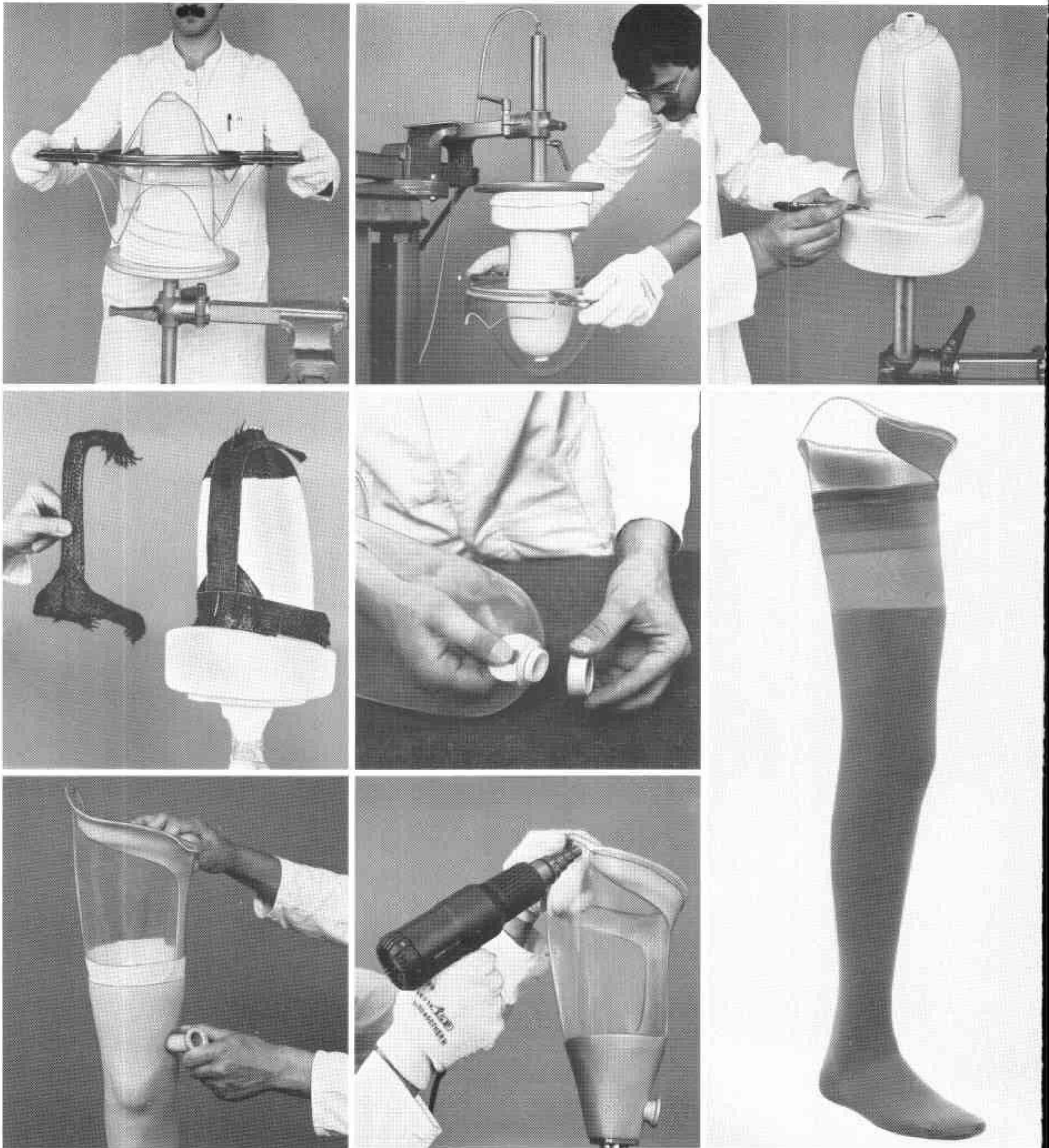
The Journal of the International Society for Prosthetics and Orthotics

Prosthetics and Orthotics International

December 1988, Vol. 12, No. 3



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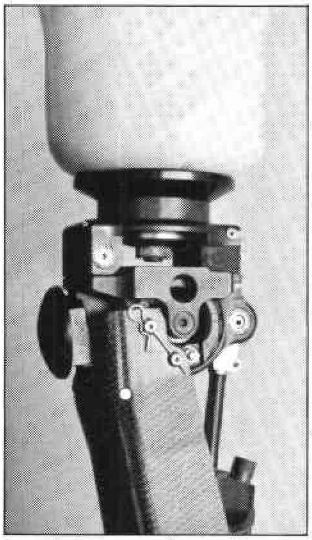

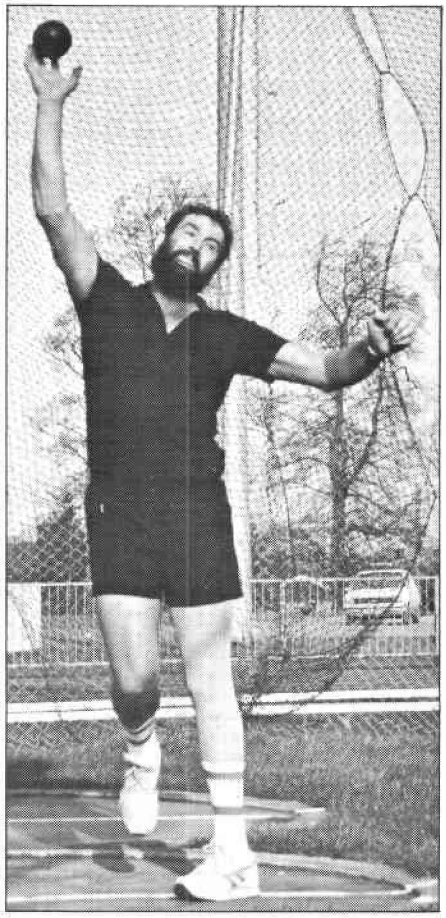

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The Journal of the International Society for Prosthetics and Orthotics

December 1988, Vol. 12, No. 3

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ISPO

Prosthetics and Orthotics International, 1988, 121–122

Editorial

The activities of our Society continue to multiply. Our National Member Societies provide at national level a forum and a focal point for the clinic team to improve standards of patient care. The Executive Board tries to be supportive of National Member Society activities, but naturally concentrates much effort on the international aspects of our affairs. It tries to maintain a balance between the industrial and the developing world and the varying interests of our diverse membership. Thus we see side by side in our calendar such events as a meeting on sophisticated Computer Aided Design and Manufacturing techniques and a workshop on education and training requirements for developing countries.

So far as the developing world is concerned, although membership is available at a reduced fee, we really have rather few members. Frequently, therefore, the initiative for an event or activity related to the developing world has to be generated from outside. This has certainly been true of the Executive Board's initiatives on training. It is always difficult to strike the right balance between funding activities which relate to the majority of the membership in the industrial or the minority in the developing world. It is, therefore, reassuring to have our National Member Societies also promoting activities and therefore spending which will not directly benefit them, but which displays their concern and adherence to the aims of the constitution.

Such an initiative has come from the United Kingdom National Member Society, which suggests that one way of improving the lot of our colleagues and their patients in the developing world may be by a mechanism of "twinning". The substance of their proposal, which is to facilitate the development of co-operative links between ISPO members and their National Societies in the industrial and the developing countries of the world, has two main elements and is oulined by them as follows:-

1. **Information Provision**

   Access to journals, books and technical literature is frequently very limited in developing countries either due to cost or simple unavailability.

   It is proposed that a member society in an industrial country could collect and regularly ship literature of a general nature donated by members to a distribution point in a selected developing country.

   Requests for specific items of literature could also be considered. In certain instances it might be necessary to consider the translation of specific *key items* of literature.

   Literature collection and transportation would be at the cost of the donor society; however, the cost of translation might require financial support from ISPO.

2. **Educational Travel**

   Education and training of ISPO members in developing countries might be advanced in several ways:

   a) by providing a scholarship for an ISPO member in the country to attend a World Congress,

   b) by planning and organizing a visit by an ISPO member in the country to the industrial country to follow an appropriate programme of visits and/or practical element experiences,

   c) exceptionally, by organizing a visit by a specialist from the industrial country at the request of the host country to assist with a specific task or problem.

The selection of candidates and the planning of the itinerary or programme for educational travel projects is extremely important if real benefits are to be obtained by the recipient country. It should be the responsibility of the member society in the industrial country which proposes the project to ensure that these matters are fully investigated prior to submitting a proposal and adequately monitored during their implementation.

The Executive Board has welcomed this proposal in principle and agreed that it should be displayed to National Member Societies generally. Naturally, specific proposals will have to be considered on an individual basis and against the funding available, but this initiative represents a good prospect for providing real help in many areas of desperate need.

John Hughes
President

Prosthetics and Orthotics International, 1988, 12, 123–124

Kobe — November 1989

Report from the President and President-Elect

Your President and President-Elect have recently taken part in the 16th World Congress of Rehabilitation International in Tokyo. The President was giving a Key-Note Lecture on New Technology and both were taking part, along with other ISPO members, in the Sectoral Session on the same subject presented by ISPO and organized by the President-Elect. One of the aims of ISPO's involvement, as planned by our own Japanese Congress Committee, was to publicise next year's World Congress in Kobe. We believe this opportunity was well taken and much interest aroused. The opportunity was also taken to meet with our Japanese Committee and to visit the site of the Congress in Kobe.

There can be nothing but praise for the marvellous job which our Japanese colleagues are doing. The committee, under the able Chairmanship of Professor Tsuchiya and with the boundless energy and enthusiasm of our Secretary-General, Doctor Seishi Sawamura, has identified an excellent site and created an efficient organization to ensure the success of the Congress in every aspect. Our visit to Kobe was accompanied by pleasant and interesting meetings with the Provincial Governor and the Lord Mayor, both of whom have generously promised their support for our meeting. An extremely high level of social awareness in respect of the disabled is generally evident in Japan, and particularly in Kobe. The facilities of the Congress Centre are first-class, probably better than any we have previously used, with an excellent Exhibition Area. The exhibition itself is being actively promoted by our friends in Interbor, and is under the management of Mr. Kawamura. The Congress Hotel, the Portopia, is immediately adjacent and can only be described as De Luxe with large, beautifully appointed rooms. The venue is ideal in every respect.

So far as the World Congress is concerned, plans are well advanced, everything is on schedule, and the second announcement, with detailed programme, should be in members' hands before the end of the year. All that is now required to ensure success is a good attendance by the membership. Before our visit both of us were apprehensive about costs in Japan, having heard the familiar horror stories! We were so astonished at the actuality that we felt it important to share our feeling about prices with members.

Accommodation prices in Kobe do not appear high by any standard. A single room in the Portopia, which is a luxury hotel, is, at the rate arranged by our Congress organizers, about US $90 per night. We also had pointed out to us nice, simple hotels in Kobe, where a room with bath and WC is less than $40. In the immediate vicinity of the Congress Centre are many small restaurants where a simple Japanese meal costs between $5 and $8. All of these restaurants either had illustrations of, or, more often, the dishes themselves displayed outside with the cost clearly indicated. Taxis for local journeys did not seem to be expensive. (The fantastic taxi fares frequently quoted for the journey from the Airport to Tokyo should be viewed against the journey time of about 90 minutes!) However, public transport (e.g. underground train) is good, cheap, clean, widespread and easy to use — also for the disabled, and very safe, as is the rest of Kobe.

All of this says nothing about the charm and interest of the country, the excellent service provided without thought of gratuity, or perhaps most of all, the hospitality of the people. Following this report we publish an extract from an exchange of correspondence between two of our members. We believe it bears out our impressions — it may even be generous in its estimates. Our advice is to make realistic estimates of your likely cost. Travel obviously varies, depending on where you are sited, but good packages are available. We think this venue may be less expensive than most we have previously used!

"Regarding costs, I hope I can give you a more realistic idea of the situation here. The person who quoted you figures of $175 for a cab fare and $1,000 for a hotel room must have had a wonderful time during his stay. Tokyo and Kobe are expensive cities by international standards, but there is no necessity for spending those sums. It is certainly possible to spend $175 riding by taxi from Narita Airport into Tokyo, but there is also an excellent limousine bus service running every 20–30 minutes for less than $20. By the same token, it is easily possible to spend $1,000 or more per night for a luxurious hotel suite, but a realistic estimation of average room rates would run from $35 to $150 for a single room, slighty higher for a double. Meals would run as follows: breakfast: $5–10, lunch: $5–15, dinner: $10–20. It would be a good idea to encourage people to eat at restaurants outside of the hotels as much as possible as those inside tend to be expensive, as they do in any country.

Your third request, regarding the cost of "a night on the town", is much more difficult. It would, of course, depend on one's idea of a night on the town. An individual of modest means could have a hamburger and watch a movie for under $15, while a true man of the world could easily spend thousands of dollars in some of the city's geisha clubs. The rest of us fall somewhere in-between, so I've outlined some basic costs below and hope they prove useful:

Movie admission:	$5–15
Disco:	$15–20 (usually includes one drink, snacks)
Drinks:	Beer — $5, mixed drinks, etc. — $10+

Regarding clubs, good advice would be to go with a Japanese guide or friend, since substantial cover charges exist in some which are not always announced. In summary, as in most of the world's major cities, one really does *not* have to spend a lot of money to enjoy oneself. Complete details regarding social and accompanying persons' programmes will be available in the Final Programme to be published in early September."

We hope that with the support of the membership, our first World Congress in Asia will be a truly memorable event.

John Hughes
President

Willem Eisma
President-Elect

Prosthetics and Orthotics International, 1988, 12, 125–127

Executive Board Meeting

26th and 27th August, 1988

The following paragraphs summarize the major discussions and conclusions of the last Executive Board Meeting held in Heidelberg. They are based on the draft minutes of that meeting which have not yet been approved by the Executive Board.

Chairman and Task Officer Reports

The Honorary Treasurer reported on the Final Accounts for 1987 which were published in the April edition of the Journal. He presented a revised budget for 1988 which anticipated a deficit of approximately 128,000 Danish Kroner and outlined a proposed budget for 1989 which anticipated a deficit of 211,000 Danish Kroner, which was largely due to the high costs to be incurred in activities associated with the World Congress in Japan. The Executive Board approved the revised budget for 1988 and the proposed budget for 1989.

The Protocol Committee presented a draft document of 'Guidelines for Organizing Conference-type Events'. The Executive Board made recommendations for amendment of the paper and agreed that it would be useful for organizers of local and regional ISPO events. A definitive document would be produced and circulated to National Member Societies. The Protocol Committee also presented proposals for certificates for locally organized meetings. It was agreed that a sample certificate should be made up and circulated as a suggestion for use by National Member Societies.

The Executive Board formally approved the formation of the New Zealand National Member Society. The Honorary Secretary indicated that there were strong moves in Austria, Korea and Jordan for the establishment of National Member Societies in those countries (since the Executive Board Meeting, a National Member Society has been established in Austria). The Honorary Secretary informed the Board that membership of the Society was increasing and at present was approximately 1,950 with, in addition, approximately 400 subscribers to the Journal.

The Task Officer for Education reported that the Strathclyde and Toronto Reports were almost completed. He indicated that the major recommendation from the Strathclyde meeting was that the Society should attempt to run a pilot course for upgrading short course trained technicians, if it were possible to find money to sponsor this task. To this end, discussions were underway in an attempt to find the means of raising the funds to initiate such an activity.

The Task Officer reported that the Tanzanian Training Centre for Orthopaedic Technologists (TATCOT) had been inspected by himself and the Honorary Secretary. The Board approved their recommendation that TATCOT be recognised as training orthopaedic technologists for a further three years. The protocol for the inspection of prosthetic and orthotic education centres was at present being amended to include centres in the industrial as well as the developing world and in future centres wishing inspection would be provided with the guidelines.

The Chairman for the Publications Committee reported on the difficulties in the production of the International Newsletter in using two co-editors, as a result of which David Condie had offered his resignation which the Executive Board received with regret. The Proceedings of Dundee '85 are presently being printed and will be published under the title of "Amputation Surgery and Lower Limb Prosthetics". A draft report of the CAT/CAM meeting in Florida has now been prepared but has yet to be finalized before publication. A report on the CAD/CAM meeting held in Seattle was now being prepared and it was hoped that there would be an early publication. Investigations are being made on how best the proceedings from the Heidelberg meeting on the limb deficient child can be published. The editors of 'Prosthetics and Orthotics International' are pursuing the means to produce a ten year index for the Journal. If the funds to do this cannot be found, the possibility of producing a 15 year index will be considered.

Work is continuing in the International Standards Organization, Technical Committee 168, 'Prosthetics and Orthotics'. A further meeting of the Working Groups was to be held in Italy in October.

The Task Officer for the Limb Deficient Child indicated that a Committee on the Limb Deficient Child would be formed at the meeting in Heidelberg. He hoped to be in a position to make a proposal to the Board as to who the Chairman for this committee might be in the near future.

The Task Officer on Socket Design reported on the recent CAD/CAM meeting held in Seattle. This had been well attended by the majority of interested parties and was strongly supported by the American Academy of Orthotics and Prosthetics as well as the Veterans Administration.

The Task Officer for the Professional Register reported on a pilot study of the proposed questionnaire from which it would appear there were no technical difficulties. The questionnaire should now be finalized after which it should be circulated to the membership and the Professional Register instituted.

The Honorary Secretary reported to the Executive Board that regretfully, Gertrude Mensch would no longer be able to perform as Task Officer for Journal Promotion. Meanwhile, this task would be carried out by the Editorial Office of the Journal.

Public Relations

The Executive Board discussed the need to prepare a leaflet which would help promote the Society's image. It was agreed that this matter should be pursued.

Internationl Organizations

The new President of INTERBOR is now Jose Camos, however, the immediate past President, Jacques van Rolleghem will continue to be INTERBOR's representative on ISPO's Board. The ISPO/INTERBOR Education Commission had met in Paris in March of this year in an attempt to reach a mutually acceptable agreement with regard the standards for training and education in prosthetics and orthotics. This is especially important in order that both Societies may influence the European Economic Community (EEC) Regulations which are to be introduced in 1992 with regard to reciprocal recognition of professional training. The recommendations of the joint commission was approved by the Executive Board and these recommendations shoud be made known to the EEC.

The World Health Organization (WHO) is developing a strategy for the management of services to deliver orthopaedic appliances in developing countries. The Executive Board agreed that the Society should continue to involve itself in helping WHO to develop this strategy.

The President would be making a plenary session presentation at the forthcoming Rehabilitation International (RI) Congress in Japan. In addition, the Society was responsible for preparing a session on Developments in Prosthetics and Orthotics at this Congress. It was hoped that these activities would help develop an interest in ISPO's World Congress in Japan next year.

The President reported on an agreement between the Society and the Internationaler Verband der Orthopadie-Schuhtechniker (IVO) to have a mutual exchange of observers at Board Meetings of the Societies. The President Elect would represent ISPO on the IVO Board and Rolf Henz, General Secretary of IVO, would be their representative on ISPO's Board.

The President reported that he had attended the last World Orthopaedic Concern (WOC) Executive Board meeting during which further collaboration between WOC and the Society was suggested. A further meeting between representatives of both Societies would be held in September and these suggestions would be explored further.

A meeting was held in Tanzania in July which was organized by an agency of the United Nations, the Center for Social and Humanitarian Affairs, in conjunction with Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) and in collaboration with ISPO. The meeting examined education and training in prosthetics and orthotics, levels of technology and local production of components amongst other subjects. The Honorary Secretary was appointed as Rapporteur for this meeting and will help prepare the official report which should be available early next year.

Congresses

The organization of the VI World Congress was almost completed. The final announcement would be available in the near future. Further details of the Congress are available elsewhere in this issue of the Journal.

The Swedish National Member Society have withdrawn their invitation to host the 1992 Congress. However, the United States has supplied further information with regard to their invitation. The Board discussed this invitation and raised a number of questions related to the budget. A more comprehensive budget requires to be prepared before further action can be taken.

Conferences and Meetings

a) The Board were informed that the response to the meeting of the Limb Deficient Child which was to be held in Heidelberg following the Executive Board Meeting was good. There were over 170 registrations and 27 exhibitors.

b) The Symposium on Wheelchairs and Special Seating held in Dundee, Scotland was well attended. Approximately 300 people participated in this meeting.

c) The Society had agreed to collaborate in the third International Conference on Musculoskeletal Accidents and Injuries in the Workplace to be held in November in Bangkok. It was agreed that Thamrongrat Keokarn should represent ISPO's interests at the meeting.

d) Planning for a meeting in Sweden on the Deformed Foot and Orthopaedic Footwear was still continuing. It is hoped that this meeting will be held in Jonkoping in June 1990. It was agreed that the Swedish National Member Society should continue with the planning of this conference and report to the next Board meeting.

e) The Executive Board were informed that a meeting on prosthetics and orthotics in the developing countries of the Americas was being organized by the United States National Member Society, in October of this year. The purpose of this meeting was to bring together all American agencies involved in this field with a view to co-ordinating their activities.

Fellowships

Honorary Fellowships have been awarded to Eric Lyquist (Denmark), Ernst Marquardt (Germany).

Fellowships have been awarded to Roy Nelham (UK), William Doig (Australia).

Norman A. Jacobs
Honorary Secretary

Obituary

Daniel Wijkmans

22nd June, 1938 — 28th April, 1988

On the 4th May 1988, many were gathered for a final farewell to Daniel Wijkmans. A fatal illness had cut a fine life too short.

For his family a sad bereavement and for ISPO a great loss the extent of which will soon become evident.

Since 1983 a Committee Member of the Netherlands National Member Society of ISPO and acting as vice-president during the last year, Daniel was the head and the heart of the very successful mini-symposia, and co-responsible for the explosive increase in membership over the last few years. His knowledge of the problems of disability and his many professional and personal relations guaranteed new and original projects for ISPO-Netherlands. He took special interest in the challenging field of rehabilitation-technology and repeatedly stressed its importance for national and international progress. In this role he was invited to the Seattle workshop on the development of CAD-CAM in June 1988 and looked forward to discussing advance with other international experts. But for him this meeting came too late.

Being a member of the International Scientific Committee for the Copenhagen World Congress he seriously applied himself to this task and as a matter of course was appointed again for the next international event in Kobe, Japan.

His job at the National Institute for Preventive Healthcare, in charge of supplies for the disabled, amalgamated easily with his hobby, ISPO. As well as his inspiration he also provided us with efficient and hard work as organizer of many ISPO events. In the last few years he often complained about the lack of time to execute all the plans he had in mind. With his early death an invaluable potential has been lost.

Concern, know-how, ambition and diligence made him a Committee member of our National Member Society, but there we met a dedicated person and a warm, feeling, friend. The sudden death of Daniel Wijkmans leaves us with deep sorrow. There only remains for us the indelible remembrance and the inheritance of his ideas.

J. H. Arendzen
Hon. Secretary
Netherlands National Member Society

Prosthetics and Orthotics International, 1988, 12, 129–135

The role of rigid and hinged polypropylene ankle-foot-orthoses in the management of cerebral palsy: a case study

E. A. MIDDLETON, G. R. B. HURLEY and J. S. McILWAIN

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Abstract

Ankle-foot orthoses are commonly used in the treatment of spastic cerebral palsy to hold the foot in a position conducive to a more functional gait. This study, utilizing quantitative biomechanical techniques, evaluates the effects of a rigid ankle-foot orthosis and a hinged ankle-foot orthosis on spastic cerebral palsy gait. The subject was a 4.5 year old female diagnosed as spastic diplegic cerebral palsied shortly after birth. Testing involved collection of kinematic coordinate data employing a WATSMART video system and ground reaction force data using a Kistler force plate. Jensen's (1978) photogrammetric method was used to estimate body segment inertial parameters. The hinged ankle-foot orthosis was found to be more effective than the rigid ankle-foot orthosis. The subject exhibited a more natural ankle motion during the stance phase of gait, greater symmetry of segmental lower extremity motion, and decreased knee moments during stance while wearing a hinged ankle-foot orthosis.

Introduction

In spastic diplegic cerebral palsy, the upper motor neuron lesion produces weakness and increased muscle tone which results in varying degrees of disability. The aim of orthotic management in spastic cerebral palsy is to produce a more normal gait pattern by positioning peripheral joints in a way that reduces pathological reflex patterns or by blocking pathological movement of the joint. Analyses of cerebral palsy gait, employing qualitative (Mann, 1983) and quantitative methods (Hershler and Milner, 1980; Skrotzky, 1983; Lee et al., 1985), have been reported in the literature. However, little research has been done evaluating the effects of orthotic devices on the gait of the cerebral palsied child. The studies that have been reported use subjective (Rosenthal, 1984) and qualitative (Taylor and Harris, 1986) means of evaluation. Bertoti (1986) investigated the effect of inhibitive casting on cerebral palsy gait, however, the subjectiveness of evaluating ink blots renders the interpretation of the results questionable. The purpose of this paper is to evaluate the effects of a rigid ankle-foot orthosis (AFO) and a hinged AFO on spastic cerebral palsy gait utilizing quantitative biomechanical techniques.

Spastic cerebral palsy is characterized by abnormal reflex patterns, retention or surfacing of primitive reflexes, and an abnormal increase in muscle tone (Pederson, 1969). Spasticity develops when the inhibitory effects of higher brain centres are removed as a result of damage to the upper motor neurons. The result is abnormal posture and movement patterns (Bobath, 1971). In an attempt to improve balance and normalize movement patterns of spastic individuals, a variety of orthotic devices are used.

The majority of spastic cerebral palsy patients exhibit high tone in the extensor muscles of the lower extremity. Spastic plantarflexors and invertors pull the foot into an equinovarus position. The effective use of inhibitive plaster casts to position the spastic equinus ankle and foot in a functional plantigrade position has been documented (Sussman and Cusick, 1979; Cusick and Sussman, 1982). Extension of the metatarsalphalangeal joint by a raised toe plate may aid in reducing the positive support reaction. The casts position the patient's feet and ankles in a functional alignment allowing more normal movement patterns to be established. Inhibitive casting has been

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reported to aid in reducing foot deformity and muscle tone in the affected extremity (Duncan and Mott, 1983) and in improving stride symmetry and length (Bertoti, 1986).

Tone-reducing ankle foot orthoses (TRAFO's) were developed as removable splints that function in a manner similar to the inhibitive cast. More specific guidelines pertaining to the positioning of the ankle and foot accompanied the introduction of this AFO (Jordan et al., 1984). Fabrication utilizes lightweight fibreglass casting wrap in place of standard plaster bandages. TRAFO's are used as an adjunct to physical therapy to reduce spasticity and aid in unassisted standing and walking (Jordan et al., 1984).

Following improvement in motor performance the casts or TRAFO's may be replaced with rigid polypropylene AFO's. As with inhibitory casts, the AFO's rigid posterior section locks the ankle in a functional position. Rigid AFO'S are lightweight and more cosmetic than plaster casts and are designed to be worn inside regular shoes. Stabilization of the foot and ankle aids in proper heel-strike and enhances standing balance by blocking all motion at the ankle (Rosenthal, 1984; Harris and Riffle, 1986).

Recently, the custom-moulded polypropylene hinged AFO, with a plantarflexion stop (Figure 1), has become a popular device used to inhibit pathological plantarflexion yet allow some range of normal dorsiflexion to occur at the ankle joint. The potential for ankle dorsiflexion will allow

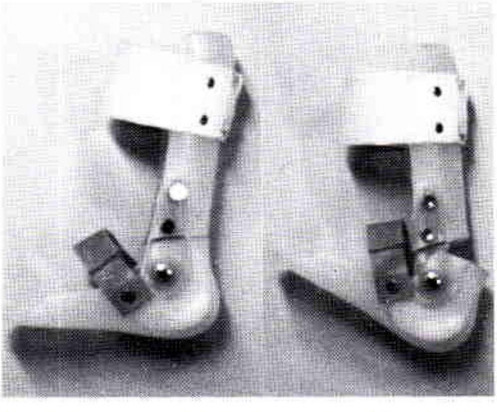

Fig. 1. Custom moulded polypropylene hinged ankle-foot orthosis. Left, plantarflexion stop. Right, dorsiflexion range

stretching of the Achilles tendon which may result in reduced spasticity of the triceps surae muscle. It is presumed that bracing with the hinged AFO produces a more normal gait pattern, however, there is no information examining the effects of the hinged polypropylene orthosis on spastic gait.

Methodology

The subject was 4.5 years of age and diagnosed as spastic diplegic cerebral palsied shortly after birth. Physical assessment revealed full range of plantarflexion and up to 5 degrees of dorsiflexion at the ankle bilaterally. Knee range of motion showed approximately 3 degrees of hyperextension but was otherwise normal. Within the limitations of the spasticity grading scale and subjective gait analysis, both lower extremities exhibited equal degrees of spasticity and were classified as moderately spastic. The subject's first orthoses were bilateral TRAFO's (age 2.3 years and worn for 10 months). These were replaced by rigid custom-moulded polyproplyene AFO's at 3.2 years of age. The rigid AFO's were worn for one year and 4 months. Hinged custom-moulded polypropylene AFO's were dispensed 3 months prior to testing and were being used at the time of the testing. The subject was a voluntary participant and informed consent was obtained from the parents prior to testing.

Fabrication technique

Two pairs of custom-moulded polypropylene AFO's were fabricated for the subject. A negative cast was produced by casting the subject with plaster-of-Paris wrap. The subtalar joint axis was positioned in neutral and the ankle joint was cast in 5 degrees of dorsiflexion. A positive mould was made by filling the negative mould with plaster. This was then modified for the production of a hinged AFO. The axis of the mechanical ankle joint was placed at the distal tip of the medial malleolus, in the line of progression, reflecting normal toe-out. Two Ortholen plates were fabricated and moulded to the positive cast at the ankle axis. The polypropylene was drape-moulded, trimmed and cut into two sections approximately 1.5 centimetres above the ankle axis leaving the Ortholen intact. The calf section of the orthosis was permanently attached to the upper area of the Ortholen plates and the foot section was attached to the

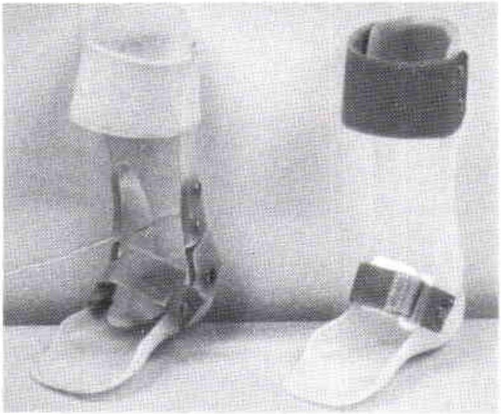

Fig. 2. Hinged and rigid AFO's fabricated for the subject.

Ortholen by two Chicago screws. The foot section was free to rotate on the Ortholen hinge through a range from 5 to 35 degrees of dorsiflexion. Two Velcro straps were attached, one over the proximal tibia and one at the proximal foot section. Rigid AFO's were fabricated from the same positive casts (with the ankle re-modified to form a rigid structure) in an attempt to maintain similar structure for both orthoses (Figure 2).

Data collection

Testing involved collection of kinematic coordinate data using a WATSMART video system and ground reaction force data employing a Kistler force plate. A 35mm photograph of the subject was taken in order that segment inertial parameters could be estimated. Force plate and kinematic coordinate data were collected for the right lower extremity and kinematic coordinate data were collected for the left lower extremity. Two independent three segment link systems were used to model the motion of the lower extremities during ambulation.

A two camera WATSMART kinematic data acquisition system was used to acquire the two-dimensional positions of four anatomical landmarks on each lower extremity (50 hertz sampling rate). Three centimetre diameter disks containing 3 infra-red emitting diodes (IREDS) were placed over the anatomical landmarks. These landmarks located the anatomical joint centres of the hip, knee and ankle, and the distal end of the foot segment. The cameras were placed perpendicular to the sagittal motion of the lower extremities. The subject was familiarized with the testing area to promote natural performance during data collection. Walking trials lasted approximately 3–4 seconds and 20 walking trials were carried out for each of the three test conditions (unbraced, wearing rigid AFO's wearing hinged AFO's). The subject wore shoes throughout the testing.

The 35mm still photograph was analyzed by projecting the image on an X-Y digitizer and following procedures consistent with Jensen's (1978) photogrammetric method. Estimation of segment inertial parameters (mass and moment of inertia about the transverse proximal axis) were determined mathematically by modelling body segments as standard geometric shapes. The model employed considers the body segments to be composed of elliptical zones two centimetres wide. Segment densities are assumed (Clauser et al., 1969) and used with the calculated segment volumes to give the segment masses. A computer program was used to calculate inertial parameters, for the thigh, leg and foot segments, from the digitized record.

Subsequent kinematic and kinetic analyses of coordinate data records were performed using the Waterloo Biomechanical Motion Analysis Software Package. Three walking trials from each of the three test conditions were selected for analysis from available trials based on the subject's success in hitting the force plate. Each walking trial was composed of one complete stride and both left and right lower extremities were analyzed. All joint coordinate data were filtered through a low pass recursive second order Butterworth digital filter using a 5 hertz cutoff frequency (Pezzack, 1977). Waterloo Program input parameters were selected and employed in the established manner (Winter, 1979).

Discussion

Quantitative biomechanical analysis was employed to evaluate the influence of the rigid and hinged ankle-foot orthoses on cerebral palsy gait. Ankle relative joint angles (the angle of the foot in relation to the leg) were determined bilaterally so that ankle movement during stance could be evaluated. Absolute angular displacements (the angle of the segment relative to the ground) of the thigh and leg segments were calculated, and bilateral leg/thigh angle-angle diagrams were used in evaluating the degree of symmetry between lower extremity action during the gait cycle. Resultant muscle moments applied to the leg at the knee were calculated during stance for both braced conditions. Parameters reflecting ankle motion, and lower extremity action were selected to determine objectively the effect of the orthoses on the gait pattern. Knee kinetics were used to evaluate the resultant moment acting about the knee with respect to rigid versus hinged AFO gait. These variables are considered clinically relevant in assessing pathological gait.

Ankle motion

Figure 3 depicts left and right ankle relative joint angles for each of the three test conditions (unbraced, rigid AFO, hinged AFO) during stance. Dorsiflexion, displayed most dramatically in unbraced and hinged AFO trials, occurs following foot-floor contact in all three test conditions. The ankle dorsiflexes at weight acceptance since the subject strikes the ground with the forefoot rather than the heel. Dorsiflexion following foot-floor contact is less prominent while wearing the rigid AFO. The rigid AFO shows some ankle motion at weight acceptance as the polypropylene is stressed and bends slightly. As the subject progresses through stance phase the polypropylene rebounds to its original position.

While unbraced or wearing the hinged AFO, both ankles dorsiflex following midstance. This dorsiflexion reflects the forward progression of the body over the base of support. This progression is evident in both

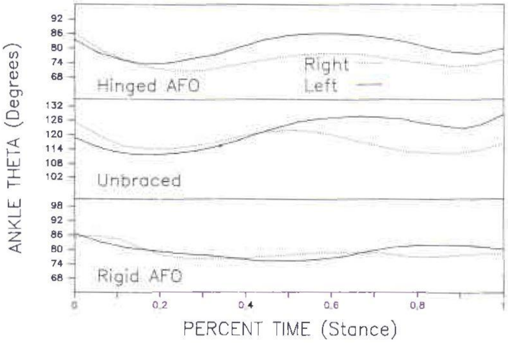

Fig. 3. Ankle relative joint angles, during stance, while wearing rigid AFO's, hinged AFO's and unbraced.

hinged AFO and unbraced conditions, however, while unbraced, the foot remains in a plantarflexed position throughout stance. This plantarflexed foot position is characteristic of unbraced spastic diplegic gait (Lee et al., 1985; Gage, 1983). Plantarflexion following foot-ground contact and during push off, displayed in normal gait (Mann, 1983), is not possible due to the solid structure of the rigid AFO and the plantarflexion stop incorporated into the hinged AFO. The hinged AFO appears to elicit a more desirable ankle joint action since the foot remains in a dorsiflexed position and dorsiflexion occurs during stance. Ankle dorsiflexion during weight-bearing allows stretching of the Achilles tendon which may result in reduced spasticity of the triceps surae muscle.

Lower extremity symmetry

Symmetrical segmental lower extremity motions are characteristic of normal gait patterns. Angle-angle diagrams were produced to illustrate the motions of the right and left lower extremities for one stride. An estimate of congruity or similarity in shape between any two XY patterns may be obtained by chain encoding each pattern and then determining the cross-relation function from the two generated chains (McIlwain and Jensen, 1985; Whiting and Zernicke, 1982). This function, referred to as the recognition coefficient (C), can vary from 0.0 to 1.0. A value of 1.0 indicates perfect congruity or exact symmetry and a value of 0.0 indicates absence of congruity between patterns. This chain encoding technique was employed in determining the degree of symmetry between right and left sides for all walking trials. Furthermore, all trials (both right and left sides) within each of the three test conditions were chain encoded to evaluate between trial variability.

Angle-angle plots of relative joint angles have been used in the assessment of cerebral palsy gait (Hershler and Milner, 1980). Absolute segmental angular displacements for the leg and thigh were selected for this study since the use of ankle relative joint angles was contraindicated due to the lack of ankle motion inherent to the wearing of a rigid AFO. Furthermore, it was felt that absolute angular displacements of the thigh and leg segments better depicted the action of the lower extremity. Figures 4, 5 and 6 illustrate angle-angle plots for unbraced, rigid AFO and hinged AFO trials. Tables 1, 2 and 3 present the results of chain encoding both right and left side angle-angle plots for all trials within each of the three test conditions.

Unbraced walking trials exhibit the least degree of symmetry between right and left lower extremities. Rigid AFO trials are more symmetrical than unbraced trials with the exception of trial 2 which demonstrates a degree of symmetry comparable to the unbraced trials. All three hinged AFO trials display a greater degree of symmetry than the unbraced trials. Hinged and rigid AFO trials are generally comparable in degree of symmetry. Within test conditions variability is highest in the unbraced condition. Unbraced lower extremity movements in cerebral palsy gait may be characterized as lacking in symmetry and variable between cycles. Braced lower extremity movements tend to have a greater degree of symmetry between cycles. Both hinged and rigid AFO trials have similar between trial variability. The results indicate that bracing spastic diplegic gait increases the degree of lower extremity symmetry.

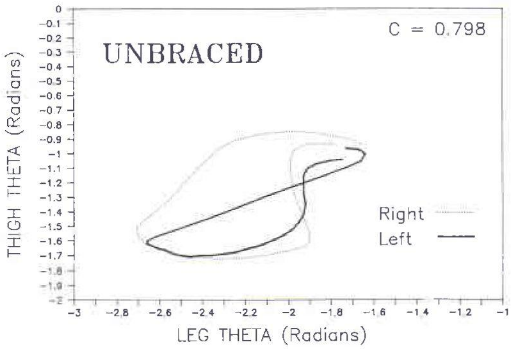

Fig. 4. Angle-angle plots of leg and thigh during an unbraced stride.

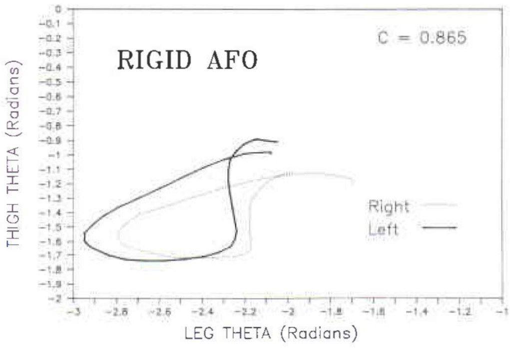

Fig. 5. Angle-angle plots of leg and thigh for one stride while wearing rigid AFO's.

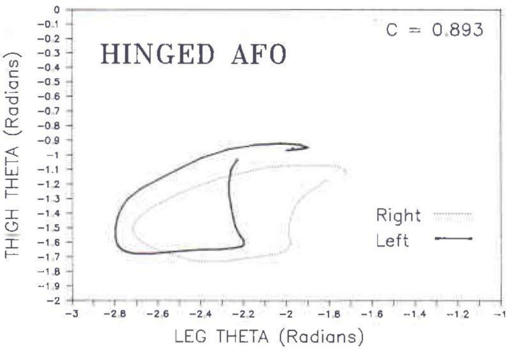

Fig. 6. Angle-angle plots of leg and thigh for one stride while wearing hinged AFO's.

Table 1. Chain encoding results of angle-angle plots for unbraced walking trials.

	Trial 1 Left	Trial 2 Right	Trial 2 Left	Trial 3 Right	Trial 3 Left
Trial 1 Right	**0.831**	0.713	0.799	0.836	0.739
Trial 1 Left		0.751	0.859	0.844	0.819
Trial 2 Right			**0.798**	0.757	0.792
Trial 2 Left				0.839	0.814
Trial 3 Right					**0.799**

Table 2. Chain encoding results of angle-angle plots for rigid AFO walking trials.

	Trial 1 Left	Trial 2 Right	Trial 2 Left	Trial 3 Right	Trial 3 Left
Trial 1 Right	**0.851**	0.806	0.853	0.860	0.841
Trial 1 Left		0.785	0.822	0.854	0.846
Trial 2 Right			**0.796**	0.789	0.792
Trial 2 Left				0.856	0.768
Trial 3 Right					**0.865**

Table 3. Chain encoding results of angle-angle plots for hinged AFO walking trials.

	Trial 1 Left	Trial 2 Right	Trial 2 Left	Trial 3 Right	Trial 3 Left
Trial 1 Right	**0.836**	0.897	0.825	0.860	0.833
Trial 1 Left		0.816	0.833	0.816	0.821
Trial 2 Right			**0.850**	0.870	0.850
Trial 2 Left				0.810	0.805
Trial 3 Right					**0.893**

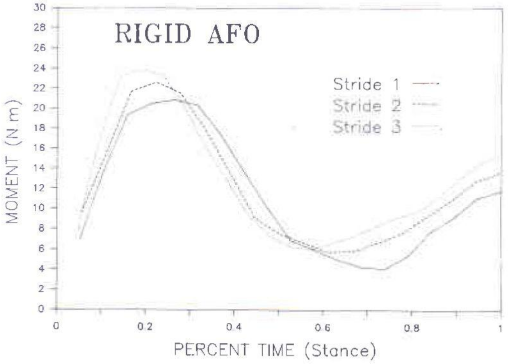

Fig. 7. Muscle moments applied to the right leg, at the knee, during stance while wearing rigid AFO's (positive values indicate extension).

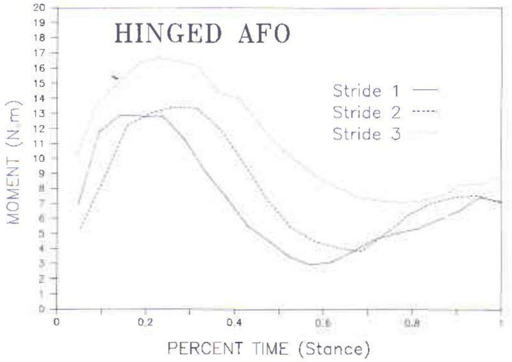

Fig. 8. Muscle moments applied to the right leg, at the knee, during stance while wearing hinged AFO's (positive values indicate extension).

Knee kinetics

The resultant muscle moments applied to the leg, at the knee, during stance for all braced walking trials are depicted in Figures 7 and 8. Resultant muscle moment data estimates the internal moment generated by the muscles and is presented for stance phase only since the magnitude during swing is comparitively small. All knee moment data corresponds to the right lower extremity. Walking velocity for each trial is presented in Table 4.

Table 4. Walking velocity.

	Rigid AFO	Hinged AFO
Trial 1	0.792 ms^{-1}	0.760 ms^{-1}
Trial 2	0.853 ms^{-1}	0.786 ms^{-1}
Trial 3	0.903 ms^{-1}	0.835 ms^{-1}

In all braced trials, peak extension muscle moments occur shortly after foot-floor contact. This peak corresponds to weight acceptance and increases with walking velocity. The magnitude of the resultant extension moments occurring during hinged AFO trials is less than in the rigid AFO condition. Walking velocities between each of the test conditions are comparable suggesting that the differences in magnitude of knee muscle moments between test conditions may not be attributed to differences in walking velocity. In normal gait, ankle dorsiflexion during stance allows smooth forward progression of the body over the base of support. Rigid AFO's prevent dorsiflexion making it necessary for knee extension to be used to advance the body forward and, subsequently, cause greater extension moments about the knee during stance. Decreased knee muscle moments are desirable since they influence energy expenditure and stability during ambulation. This data clearly demonstrates that hinged AFO gait exhibits lower knee resultant muscle moments throughout stance than rigid AFO gait.

Conclusion

Ankle-foot orthoses are commonly used in the treatment of spastic cerebral palsy to hold the foot in a position conducive to a more functional gait. The results of this study demonstrate the effectiveness of bracing in spastic diplegic gait based on increased lower limb symmetry. For the subject evaluated in this study, the hinged ankle-foot orthosis was found to be more effective than the rigid ankle-foot orthosis. The subject exhibited a more natural ankle motion during stance, greater symmetry of segmental lower extremity motion and decreased knee moments during stance while wearing the hinged ankle-foot orthosis. Within the limitations of this study, it appears that the hinged ankle-foot orthosis provides the clinician with a more effective tool for treating spastic cerebral palsy patients than the rigid ankle-foot orthosis.

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Measuring the shape and volume of an above-knee stump

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Abstract

A set of design criteria for sensing the shape of an above-knee (AK) stump is presented and used as the basis for evaluating various shape sensing technologies. A mechanical probe type shape sensing system is described and its use in quantifying the external shape of the AK stump is discussed as it relates to generating a grid for finite element analysis in CAD/CAM studies and comparing the segmental volumes of the loaded and unloaded stump. This study also discusses a method that uses circumferential measurements to compute total and incremental volumes of the stump.

Introduction

Quantifying the surface topology of an object is the first step in numerous processes ranging from making topographical maps to making coins and artificial parts for the body. Each application has its own requirements for accuracy, precision, and surface smoothness. To satisfy such diverse requirements, a number of techniques have been developed (Foort and Pentland, 1975; Zuniga et al, 1978; Karara, 1979; Duncan et al, 1980; Rongo and Gallios, 1981; Saunders, 1982; Diels and Fontaine, 1983; Saunders and Vickers, 1984). New applications for these techniques have met with varying degrees of acceptance. Before the most effective technology can be selected, the investigator must carefully delineate the required results. Sensing the shape of an amputee's stump requires a measuring system that can collect the necessary data before the amputee tries on a prosthesis. Furthermore, this system must provide data that are at least as precise as the data currently collected by a prosthetist.

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Technologies that have been applied to quantifying the shape of an amputee's stump can be classified into two basic groups: contacting and non-contacting sensors. In the first category are the laser-based measuring systems and stereophotogrammetry (Zuniga et al, 1978; Karara, 1979; Rongo & Gallios, 1981; Beiser, 1983; Yamashita et al, 1983; Fernie et al, 1985), while the second includes mechanical probes (Zuniga et al, 1978) and ultrasonic systems that require the leg to be immersed in water. The devices in the first category generally provide very fast data collection (2–5 seconds), but require a mainframe computer to transform the data into useful information and a room large enough to accommodate the often bulky equipment that is needed to do the measuring. Moreover, when stereo-photography is used, the space available in many prosthetics shops may be inadequate. The other performance characteristics of the measuring systems that fall into the first category are well-documented (Karara, 1979; Beiser, 1983; Yamashita, 1983; Saunders and Vickers, 1984). The devices in the second category generally require less space for operation and less computing power to create useful information, but they require substantially more time to capture the data (4–7 minutes). This data capture time requires that the subject be stabilized so that the limb segment does not move; taking simultaneous diametrically opposed readings can help reduce the effects of slight motion of the limb. Large motion artifacts can be detected during the data collection and used to signal the operator that the data must be recaptured. If efficient data transformation algorithms are used, the information generated using instruments from this category can be available for clinical use as quickly as that generated using instruments from the first category. A second issue that limits the utility of contacting shape sensors is the deformation produced when the probe touches the tissue; however, by using capacitance sensitive switches to contact the tissue, the deformations can be kept to less than 0.01cm.

The objectives of this study are to develop a sensing system for measuring the shape and volume of the loaded and unloaded stump of AK amputees and to analyse the relationship between the form of an AK socket and the volume distribution of the socket and stump.

Criteria for designing a shape sensing system

In designing a contact-type shape-sensing apparatus, it is imperative to consider a number of traditional electronic design parameters. The linearity of the potentiometers or Linear Voltage Dispacment Transformers (LVDT) used has to be examined and assessed in the design. When the voltage output from these devices is to be buffered and/or amplified, the offset error, maximum nonlinearity, and gain error must be considered in a worse-case-analysis to ensure that the final design remains within the constraints of the original specifications. When the system logs the data digitally, the analog to digital (A to D) converter needs to be selected by considering: 1) the least significant bit uncertainty error (assuming the utilization of the full dynamic range of the converter), 2) offset error, and 3) the speed of conversion to assure that the required data acquisition rate can be achieved. Position encoders may be used instead of LVDTs or potentiometers provided that the maximum resolution of the encoder is considered and the maximum rate of change in position does not cause counts to be missed; this is particularly important if these counts are logged by the microprocessor. Stepper motors can also be implemented in the design, assuming that the system can accurately remember the actual position of the probe. Mechanical linkages need to be minimized to reduce inaccuracies in the system, which could lead to significant uncorrectable errors.

By working with several prosthetists, it has been possible to determine a set of criteria that the shape sensing system must satisfy if it is to match the stump characterization which is generated using a plaster wrap and tape measure. The criteria are:

1. The shape sensing process should take no more than seven minutes to collect the required data.
2. The measurements should be precise enough to match the current circumferential measurement error of ±0.64cm. This requirement means that radial distances must be accurate to ±0.1cm.
3. Vertical "z" measurements should be accurate to ±0.25cm.
4. Measurements should be reproducible within two per cent.

Methodology

Shape sensing instrumentation

The contourgraph (Fig. 1), a robotic device for sensing AK shapes, is one instrument designed to satisfy these criteria. This device is designed to take advantage of the overall cylindrical features of the body segment. The hardware is schematically illustrated in Figure 2. It utilizes a stepper motor attached to a base to drive a set of sensing heads in the theta and minus theta circumferential directions. The sensing heads read the radial distance from calibrated reference points. The "z" axis information is generated by a counter that logs the number of "next z" toggles that have

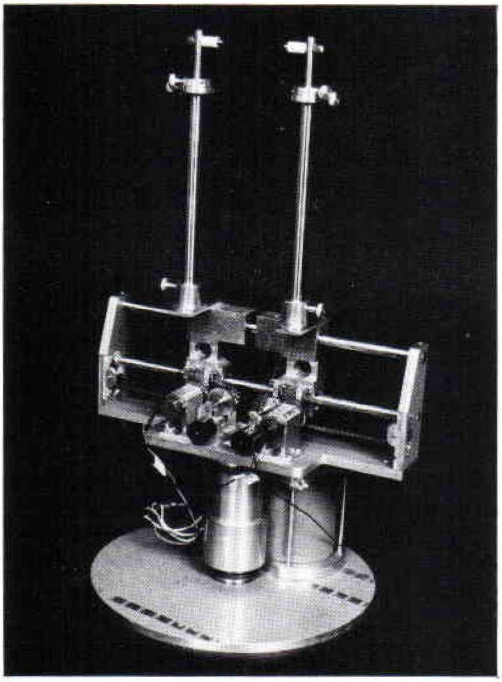

Fig. 1. The automated shape sensing instrument.

CONTOURGRAPH HARDWARE

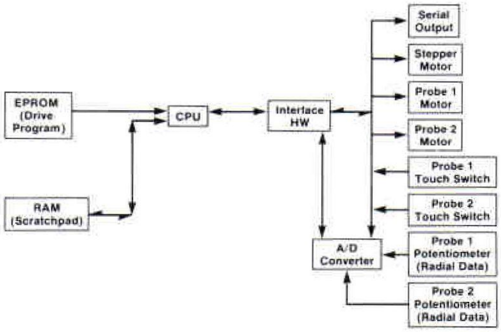

Fig. 2. Contourgraph operation schematic.

occurred; one is required for each data acquisition plane. The "z" levels are generated manually by moving the sensor head antennae to the next elevation.

The data acquisition is controlled by software that is charted in Figure 3. The radial information is generated by the sensor heads contacting the tissue. The sensor heads are driven by geared DC motors, which are pulsed by a microprocessor. The sensors are capacitance-touch switches coupled to two of

CONTOURGRAPH SOFTWARE

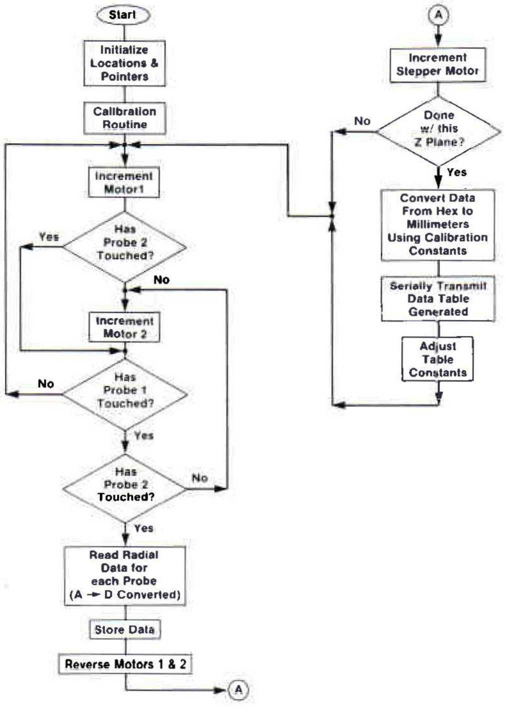

Fig. 3. Control software for shape data collection.

the computer's interrupt lines so that when one of the sensors encounters the leg, it generates an interrupt signal. This signal causes the processsor to call a subroutine to brake both motors, log the radial position of the sensor causing the signal, restore registers as needed, and return to drive the remaining motor until the sensor driven by it contacts the limb. This motor is then braked and its radial position is logged. Braking is an important step in the process, since it affects accuracy of the data. It is achieved by using an infrared coupled triac driver and triac that is tied across the terminals of the DC motor. The processor pulses the appropriate motor output port, which activates the triac to short the terminals together. This halts the motor in less than 0.003cm of travel.

The radial information is provided by sensing the voltage level generated at the wiper of a potentiometer that is gear-coupled to the motor-drive mechanism. This potentiometer output (0.03% linearity) is buffered by an operational amplifier and fed to a multiplexing device to permit multiple analog inputs to the microprocessor. The processor selects which channel it desires to interrogate and initiates a 10 bit analog-to-digital converter to encode the signal. The information is then stored in memory for later calculations.

In this system, an integral calibration routine sets maximum and minimum radial measurements. Using a set of precision cylinders, the system measures their diameters and logs the radial endpoints. The differences between the endpoints are then stored in the processor as constants that are used to calculate an adjustment factor for the stump data as they are collected. This process is necessary to account for changes in the mechanical adjustments that are made as part of the premeasurement setup procedure; this calibration scheme also compensates for variations in voltage offsets and gains.

Theta direction data are logged by counting the number of pulses sent to the stepper motor that drives the carriage. Due to the gearing between the motor and the carriage, one pulse rotates the carriage 1.25 degrees. This enables the system to conveniently use theta increments of 5, 10, 15, 20, 30, 45, and 60 degrees. However, information every 20 degrees for the AK amputee seems sufficient. Since the system is a two-sensor device, it only needs to travel

180 degrees to characterize a given elevation. When it is ready to move to the next "z" elevation, the processor knows which direction the sensors should rotate, making it possible to collect the required data without developing cable difficulties.

Once a "z" level is complete, the system stops to allow the operator to increment the sensor supports to the next level. During this time, the computer is taking data it just acquired and processing it into a tabular format. This information is then stored or downloaded in serial ASCII form to a viewing device, printer, etc. When this cycle is complete, the user may inspect the data before proceeding to the next elevation. Once satisfied with the data, the user restarts the device by pressing the "next-z" button. If the data are not satisfactory, the user pushes the "redo-z" button and the data are remeasured.

Validation tests

To evaluate the precision and reproducibility of the shape measurements, two tests were performed using the contourgraph as shown in Figure 4. In the first test, an immersion method and the standard prosthetic shop method of tape measuring were compared with the measurements obtained with the contourgraph. A prosthetist marked and measured the circumferences of a series of casts, a procedure normally done by placing the top mark at the level of the ischium and others every 5cm down the length of the stump to the tip, then measuring the circumferences at each level using a tape measure. The total and incremental volumes were then calculated with these circumference measurements. Using the immersion method, the incremental volumes, volumes between two consecutive markings, and the total volume of the cast were determined. This was done by placing a tank inside a larger tank, then filling the smaller vessel with water until it just overflowed. The whole system was then placed on a balance and weighed. After noting the weight of the system, the cast was immersed in the water. The amount of water that overflowed from the inside tank was equal to the volume of the cast. The weight of the overflow water was recorded and its temperature noted. By knowing the density of water at this temperature, the volume of the cast could then be determined. For incremental volumes, five casts chosen at random were tested by submerging them 5cm at a time and weighing the overflow after each submergence.

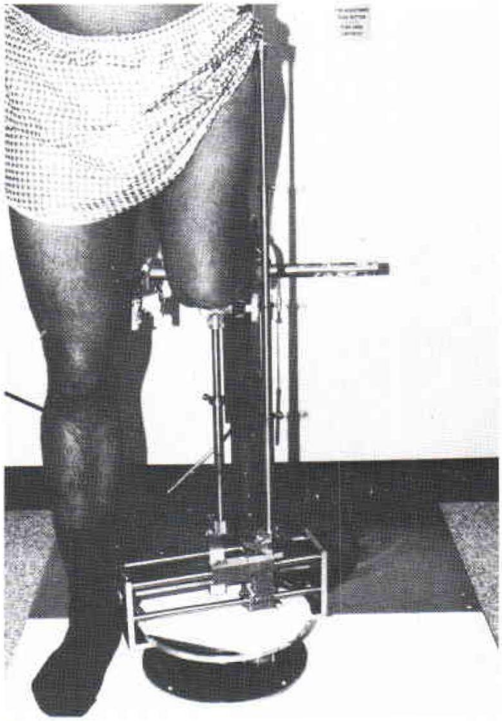

Fig. 4. Contourgraph in use to measure the shape of an above-knee stump.

The procedure for making the shape measurements with the contourgraph was to suspend the plaster cast in a vertical position over the shape sensor. Circumferential tracings were then made at 2.5cm increments, starting at the ischial level and moving down the length of the cast. The areas of the cross sections were then calculated using a planimeter. The circumferences were measured using a small wheel device often used to measure distances on road maps to trace the length around the cross-sectional shape.

In the second test, an attempt was made to evaluate the volumetric differences between the plaster cast, which represented the stump, and the plastic mould of the socket. This was accomplished by measuring the circumferences at marked levels of the casts of five amputees and calculating the total volume by the mensuration formula, as in the first test. Then, plastic moulds of these stumps were made, and after all the holes were covered with tape so that no water could leak out, they were filled with water until they just overflowed. The volume of the water in the mould of the socket was measured with a 5000ml (50ml divisions) graduated cylinder. The volumes of the sockets were then compared with the cast volumes.

These tests demonstrated that the contourgraph produced repeatable shape and volume characterizations of an AK stump that compared well with the measurements made by a prosthetist using a tape measure.

Clinical tests

A series of 100 AK amputees was evaluated to study the shape and volume relations in sockets that were considered to fit well. A good-fitting socket was defined as one that did not produce pain when worn daily for at least eight hours. The subjects used in the clinical tests were AK amputees selected from the amputee clinics in the Baylor College of Medicine Affiliated Hospital Programme and the large reservoir of amputees who have been fitted by Muilenburg Prosthetics, Inc., Houston, Texas. Since the majority of amputees are male, an equal balance between the sexes was not possible. Males made up 90% of the total sample. All subjects were between 18 and 80 years of age. Fifty-four per cent were left-leg amputees, 45% right leg, and one per cent bilateral. Follow-up measurements were made on 80 of the subjects.

Contourgraph characterizations of the unloaded stump and prosthetic socket were obtained when the amputee's prosthesis was initially issued. At sequential intervals, contourgraph measurements were made of the stump to determine the changes in shape and size that had occurred at given cross-sectional levels. This was done by determining the variances of the contourgraph readings.

The procedure for making the measurements was as follows. With the amputee seated or standing comfortably, circumferential measurements of the amputation stump were made at designated and marked levels. To perform the contour tracing of the prosthetic socket, the prosthesis was mounted upside down on an adjustable support. Contour tracings of the inverted socket were made, distal to proximal, at one inch levels corresponding to the stump contour tracings levels. The topographic relationships (anterior, posterior, medial and lateral) and cross-section levels of each stump and socket tracing were identified. The circumference and cross-section levels of each stump and socket were then calculated as in the calibration test. A good approximation of both the stump or socket volume was obtained by using three cross-sectional areas and the linear distance between the consecutive cross-sectional areas.

The data were then represented graphically to show: (a) respective stump and socket volume distribution curves, (b) socket-stump volume differences, and (c) variations of stump or socket volumes at sequential intervals.

Results and discussion

The results of the tape mensuration technique and the immersion technique are given in Figure 5.

When the direct mensuration technique was employed, the total volume of the cast was obtained by adding each incremental volume approximated by equation 1:

$$V_i = \frac{h}{12\pi}(C_k^2 + C_j^2 + C_kC_j) \qquad (1)$$

where h is the thickness of the increment, C_j is the circumference of the top cross section and C_k is the circumference of the bottom cross section.

In this case, an additional volume had to be added to the sum of the incremental volumes to account for the tip of the stump. To calculate the volume of the tip portion, the tip was assumed to be a section of a sphere, and the following formula was used to approximate it:

$$V_t = \frac{\pi h^3}{6} + \frac{hC^2}{8\pi} \qquad (2)$$

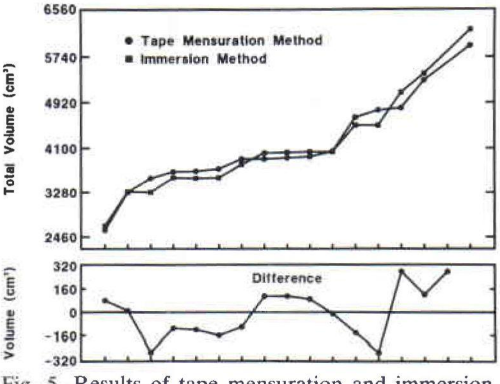

Fig. 5. Results of tape mensuration and immersion techniques.

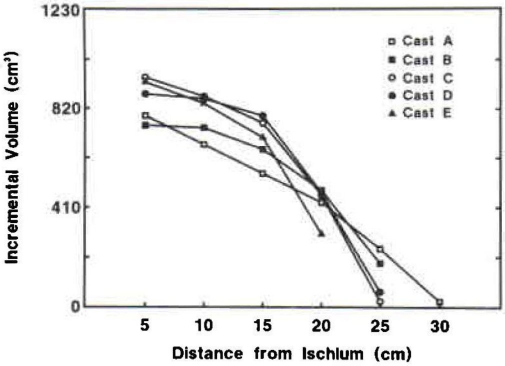

Fig. 6. Comparison of incremental volumes of casts.

where h is the thickness of the tip increment and C is the circumference of the top cross section of the tip increment.

Figure 6 depicts the volume distribution for the casts as a function of the distance from the ischium. The trend in this figure shows an elevated level at 15cm from the ischium. This is attributed to the residual build-up of water in the outside tank for casts B through E, since the outside tank was dried only half-way through each measurement. The drying of the outside tank in the case of cast A was done after the 20cm mark. The mean of the differences in the volumes measured by the immersion method and the tape mensuration technique was 10 cubic centimetres, with a standard deviation of 185. The incremental volumes were also analysed and the results are shown in Figure 6.

The results of measuring the casts of the unloaded stumps and corresponding sockets are shown in Figure 7. This figure shows the volume distribution in increasing orders of volume. The differences between the socket and cast volumes, approximated by two

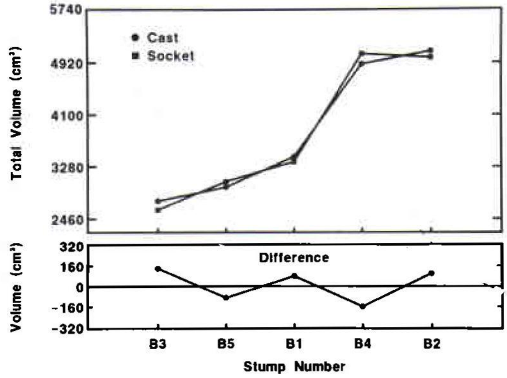

Fig. 7. Comparison of cast and socket volumes.

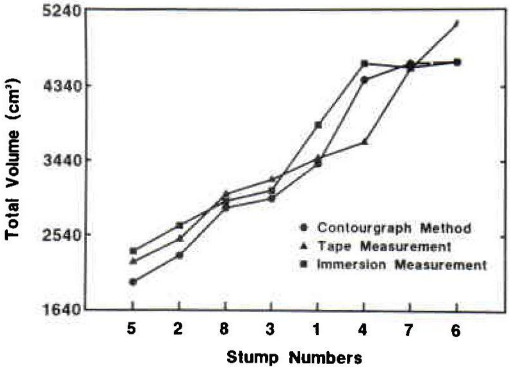

Fig. 8. Contourgraph results compared with tape mensuration and immersion measurement techniques.

different methods, indicate that the overall difference is less than 0.1%. This implies that the immersion method and the tape measurement method predict the volume with the same accuracy. The results of comparing the contourgraph measurements to the other two measuring techniques are shown in Figure 8. As can be observed in this figure the three methods of measuring the stump volume are within 3–6% of each other. In one stump (number 4), all three measurements gave a large difference. In this case, the AK amputee was at his second fitting and his stump was swollen and very soft. When the amputee was being measured with the contourgraph, he was unable to hold his stump steady. The great variation possible in the measurement implies that the amputee must be very steady during the measurements.

The clinical data were analysed. Typical results for the stump-socket volume relationship found with sockets that fit well are given in Figure 9. Reproducibility of the

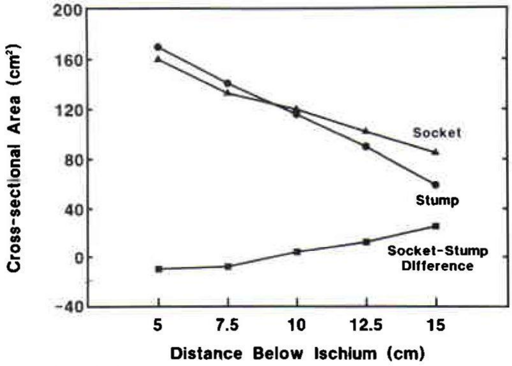

Fig. 9. Typical results with well fitting socket.

measurements within 1% was obtained using the contourgraph. A 0.25% – 1.0% variation of socket volume difference was also obtained. Variation of stump volume difference was found to be 1.5% with an amputee seated and leaning forward compared to an amputee seated upright.

Conclusions

Based on the results of this study, the following conclusions have been drawn:

1. When used by a trained operator, the contourgraph is capable of producing stump measurements that are as precise as those made by a trained, experienced prosthetist.
2. The contourgraph is able to produce reliable, reproducible data.
3. There is a relationship between the volume distribution of the AK socket and the stump and socket fit. The proximal 30% of the socket must have a volume between 5–8% less than the corresponding unloaded stump for a good fitting socket.

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Memory plastics for prosthetic and orthotic applications

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Abstract

Shrink forming prosthetic sockets from memory plastics offers several advantages over existing techniques. The manual skill requirement is reduced relative to drapeforming flat sheet while compared with the Rapidform process, the requirement for a purpose-built vacuum forming machine is eliminated.

Two methods for producing thermoplastic sockets from heat shrinkable preforms are described. One uses established heat shrink technology and crosslinked thermoplastics. The second based on blowmoulding simplifies preform manufacture relative to existing techniques by reducing it to a single stage operation. Shrink formed sockets have been produced for three application areas concerned with the lower limb namely load bearing sockets, flexible ISNY type and rigid transparent check sockets. Static testing has demonstrated the ability of shrink formed, load bearing sockets to surpass Philadelphia Static Load Levels (ISPO, 1978) while fatigue testing has indicated a capability for long service life.

Introduction

Several recent advances in prosthetic practice and hardware have been achieved through innovative use of thermoplastics materials. In England and Wales for example thermoformed polypropylene (PP) load bearing sockets are gradually replacing the traditional types based on fibre reinforced thermosetting plastics (FRP). Manufacturing time is reduced and the overall process is simpler and cleaner since use of liquid matrix resins such as acrylic and polyester, with their associated problems of storage and handling, are avoided. Patients have welcomed the increased comfort of polypropylene sockets arising from their greater flexibility relative to FRP sockets. The establishment of ISNY type sockets and fitting techniques for below-knee (BK) (Fishman et al, 1986) above-knee (AK) (Kristinsson, 1983; Pritham et al, 1985) and below-elbow (Supan, 1987) prostheses has further extended thermoplastics usage. In the ISNY system a flexible thermoplastic socket made from low density polyethylene (LDPE) or clear Surlyn Ionomer is supported in a load bearing laminated frame which transmits patient loading through the prosthesis to the floor. The advantages of the ISNY system over conventional sockets are said to include enhanced patient comfort and sensory feedback due to the lightness, flexibility and coolness of the thin socket. Impact loading on the residual limb during stance phase is also reduced by deflection of the flexible socket (Fishman et al, 1986). A third and expanding area of thermoplastics application in prosthetics practice is the use of Transparent Check Sockets to improve socket fit and thereby patient comfort (Abrahamson et al, 1987).

One of the earliest investigations of socket fabrication from thermoplastics was carried out in 1970 at Rancho Los Amigos Hospital by Mooney and Snelson (1972). A vacuum forming technique using heat softened polycarbonate sheet was used to produce transparent check sockets over a rectified plaster cast of a patient's amputation stump. Vacuum forming of sheet thermoplastic is a widely used long established technique for producing thin walled formings from positive moulds. However socket production over plaster casts requires extensive stretching or drawing of heated sheet which can cause problems of web formation and thinning in the finished socket. The interesting point about the

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technique developed at Ranchos Los Amigos, which is different to conventional vacuum forming is that the hot plastic sheet (9mm thick) was allowed to sag under its own weight to a distance of approximately 2/3rd the length of the positive cast forming a cone or bubble. This was then inverted resulting in a preform which was drawn down over the positive model before vacuum was applied. The preform is of course closer in dimensions to the positive stump model than the sheet form and the act of drawing the bulbous preform down over the cast further adjusts the shape so that it is even closer to the finished product. The result of this approach is that webbing due to excess material associated with the drawing process from flat sheet is reduced. This technique is termed drape forming in the prosthetics industry and is widely used nowadays for producing thermoplastic sockets in a variety of materials. (In conventional thermoforming the problem of large draw ratios is often approached by using "plug assist" or "bubble assist" to pre-stretch the hot plastic sheet into a preform using a solid intermediate former or air pressure respectively.)

The preform approach to thermoplastic socket production lies at the centre of three manufacturing techniques which have been developed over the last few years namely the Rapidform technique (Knox et al, 1982) Otto Bock's Orthoglass cone system (Pike and Black, 1982) and latterly the heat shrink technique (Hagglund, 1983; Otto Bock; Berteele, 1986). All represent attempts to control more precisely the process variables which can affect socket performance to reduce or eliminate the manual skill content associated with socket forming from flat sheet and to reduce socket fabrication times.

The Rapidform technique makes use of a bell shaped plastic preform "substantially corresponding to the (socket) moulding" (Knox et al, 1982). This preform is securely clamped and heated in the oven of a semi-automatic purpose built Rapidform vacuum forming machine. A plaster cast of the patient's stump is then driven into the softened preform by means of a mechanical ram after a preset heating time. The preform is invariably shorter than the cast so that stretching of the preform occurs during the forming operation. Vacuum is then applied to draw the preform material into contact with the cast and is maintained during cooling and solidification of the plastic. The plaster is removed to leave a semi-finished socket. The Rapidform process overcomes the problems associated with large scale deformation of plastic sheet by stretching a standard shaped, heated preform by means of the plaster cast itself to effect an intermediate shape change. In this way the dimensions of the original preform are adjusted during stretching and conform more closely to each individual plaster cast before vacuum is applied. Web formation due to excess material around the cast is thereby reduced. Otto Bock Orthopaedic Industries use a similar technique based on conical acrylic preforms for producing check sockets (Pike and Black, 1982). The cone is heated to soften it, then pulled by hand over a plaster model before vacuum is applied to ensure good following of the contour by the thermoplastic.

It is well known that certain thermoplastics have "memory properties" such that on stretching under certain conditions and cooling in the stretched form they will retain the stretched form until heated to a particular temperature whereupon shrinkage will occur unless the plastic is restrained. Heat shrink techniques for thermoplastic socket production have attracted the attention of commercial organisations such as LIC (Hagglund, 1982) and Otto Bock and researchers in the prosthetics field (Berteele, 1986). In the LIC method a positive cast of a patient's stump is positioned inside a heat shrinkable plastic preform which is subsequently heated to soften it and to cause it to shrink so that it conforms closely to the cast contours. Final shaping is performed by applying a vacuum so that the hot plastic is drawn into contact with the cast and is maintained while the plastic cools and hardens. Otto Bock have recently started marketing a Pedilon thermoplastic socket-shaped preform which is shrunk directly onto the patient's stump to produce a temporary above-knee (AK) socket without vacuum application.

The production of thermoplastic sockets using shrink fit techniques is not new, A UK patent was granted to C. H. Davis in 1932 which describes the production of sockets from tubes of cellulosic material which had been softened in hot water, expanded over a mandrel and cooled to retain the expanded form. This conical open ended preform was subsequently shrunk onto a plaster replica of the patient's stump by re-immersing it in hot water. Vacuum application was not recommended to ensure good contour following presumably since the author mentions that the shrunken preform "becomes an exact duplicate of the cast element". The author also reminds the reader of perhaps the very first use of shrink fit techniques for producing sockets for artificial limbs. Leather was saturated with water and stretched around the cast, hammered to bring out indentations essential to the fit of a socket then dried. On drying the leather contracts to provide good socket fit. LIC's method updates, only in its use of modern thermoplastics and final vacuum shaping, that described by C. H. Davis in 1932 who must be credited for his innovative use of the reversion shrinkage characteristics of plastics.

The manufacture of thermoplastic sockets for artificial limbs from heat shrinkable preforms is potentially simpler than drape forming from flat sheet as well as reducing the manual skill content of the process. In addition, heating time could be reduced since preform thickness is less than the sheet thickness used in drapeforming and the resulting socket should exhibit greater uniformity of wall thickness.

Compared with the Rapidform process shrinkforming eliminates the requirement for a purpose built vacuum forming machine.

The aim of this paper is to describe two methods for producing heat shrinkable, thermoplastic preforms for socket manufacture, to identify their heat shrinkage behaviour and to display the performance of heat shrink sockets under laboratory testing conditions. One method uses established heat shrink technology and crosslinked thermoplastics. The second technique based on blow moulding simplifies preform manufacture by reducing it to a single stage operation. Existing techniques first involve production of an intermediate moulding which is then reheated and expanded to give the heat shrinkable preform.

Manufacture of heat shrink preforms

Crosslinked thermoplastic preforms

Semi-crystalline thermoplastics consist of crystalline and non-crystalline (amorphous) phases. When heated above the crystalline melting point, the polymer softens and flows readily. However, if the same polymer is subjected to ionizing radiation, crosslinks form between the individual polymeric molecules. When the crosslinked polymer is heated above the crystalline melting point, the crystalline areas melt but the polymer itself does not flow since it possesses form-stability due to the presence of crosslinks. At this stage the polymer is similar to an elastomer. If the shape of the material is changed, it will return to its original shape. However, if the polymer is held in a new shape whilst above the crystalline melting point, and then allowed to cool in this condition, crystalline areas will re-form. Crystalline forces will then keep the crosslinked polymer from returning (shrinking) to its original shape. Once the polymer is reheated above its melting point, thereby eliminating the crystalline forces, the elastic forces will cause it to recover back to its original form.

Thermoplastics suitable for radiation crosslinking are initially moulded to give an "intermediate" preform using standard manufacturing processes such as extrusion, injection moulding and blow moulding. The material is next subjected to high energy electron-beam irradiation. This causes some molecules to break down (chain scission) and crosslinks to form between molecules. The former is detrimental to the mechanical properties of the polymer and is suppressed in a limited number of polymers with additives. For this reason, the materials available are generally limited to grades of polyethylene, PVC and fluoropolymers. The crosslinked intermediate preform is then heated above the melting point, expanded to the required diameter (generally 2 to 3 times the original diameter), and cooled to room temperature in the expanded form. When the object to be covered is placed inside the heat-shrinkable moulding and the moulding heated, it will shrink around and conform to the object as it attempts to return to its original crosslinked shape.

A heat shrink preform suitable for BK sockets was produced by Raychem, the size being based upon the largest IPOS casting brims (Fig. 1). These preforms are also suitable for small AK sockets, the development of an exoskeletal prosthesis and some orthotic applications. A smaller intermediate preform was first blow moulded, irradiated and then expanded to the final preform shape.

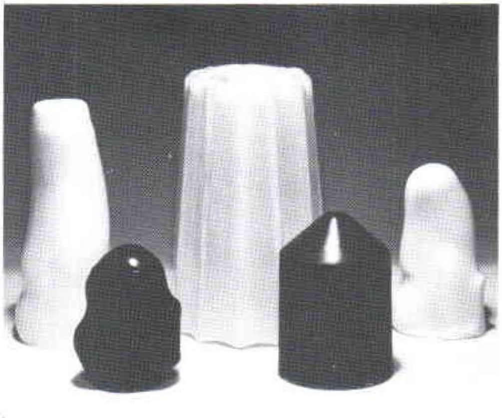

Fig. 1 Crosslinked HDPE preforms and shrink formed sockets

A grade of High Density Polyethylene (HDPE) was selected for load bearing structure. Potentially suitable thermoplastics are available for flexible socket applications (such as ISNY).

Shrink forming technique

Generally, an object to be covered by heat shrinking plastics is simply inserted inside the preform which is then heated to cause it to shrink and conform to the contours of the object. The simplest method for producing heat shrink sockets is to place a preform over a plaster cast of the stump and insert the set up into an oven maintained at a particular temperature. This appoach when applied to PElite foam lined plaster casts caused unacceptable thinning of the liner due to the large forces of retraction developed by the preform, aggravated by softening of the polyethylene foam liner itself during the heating process. Direct forming onto wet plaster casts increased preform heating time to an hour due to a "cooling by evaporation" effect. A particular shrink forming technique was therefore developed for crosslinked HDPE preforms which eliminated excessive thinning of the PElite liner and at the same time yielded significant process time savings by increasing the efficiency of heat transfer to the preform. In addition the technique established could be applied to wet casts.

The preform is positioned over an open ended, conical, thin sheet metal former for heating to translucency in an oven. The metal former restrains the preform from shrinking and also reduces heating time to approximately seven minutes. Shrink forming is performed outside the oven by locating the metal former/preform system over a "cold" lined cast then withdrawing the metal former so that the heat softened preform shrinks onto the cast. Vacuum application improves replication of the cast contours by the thermoplastic. The plastic is allowed to cool to room temperature before removing the plaster to leave a semi-finished socket. By this means, the lined cast is not itself heated during the preform heating stage and excessive thinning of the liner is avoided. Wet unlined casts can therefore also be used without the need for barrier coatings to prevent water vapour transmission.

Some examples of sockets produced from crosslinked HDPE are shown in Figure 1. The small black socket in the foreground was produced from a Raychem End Cap and illustrates the scope for size and colour variation using this heat shrink process. As mentioned above heating time has been reduced to seven minutes a significant time saving compared with the time for drapeforming structural PP sockets (22 minutes) and shrink forming of "reversion" type preforms (15 minutes) mentioned below.

Reversion type preforms

The hot drawing behaviour of thermoplastics such as polypropylene, polyethylene, polystyrene and ABS is sensitive to process conditions such as temperature and draw speed. Large and uniform sample extensions can readily be obtained if the draw temperature is controlled. Upon reheating the stretched samples also exhibit high shrinkage — reversion shrinkage. Basically low draw temperatures limit the extent of draw and increase the required extensional force while too high a temperature results in non-uniform or neck draw and frequent sample fracture. Sample extension is limited by the decrease in melt viscosity or melt strength at elevated temperatures and by reduced chain mobility at low temperatures. The visco-elastic character of the thermoplastic at "optimum" draw temperatures, described in terms of a chain entanglement model, promotes chain extension and orientation during draw and consequently high recovery or shrinkage when the stretched and cooled sample is reheated.

Blow moulded preforms have been produced under a set of conditions which promote orientation and chain extension, so that associated large scale reversion shrinkage can be used to produce a socket or load bearing shank for instance over a positive model (Figs. 2–5). Existing methods for producing heat shrinkable preforms include two or more stages comprising production of a smaller intermediate preform by injection moulding (Hagglund, 1983) followed by a separate reheating and expansion stage to give the final heat shrinkable preform. In the case of crosslinked preforms mentioned earlier, the intermediate preform also undergoes a crosslinking process prior to reheating and expansion to the finished form. Production of heat shrinkable preforms by blowmoulding — designated reversion type preforms in this document — is a single stage operation which markedly simplifies preform production. The parison (or extruded tube of molten plastic) produced by the blowmoulding machine is expanded to the final preform dimensions defined by the mould cavity and cooled by contact with the mould surface to retain the moulded geometry. Cooling of an intermediate preform to room temperature then reheating prior to expansion is eliminated.

Shrink forming

Two types of blow moulded thermoplastic preforms have been produced for BK and AK socket applications respectively, exhibiting a degree of reversion shrinkage which enables them to be heat shrunk over positive models of the residual limb (Figs. 2–5). Process conditions and materials have been investigated for the three main socket application areas mentioned earlier namely flexible sockets, structural or load bearing sockets and rigid, transparent check sockets. Typical shrink forming conditions are presented in Table 1.

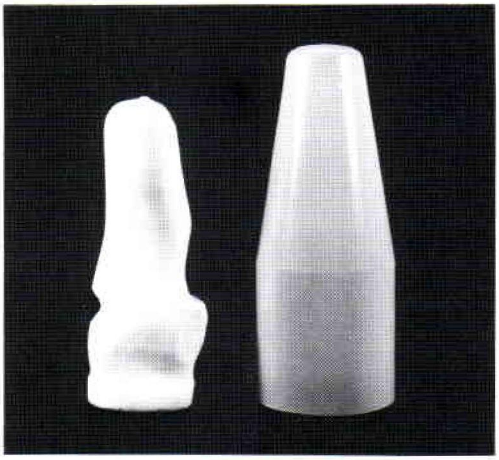

Fig. 2 LDPE reversion type preform and socket forming

Shrink forming is a relatively simple operation. A preform cut to the required length is placed over the rectified cast and the asssembly is placed in an oven maintained at the required temperature. In general the preform is observed to shrink once melting or adequate heat softening has occurred and conforms closely to the cast surface aided by an element of drapeforming of the softened thermoplastic. Replication of the cast contours is improved by vacuum application. Once the thermoplastic has cooled sufficiently to retain the thermoformed shape, the plaster cast is removed to leave the semi-finished socket.

For polypropylene preforms in particular, casts must be dry or a suitable barrier layer must be applied to the cast to prevent water

Table 1. Typical shrink forming and drapeforming conditions

	SHRINK			DRAPE			
Material	Preform wall thickness (mm)	Oven temp (°C)	Heating time (minutes)	Sheet thickness (mm)	Oven temp (°C)	Heating time (minutes)	Reference
Polypropylene	2	210	15	12	240	22	Charles A. Blatchford
Crosslinked HDPE	—	210	7	—	—	—	
LDPE	1.4	170	8	6	165–177	8–10	New York University
Surlyn	1.4	170	8	6	175–204	7	Stills and Wilson
Rigid, transparent	2	210	8	3–4.5	150	6	Durr-Fillauer Medical Inc.

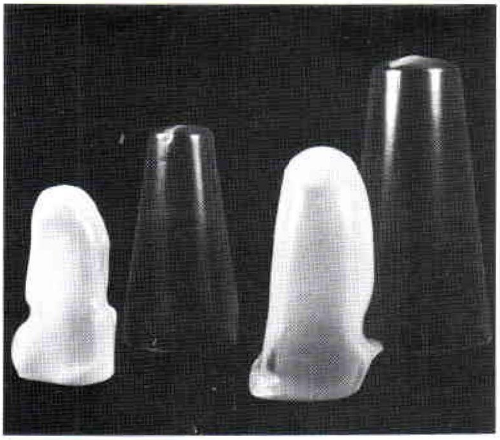

Fig. 3 Surlyn reversion type preforms and shrink formed sockets

vapour transmission during the heating process and consequently preform cooling as mentioned above.

LDPE and Surlyn preforms intended for socket applications of the ISNY type are shown (Figs. 2 and 3). Three grades of Surlyn have been investigated spanning a range of Flexural Modulus from $90 MN/m^2$ to $380 MN/m^2$. The prosthetist could therefore be offered a selection of materials of different flexibility. It will be noticed that the Surlyn socket formings are not clear like the starting preform. This is due to the stockinette impression on the inner surface of the forming and slow cooling of the thermoplastic which promotes the development of larger crystals. Nonetheless the formings are translucent and still enable observation of the patient's stump through the socket wall for checking socket fit.

The long BK forming in LDPE shown in Figure 2 was produced over a computer rectified and machined cast, illustrating the size and shape range of sockets which can be produced using reversion type preforms. This particular forming is to be incorporated in a BK, ISNY socket.

Shrink formed polypropylene sockets produced from reversion type, blow moulded preforms are shown in Figure 4 and are intended for load bearing socket applications. To the left in Figure 4 is a polypropylene socket with a bonded fabric covering which was applied to the molten surface of the shrink forming. This technique, based on bicomponent fabrics described in an earlier publication (Coombes et al, 1985) enables shrink formed polypropylene sockets to be adhesively bonded to artificial limb systems if required.

Reversion shrinkage preforms suitable for rigid transparent check socket applications are shown in Figure 5 with examples of BK and AK socket formings.

The process conditions listed in Table 1 indicate typical heating times for shrink forming reversion type preforms compared with drape forming. Significant time savings are achievable for polypropylene. The main advantages of shrinkforming over drapeforming for Surlyn,

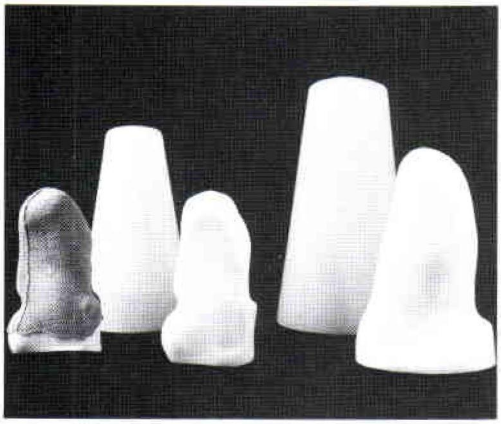

Fig. 4 Polypropylene reversion type preforms and shrink formed sockets

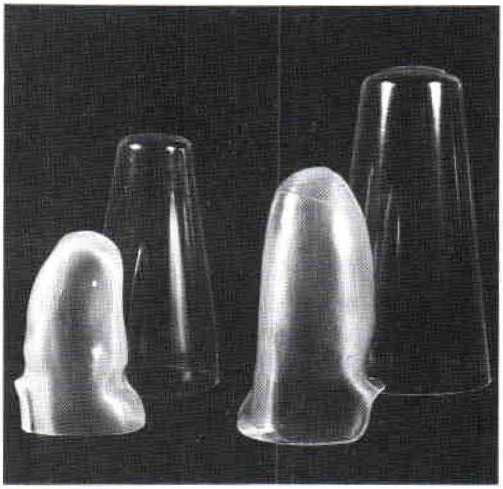

Fig.5 Rigid, transparent check sockets and reversion type preforms

LDPE and rigid transparent materials would be the reduced manual skill requirement which could also result in greater uniformity of socket wall thickness. For example Kawamura and Kawamura (1986) quote a wall thickness range of 1.2–2.5mm for LDPE, AK sockets. Measurements of wall thickness taken from a shrink formed LDPE, AK socket generally ranged from 1.7–2.3mm although the thickness at the extreme distal end of the socket increased to 3.4mm. A further advantage of reversion type preforms is that the pre-shrink wall thickness can be easily adjusted during processing so that a minimum value of post shrink wall thickness can be assured in the socket.

Mechanical testing

The mechanical testing procedure followed the Philadelphia recommendations (ISPO, 1978). A Static Load Level was defined during the Philadelphia proceedings such that application of a compressive load of 2.5kN which produces a bending moment at knee and ankle of 230Nm and 250Nm respectively should not produce permanent deformation of the limb structure. Shrink form sockets were tested using an offset loading arrangement to apply AP bending moments to the test sample. Equal offsets of 100mm from the load axis were arranged at proximal and distal ends using pivotted extension bars. At the distal end the test fixture was bolted directly to the socket via an alignment base using a single M10 bolt fixing. Loading was transmitted to the socket by means of a loading bar embedded in a plaster of Paris stump replica. A 20mm thick pad of Plastazote polyethylene foam was located below the plaster to simulate the foam build-up which is normally bonded to the distal end of soft foam socket liners. (This blends the cast contours with the metallic cup incorporated in socket systems based on bolt fixings.) Sockets were static tested using a Zwick Universal Testing Machine and a loading rate of 100mm/min.

Fatigue testing was also carried out on shrink formed sockets attached to Roelite alignment bases. The same system of offset loading described above was used to apply an AP bending moment of 140 Nm at distal and proximal ends of the test sample. The Philadelphia recommended bending moments for testing BK prostheses are 140 Nm and 120 Nm at ankle and knee respectively generated by a 135kN compressive force. The test frequency was 1Hz.

Crosslinked HDPE sockets

Static failure loads obtained for crosslinked HDPE sockets connected to Roelite and Endolite alignment systems are shown in Table 2. Maximum loads are limited by buckling of the socket wall in the anterior aspect and distortion of the distal end of the socket at the alignment device/socket interface which results in a levelling off of the load/displacement curve. Static failure loads vary from 2 to 5.5 kN depending on preform thickness and socket geometry. The effect of the latter variable is highlighted by the test results for sockets containing a 65mm and 75mm Roelite cup respectively where increased load bearing area at the socket distal end results in an increase of approximately 30% in failure load. The Philadelphia recommended Static Load Level for BK prostheses is 2.5 kN and the test results listed indicate that this value can be exceeded by sockets produced from crosslinked HDPE heat shrinkable preforms.

Fatigue testing of experimental sockets carried out under offset loading conditions to Philadelphia recommendations demonstrated

Table 2. Static failure loads for shrinkformed crosslinked HDPE sockets

Preform designation	Maximum recoverable wall thickness (mm)	Alignment system	Static failure load (kN)
Medium	3.5–3.7	Ultra Roelite: 65mm cup	2.08
Medium	3.5–3.7	Ultra Roelite: 75mm cup	2.62
Thick	4–4.5	Ultra Roelite: 65mm cup	2.76
Ultra thick	6.1–8.9	Endolite	5.52

Ultra Roelite system
65mm Roelite cup, Hanger code 202–U8 766
75mm Roelite cup, Hanger code 204–U8 768
Alignment base, Hanger code 50–U9 111

Endolite system
Socket plate/bolt assembly, Blatchford code 189305
Upper alignment coupling, Blatchford code 189505

the long term durability of this particular memory plastic. Two sockets withstood cyclic loading to 1.4 and 1.9 million cycles respectively before cracking was observed at the distal end of sockets corresponding to the perimeter of the alignment device. Socket load bearing ability was not impaired despite crack growth over approximately 50% of the socket circumference.

Reversion type PP sockets

Test samples consisted of a shrink formed PP socket incorporating a 75mm diameter Roelite metal cup (Hanger Code 204–U8768) at the distal end. The socket was in turn attached to a Roelite alignment base (Hanger Code 50–U9111) using the four fixing bolts supplied with the kit.

Socket distortion in the anterior aspect limited the applied load to 2.4 kN in one case for polypropylene copolymer (nominal preform thickness of 2mm). A socket produced from polypropylene homopolymer (nominal preform wall thickness of 2mm) withstood a static load of 3.8 kN before distortion of the socket at the distal end produced a levelling-off of the load displacement curve. The higher static load value attained in the latter case reflects the higher flexural modulus of the homopolymer (1.7 GPa) relative to the copolymer (1.1 GPa). In the case of polypropylene copolymer there is scope for improvement of static test performance simply by increasing the preform wall thickness.

A fatigue of 2.4 million cycles was achieved for a PP copolymer socket attached to a Roelite base without visible deterioration of the socket. The test was terminated at this point. Two million loading cycles represents an expected service life of 5 years on the basis of Department of Health (England) test guidelines.

Summary and conclusions

The production of thermoplastic sockets from heat shrinkable preforms or memory plastics offers several advantages over existing techniques. Compared with the Rapidform process, shrink forming eliminates the requirement for a special purpose, thermoforming machine. Greater control over socket manufacture is achieved using heat shrinkable preforms relative to hand draping from flat sheet since the degree of manual skill required is reduced. The two heat shrink techniques described in this paper extend both the range of manufacturing options and materials options which can be considered for prosthetic and orthotic applications. The use of crosslinked HDPE preforms for structural sockets offers significant time savings over drapeforming PP sheet (seven minutes compared with 22 minutes) and the potential range of materials available means that alternatives to LDPE and Surlyn could also be provided for flexible socket applications. The production of reversion type preforms in one operation by blowmoulding simplifies preform production with concomitant time and cost savings. Existing methods for producing heat shrink preforms, are based on reheating then expanding a smaller intermediate moulding. Production of crosslinked HDPE preforms also involves a crosslinking stage prior to reheating and expansion which increases further the cost of the preform. The versatility of the reversion method is underlined by its extension to flexible socket applications based on Surlyn and LDPE and rigid, transparent check sockets as well as PP load bearing sockets.

Mechanical testing to date has demonstrated that Philadelphia recommended load levels can be surpassed by shrink formed sockets produced from both crosslinked HDPE preforms and reversion type PP preforms albeit when attached to Roelite limb systems which employ a four bolt socket fixing. These shrink fit sockets can also be expected to exhibit long service life. Further laboratory and service testing are planned to assess patient acceptance and to evaluate the performance of shrink formed, load bearing sockets attached to prostheses by bolt fixings and adhesive bonding respectively. In addition other categories of shrink formed sockets namely flexible sockets and transparent check sockets are to be subjected to evaluation under laboratory and service conditions in collaboration with UK limb manufacturers. The results of these trials will be the subject of a future publication.

Socket manufacture for the lower limb represents just one application of the heat shrink preforms described here to which can be added the production of load bearing shanks (Convery et al, 1984), orthoses such as drop foot splints, and spinal jackets and sockets for upper limbs (Berger et al, 1986; Supan, 1987). The heat shrink technique is suited to all existing commercial operations and the emerging technologies based on Computer Aided Design/Computer Aided Manufacture (CAD/CAM).

Acknowledgement

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Use of prosthetic prehensors

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Abstract
Estimates are given of the type and number of prosthetic prehensors — both hooks and hands — used in the USA, United Kingdom, West Germany and Sweden by upper limb amputees. Implications are made for differences between countries and for thorough assessment of amputees before clinical fittings.

Introduction

The first record of an artificial hand is an iron hand fitted to a Roman general who lost his own hand during war about 200 BC (AAOS, 1960). At some point Captain Hook and other "pirates" were using hooks. In the later years of knights and armour, various prosthetic hands were fashioned out of metal. In the 1890's, D. W. Dorrance developed the split hook which survives today. And, of course, prosthetic hands have improved greatly with significant work undertaken more recently in the USA, West Germany and elsewhere.

Besides the obvious need for function in hand prostheses, amputees have other needs which sometimes are not as well identified and recognized. Appearance and body image are important to most amputees, although cosmetic considerations are not always addressed directly. Also, there are social/cultural needs depending upon the country (Alpenfels, 1955). In some cultures, the right hand is used for "clean" activities and the left for "dirty" activities. In other cultures, the hand assumes great significance because thieves lose their hands as punishment for crimes, and to be without a hand subjects one to suspicion. So, there are many considerations — functional and otherwise — that enter into the assessment and selection of prehensors for arm amputees.

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Currently, the most popular prosthetic prehensors are hooks, mechanical or electrical active hands, and passive hands (Fig. 1).

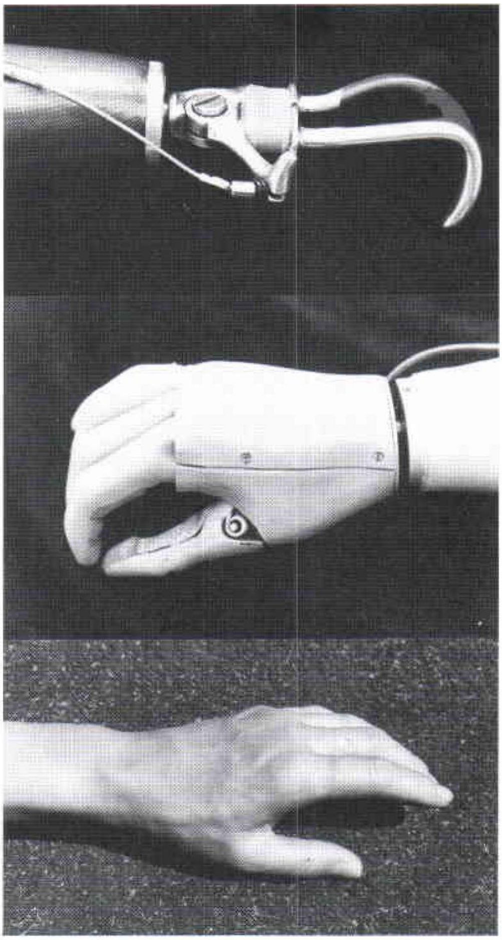

Fig. 1. Top split hook. Hosmer-Dorrance 5XA with rubber bands for spring closing and voluntary opening. Centre, mechanical hand. APRL voluntary closing and spring opening type which would be worn with a cosmetic glove. Bottom, passive hand. In this case with a foam core inside and cosmetic glove outside.

Estimated use of prehensors

The use of the various types of prehensors varies significantly around the world. Estimates of use in a few major countries are shown.

Table 1. Estimated use of prehensors

Country	Active hands	Passive hands	Total hands	Total hooks
United States (1)	21%	7%	28%	72%
United Kingdom (2)	16%	60%	76%	24%
West Germany (3)	66%	22%	88%	12%
Sweden (4)	20%	50%	70%	30%

Notes: 1. Driver (1986), Edwards (1986), Hendrickson (1986).
2. Cooper (1987).
3. Boenick (1988), Hendrickson (1987).
4. Lymark (1987).

Estimated numbers of prehensors

These numbers are difficult to arrive at and should be considered as rough estimates. However, it may be of interest to put the numbers in perspective relative to use among countries and among other rehabilitation devices.

Table 2. Estimated numbers of prehensors

Country	Prehensors per year (1)	Upper-limb prosthesis users	Prehensors per amputee (2)
United States	10,000	50,000 (3)	one every 5yrs
United Kindom	7,500	12,500 (4)	one every 1–2/3 yrs
West Germany	(5)	14,000 (4)	(5)
Sweden	500	1,500 (6)	one every 3 yrs

Notes: 1. These numbers come from estimates of the number of prehensors sold per year by manufacturers.
2. These numbers reflect, in part, the frequency of replacement and in part the number of prehensors provided per amputee.
3. LeBlanc (1973).
4. These numbers are scaled to the national population in each country using the same incidence of amputation and prosthetic use in the USA.
5. Figures not available.
6. Lymark (1987).

Implications

European countries have much the same technology available as in the USA but apply it differently. Cultural and psychosocial factors play a big role on the way technology is used in clinical practice.

Recognizing the differences in application of technology and the need to fit "the whole person" as well as the missing arm stresses the importance of a complete and thorough assessment of the amputee before prescribing and fitting a prosthesis. It is even more important as (1) more options in components and techniques become available, (2) cost containment is prevalent in the medical field, and (3) amputees are becoming more informed consumers.

The statistics show (1) very high use of hooks and a very low use of passive hands in the USA, (2) high use of passive hands in the UK and Sweden, and (3) very high use of active hands in West Germany. One can provide one's own explanations on this matter. The author's theory is that in the USA function and getting the job done is emphasized; the population is not terribly bound to culture and customs; it is accustomed to using tools; the Nation is very "out front" about disabilities; there is some natural bias and precedent towards the split hook because it was developed there. By contrast, people in Europe have more history and customs, less assertive attitudes on disability, and more romanticism in art and culture — all of which make prosthetic hands a more popular choice. As for the high use of active hands in West Germany, this seems consistent with their industriousness, efficiency and inventive spirit. Also, some of the active hands in West Germany are being worn passively, i.e. they are mechanical hands with manual opening rather than cable/harness opening.

Conclusion

This article is intended to show, as a matter of interest, the differences in use of hooks and hands in the USA and a few other countries for comparison. However, the point with which the author would like to leave the reader is the necessity of a thorough assessment before prosthetic fitting to take into account each amputees's functional, psychosocial, and cultural needs which will influence acceptance and use of the prosthesis.

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Dust emission during cutting of polyurethane-impregnated bandages

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Abstract

The airborne dust generated when cutting splinting bandages represents a potential respiratory hazard, particularly to those who regularly remove casts with a power saw. Plaster of Paris (POP) dust is already classified by the Health and Safety Executive as a nuisance dust.

This paper reports on a study to determine the nature, size and concentration of dust produced when cutting polyurethane (PU) impregnated bandages using a power saw. It has been shown that, under severe conditions PU bandages produce lower airborne dust concentrations than POP bandage but that all of the bandages tested produced particles small enough to reach the final divisions of the lung. It is therefore recommended that a dust extraction unit be used when cutting all types of bandage.

Introduction

PU impregnated fabric bandages are becoming increasingly popular in the management of fractures owing to their high strength/weight ratio, durability and ease of application. Currently the most popular fabric is knitted continuous filament glass fibre, although cotton and polyester fabrics are also used (Wytch et al, 1987).

Plaster room personnel have expressed concern over the potential hazards resulting from the normal use of these materials (Wytch et al, 1988). These hazards include the isocyanates and other chemicals in the resin, the potential fire risk associated with polyurethanes in general (Ritchie et al, 1988), and the effects of the dust produced when casts are removed with an oscillating saw. Many plaster room staff experience irritation around the wrists, neckline and on the face during cast removal.

The high levels of POP dust generated during cutting with a power saw can be observed in every hospital casting room. There are however no published results on dust levels for POP or PU impregnated fabric bandages reported in the literature.

This paper reports on an investigation carried out to determine the airborne dust concentration, the nature and size of the particles produced during cutting of both POP and PU bandages using a power saw. The potential risk from airborne dust when cutting these materials is assessed.

Dust is defined by the Health and Safety Executive (MDHS 14, 1986) as an aerosol of solid particles, mechanically produced, with individual particle diameters 0.1um upwards. Respirable dust is that fraction of the total dust cloud capable of reaching the final lung divisions and is defined by the "Johannesburg Curve" (International Conference on Pneumoconiosis 1961), as any particle of less than 7um in diameter. For the purposes of optical counting, dust samples were classified as particles or filaments. Particles are defined as being essentially spherical in shape whilst filaments have a length to diameter ratio of greater than 3:1. The fate of any particle after entry to the human respiratory system depends on the nature and size of the particle. Occupational exposure limits have been defined for many individual dusts in Health and Safety Executive (HSE, 1987) Guidance Note

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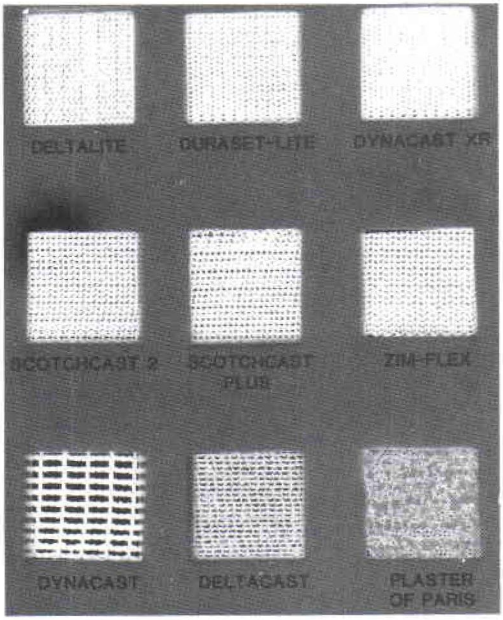

Fig. 1. Materials tested for dust production.

Table 1. Materials tested for dust production.

Type of bandage	Product name
Knitted glass fibre impregnated with polyurethane resin	Delta-lite Dynacast XR Duraset-lite Scotchcast 2 Zimflex Scotchcast Plus
Knitted polyester impregnated with polyurethane resin	Dynacast
Knitted cotton impregnated with polyurethane resin	Deltacast
Leno weave cotton impregnated with plaster of Paris	Gypsona

EH 40/88. Plaster of Paris dust has been assigned a recommended exposure limit of $10mg.m^{-3}$.

Man-made mineral fibre (including glass fibre) has an exposure limit of $5mg.m^{-3}$. Both these limits are in terms of an 8 hour time-weighted average exposure. No short term exposure limit has been specified for either substance but it is recommended by HSE that in such instances a value of three times the 8 hour figure be used for control purposes to apply to 10 minute periods. Thus values of 30 and $15mg.m^{-3}$ respectively can be taken to apply.

Materials and methods

Sample preparation

Eight PU impregnated fabric bandages and POP bandage (Table 1 and Fig. 1) were compared for dust emission during cutting with an oscillating power saw. Bandages of each material 10cm (4 inch) wide were activated according to manufacturers instructions and formed into slabs 7 layers thick and 50cm long. All slabs were prepared in an identical fashion by one of the authors (RW). The slabs were cured for 72h under standard laboratory conditions, 22(+/−1) degrees Celsius, and a relative humidity of 65% (+/−2%) before testing. Each slab was mounted on a foam block covered with fresh stockinette to simulate normal cutting conditions and secured with adhesive tape at either end. Three samples of each material were tested. The results for the six glass fibre bandages have been averaged.

Test environment

Tests were carried out in a specially prepared room 4 × 3 × 3m with a filtered air inlet in one corner and a high powered suction unit (Dronsfield) in the opposite corner, capable of providing 21 complete air changes per hour. Prior to each test the room surfaces were thoroughly cleaned with an industrial vacuum cleaner and purged using the Dronsfield suction unit until the particle count measured less than 0.3 particles per metre recorded by an electronic particle counter (Royco model 218).

Test procedure

A 10 minute test period for each sample was chosen to represent intentionally severe conditions when compared to a typical time of 5 minutes for the removal of a below-knee cast. Three samples of each material were subjected to 10 minutes of continuous cutting with an oscillating saw and dust samples collected. To provide uniformity in cutting technique all samples were cut in an identical fashion with a series of parallel cuts by one of the authors (IKR). A new P.T.F.E.-coated chrome steel saw blade (Desoutter 16882) was fitted to the power saw (Desoutter C.C.1) prior to cutting the first sample of each material.

Dust sampling

Three types of dust sample were taken during each test;

(a) personal sampling for total dust.
(b) fixed position sampling for total dust and
(c) fixed position sampling for subsequent particle identification and size distribution using light and scanning electron microscopy (SEM).

The personal dust sampling head was attached to the lapel of the operator, and the fixed position dust sampling head was positioned directly in front of the operator 1m away at head height. In each case an open 25mm dia. sampling head was employed with air being drawn through a glass fibre filter at a rate of 40 l. per. min. using mains-powered rotary vane pumps to give a smooth airflow.

The fixed position sampling was in accordance with the HSE recommended method (MDHS 14) but the personal sampling was non-standard in that the airflow was 20 times the 2 l. per. min. recommended. This was necessary to enable a significant weight of dust to be collected on the sample filter in the 10 minute period. Also open faced filter holders were used instead of the modified U.K.A.E.A. sampling head specified by MDHS 14. Consequently the concentration values obtained from the personal sampling relate to total dust and not total inhalable dust (the latter being used normally for reference to occupational exposure limits). However, it is considered that the results obtained give a good indication of the relative dust emissions of the various materials.

Two further samples were taken to the right of the operator also 1m away at head height, one for particle size distribution using light microscopy and the other for particle identification using SEM. One sample head was fitted with a cellulose membrane filter with a pore size of 0.8um through which air was drawn at a rate of 10 l. per. min. for all materials except POP for which the rate was reduced to 2 l. per. min. to allow for the greater volume of dust produced. The second sample head utilized a polycarbonate membrane filter with a pore size of 0.8um and a flow rate of 3 l. per. min. for all materials except POP when a reduced rate of 2 l. per. min. was used to allow for the greater volume of dust produced by POP.

Both samples were taken throughout the total test period of 30 minutes for each type of material.

Evaluation techniques

a) Gravimetric — Personal and fixed position dust samples were evaluated using simple gravimetric techniques conforming to those given in MDHS 14. Airborne dust concentrations are determined by passing a known volume of contaminated air through a filter of predetermined weight. By re-weighing the filter at the end of the sampling period, the quantity of material is determined by the difference in weight. The concentration of total dust was found by dividing the weight gain by the volume of air passed through the filter and is quoted in mg. m^{-3} of air.

b) Particle size distribution — Standard light microscopy techniques were used to determine the size distribution of 200 particles collected on cellulose membrane filters. The cellulose membrane filter was rendered transparent by exposure to a stream of acetone vapour and the deposit sealed by the addition of a cover glass secured by Glycerol Triacetate. These were examined under bright field conditions at an overall magnification of 400x. Scanning electron microscopy (SEM) was used at magnifications of up to 9,900x to determine the nature and shape of a random selection of particles collected on a polycarbonate membrane filter. Filament length determination was carried out separately from the 200 particles. Fifty filaments with a diameter of 6–8um were sized.

SEM methods

Samples of resinated and un-resinated knitted glass fibre fabric bandage, or segments of polycarbonate filter with attached dust particles were mounted on stubs with colloidal silver adhesive, sputter-coated with platinum (20nm for bandage samples, 15nm for filter samples) and examined in a Jeol JSM — 35CF scanning electron microscope (at 5kV for material samples, 10 kV for filter samples)

Results and discussion

Figure 2 shows scanning electron micrographs of a typical knitted glass fibre fabric un-resinated and resinated.

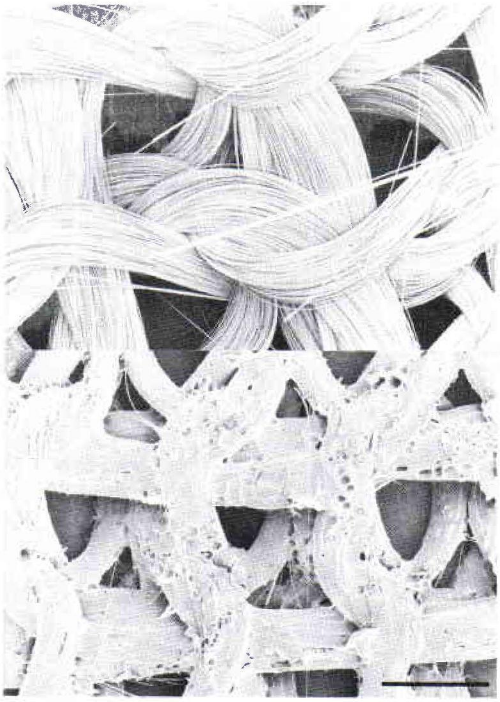

Fig. 2. Top, scanning electron micrograph showing the knitted pattern of the glass fibre bandage. Bottom, the same bandage impregnated with polyurethane resin (Bar line for both figures = 1mm).

The results for personal and fixed postition dust sampling are shown in Table 2. This shows that in this case the personal sample was always higher than the fixed position sample and serves to illustrate that the personal sampling is a more critical measure of the airborne dust level to which a person is exposed.

Both personal and fixed position dust levels for the PU impregnated materials were significantly lower than for POP. It is interesting to note that no significant level of dust was recorded for the Cotton fabric (Deltacast) and the Polyester fabric (Dynacast). However, there were significant levels of dust produced for all of the glass fibre bandages with the exception of Scotchcast Plus.

Table 3. Ratio of personal dust concentration/length of cut and ratio to POP

Material	Personal total dust concentration / length of cut	Ratio to POP
Plaster of Paris	0.026	1.00
Glass fibre bandage	0.005	0.19
Polyester	‹0.002	‹0.08
Cotton	‹0.002	‹0.04

When the results from the personal dust concentrations (Table 2) for the different types of fabric are compared with the dust produced for each centimetre (cm) of bandage cut (Table 3), it can be seen that the same rank order is obtained.

The determination of particle size distribution for plaster of Paris was not possible since the dust samples collected were too dense. This was in spite of reducing the air flow rate through the sampling head to 2 1. min−1. However from previous (unpublished) work by the authors it was established that the particles from POP dust showed a similar size distribution to the synthetic bandages.

The electron micrograph in Figure 3, shows an example of the quantity and types of dust collected on the polycarbonate filters. These were either glass fibre filaments or particles of resin, or aggregates of resin and glass fibre.

From the particle size distribution shown in Figure 4 it can be seen that 90 per cent of the glass fibre particles to 98 per cent of the cotton and polyester fabric bandage particles were respirable if the upper limit for respirability is taken as 7um (Orenstein, 1960).

The upper limit for respirability of filaments has been taken as 3um diameter (W.H.O. 1985). All the filament diameters were found to be 6um or greater. The average filament length

Table 2. Airborne dust concentrations and length of material cut

Material	Airborne dust concentration (mg. m^{-3})				Average length of cut (cm)
	Personal	S.D.	Fixed position	S.D.	
Plaster of Paris	35.5	1.5	17.1	2.9	823
Glass fibre bandage	3.9	1.2	1.3	0.8	774
Polyester bandage	n/s	—	n/s	—	532
Cotton bandage	n/s	—	n/s	—	1103

n/s — not significant
S.D. Standard Deviation

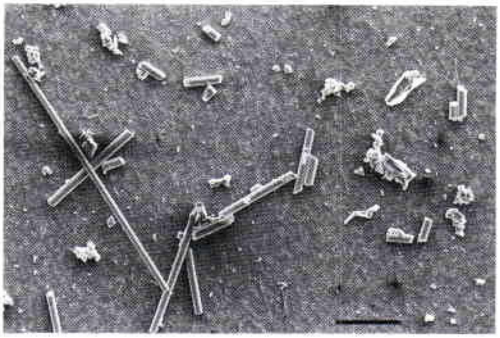

Fig. 3. Scanning electron micrograph showing a typical sample of dust collected during cutting of PU-impregnated glass fibre bandage. A combination of glass fibre filaments and particles of resin or glass fibre and resin can be seen (Bar line = 50um).

for the glass fibre bandages is shown in Figure 5 and was found to vary form 8um to over 100um. The maximum recorded length for any filament was 300um.

Conclusions and comments

The effects of inspired dust on the lungs may be categorized as toxic, allergic, fibrogenic, carcinogenic or inert. This study has determined the concentration, the nature and

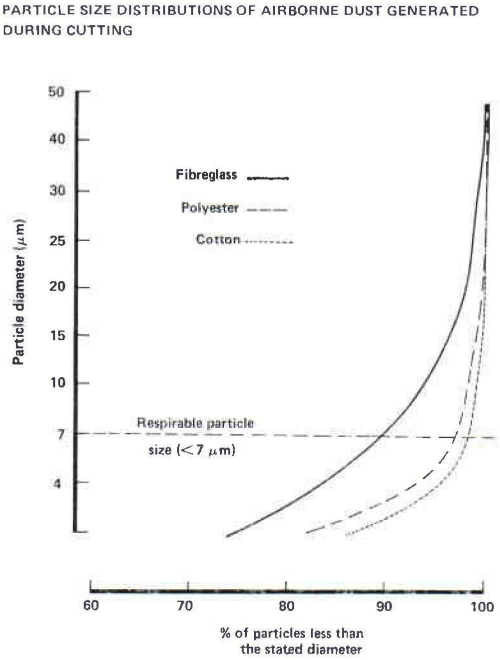

Fig. 4. Particle size distribution of airborne dust generated during cutting of bandages.

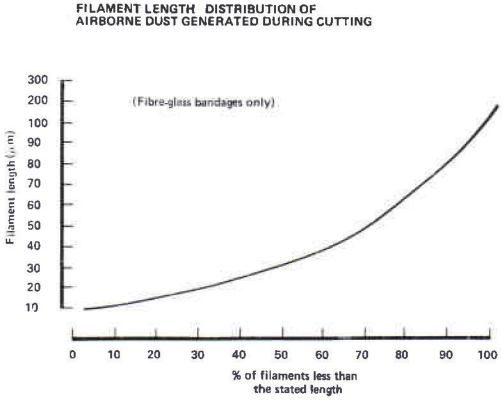

Fig. 5. Filament length distribution of airborne dust generated during cutting of glass fibre bandages.

the size of the dust generated during cutting of PU bandages with a plaster saw to establish whether a potential hazard exists which could lead to fibrogenesis of the lungs. The toxic, allergic and carcinogenic effects of dust produced by these materials has not been assessed.

Although cured PU resin is a stable compound and glass fibre is an inert material the potential fibrogenic effects from these substances will depend on whether dust is able to reach the alveoli. This study has shown that during removal of orthopaedic casts with a power saw, the PU impregnated bandages produce much lower concentrations of dust than POP, less than one third in the worst case.

The filaments produced by the synthetic materials are too large to reach the final divisions of the lungs and are unlikely to produce a respiratory hazard. These filaments are thought to be the cause of skin irritation experienced by some plaster room staff.

It has also been shown that at least 90% of the particles in the dust cloud are respirable and that these contain fragments of PU resin. There are no Occupational Exposure Limits for polyurethane dust, but the absence of a limit does not imply that the material is inert. It is therefore recommended that a dust extraction unit be used when cutting all types of splinting bandages with a power saw.

Acknowledgements

Dr. E. Bootheroyd, Health and Safety Executive. Gallowgate, Aberdeen, for his help and advice.

Smith and Nephew Ltd for their help and financial assistance.

Mrs T. M. Brindle for her expert technical assistance.

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RITCHIE I. K., WYTCH R., WARDLAW. (1988). Flammability of modern synthetic bandages. *Injury.* **19,** 31–32.

WORLD HEALTH ORGANIZATION (1985). Reference methods for measuring airborne man-made mineral fibres; WHO/EURO MMF reference scheme: monitoring concentration using a phase contrast optical microscope: determining using a scanning electron microscope: prepared WHO/EURO Technical Committee—Copenhagen: WHO.

WYTCH R., MITCHELL C. G., RITCHIE I. K., WARDLAW D., LEDINGHAM W. (1987). Technical note: new splinting materials. *Prosthet. Orthot. Int.* **11,** 42–45.

WYTCH R., MITCHELL C. G., WARDLAW D., LEDINGHAM W., RITCHIE I. K. (1987). Mechanical assessment of polyurethane impregnated fibreglass bandages for splinting. *Prosthet. Orthot. Int.* **11,** 128–134.

WYTCH R., RITCHIE I. K., CLAYTON R. (1988). Potential hazards of modern splinting materials. *Occup. Health.* **11,** 492–494, 1988.

Prosthetics and Orthotics International, 1988, 12, 161–162

Calendar of events

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

Courses for Physicians, Surgeons and Therapists

NC511 Clinical Gait Analysis; 18th–20th January, 1989.
NC505 Lower Limb Prosthetics; 23rd–27th January, 1989.
NC502 Upper Limb Prosthetics and Orthotics; 30th January–3rd February, 1989.
NC506 Fracture Bracing; 3rd–7th April, 1989. (Also suitable for orthotists and plaster technicians).
NC510 Wheelchairs; 18th–20th April, 1989.

Courses for Prosthetists

NC219 Below-Knee Modular Systems (Revision Course); 20th–24th February, 1989.
NC209 Below-Knee Modular Systems; 6th–17th March, 1989.
NC220 Above-Knee Modular Systems (Revision Course); 24th–28th April, 1989.
NC210 Above-Knee Modular Systems; 15th–26th May, 1989.

Course for Orthotists

NC221 Reciprocating Gait Orthotics; 1st–12th May, 1989.

Course for Prosthetics Technicians

NC606 Above-Knee and Below-Knee Modular Systems; 6th–10th February, 1989.

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 1989

Course for Physician, Surgeons and Therapists

602 C Lower and Upper Limb Prosthetics; 6th–10th March, 1989.
603 C

Courses for Physicians and Surgeons

703 B Spinal, Lower and Upper Limb Orthotics; 3rd–7th April, 1989.
603 D Lower and Upper Limb Prosthetics; 10th–14th April, 1989.
603 E Lower and Upper Limb Prosthetics; 15th–19th May, 1989.

Courses for Therapists

622 A Lower Limb Prosthetics; 23rd–27th January, 1989.
622 B Lower Limb Prosthetics; 1st–5th May, 1989.

Course for Rehabilitation Counsellors

640 Orientation in Prosthetics; 24th–25th April, 1989.

Course for Pedorthists

801 Pedorthic Management of the Foot; 8th–12th May, 1989.

Further information may be obtained by contacting Charles M. Fryer, Director, Prosthetic-Orthotic Center, North Western University, 345 East Superior St., Room 1723, Chicago, Illinois 60611, U.S.A. Tel: (312) 908–8006.

New York University Medical School
Short Term Courses 1989

Courses for Physicians and Surgeons

751 B Lower Limb and Spinal Orthotics; 6th–10th March, 1989.
741 B Lower Limb Prosthetics; 13th–17th March, 1989.
744 A Upper Limb Prosthetics and Orthotics; 10th–14th April, 1989.
751 C Lower Limb and Spinal Orthotics; 24th–28th April, 1989.
741 C Lower Limb Prosthetics; 1st–5th May, 1989.
754 B Foot Orthotics; 11th–12th May, 1989.

Courses for Therapists

752 B Lower Limb and Spinal Orthotics; 6th–10th March, 1989.
742 A Lower Limb Prosthetics; 27th–31st March, 1989.
745 A Upper Limb Prosthetics and Orthotics; 10th–14th April, 1989.
752 C Lower Limb and Spinal Orthotics; 24th–28th April, 1989.
754 B Foot Orthotics; 11th–12th May, 1989.

Course for Prosthetists

7432 The Ischial Containment (NML) Above-Knee Socket; 12th–14th January 1989.

Further information may be obtained by contacting Ms. Sandy Kern, Registrar, Prosthetics and Orthotics, New York University Post-Graduate Medical School, 317 E. 34th St., New York, NY 10016. Tel: (212) 340–6686.

9–11 March, 1989
9th Annual Scientific Meeting of the Australia College of Rehabilitation Medicine, Sydney, Australia.
Information: Anne Worden, 55 Charles St., Ryde, New South Wales, Australia 2112.

14–15 April, 1989
Conference on The Changing role of Engineering In Orthopaedics – Call For Papers. London, England.
Information: Andree Johnson, Conference Department C384, The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London SW1H 9JJ, England.

16–19 April, 1989
69th Annual Conference of the American Occupational Therapy Association, Baltimore, U.S.A.
Information: AOTA, 1383 Picard Dr., PO Box 1725, Rockville, Maryland, U.S.A.

3–6 May, 1989
British Orthopaedic Association Scientific Meeting, Rhodes, Greece.
Information: B.O.A., 35-43 Lincoln's Inn Fields, London, WC2A 3PN, England

3–6 May, 1989
Annual Scientific Meeting of the International Medical Society of Paraplegia, Rome, Italy.
Information: Prof. S. Giacobini, Via Cassia Antica 240, 00191 Rome, Italy.

3–7 May, 1989
6th Annual Meeting of the Southern Orthopaedic Association, Edinburgh, Scotland.
Information: Sherrie Coffee, Southern Orthopaedic Association, PO Box 190088, Birmingham, Alabama, USA.

Prosthetics and Orthotics International, 1988, 12, 163–178

Congress site and Kobe Portopia Hotel

VI World Congress

12th–17th November, 1989, Kobe

Supported by:
Japanese Society for Rehabilitation of the Disabled
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Message from the President

The Triennial World Congress is the single most important event in the Society's calendar of courses and seminars. It is the one international event in which all members have the opportunity to participate in an active role. This, our Sixth Congress, is the first outside Europe and North America and I am sure the membership will share the Executive Board's pleasure that it will be held in Japan.

Your International Congress Committee has assembled an excellent programme, developed from their experience of the needs of the members. The Main Topic Sessions involve speakers of international repute presenting the latest developments in subjects selected for their topicality. The Panel Sessions focus in depth on subjects of continuing concern. The Instructional Courses provide the opportunity for an educational experience encompassing the state of the art in a variety of subjects. The Free Paper Sessions, in appropriate groupings, afford the opportunity for all to present their latest work in research, clinical practice or technological application. The scientific programme is enhanced by the commercial exhibition and by manufacturers' presentations within the scientific programme itself. At any time the participant will have a choice available in a programme designed to provide for the needs of all.

Of course, Congress attendance is not all work, and our Japanese hosts have arranged an exciting social programme and accompanying persons' programme to provide us with a generous flavour of their beautiful country.

All of these are simply the bare facts of the programme! No doubt the arrangements will be organized with the efficiency for which Japan is deservedly famous. A successful meeting is already ensured by the enormous amount of effort expended by our Japanese Organizing Committee and by the support of the various Ministries and Associations listed elsewhere in this programme. How much more is offered to us in the opportunity to visit this historic country and to sample its culture and beauty.

All of the preparations have now been made! I urge the Society's members and the membership of our collaborating organization, INTERBOR, to grasp this opportunity and participate in our Sixth World Congress. Come to Japan!

John Hughes
President
ISPO

Message from the Organizing Committee Chairman

Every three years an ISPO World Congress has been held in various capitals of the world and, in 1989 we have the great honour of hosting the sixth ISPO World Congress in Kobe, Japan and the Organizing Committee has been making every effort to prepare an interesting and scientifically valuable programme for both participants and accompanying persons.

It is anticipated that more than one hundred well-known specialists from a variety of countries will attend this Congress to exchange and share the results of their scientific research and experience. Participants will include people from such fields as prosthetics, orthotics, physical and occupational therapy, rehabilitation engineering, and representatives of physically handicapped groups.

We sincerely hope that one major result of the Congress will be animated and informative discussions among the attending professionals in such areas as, not only in the proper prosthetic and orthotic problems, but also in the fields of wheelchair engineering, environment control systems and communication engineering.

As Kobe itself is the oldest port city in Japan, there is much of the traditional to experience as well as the more contemporary in Japanese society. Also well within touring distance from Kobe are the cultural cities of Kyoto and Nara, the old capitals of Japan. Accordingly, in addition to the scientific programme itself, we are also planning a variety of attractive social events to entertain participants and their accompanying persons. We very much hope all of you will enjoy these activities and that they will cultivate a mutual understanding and friendship among you.

We are looking forward to seeing you in Kobe.

Kokichi Tsuchiya
Chairman
Organizing Committee

Scientific Programme

Knud Jansen Lecture

The Knud Jansen Lecture will be given on the occasion of the VI ISPO World Congress by Prof. P. K. Sethi.

The lecture will be given immediately after the Opening Ceremony.

Main Topic Sessions

These sessions will feature current trends and recent developments in various subjects, presented by prominent speakers chosen according to their international reputations. Individual speaking time will range between 15 and 20 minutes with an appropriate amount of time reserved for discussion. The following topics have been chosen:

M-A-1 Environmental Engineering for the Severely Disabled.
Key Words: environment control system, normalization, building accessibility, public transport systems for the severely disabled, mobility, wheelchair, ergonomics.

M-A-2 Amputation Surgery (including Traumatic Amputation).
Key Words: epidemiology, level selection, traumatic amputation, amputation technique, pre- and postoperative management, immediate or early prosthetics fitting, compensation, social aspects of the patient, phantom pain, psychological treatment, limb salvage, replantation.

M-A-3 Low Back Pain — Surgery and Orthotic Treatment.
Key Words: spondylolisthesis, herniated nucleus pulposus, indication and prescription of orthosis, pain, exercise, economics, ergonomics.

M-A-4 Sports Injuries and Orthotics
Key Words (1) Injuries in General: biomechanics of running, classification, orthotics and footwear.
(2) Knee Instability: ACL injury, PCL injury, MCL injury, biomechanics, orthotics.

M-A-5 Upper Limb Orthotics.
Key Words: hand surgery, hand therapy, biomechanics, classification, prescription, assessment, treatment programme, finger and hand splints, wrist, elbow and shoulder orthoses.

M-A-6 Upper Limb Prosthetics.
Key Words: historical review and future trends, clinical indications, assessment, logistics problems (supply, maintenance), applications for A/E amputation-body-powered vs externally-powered.

M-A-7 Neuropathic Foot.
Key Words: etiology, operative treatment, non-operative treatment including footwear, geriatric foot disorders.

M-A-8 Prosthetics and Orthotics in Developing Countries.
Key Words: information exchange, development of prosthetics and orthotics, training of prosthetists and orthotists, local materials.

M-A-9 Scoliosis and its Treatment.
Key Words: classification, school screening, rationale of brace treatment, long brace vs short brace, results of brace treatment, patient selection, limitations of brace treatment, natural history, economy, synopsis of surgical treatment.

M-A-10 Lower Limb Prosthetics (Stump and Socket Interface).
Key Words: socket design, flexible socket, weight-transmitting structure, stump environment, comparison between subjective and biomechanical data.

Panel Sessions

These discussions will attempt to focus on a selected theme by a panel of experts representing varying professional and regional viewpoints. Time allocation for each panel member will be set in advance, and the ensuing 30-minute discussion will be moderated by the Co-chairman. The following topics have been chosen:

P-A-1 Team Approach in Prosthetics.
Key Words: training principles and role of each specialist, amputation due to malignant tumours and peripheral vascular insufficiencies, expectation, acceptance, cooperation between patient and rehabilitation team, home exercise programme.

P-A-2 Orthotic Treatment for Stroke Patients.
Key Words: spasticity, contractures, reflexology, selection of orthoses, training and ambulation, hand function, arm sling.

P-B-1 Historical, Geographical, Climatic and Cultural.
Considerations in Prosthetic Design.
Key Words: history, life style, cultural considerations, local materials.

P-B-2 New Advances in Lower Limb Prosthetic Component Design.
Key Words: function, prescription, energy, biomechanics, evaluation.

P-B-3 Cerebral Palsy.
Key Words: classification, reflexology, treatment program, orthotic management.

P-B-4 Spina Bifida
Key Words: principles of orthotic management, mobility aids, standing orthoses, reciprocating gait orthoses, surgery.

P-B-5 Management of Spinal Cord Injury.
Key Words: conservative or surgical treatment, physical therapy, occupational therapy, orthotic treatment, wheelchair and seating ADL, QOL.

P-B-6 Education in Prosthetics and Orthotics.
Key Words: international standards, curriculum, postgraduate programme.

P-B-7 Functional Electrical Stimulation.
Key Words: surge electrode, implantable electrode, multi-channel stimulation, restoration of extremity function, control of micturition.

P-B-8 Limb Deficiencies Present at Birth.
Key Words: classification, management of multiple-limb-deficient children, management of bony overgrowth, psychosocial treatment for parents.

P-B-9 CAD/CAM in Prosthetics and Orthotics.
Key Words: socket design, footware design, computer aided design and manufacturing, shape sensing measurement of physical properties of human limbs, computer programme for shape design, curving of socket shape, evaluation of fitting.

P-B-10 Recent Development in Lower Limb Socket Configuration.
Key Words: biomechanics, A/K, B/K, suspension, function, evaluation, prescription.

P-B-11 Wheelchair and Seating Design and Prescription.
Key Words: manual and electric wheelchairs, prescription, evaluation, seating system.

P-B-12 Orthotic Treatment in Poliomyelitis.
Key Words: epidemiology, evaluation, surgery, selection of orthosis, use of local materials.

P-C-1 Amputation Surgery.
Key Words: epidemiology, level selection, traumatic amputation, amputation technique, pre- and postoperative management, immediate or early prosthetic fitting, compensation, social aspects of the patient, phantom pain, psychological treatment, limb salvage, replantation.

Free Paper Sessions

The purpose of this type of session is to give Congress participants an opportunity of presenting the results of their research work and/or clinical and technological experience, to benefit those who are interested and engaged in the same field of activity. Ten minutes will be allocated per paper (8 minutes for presentation and 2 minutes for discussion).

Instructional Course Lectures

The aim of this lecture series is to present well-prepared and thoroughly organized educational sessions to the audience, who will thereby benefit from material which clearly conforms to the most accepted philosophy of each given theme.

Each instructional course will be organized by an authorized expert in the field. Lecturers should not confine their material to only his or her individual field of research or experience.

Proposed Instructional Course Lecture Topics

ICL-1 Lower Limb Prosthetics (7 units).
Organizer: Norman Govan (Scotland) P. O.
—Below-Knee Prosthetics, Biomechanics of Below-knee Prosthetics, Below-knee knee Socket Variation.
—Suction Below-knee Prosthetics, Below-knee Vacuum Casting C. P. C. M. Casting Technique.
—Below-knee Prosthetics, Various Casting Techniques, Suction Below-knee Prosthetics.
—Above-knee Prosthetics, Biomechanics of A/K Prosthetics Gait Training of A/K Amputee.
—CAT/CAM Above-knee Socket, NSNA Above-knee Prosthetics, Narrow ML Above-knee Socket.
—Above-knee Prosthetics, Biomechanics of A/K Prosth.
—Hip Disarticulation Biarticular Control System.

ICL-2 Lower limb Orthotics (5 units).
Organizer: David Condie (UK) Eng.
—Introduction & General Topics.
—Special Foot Wear.
—Ankle Foot Orthoses.
—Knee Orthoses & Knee Ankle Foot Orthoses.
—Hip Knee Ankle Foot Orthoses.

ICL-3 Fracture Orthoses (2 units).
Organizer: M. L. Stills (USA), P. O.
—History and Current Concepts of Fracture Management.
—Orthotic Management of Fractures of the Extremities.
—Orthotic Management of Spinal Fractures.
—Cast Bracing of Extremities Fractures.
—Cast Bracing of Extremities Using Prefabricated Bracing Components.

ICL-4 Upper Limb Orthotics (4 units).
Organizer: Margaret Ellis (UK), O. T.
—Anatomy & Pathomechanics.
—Hand Orthoses & Wrist-Hand Orthoses.
—Elbow Orthoses & Shoulder Orthoses.

ICL-5 Scoliotic Orthoses (3 units).
Organizer: Ed Van Hanswyck (USA), P.O.
—Anatomy & Pathomechanics.
—Cervico-Thoraco-Lumbo-Sacral Orthoses.
—Thoraco-Lumbo-Sacral Orthoses.

ICL-6 Management of Stroke Patients (2 units).
Organizer: Shigenobu Ishigami (Japan), M. D.
—Choice of Medical Treatment.
—Orthotic Management.
—PT at Therapy Group.
—Conventional AFO vs New Orthotics.

ICL-7 Amputee Gait Training (2 units).
Organizer: Joan Edelstein (USA), P. T.
—Lower-Limb Amputee Gait Training.
—Lower-Limb Amputee Gait Deviations: Prosthetic Factors.
—Lower-Limb Amputee Gait Deviations: Training Factors.

ICL-8 Upper Limb Prosthetics (3 units).
Organizer: Takashi Aoyama (Japan), M. D.
—Amputation Surgery in the Upper Limb.
—Prosthetics for Child Upper Limb Amputee.
—Training of Upper Limb Amputee.
—Recent Advances in Externally Powered Upper Limb Prosthetics.

ICL-9 Clinical Gait Analysis (2 units).
Organizer: Saed Zahedi (UK), Eng.
—Laboratory Methods and Treminology.
—Normal Walking.
—Classification and Clinical Evaluation of Pathological Walking.
—Role of Clincial Gait Analysis in Management of Cerebral Palsied.

ICL-10 Wheelchairs and Seating for the Severely Disabled (3 units).
Organizer: Geoffrey Bardsley (UK) Eng.
—Anatomy of the Wheelchair.
—Prescription of the Wheelchair.
—Evaluation of the Wheelchair (Including ISO standardization).
—Prescription & Evaluation of Seating Systems for the severely Disabled.

ICL-11 Neuropathic Foot (2 units).
Organizer: A. Jernberger (Sweden) M. D.
—Introduction.
—Neuropathy in Leprosy.
* Neuropathy and Osteopathy.
* Prevention of Foot Lesions.
—Treatment Programme for Neuropathic Ulcers and Gangrene in Diabetes.
—Treatment Programme for Neuropathic Ulcers and Gangrenes in Leprosy.
—Application Technique of Composite Total Contact Cast.
* Salvage of the Neuropathy by the Auto-amputation and Amputation through the Ankle as a Better Alternative than Below Knee Amputation.
—The Mechanism of Neuropathic Foot Lesions.
* Acute Osteopathic Breakdown.
* Epidemiological Aspects.

ICL-12 Amputation Surgery (2 units)
Organizer: George Murdoch (UK) M. D.
—Above Knee & Through-Knee Amputations.
—Below-knee Amputation.
—Syme's and Partial Foot Amputations.
—Level Selection.
—The Limb Deficient Child & Amputations in the Growth Period.
—Amputations in Trauma.
—The Role of Amputation in Tumour Management.
—Stump Environment & Immediate Pre and Post-Operative Care.
—Rehabilitation of the Leg Amputee.
—Amputation Surgery in the Upper Limb.

VI World Congress of
International Society for Prosthetics and Orthotics

Form A

12th–17th November 1989
Kobe, Japan

Registration form

Dr/Prof/Mr/Mrs/Miss/Ms

Personal Information

Surname ______ Given name ______ (M/F)

______

Profession (M.D./P.T./O.T./Eng./Student/others______)

Mailing Address

______

Postal code ______ Country ______

Telex ______ (Answer back code) ______ Cable address ______

Telephone ______ Telefax ______

Institution ______ Position held ______

Accompanying Person(s)

Surname ______ Given name ______

Surname ______ Given name ______

Registration

Fees (in Japanese Yen)	By 4/30/89	On/After 5/1/89	No. of persons	Total
ISPO Member INTERBOR Member	¥50,000	¥60,000		
Non-member	¥65,000	¥80,000		
One-day Participant	¥25,000			
Student Participant	¥25,000			
Instructional Course Lecture	¥5,000/unit			
Accompanying Person	¥18,000			
Congress Dinner	¥8,000			
Lunch: ☐ Nov. 12 ☐ Nov. 13 ☐ Nov. 14 ☐ Nov. 15 ☐ Nov. 16 ☐ Nov. 17	¥1,100/lunch (Please tick off the date)			
			Grand Total	¥

INSTRUCTIONAL COURSE LECTURES (Please tick off)

☐ ICL-1-a	☐ ICL-1-b	☐ ICL-1-c	☐ ICL-1-d	☐ ICL-1-e
☐ ICL-1-f	☐ ICL-1-g			
☐ ICL-2-a	☐ ICL-2-b	☐ ICL-2-c	☐ ICL-2-d	☐ ICL-2-e
☐ ICL-3-a	☐ ICL-3-b			
☐ ICL-4-a	☐ ICL-4-b	☐ ICL-4-c	☐ ICL-4-d	
☐ ICL-5-a	☐ ICL-5-b	☐ ICL-5-c		
☐ ICL-6-a	☐ ICL-6-b			
☐ ICL-7-a	☐ ICL-7-b			
☐ ICL-8-a	☐ ICL-8-b	☐ ICL-8-c		
☐ ICL-9-a	☐ ICL-9-b			
☐ ICL-10-a	☐ ICL-10-b	☐ ICL-10-c		
☐ ICL-11-a	☐ ICL-11-b			
☐ ICL-12-a	☐ ICL-12-b			

Payment must be made by bank draft (with authorised signature) in **Japanese Yen** made payable to: **ISPO VI WORLD CONGRESS.**
The name of the participant for whom the payment is being made must be clearly indicated.

No other form of payment will be accepted.

Please refer to Complete Announcement for details on cancellations and refunds.

Date ______________________ Signature ______________________________

Provisional Programme

	November 12 (Sun)	November 13 (Mon)	November 14 (Tue)	November 15 (Wed)	November 16 (Thu)	November 17 (Fri)
9:00–10:40	ICL-1-a (Hall A) ICL-2-a (Hall B) ICL-4-a (Hall C) ICL-6-a (Hall D) ICL-9-a (Hall E) ICL-12-a (Hall F)	M-A-1 (Hall A) P-B-1 (Hall B)	M-A-4 (Hall A) P-B-4 (Hall B)	M-A-7 (Hall A) P-B-7 (Hall B)	M-A-8 (Hall A) P-B-8 (Hall B)	M-A-10 (Hall A) P-B-11 (Hall B)
	COFFEE BREAK				COFFEE BREAK	
11:00–12:40	ICL-1-b (Hall A) ICL-2-b (Hall B) ICL-4-b (Hall C) ICL-6-b (Hall D) ICL-9-b (Hall E) ICL-12-b (Hall F)	M-A-2 (Hall A) P-B-2 (Hall B) Free Paper (Hall C) Free Paper (Hall D) Free Paper (Hall E) Free Paper (Hall F)	M-A-5 (Hall A) P-B-5 (Hall B) Free Paper (Hall C) Free Paper (Hall D) Free Paper (Hall E) Free Paper (Hall F)	ICL-1-e (Hall A) ICL-2-e (Hall B) ICL-5-a (Hall C) ICL-8-a (Hall D) ICl-10-c (Hall E)	M-A-9 (Hall A) P-B-9 (Hall B) Free Paper (Hall C) Free Paper (Hall D) Free Paper (Hall E) AV Session (Hall F)	ICL-1-g (Hall A) ICL-3-b (Hall B) ICL-5-c (Hall C) ICL-8-c (Hall D) ICL-11-b (Hall E) AV Session (Hall F)
	LUNCH	[Lunch service will be provided at Kobe International Exhibition Hall]			LUNCH	
14:00–15:40	**Opening Ceremony** The Knud Jansen Lecture Prof. P. K. Sethie	M-A-3 (Hall A) P-B-3 (Hall B) P-C-1 (Hall C) Free Paper (Hall D) Free Paper (Hall E) AV Session (Hall F)	M-A-6 (Hall A) P-B-6 (Hall B) Free Paper (Hall C) Free Paper (Hall D) Free Paper (Hall E) AV Session (Hall F)		P-A-1 (Hall A) P-B-10 (Hall B) Free Paper (Hall C) Free Paper (Hall D) Free Paper (Hall E) AV Session (Hall F)	P-A-2 (Hall A) P-B-12 (Hall B) AV Session (Hall F)
		COFFEE BREAK			COFFEE BREAK	
16:00–17:40		ICL-1-c (Hall A) ICL-2-c (Hall B) ICL-4-c (Hall C) ICL-7-a (Hall D) ICL-10-a (Hall E) AV Session (Hall F)	ICL-1-d (Hall A) ICL-2-d (Hall B) ICL-4-d (Hall C) ICL-7-b (Hall D) ICL-10-b (Hall E) AV Session (Hall F)	**Official Reception Party** (4 PM) [Soraku Japanese Garden]	ICL-1-f (Hall A) ICL-3-a (Hall B) ICL-5-b (Hall C) ICL-8-b (Hall D) ICL-11-a (Hall E)	**ISPO World Assembly Paper Awards Presentation & Closing Ceremony** (4PM) [Hall A]
Evening	**Welcome Party** (5 PM) [Kobe International Exhibiton Hall]	**Japan Night** (6 PM) [Hall A]			**Congress Dinner** (7 PM) [Kobe Portopia Hotel "Ohwada"]	

CODES: ICL-1-a: Instructional Course Lecture No. 1 - Unit "a" M-A-1: Main Topic Session - No. 1 at Hall A P-B-1: Panel Session - No. 1 at Hall B AV Session: Audio Visual Presentation

Paper Awards

The Brian Blatchford Prize

The Brian Blatchford Prize has been established by the Blatchford family to honour the memory of Brian Blatchford. It will be awarded every three years at the World Congress of the International Society for Prosthetics and Orthotics.

The first Brian Blatchford Prize will be awarded at the Sixth World Congress of ISPO to be held in Kobe, Japan from November 12th–17th, 1989. On this occasion the Prize will be £2,000 and will be awarded for the most outstanding innovation in prosthetics and/or orthotics practice over the previous three-year period. The innovation should be related to a piece of prosthetic and/or orthotic hardware, or a scientifically based new technique which results in a better prosthesis or orthosis. The innovation should have reached a sufficiently advanced stage to ensure that it can be used successfully on patients.

The applicant or nominator should initially present evidence detailing the innovation, together with a sample of the device if appropriate, and send it to reach the President of ISPO by 31st December 1988 at the following address:

Professor J. Hughes,
National Centre for Training and Education
in Prosthetics and Orthotics,
Curran Building,
131 St. James Road,
Glasgow G4 0LS
Scotland

The innovation shall be presented at the Sixth World Congress and duly published in 'Prosthetics and Orthotics International'.

The President and Executive Board of the International Society for Prosthetics and Orthotics and the Blatchford family reserve the right to withhold the Prize should no suitable application be submitted.

The Forchheimer Prize

The Forchheimer Prize has been established by the Forchheimer family to honour the memory of Alfred Forchheimer. It will be awarded every three years at the World Congress of the International Society for Prosthetics and Orthotics.

The first Forchheimer Prize will be awarded at the Sixth World Congress of ISPO to be held in Kobe, Japan from November 12th–17th, 1989. On this occasion the Prize will be 4000 SEK and will be awarded for the most oustanding paper on 'Objective Clinical Assessment', 'Clinical Evaluation', or 'Clinical Measurement' published in 'Prosthetic and Orthotics International' during the three years prior to the Congress.

The President and Executive Board of the International Society for Prosthetics and Orthotics and the Forchheimer family reserve the right to withhold the Prize should no suitable paper be published.

General Information

Locations:

Kobe Convention Center*

—International Conference Center, Kobe
—Kobe International Exhibition Hall

*Kobe Covention Center is located on Port Island, a new cultural city built on an artificial island. The Portopia Hotel, with 1000 rooms, is located adjacent to the Convention Center. The city of Kobe, with a population of 1,350,000, is known historically as one of the first international ports in Asia. Kobe is situated in the centre of the Japanese Islands and is considered pivotal in cultural exchange in Japan.

Audiovisual Presentations

Great emphasis will be put on audiovisual presentations, incorporating both films and videotapes.

Poster Presentations

There will be ample facilities for the display and discussion of poster presentations.

Manufacturers' Presentations and Demonstrations

Time will be available within the Scientific Programme for those taking part in the commercial exhibition to present and demonstrate new products and developments.

Scientific Exhibition

Space will be available for scientific exhibits from noncommercial institutions and organizations. We are particularly hoping to arrange exhibits not only from Asian countries but also many other countries of traditional prostheses and orthoses using local materials.

Commercial Exhibition

A commercial exhibition will be held in

conjunction with the Congress at the Kobe International Exhibition Hall.

A Cafeteria and Hospitality Lounge will be available at the Exhibition Hall. Lunch and selected free refreshments will be provided.

For receipt of the Exhibition Guide and all relevant information, please contact the Congress Secretariat.

The Congress Secretariat:
All inquiries relating to the congress should be directed to the following address:

The Secretariat
ISPO VI World Congress Kobe
c/o International Conference Organizers, Inc. (ICO)
1F, Cresent Plaza Building
2–4–6, Minami Aoyama
Minato-ku, Tokyo, 107 Japan
Tel: (03) 470–3766
Fax: (03) 405–8638

Languages:
English and Japanese will be the working languages of the Congress. Stimultaneous translation will be provided in Auditoriums A and B.

Participation:
Members of ISPO, INTERBOR, their guests and non-members are all invited to participate in the Congress.

Registration:
(1) Registration Forms
You are encouraged to register for the Congress as early as possible.

For Congress registration, complete and return Form A (which may be obtained from the Secretariat) with the appropriate fees at your earliest convenience, and **not later than August 1, 1989,** in order to ensure receipt by post of the latest information, and the complete set of congress documents upon checking in at the Congress site.

If you wish to submit a scientific presentation(s), please return both Form A and Form B (which may be obtained from the Secretariat) together with payment of the appropriate fees by **not later than February 1st, 1989.**

REGISTRATION FEE	By April 30, 1989	On or After May 1, 1989
ISPO MEMBERS INTERBOR MEMBERS	¥50,000.–	¥60,000.–
NON MEMBERS	¥65,000.–	¥80,000.–
One-Day Participant	¥25,000.–	
Student Participant (bona fide only)	¥25,000.–	
Instructional Course lectures	¥5,000 per unit	
Accompanying Person	¥18,000.–	

(2) Fees
Registration fees for participants from abroad are as indicated below, Japanese participants are asked to follow the instructions given in the Japanese language version of the announcement.

Congress participant's registration fee includes:
—Submission of scientific presentation(s).
—Opening Ceremony, Welcome Party, Japan Night and Official Reception Party.
—Admission to all scientific sessions and Commercial Exhibition.
—Congress documentation.
—Closing Ceremony.

Accompanying person's registration fee includes:
—Opening Ceremony, Welcome Party, Japan Night, and Official Reception Party.
—Participation in Accompanying Persons' Programme (excluding optional programmes with separate fee) and commercial Exhibition.
—Accompanying person's kit.
—Closing Ceremony.

(3) Payment
Payment from abroad must be made by bank draft (with authorized signature) in Japanese Yen made payable to "ISPO VI World Congress Kobe" (please type exactly as indicated).

The name of the participant for whom the payment is being made must be clearly indicated. No other form of payment will be accepted.

On receipt of both the completed registration forms and the appropriate fees, the Secretariat will send each participant a payment receipt and Registrant's Card as confirmation of registration and payment. The Registrant's Card must be presented to the receptionist upon checking in at the Congress in Kobe.

(4) Cancellation and Refunds
The Secretariat must be notified in writing of all canellations.

The Organizing Committee will refund registration fees less 20%, for all notices of cancellation reaching the Secretariat not later than August 31, 1989.

Student Participants
Students who are engaged in the study of prosthetics and orthotics and rehabilitation engineering will receive partial assistance in meeting the costs for attending the Congress. To apply for this Programme, make the appropriate indication on Form B "Application Form for Scientific Presentation" and be sure to indicate you curriculum vitae along with forms A and B.

Official Invitation Letter
An official letter of invitation will be sent upon request. This invitation will not, however, obligate the Organizing Committee to assume any financial burden.

Climate and Clothing

The Congress will be held in the middle of autumn and the temperature in Kobe during the past five years has ranged between a daytime high of 17°C (63°F) and a nighttime low of 10°C (43°F).

Participants may enjoy Japan's most beautiful season with the leaves changing their colours into various shades of red and yellow. Numerous temples and shrines are found along the mountainsides in the crisp, serene air.

Dress for all congress events will be informal.

Electrical Appliances

Japan operates on 100–110 volt for electrical appliances. The frequency is 50 cycles (Hz) in eastern Japan including the Tokyo area and 60 cycles (Hz) in western Japan including the Kobe/Kyoto areas.

Passports and visas

Participants are requested to ensure they are in possession of all essential travel documents.

Official Travel Agency

Japan Travel Bureau (JTB)
Convention Center, Foreign Tourist Dept.
1–13–1, Nihonbashi
Chuo-ku, Tokyo 103 Japan
Tel: (03) 276–7885
Telex: J24418
Cable: TOURIST TOKYO

Transportation

Airport Limousine Bus

The bus takes you to downtown Kobe and costs only 620 yen while a taxi ride over the same distance may cost over 10,000 yen. The limousine bus is available every 15–20 minutes from the airport. There are 4 buses a day that go directly to the Kobe Portopia Hotel

Portliner

This monorail-like train takes you from downtown Kobe to Port Island where the Kobe Convention Center is located. It costs 210 yen and is available every 4–6 minutes.

Shopping

Saturdays and Sundays are major shopping days in Japan. All department stores and other shops and stores are usually open until approximately 7:00pm.

Exchange

Foreign currency may be exchanged at banks at the airport after arrival in Japan and around the congress site. Most hotels will exchange foreign curency for their guests.

Vaccination

As of August 1988, no special vaccinations are necessary unless a visitor is entering Japan within 14 days of being in a smallpox-infected area, in which case he must possess a valid international certificate of vaccination against smallpox. A cholera certificate will also be necessary if coming from or through an infected area. For details, please contact local travel agents or carriers.

Social Programme

Opening Ceremony

Sunday, November 12
2·00 p.m.
Auditorium A, International Conference Center, Kobe.

President's Welcome
Official Speakers' Welcome
Music Presentations: Traditional Japanese instruments (Koto & Shakuhachi) played by Dr. Takahara's band
Knud Jansen Lecture

Welcome Party

Sunday, November 12
Evening
Kobe International Exhibition Hall.

A Welcome Party will be held immediately following the Opening Ceremony of the Congress. All participants, accompanying persons and exhibitors will be invited to attend both the Opening Ceremony and Welcome Party.

Japan Night

Monday, November 13
Evening
Auditorium A, International Conference Center, Kobe.

To enable our congress guests from overseas to appreciate and fully enjoy the traditional modern culture of Japan such as music, theatre, fine arts, handicrafts, etc. the Committee is planning an attractive series of events. Details will be provided in the Congress Programme.

Official Reception Party

Wednesday, November 15
Evening
At Soraku Japanese Garden

Free admission for all overseas participants.

Japanese cultural attractions will include a Bonsai chrysanthemum festival, and the traditional tea ceremony. Set in the serene elegance of this classical Japanese garden.

Congress Dinner

Thursday, November 16
7:00 p m.
Ohwada-no-ma, Kobe Portopia Hotel
Fee: ¥8,000 (Japanese Yen)

A gala event including a selection of Japanese traditional and modern cultural attractions.

- Classical Music (String Quartet)
- Japanese Traditional Dance
- Dr. Nobuhara's Jazz Band

Please purchase tickets by mail. For your convenience, remit the dinner fee together with your registration fee. (Please refer to Form A).

Closing Ceremony

Friday, November 17
Auditorium A, International Conference Center, Kobe.

All Congress participants, accompanying persons and exhibitors will be invited to attend.

Accompanying Persons' Programme

The organizing committee has prepared the following Accompanying Person's Programme so that accompanying persons may fully enjoy their short stay in Japan. This programme will provide an occasion for people of many different countries to get to know each other.

HIMEJI FULL DAY TOUR
Tuesday, November 14th (9:00–17:00)

Free Admission to all registered Accompanying Persons.
Tickets will also be available at Tour Ticket Counter for others who would like to participate in this event.

Greater Kobe area sightseeing by special limousine bus and gorgeous boat. We take you to the lovely and lively places in Kobe and also to the historical city, Himeji.

8:40	Leaving from Congress Center.	
9:20	Seaport Tour (Naka Pier)	You will get on a tour boat. The view of Kobe city will attract you with the Port-Tower, houses and buildings on the hill side in the greenery and their reflections on the blue water. (1 hour tour).
11.30	Municipal Kobe Winery (Wine Castle & Farm-land Park)	You can enjoy the local-made wine and also the Kobe beef and fresh water (most delicious in Japan). You will have barbecue for lunch here under the blue sky and by a French Chateau like the Wine Castle.
14:10	Himeji-Jo (Japanese White Castle)	This most beautiful Japanese castle is called "White Egret" Castle since its stretching out white walls are just like the wings of a white egret in flight. You will enjoy this architectural beauty with its grand view.
17:10	Arriving at Congress Center	

In addition to the above programme, an interesting variety of modestly-priced events as described below are now being planned by the Accommodation Committee. Complete details will be provided in the Congress Programme. Accompanying persons are encouraged to take part in these programmes, thereby furthering the international exchange of friendship and goodwill.

Examples:

CHANOYU (The Japanese Tea Ceremony)
IKEBANA (The art of Flower Arrangement)
A visit to Japanese MUSEUM & CLASSIC JAPANESE GARDENS

A Hospitality Center will be located in the Exhibition Hall during the Congress period. Please stop by, have a complimentary cup of coffee, tea, or wine and let us help you make your visit to Japan a memorable experience.

Travel Information

1. Official Travel Agent

The Japan Travel Bureau, Inc. (JTB) has been appointed official travel agent for the conference and will handle all travel arrangements related to the congress including hotel accommodation and tours. All inquiries and applications in this regard should be addressed to:

Japan Travel Bureau, Inc.
Foreign Tourist Division
Convention Center (Ref. CD 11–7101–89)
1–13–1, Nihonbashi, Chuo-ku, Tokyo 103

Phone: Tokyo (03) 276–7885
Telex: TOURIST J24418 (Answer Back)
Cable: TOURIST
Fax: Tokyo (03) 276–7806

2. Hotel Accommodations

The Organizing Committee and JTB have reserved a sufficient number of rooms at the hotels below for the conference period in Kobe. Application for room reservations should be made directly to JTB with the attached Reservation form (Form C). Participants in a group organized by a travel agent are requested to enter the name of the agent in order to avoid the possibility of a duplicate booking. Reservations should be accompanied by the remittance of a hotel deposit in the amount of ¥20,000 per room. No reservation will be confirmed in the absence of a deposit.

The hotels and room charges are:

Grade	Name of hotel	Twin w/bath	Single w/bath	Address & Phone	Access
A	KOBE PORTOPIA	¥21,000** ¥17,000***	¥12,000**	Minatojima Nakamachi Chuo-ku, Kobe Phone: (078) 302–1111	Congress site
	OKURA KOBE	¥21,000*	¥16,000*	48 Hatoba-cho Chuo-ku, Kobe Tel: (078)333–0111	10 m. by taxi
B	ORIENTAL	¥16,000	¥8,500	25 Kyomachi Chuo-ku, Kobe Tel: (078) 331–8111	10m. walk & 15m. by Portliner
	SAN-NOMIYA TERMINAL	¥15,460*	¥7,910*	8–1–2 Kumoi-dori Chuo-ku, Kobe Tel: (078) 291–0001	15 m. by Portliner
	KOBE WASHINGTON	¥11,000	¥6,500	2–11–5 Shimoyamate Chou-ku, Kobe Tel: (078) 331-6111	8 m. walk & 15 m. by Portliner
C	CHISAN KOBE	¥11,000*	¥6,600*	2–3–1 Nakamachi-dori Chou-ku, Kobe 650 Tel: (078) 341–8111	8m. JR line & 15m. by Portliner

Notes: 1) *includes tax and service charge
2) **includes tax, service charge and breakfast (No refund will be made for breakfast which is not taken).
3) ***for single use of twin bed room.
4) A 10% tax and a 10% service charge will be added to the bill when checking out at Oriental and Kobe Washington.
5) The hotel deposit of ¥20,000 will be deducted when paying the hotel bill.

Optional Tours

The Organizing Committee and JTB offers the following optional tours during the congress period for participants and their accompanying persons who whish to see more of Japan during their short stay.

OP-1 KYOTO FULL-DAY TOUR
Date/Time: November 13 (Monday) 9:00 AM — around 6:00 PM
Tour Fare: ¥13,000/person (Lunch included)

Tour Highlights:
* Golden Pavilion, a gilded symmetrical structure, originally a nobleman's villa.
* Vermilion Heian Shrine, a magnificent structure strongly influenced by Chinese architecture.
* Kiyomizu Temple, noted for its 164-foot-high wooden veranda.

OP-2 SUMA TEMPLE AND TEA CEREMONY
Date/Time: November 13 (Monday) 9:00 AM — around 4:30 PM
Tour Fare: ¥13,000/person (Lunch included)

Tour Highlights:
* Suma Temple or Fukushoji, headquarters of the Shingon sect (Sumadera School) of Buddhism.
* Municipal Kobe Winery for barbecue lunch.
* Tea Ceremony at Hyogo Prefecture Ceramic Museum.

OP-3 MT. MAYA AND SAKE BREWERY
Date/Time: November 15 (Wednesday) 12:00 AM – around 4:00 PM
Tour Fare: ¥6,500/person

Tour Highlights:
* Mt. Maya, the second-highest peak of the Rokko mountains and the site of the popular Buddhist temple called Toritenjoji.
* Hakutsuru Sake Brewery Museum which illustrates the process of brewing sake by using life-size models, old tools and utensils.

OP-4 NARA FULL-DAY TOUR
Date/Time: November 16 (Thursday) 8:00 AM – around 6:00 PM
Tour Fare: ¥13,000/person (Lunch included)

Tour Highlights:
* Horyuji Temple, one of the most magnificent repositories of the architectural, sculptural and pictorial art objects of Japan.
* The 50-foot-high Giant Buddha housed at Todaiji Temple in the world's largest wooden building.
* Colorful Kasuga Shrine with thousands of lanterns.

OP-5 MT. MINO AND EXPO MEMORIAL PARK
Date/Time: November 16 (Thursday) 8:00 AM – around 5:00 PM
Tour Fare: ¥11,000/person (Lunch included)

Tour Highlights:
* Mino-o Quasi-National Park with an area of some 10 sq. km, well known for the autumnal tints of its huge maple trees.
* Expo Memorial Park, former site of the World Expositon in 1970, where visits will be made to the National Museum of Ethnology, and a fine Japanese Garden.

Post-Congress Tour

Post-Congress Tours are planned for particpants and accompanying persons to enable them to experience more of Japan.

PT-1 ISE, TOBA AND TOKYO 3 DAYS
Tour fare: ¥65,000/person (double occupancy)
¥75,000/person (single occupancy)

Itinerary:
Nov. 18 (Sat.) KOBE–KYOTO–TOBA–ISE–NAGOYA–TOKYO

Morning transfer to San-nomiya Station to board JR local train to Kyoto. Change to comfortable limited express train to Toba, the gateway to Ise-Shima National Park. Sightseeing in Toba and Ise, visiting Mikimoto Pearl Island, Ise Jingu Shrine. Lunch at a local restaurant. Kintestu limited express and "Bullet" train to Tokyo. Accommodations in Tokyo for 2 nights.

Nov. 19 (Sun.) TOKYO
Morning free.
Afternoon sightseeing of the city, visiting Imperial Palace East Garden, Asakusa Temple with its bustling arcade of souvenir shops, Sumida River which includes cruise on the river.

Nov. 20 (Mon) TOKYO
Tour disbands in the morning.

PT-2 INLAND SEA 3 DAYS
Tour Fare: ¥78,000/person (double occupancy)
¥ 86,000/person (single occupancy)

Itinerary:
Nov. 18 (Sat.) KOBE – HIROSHIMA

Morning transfer to Shin-Kobe Station to board "Bullet" to Hiroshima.

Sightseeing of the city and Miyajima, visiting Peace Memorial Park with its museum of A-bomb devastation relics, and colorful Itsukushima Shrine with its red torii gate. Accommodations in Hiroshima.

Nov. 19 (Sun.) HIROSHIMA – INLAND SEA – OSAKA

Morning transfer to the pier and board a hydrofoil which speeds through the picturesque islet-dotted Inland Sea.

En route, land on Omishima Island for a visit to Oyamazumi Shrine and its museum of ancient armour, and Ikuchijima Island, famous for Kosanji Temple.
Lunch at a local restaurant
JR "Bullet" train to Osaka.
Accommodations in Osaka.

Nov. 20 (Mon) OSAKA
Tour disbands in the morning

Tour Conditions

Tour fare includes: 1) HOTEL ROOMS: Standard rooms on half-twin or single basis; 2) MEALS as specified in each itinerary; 3) RAILWAYS: tourist-class reserved tickets on "Bullet" and express trains; best available seats on other railways; 4) SIGHTSEEING AND TRANSFERS as shown in the itineraries, by motorcoaches and/or sightseeing boats on a seat-sharing basis, including admission fees to temples, shrines, etc.; 5) BAGGAGE: transfer and handling (one or two normal size pieces per person); 6) ESCORT SERVICE by an English-speaking guide.

Notes: Places to visit are subject to change with or wihtout notice. The tour may be cancelled should the number of participants fail to exceed 25.

3. Reservation and Payment

For reservations for hotel accommodations and tour described herein, please complete Reservation Form C and return it to JTB no later that August 31, 1989. Request should be accompanied by a remittance covering the hotel deposit and total tour fare: no reservation will be confirmed in the absence of this payment. No personal checks will be accepted. **All payments must be made in Japanese Yen.**

Payments should be in the form of:
—A bank draft payable to the order of the Japan Travel Bureau, Inc., or
—A bank transfer to be sent to the Japan Travel Bureau, Inc., account at

The Bank of Tokyo, Marunouchi Office,
1–4–2 Marunouchi, Chiyoda-ku,
Tokyo, 100 Japan
(Account Number: 211494/Ref. CD 9–7301–88).

Note: We would appreciate you kindly sending us a copy of the bank receipt for the remittance to avoid money transfer difficulties.

A reservation form received without a remittance does not constitute reservation. If it is impossible to send the hotel deposit and/or total tour fare with your reservation form due to currency or other restrictions, a letter to this effect must be appended to the form.

Cancellation

In the event of hotel and/or excursion reservations having to be cancelled, written notification shoud be sent to JTB. The following cancellation fees will be deducted before refunding:

Hotels:

Up to 9 days before the first night of stay ¥1,000
2–8 days before .... 20% of daily room charge
Less than 2 days before, or no notice given .... 100% of daily room charge

Excursion:

Up to 21 days before the departure day ¥1,000
20 — 8 days before .... 10% of tour fare (minimum: ¥1,000)
7 — 1 days before .... 20% of tour fare (minimum; ¥1,000)
Prior to the starting time of the tour or failure to show without notice........ 40% of tour fare (minimum: ¥1,000)

Prosthetics and Orthotics International Index to Volume 12, 1988

Author Index

Subject Index

SPONSORING MEMBERS

We are pleased to announce that the following organizations were Sponsoring Members of ISPO for the year 1988.

Everest & Jennings
Princewood Road
Corby
Northants NN17 2OX
U. K.

J. E. Hanger & Co. Ltd.
Roehampton Lane
Roehampton
London SW15 5PL
U.K.

Remploy Ltd.
Medical Products Division
Russ Street
Broad Plain
Bristol BS2 OHJ
U.K.

Camp Scandinavia A/S
Vallensbækvej 22 B
2605 Brøndby
Denmark

Society and Home for Disabled
Borgervænget 7,
2100 Copenhagen Ø
Denmark

Hugh Steeper Ltd.
234–239 Roehampton Lane
London SW 15 4LB
U.K.

The War Amputations of Canada
2827 Riverside Drive
Ottawa
Ontario K1V OC4
Canada

The Society is happy to announce the formation of a National Member Society in the following countries:

AUSTRIA

Chairman

Dr. Wolfgang Ott,
Leitender Arzt der Abteilung fur,
Amputierte des Rehabilitations-
zentrums Haring,
Allgemeine Unfallversicherungsanstalt,
A–6323 Bad Haring,
Klappe 217 Durchwahl,
AUSTRIA

Secretary

Mr. F. Preschan

NEW ZEALAND

Chairman

Mr. W. Beasley,
Andry House,
9 Park Street,
Thorndon,
Wellington 1,
NEW ZEALAND

Secretary/Treasurer

Mr. G. P. Comeskey