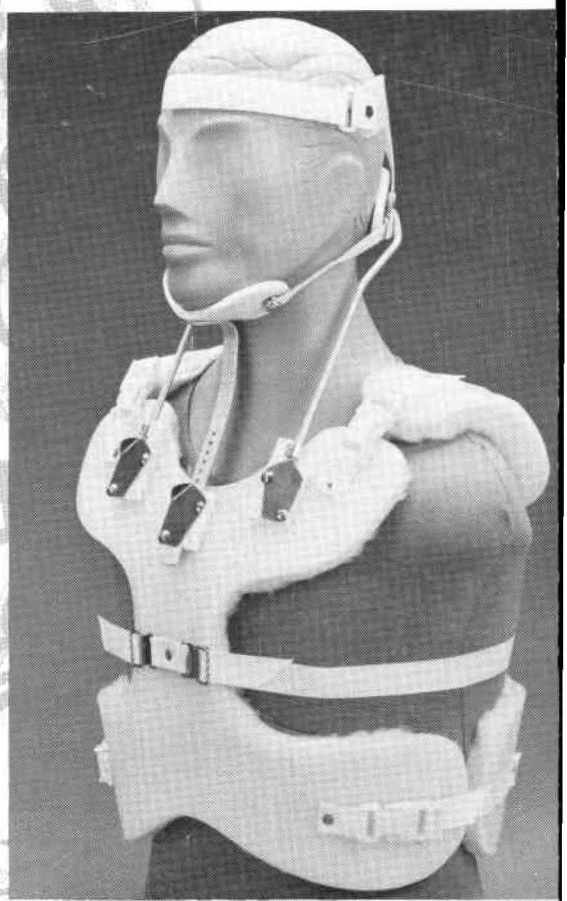
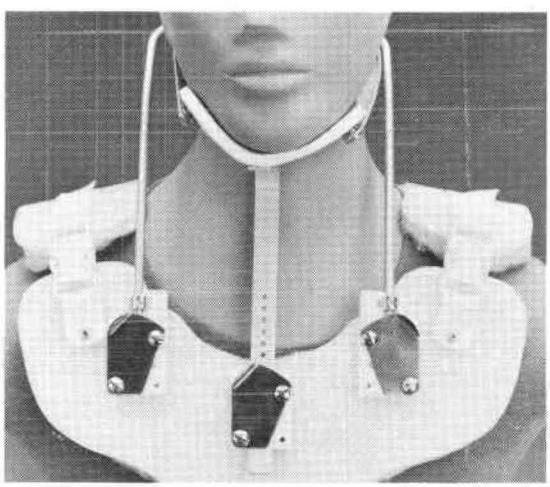
For comfort the S.O.M.I. Vest—C.T.O. body jacket is thermoformed from flexible polyethylene and covered, on the inside, with a soft Kodel liner. The liner is attached to the body jacket with Velcro® and may be easily removed, washed or replaced for patient hygiene.

The lightweight body jacket is also ventilated to help in the prevention of pressure sores.

As rehabilitation proceeds a S.O.M.I. head band may be used to allow removal of the chin plate enabling the patient to eat, wash or shave while maintaining a stable cervical spine.

Three sizes to correctly fit adults and children.
The S.O.M.I. Vest—C.T.O. is designed to provide cervical immobilization for patients ranging in weight from 75 to 200 pounds. Fully adjustable and easy to apply, the S.O.M.I. Vest C.T.O. may be fitted while the patient is in a horizontal position, such as a hospital bed or Stryker type frame.





Product Numbers:

Size	Chest Circumference	Patient Weight	Product Number
Small	26"–30"	75–100 lbs.	A30-200-000
Medium	30"–36"	100–140 lbs.	A30-200-000
Large	36"–44"	140–200 lbs.	A30-200-000

U.S. Patent Number 3,724,452

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