

The Edinburgh-ORLAU prosthetic system to provide reciprocal locomotion in children and adults with complete transverse lower limb deficiency

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Abstract

A novel prosthetic system to provide reciprocal locomotion in children and adults with complete transverse lower limb deficiency is described. This is based on the hip joints from the ORLAU ParaWalker, a system with a proven record of success in the orthotic management of paraplegic patients. The fitting of the prototype system to an eight year old girl is described. This experience shows that the orthotic principles of the ParaWalker, which provides reciprocal locomotion for the paraplegic, is equally applicable to the prosthetic situation. Developments are therefore continuing to improve the design and to enable further fittings.

Introduction

Walking for bilateral lower limb deficient patients has long been considered an impracticality. One approach involved the use of twin linked pylons attached to a prosthetic socket, with the patient performing swing through gait using a rollator, though crutches may also theoretically be used. The problems of this style of walking are: very high energy consumption, fatiguing of the upper limbs, and an obviously abnormal walking pattern. A different approach is to use a swivel walking mechanism attached to the underside of the prosthetic socket (Hall, 1962; Speilrein, 1963; Klein, 1964; Lamb *et al.*, 1970). Whilst this reduces energy consumption it is relatively slow and also produces an exceptionally abnormal style of walking.

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Additionally it is limited to flat surfaces and is therefore essentially an indoor device.

Unilateral hip disarticulation amputees often achieve an acceptable form of ambulation through the use of a Canadian Hip Disarticulation Prosthesis (McClaurin, 1957). This prosthesis requires good contralateral limb function to unlock the inherently stable hip and knee joints, and to propel the artificial limb through the swing phase. Consequently it is not appropriate to fit this limb bilaterally in an attempt to achieve reciprocal locomotion. Bilateral fittings have been reported (Frantz and Aitken, 1967), the patients ultimately achieving a swing through gait.

Whilst swing through and swivel walking devices have enabled patients to achieve ambulation it has almost always proved unsatisfactory to patients and their parents because of the high energy consumption coupled with poor performance. Many parents who have children with this disability desire strongly that they should be given an opportunity to walk. There are many perceived reasons for this, not all of them having a rational basis. In some cases the children, possibly under parental influence, also express a wish to ambulate. Clearly there are developmental reasons why a child should be given an opportunity to walk, provided this is practical. Some adults with bilateral lower limb deficiency also express a desire to walk. They will be in a position to assess for themselves the compromise that can be offered and their decision will be influenced by the ease with which ambulation can be achieved. A further factor influencing motivation will be the aetiology of the limb deficiency, whether congenital or acquired.

The wishes of some lower limb deficient patients to walk, and the perceived impracticability of current routinely available devices, provided an incentive to develop an effective ambulation system for this group.

Bilateral lower limb deficient patients are clearly analogous to paraplegic patients with complete thoracic lesions except that the latter have flail limbs which must be accommodated. Recent advances in orthotic technology have enabled this group of paraplegics to walk reciprocally with crutches. Two designs are now routinely supplied to children and adults, the Reciprocating Gait Orthosis (RGO) (Beckman, 1987; Douglas *et al.*, 1983) and the ORLAU ParaWalker (More, 1988; Rose, 1979). These two devices use differing mechanics to achieve ambulation in a reciprocal mode, but either has a potential for application to a prosthetic system, in which there is the technical advantage that the lower limbs do not require to be accommodated.

Scrutiny of the literature revealed that Ekus *et al.* (1984) had reported the fitting of a reciprocation prosthesis for a patient with sacral agenesis. This was an ingenious device based on the RGO and utilising one standard prosthetic hip joint to reinforce the orthotic joints. The fabrication process reported, however, was not without some difficulty for the prosthetic staff, requiring careful alignment of hip joint axes. The functional outcome was considered to be good.

The ORLAU ParaWalker compromises in favour of relatively low energy walking performance, rather than orthotic cosmesis (Stallard *et al.*, 1986). Since the problems of cosmesis are more easily addressed in prosthetics, and the ParaWalker design is based on a series of engineered modules, it was considered that it might resolve some of the complexities of transforming the RGO into a prosthetic advice.

ParaWalker Design Philosophy

The principles of the ParaWalker are based on the fundamental requirements of reciprocal walking. These are:

1. one leg must be cleared from the ground,
2. the cleared leg must swing from extension into flexion (i.e. swing phase),
3. the trunk must progress forwards, up and over the stance leg.

In order for the swing leg to clear the ground the ParaWalker (Fig. 1) incorporates a rigid structure



Fig. 1. The ORLAU ParaWalker.

to maintain relative abduction. Thus the patient can use a crutch to tilt himself sideways by a minimal amount in order to achieve clearance. The greater the degree of lateral stiffness the more efficiently will this be achieved. Excessive flexibility will demand that the patients lift their weight through both crutches to achieve the necessary clearance in one leg, with commensurate increase in energy expenditure. Swing phase can be achieved through gravitationally driven pendulum action of the lower limb, provided that a very low friction orthotic hip joint is used. Limitation on the available range of flexion/extension is necessary for control purposes. The trunk is progressed forwards over the stance leg by use of forces transmitted through the crutch on the swing side (which is also responsible for swing leg clearance), rearward forces being applied via the latissimus dorsi (Butler *et al.*, 1984). These mechanical

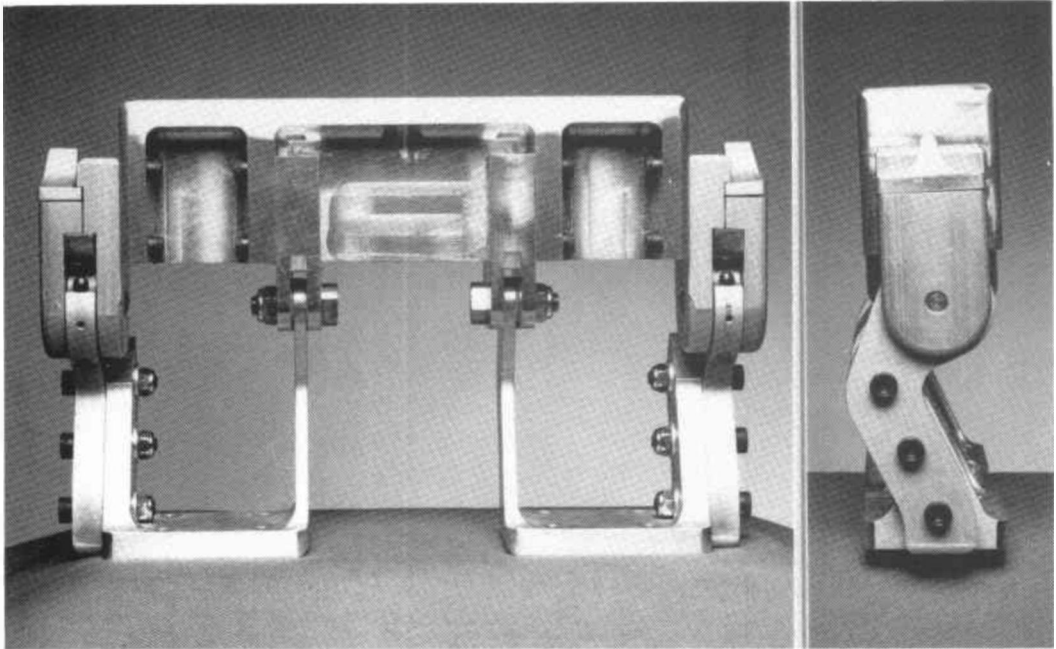


Fig. 2. Hip Joint assembly, front and side view.

features demand a controlled input from a patient who has the necessary upper limb function. For this reason the ParaWalker forms part of a complete treatment system, the other essential elements being patient assessment and training. The orthosis is made up from a series of engineered components which are only supplied to clinical teams who have received the relevant training. This philosophy has permitted good clinical results to be achieved in both paediatric patients (ORLAU, 1983) and adults (Summers *et al.*, 1988; Moore and Stallard, 1990).

Prosthetic design

The essential similarity in biomechanical terms between paraplegic and bilaterally lower limb deficient patients suggests that a prosthetic system with similar mechanical characteristics to the ParaWalker, incorporating modular lower limb components in place of orthotic stabilisation of the legs, should perform in an equivalent fashion. Such a system was produced for an eight year old girl with congenital bilateral absence of the lower limbs (she had a rudimentary left foot which was of no functional value for walking

purposes). The system consisted of a rigid cross-member to which were attached modified ParaWalker hip joints, fastened to a bracket linking them to inner bearings, to achieve maximum lateral rigidity (Fig. 2). Stanard Otto Bock titanium components were used to complete the legs. A laminated socket was attached after determining the appropriate alignment using a modified Berkely adjustable leg (Fig. 3). Cosmetic coverings and a lever system to unlock the hip joints for seating completed the prosthesis. A plastazote pad on the posterior of the socket was necessary to compensate for the relatively low hip joint axis to permit balance when seated (Fig. 4).

A physiotherapist, who had completed the ORLAU ParaWalker course, provided walking training for the patient who initially learned to walk reciprocally using a rollator. Walking progressed with relative ease to the use of crutches, with the patient eventually being able to walk outdoors with confidence (Fig. 5). A flexible type socket was used ultimately, incorporating a front opening panel to allow the child to don and doff the prosthesis independently. Standard knee joint unlocking mechanisms were incorporated for sitting purposes.

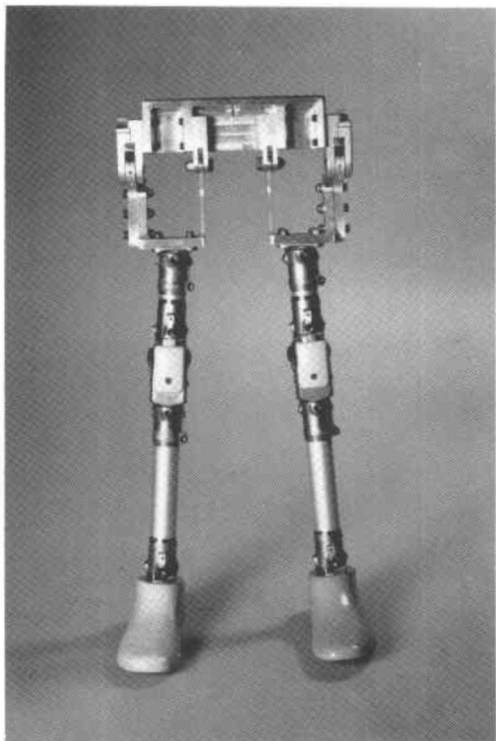


Fig. 3. Hip Joint assembly with legs attached.

Discussion

The successful provision of the Edinburgh-ORLAU prosthetic system for a patient with congenital absence of the lower limbs has demonstrated that the orthotic principles of the ParaWalker, which provides ambulation for the paraplegic, is equally applicable to the prosthetic situation.

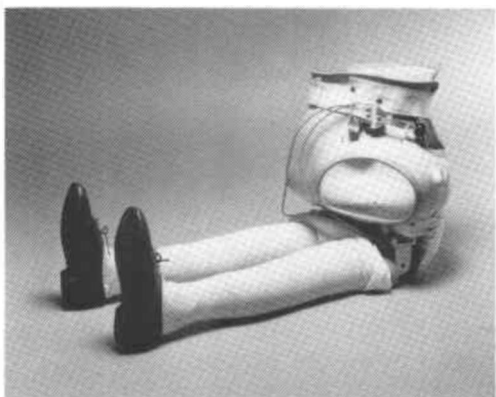


Fig. 4. Completed prosthesis.



Fig. 5. Child using prosthesis.

Whilst it is recognised that patients of this kind may discontinue the use of such a device after an initial period in which it has novelty value, experience in treating paraplegic patients with the ParaWalker showed that long term use of a well designed device was higher than might be expected. Summers *et al.* (1988) showed that 85% of adult ParaWalker patients continued to use their orthosis regularly with an average 20 month follow-up and Moore and Stallard (1990) showed that 64% of routinely supplied adult ParaWalker patients regularly used their device with an average 34.4 month follow-up period. The successful treatment of paediatric patients in Oswestry with the ParaWalker (ORLAU, 1983), in which 34% of patients achieved Community status ambulation on Hoffer's Classification (Hoffer *et al.*, 1973), suggests that perseverance with children may pay clinical dividends beyond the expectations of previous experience with lower limb deficient patients. Contraindications for the system will include those for reciprocal

walking devices for paraplegic patients. Poor upper limb function, excessive obesity, severe truncal deformity, poor intelligence will be the principal factors mitigating against prescription. It is always difficult to predict which patients will persist with walking devices of this kind. Since they never replace the use of a wheelchair, the degree to which the two may be integrated will have an influence on long term use.

Prosthetic patients can have significant advantages over those with paraplegia. The absence of the lower limbs provides space in which to engineer higher degrees of lateral stiffness, and the lack of the limbs and their dead weight can facilitate doffing and donning and transfer between sitting and standing. In addition, greater cosmesis can be achieved in modular prosthetic systems than in Hip Knee Ankle Foot Orthoses. A further benefit accruing from the absence of the lower limbs is the opportunity this affords for alignment changes to optimise function. Current developments are being undertaken to address the problems encountered with the prototype device. This will enable a more integrated hip joint assembly to be developed which incorporates the essential features of the ParaWalker joints, but takes advantage of the opportunity afforded by the absence of the lower limbs. This will enable a closer approximation of the hip joint axis to the bottom of the socket to be achieved so that relative leg length is increased, and walking performance and sitting balance improved. A standing mode will be incorporated, locking the hip joints in an appropriate attitude.

The ultimate objective of this development programme is to produce a hip joint assembly that can be incorporated into otherwise standard prosthetic practice. This assembly will contain all the specialist components appropriately aligned, thus reducing the complexities and time for fabrication, and ensuring a high quality of function. The results achieved so far suggest that this should be possible. However, it is envisaged that a similar patient training regime to that for the ORLAU ParaWalker will always be required for success to be routinely achieved.

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