Prosthetics and Orthotics International, 1989, 13, 125–129

This innovation was selected for the award of the Brian Blatchford Prize for the Triennium 1986-1989. This paper is based upon the acceptance speech of Thorkild Engen at the Annual Ceremony in Kobe, Japan on 17th November, 1989.

Lightweight modular orthosis

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Abstract

Background and highlights are presented concerning the development of a new orthotic system judged to be "the most outstanding innovation in prosthetics and/or orthotics practice" during the 1986-1989 period. The first Brian Blatchford Prize was awarded at the Sixth World Congress of ISPO held in Kobe, Japan, November 12-17, 1989. The new development selected as most deserving of this award consists of a system utilizing inexpensive, lightweight, modular components which can be quickly assembled with a few hand tools to provide custom-fitted knee-ankle-foot orthoses for persons with paraplegia and quadriplegia. These leg frames support standing and permit the patient to begin receiving the physical and psychological benefits of weightbearing as soon as medically feasible after injury. Later, if desired, specially designed knee-joints, with a variety of possible locking features, can be installed on the existing leg frames at a reasonable cost.

Introduction

It is with a deep sense of gratitude and honour that I accept this prestigious award in the memory of our colleague, Brian Blatchford.

When first informed of this award I was both elated and honoured that my project has been chosen for the Brian Blatchford Prize. To me, this award is the Nobel Prize of orthotics and prosthetics.

I am indeed grateful to my native country, Denmark, for the thorough education and training I received in orthotics, grateful for the professional opportunities extended to me in the United States, and deeply honoured to receive this tremendous recognition in this beautiful country of Japan.

The Blatchford family is to be commended for recognizing the need to stimulate interest in designing new and better means for meeting the orthotic and prosthetic needs of people throughout the world. Creation of this award to honour the most outstanding innovation in our field should stimulate renewed interest in undertaking research and development projects. Funding for projects and developments in orthotics and prosthetics has diminished to very low levels, internationally, during the past 15 years. However, our own experience has demonstrated that persistence in seeking financial support for research from governmental agencies, foundations and civic groups can be successful.

I should now like to take this opportunity to share with you some of the background and highlights of this new development. A number of follow-up studies published during the past 20 years have documented that a substantial number of paraplegic patients (approximately 80%) discard their conventional knee-ankle-foot orthoses (KAFOs) within months after receiving them (Kaplan et al. 1966; Hahn, 1970; Coghlan et al. 1980; McAdam et al. 1980; Mikelberg et al. 1981; O'Daniel et al. 1981; Priestley et al. 1982; Heinemann et al. 1987). The problems most often cited by the patients are: excessive weight, cumbersome, time consuming to donn and doff and not aesthetically acceptable. Thus, their expensive orthoses gather dust in a closet.

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Lightweight modular orthosis

The new development is an inexpensive, lightweight, modular orthosis for early standing of patients with paraplegia and quadriplegia of traumatic onset. The invention permits quick fabrication and fitting of leg frames which support standing and permit the patient to begin receiving the physical and pshychological benefits of weightbearing as soon as medically feasible after injury.

Being constructed from mass-produced plastic extrusions and other modular, plastic components (Engen, 1972), and assembled with the use of a few tools, straps and fasteners, it is possible to reduce the weight (1 to 2 pounds, 0.5 to 0.9 kilograms) delivery time and cost of these devices (Fig. 1). By making customized leg supports available as early as feasible, the patient has a choice of being weightbearing rather than confined to a wheelchair.

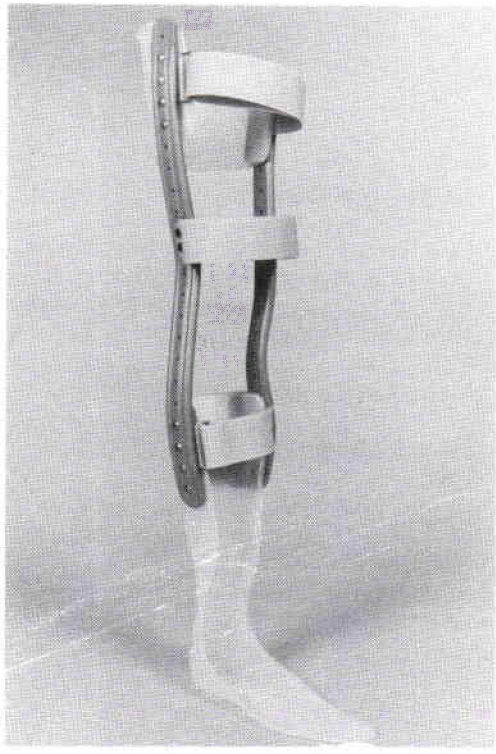

Fig. 1. New lightweight, inexpensive, modular leg frame developed by the author. Note the attachment of upright struts to the other plastic components and simple method of anterior strap attachments. Fine tuning of the foot/ankle segment of the orthosis for accurate balancing of patient is accomplished with a heat gun and heel and toe wedges. Patent process initiated.

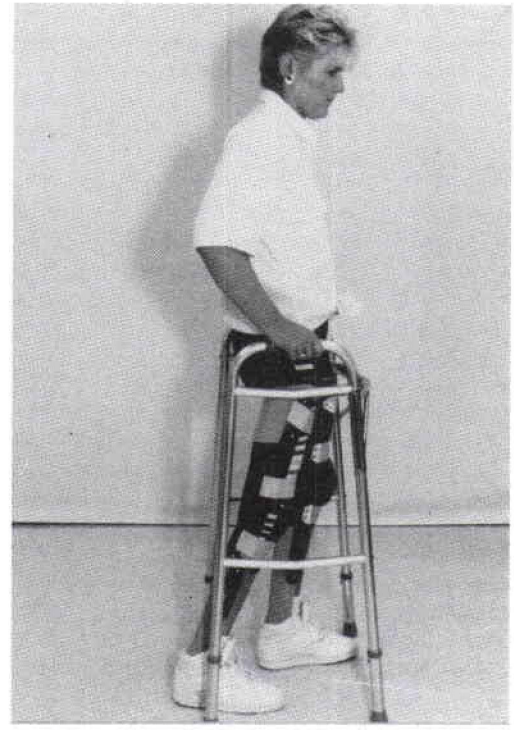

Fig. 2. Custom-fitted modular leg frames being used for early gait training by a patient with complete paralysis of muscles innervated below the T-10 spinal segment. She received a spinal injury seven months previously. Note that the plastic side members of each orthosis are *not* jointed at the knee. Patent process initiated.

In addition, the patient becomes a better informed participant in the decision about the feasibility of setting ambulation as a future goal (Fig. 2).

Such factors as effort in independent donning and doffing and expenditure of energy during ambulation with braces and crutches will have more meaning to the patient. If it is decided that even minimal ambulation is not a practical goal, the patient can still keep the inexpensive, supportive leg frames after discharge for erect weighbearing when he chooses. On the other hand, if it is determined by all concerned that the patient would benefit from an expanded ambulation programme, specially designed knee-joints, with a variety of possible locking features, can be installed on the existing leg frames at a reasonable cost (Fig. 3, top).

These transitional leg orthoses, designed to support standing in the early stages of the rehabilitation programme, have proven to be durable enough for the purpose intended. In

the course of 20 months of usage, approximately 40 patients have undergone clinical evaluations in the orthotic research programme. No structural failures, nor any adverse effects on any of the participants have occurred.

An important feature of this modular system is the design of the extruded side members of the orthosis. In order to obtain necessary strength, with minimum weight, four hollow tubes are incorporated into the profile design (Fig. 3, bottom). These tubes also serve to hold cables, wires, or fluids. Thus, hydraulic fluids, or cables, may be used to control the locking and unlocking actions of the knee joint in relation to the gait cycle. Controlling signals can emanate from impact of the heel and sole of the foot.

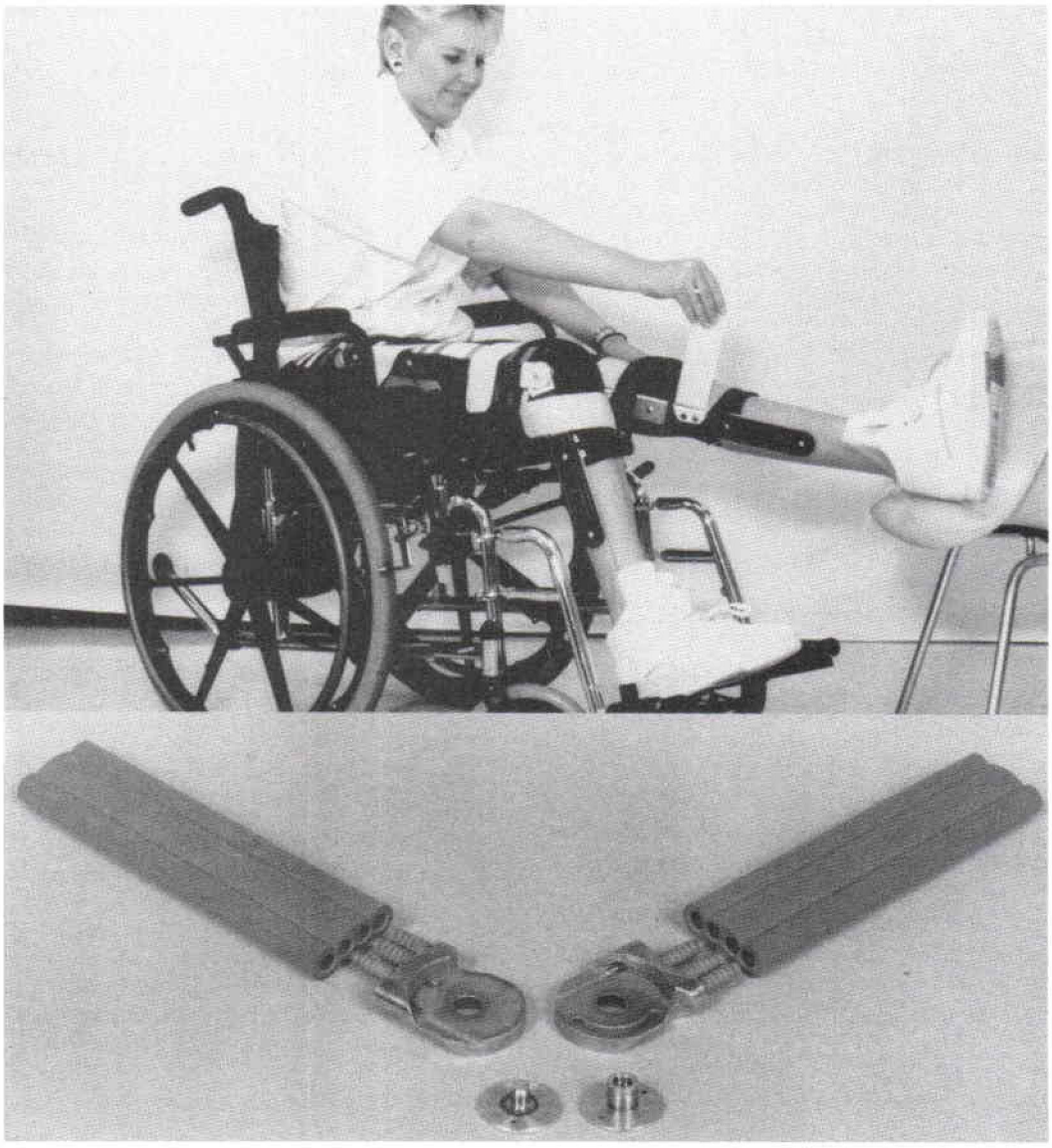

Fig. 3. Top, custom-fitted knee-ankle-foot orthosis following insertion of a modular joint into each side member to permit bending of the patient's knees. The locking mechanism for these joints is internal, thus eliminating external protrusions thereby minimizing wear on clothing. Patent process initiated. Bottom, close up, exploded view of the modular knee joint ready for insertion into the cut ends of the plastic extrusions from which the lightweight side members of the orthosis are constructed. Patent process initiated.

As reported by various groups of scientists internationally, and in the public media, functional electrical stimulation holds great promise for enhancing ambulation possibilities for the person with paraplegia (Kralj et al. 1988; Phillips, 1989). Electrical wiring connecting stimulators to muscle electrodes for functional electrical stimulation can be protected inside the tubes of the new orthotic system, thereby reducing the clutter of wires. We also anticipate that features of this new development may enhance the already developed LSU Reciprocating Gait Orthosis (Phillips, 1989). For example, the biomechanical action in walking can be more accurately duplicated using the extruded portion of our new orthosis. In all, we encourage others to capitalize on these new opportunities to further enhance the clinical usefulness of this new concept of orthotic patient management.

A number of our patients in the early part of the evaluation programme participated in a special outing to the beach (Fig. 4). For them it was a greatly appreciated experience. Such an expanded form of social involvement is possible for many others because sand and saltwater do not have any adverse effect on the devices.

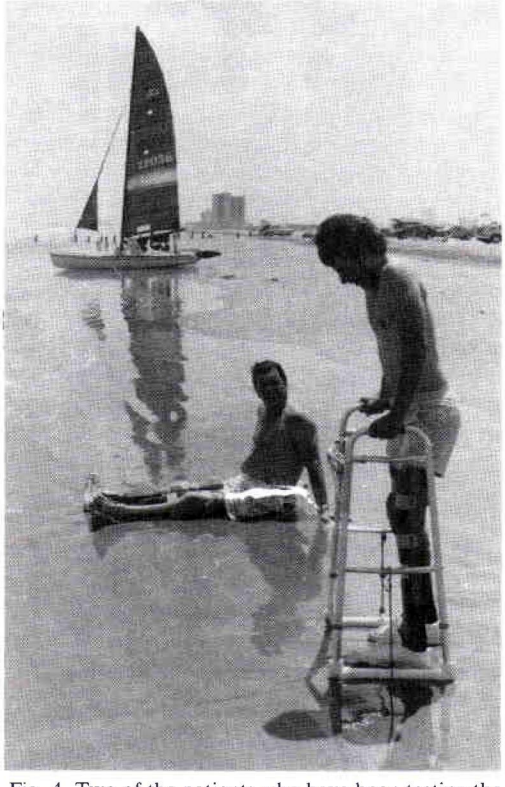

Fig. 4. Two of the patients who have been testing the utility and durability of the new, lightweight orthoses are shown wearing them at the beach. These orthoses are not damaged by salt water or sand.

The future

In our long-term forecast, we envisage the system to be especially attractive to regions of the world with limited orthotic services. When commercially available, the modular components and instructions for their use on patients can be supplied at modest expense to any setting. The components can be selected from a limited number of sizes and custom-fitted to the individual patient in the clinic using basic tools. Thus, better services can be anticipated to become available to persons with paraplegia in underdeveloped, as well as in developed, countries.

It is a well-known fact that any successful research and development programme is staffed by highly qualified individuals possessing unique capabilities and skills. I have been blessed with the assistance of a small team of competent co-workers who deserve much credit for their individual contributions to the success of this project. Don Lehmkuhl, PhD, a Neurophysiologist, Kinesiologist and Co-Investigator has been largely responsible for securing funding for this project and for the clinical research design. Members of the orthotic staff: Tony Medina (Orthotist), John Wallace (Orthotist), Alan Pennock (Machinist), Tom O'Neil (Plastic Technician) and Margaret Morales (Data Collector) provided a high standard of technical expertise and quality control. Physical therapists participating in the clinical evaluation of the experimental orthoses include Sara Herber, Mandy Smith and Carol Link. They drew upon their own clinical experiences to suggest improvements in procedures for fitting and training patients.

It has been my privilege to share with you the present status of our orthotic project at TIRR in Houston, Texas, USA. Once again, thank you to the Blatchford family. On behalf of my colleagues, patients, and myself, I am honoured to accept the First Brian Blatchford Prize and look forward to the future developments that will be encouraged in our field of orthotics and prosthetics by the creation of this award.

Acknowledgements

The development and dissemination of results of this project were partially supported by grants from the Kappa Kappa Gamma Alumnae Association of Houston, Texas, the Meadows Foundation of Dallas, Texas and the National Institute on Disability and Rehabilitation Research of Washington, D.C., USA.

REFERENCES

COGHLAN, J. K., ROBINSON, C. E., NEWMARCH, B., JACKSON, G. (1980). Lower extremity bracing in paraplegia — A follow-up study. *Paraplegia* **18,** 25-32.

ENGEN, T. J. (1972). The TIRR polypropylene orthosis. *Orthot.* and *Prosthet.* **26(4),** 1-15.

HAHN, H. R. (1970). Lower extremity bracing in paraplegics with usage follow-up. *Paraplegia* **8,** 147-153.

HEINEMANN, A. W., MAGIERA-PLANEY, R., SCHIRO-GEIST, C., GIMINES, G. (1987). Mobility for persons with spinal cord injury: an evaluation of two systems. *Arch. Phys. Med. Rehabil.* **68,** 90-93.

KAPLAN, I. I., GRYNBAUM, B. B., RUSK, H. A., ANASTASIA, T., GASSLER, S. (1966). A reappraisal of braces and other mechanical aids in patients with spinal cord dysfunction: results of a follow-up study. *Arch. Phys. Med. Rehabil.* **47,** 393-405.

KRALJ, A., BAJD, T., TURK, R. (1988). Enhancement of gait restoration in spinal injured patients by functional electrical stimulation. *Clin. Orthop.* **233,** 34-42.

MCADAM, R., NATVIG, H. (1980). Stair climbing and ability to work for paraplegics with complete lesions — A sixteen-year follow-up. *Paraplegia* **8,** 197-203.

MIKELBERG, R., REID, S. (1981). Spinal cord lesions and lower extremity bracing: an overview and follow-up study. *Paraplegia* **19,** 379-385.

O'DANIEL, W. E., HAHN, H. R. (1981). Follow-up usage of the Scott-Craig orthosis in paraplegia. *Paraplegia* **19,** 373-378.

PHILLIPS, C. A. (1989). Electrical muscle stimulation in combination with a reciprocating gait orthosis for ambulation by paraplegics. *J. Biomed. Eng.* **11,** 338-344.

PRIESTLY C., LEHMKUHL, D. (1982). Cost-benefit analysis of bracing patients with paraplegia. *Phys. Ther.* **62,** 660.

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