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# The prosthetic treatment of lower limb deficiency

R. R. HIRONS, K. B. WILLIAMS, R. F. AMOR, and H. J. B. DAY

D.S.C. Withington Hospital, Manchester, UK.

**Abstract**

The prosthesis required for a child with a transverse deficiency whilst a simple version of that appropriate for the adult follows the same principles. The child with a longitudinal deficiency may require an extension, or ortho-prosthesis and this may be combined with surgical reconstruction. The principles, technique of measurement and fabrication methods using both traditional and modern composites are described.

## Introduction

All cases of transverse deficiency save those whose level of loss is very distal require a prosthesis, whereas the prosthetic care of the child with a longitudinal deficiency may be combined with amputation or surgical reconstruction. Even after reconstruction of some of the major longitudinal deficiencies a prosthesis or orthosis may be necessary to achieve accurate length equalisation, improve the stability of joints and sometimes introduce some relief of weight bearing. However the device may be more efficient or better looking as a result of the surgery.

Whilst a lower limb prosthesis is not needed until the child is ready to stand and walk at perhaps 9–12 months, there is every need to plan the treatment and for the prosthetist to be involved at a very early stage, particularly when decisions about surgical reconstruction are being taken. It is only too common for the parent to have expectations which differ from those of the clinic team. The remark that leg lengthening will be done is heard and understood, but subsequent caveats that an orthosis may be required to brace an unstable joint are discarded by the parent who does not wish to hear this piece of information. The surgeon may recommend a procedure which allows the fitment of a prosthesis providing certain functional advantages, without realising that the relatives expect the prosthesis to look like a normal human leg.

Families need to be fully informed, understand and agree the treatment plan, and be made to feel integral members of the team. All must understand that the programme needs to be flexible, particularly as future joint development and even length discrepancy may be matters of conjecture in the early days. They must appreciate that their child's interest is not to acquire a good gait but to be able to "run" so that he can complete with his peers, as he must do if he is to achieve the overall objective of seeing himself as having the minimum possible handicap. Parents who do not agree to a proposal to amputate or reconstruct their child's leg must be allowed their view and should not be made to feel guilty.

## Transverse deficiencies

The prosthetic treatment of those with transverse deficiencies and those whose longitudinal deficiencies have been converted by amputation can be discussed together. These latter will include ankle disarticulation for deficiency of the fibula and knee disarticulation for total tibial deficiency.

The prosthetic principles are the same as those used for older patients, though there would be no point in trying to incorporate, for example, a knee mechanism with sophisticated swing and stance phase controls in the prosthesis of a young child with a transverse thigh deficiency, indeed any knee articulation is unnecessary in the first few years.

Whilst it may seem desirable to use an ischial-gluteal rigid plastic socket for the above-knee case, the difficulty of taking a cast of the small child and the fact that he will grow out of the

All correspondence to be addressed to R. R. Hirons, C. A. Blatchford and Sons, D.S.C. Withington Hospital, Cavendish Road, Manchester M20 8LB, UK.

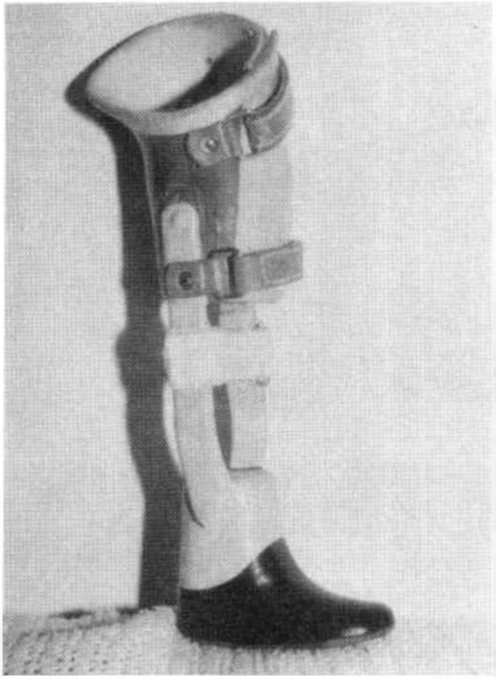

Fig. 1. Simple "first" prosthesis with leather socket.

socket very quickly often renders such a course impractical, and a leather socket which is capable both of adjustment and of being worn with diapers may be more satisfactory. Mounting this on aluminium side-bars above a foot provides a simple lightweight prosthesis (Fig. 1) which is easily lengthened. Sculpted foam between the side bars with an overall cover provides a satisfactory appearance.

A similar "long" prosthesis may be indicated as a first prosthesis for the child who has a deficiency below the knee. He can start active knee use when he is walking safely, though it may be considered wise to continue with some protection for the lower femoral epiphysis, by means of a thigh corset and side-bars and joints, and delay fitting a PTB prosthesis particularly in the child who has a short below-knee segment or is very active. In this case the lack of adjustability of the rigid socket and the child's growth in the early years may also pose logistic or financial difficulties. Conventional methods of construction, including the use of small size endoskeletal modular systems for all levels of loss, become appropriate when the child is older.

**Longitudinal deficiencies**

Those longitudinal deficiencies which have not been converted by amputation present with shortening as well as deformity, and it is the length inequality which must first be corrected if the child is to walk. Small length discrepencies, in the leg which is stable, can be corrected with a shoe raise, but if the discrepancy is greater or if there are joint defects, an extension prosthesis or ortho-prosthesis may be required.

Such a device will contain the child's leg and foot at a suitable height above a prosthetic foot (Fig. 2). The prescription requirements are set by the deformity, the ability to bear weight through the skeleton, and the power, range and stability of the joints. The amount of shortening and the alignment required will have a considerable influence on the angle of equinus which can be used and thus on the cosmetic appearance of the prosthesis. For example, in those cases with only moderate shortening the degree of equinus will be limited by the length of the child's foot, and the resulting appearance is poorer than that obtainable in a child with greater length inequality those own foot in equinus may be concealed in the prosthetic shin. In most cases the size and shape of the child's foot requires that the socket is opened to allow access, often by the use of a suitably reinforced leather bootee.

Day and Wright (1977) described the relationship between the clinical factors and

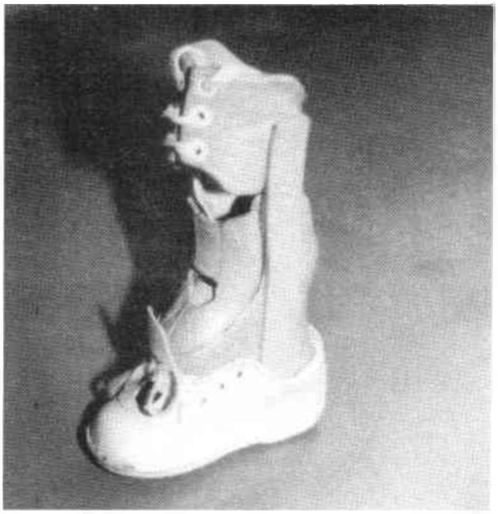

Fig. 2. Extension prosthesis with leather bootee and metal side-bars.

prosthetic prescription and demonstrated how this could be achieved using glass reinforced plastic prostheses to replace traditional leather and side-steel construction. Access to the rigid socket was achieved in one of two ways, either by a removeable access panel as in the Canadian Syme prosthesis (Foort, 1956), or by splitting the socket into anterior and posterior halves hinged together at the toe (Fig. 3). The socket is mounted at the appropriate height above a SACH foot or ankle mechanism, using a wood or rigid foam block after transferring out a child's size Berkeley alignment device.

In recent years the use of carbon fibre instead of glass as a reinforcement material in laminated polyester sockets has resulted in thinner, lighter and often cosmetically improved prostheses. This material has also been used to create a frame type socket which contains a leather bootee and replaces the simplest type of extension prosthesis consisting of a leather bootee reinforced by metal side-bars (Fig. 4).

Prostheses using carbon fibre in their construction are lighter and of improved appearance, but more frequent replacement may be required as adjustment of size and alignment to accommodate growth is limited.

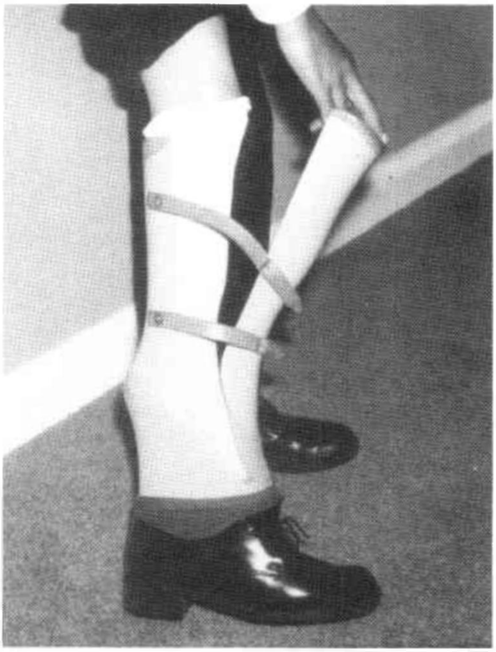

Fig. 3. Glass reinforced plastic prosthesis with hinged socket.

Fig. 4. CFRP frame with leather bootee.

These advances in fabrication techniques do not change the basic prosthetic principles which must be paramount, and the possibility of an enhanced appearance must not be allowed to compromise the optimum socket fit and alignment. For example, the flexion deformities of hip and knee accompanying proximal femoral deficiency must be accommodated and the child's centre of gravity maintained above the prosthetic foot without excessive lumbar lordosis (Fig. 5).

The desirability of this means of construction must be weighed against its cost and the fact that the required alignment is often unusual, sometimes bizarre, and not easy to determine without a trial fitting particularly when the infant is being fitted with his first prosthesis. At this stage traditional construction, using a leather "socket" mounted on aluminium side-bars has the advantage of simplicity and easy alteration.

It is important to explain to parents that adjustability in the early stages is essential and that a prosthesis with improved cosmesis can be produced once the child is walking and the optimum alignment has been established. Indeed the first device should not be referred to as a prosthesis or artificial limb, but as an aid to help their child to learn to walk.

The problems facing the prosthetist are formidable. The parents have expectations

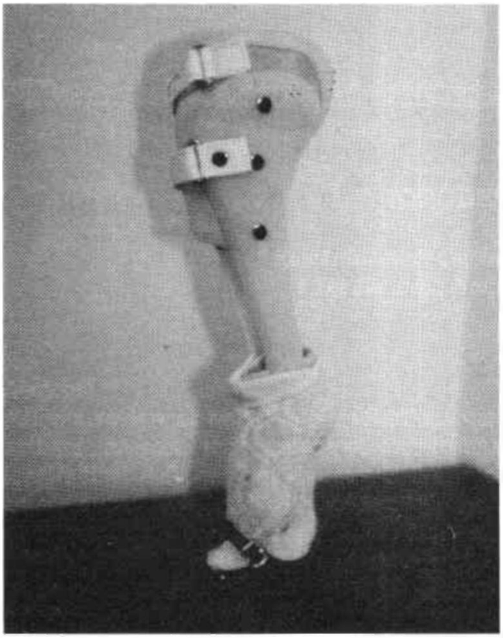

Fig. 5. Carbon fibre reinforced plastic frame with leather socket.

which are often higher than can be met, and he has to cast and measure a child who is only a few months old. He needs, perhaps, to take a full length cast encasing all the joints and to generate an ischial bearing fitting. This one limb is working in unison with three others and one small but perfectly developed mouth, all trying to keep the prosthetist as far away as possible.

A plaster impression is almost invariably needed to enable fabrication of any type of extension prosthesis, but the quality required of the cast depends on the materials to be used in the prosthesis. Thus a relatively poor cast may be adequate for the fabrication of the traditional type using leather and metal because these materials are easily adjustable. In contrast a high quality cast is mandatory if it is intended to produce a socket using reinforced laminated plastics or thermoplastics which fit very precisely and are not capable of effective alteration. The desirability of a high quality impression must be balanced against the likelihood of the prosthetist being able to achieve it. Dealing with complicated shapes is one thing, dealing with non-co-operation is another.

The prosthetist must have a plethora of techniques available for the young child, particularly on the first occasion. He has to decide whether to try and involve the child or divert its attention. The casting procedure can be segmental, starting distally, in order to immobilise each joint in turn and thus preventing destruction of the cast.

Liberal use of separating cream, apart from being fun, helps the removal of some thin casts in one piece. Deformation is minor and easily correctable at the time. Every effort is made to avoid the use of plaster shears or cutting tools for cast removal as young children remember unpleasant experiences and it will not be long before another visit will be needed.

Casts made in several sections to facilitate removal provide good quality replication but require a degree of co-operation which is unusual in a small child. However, these sessions become easier later when a relationship of trust develops between child and prosthetist and this is reflected in that between parents and prosthetist.

The manner in which the prosthesis is presented at the first trial fitting is vital. The

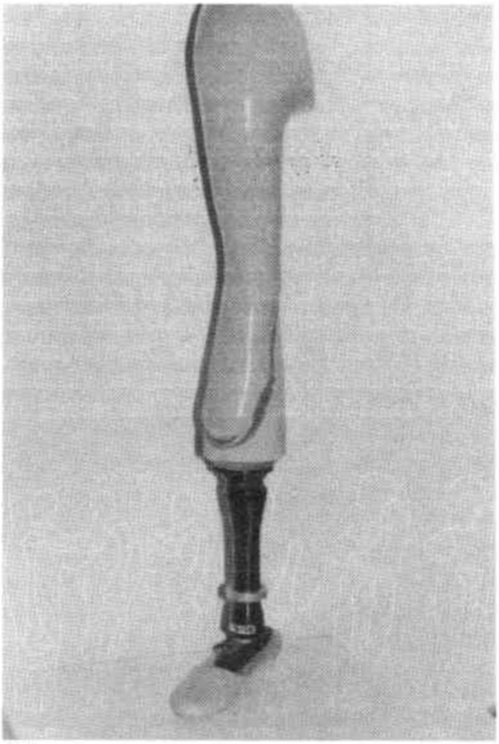

Fig. 6. Socket for child with PFFD mounted on endoskeletal components.

Fig. 7. Sitting position using Holmgren sockets.

parents' immediate reaction will dictate the mood for that session and influence future attitudes. Putting the child's own sock and shoe on the prosthesis before showing it and covering any necessary temporary junctions can be helpful. In short, no amount of technical expertise will make good any deficiency in the relationship between the prosthetist and family.

Fabrication using a wood block or rigid foam between the laminated socket and the foot is excellent for small children and those with little shortening, but older children and adults with considerable length descrepancy may benefit from the use of endoskeletal modular components distal to the socket (Fig. 6). This method of construction may provide a lighter prosthesis of improved function and appearance.

Children with bilateral gross longitudinal deficiencies whose hips are unformed or unstable pose considerable problems. Although experience shows that the majority will discard prostheses in adolescence, they should only do this on the basis of their experience. Simple flower pot types of sitting prostheses may be fitted quite early to enable the child to sit up and develop its skills. Later prostheses using swivel walkers or mechanisms similar to the parawalker or reciprocating gait orthosis may be used (Meadows *et al.*, 1990). Holmgren (1970) demonstrated a socket technique which provides good transfer of power and motion from the pelvis to the prosthesis which has proved very useful allowing some reciprocal as well as swivel gait, and enabling the wearer to sit, albeit in a semi-reclined posture, without the complications of hip locks (Fig. 7).

**Summary**

However fabricated, the fitting and alignment of the prosthesis must be based on sound biomechanical principles and an understanding of the effect of the deficiency on the anatomy, function and kinematics of the limb.

The use of modern materials and components from prosthetic systems has enabled the modern extension or ortho-prosthesis to be lighter, more efficient and better looking, though more costly than its predecessors.

Despite these advances the acceptance by the child and its family of the prosthesis depends as much on the relationship of trust built up between them and the professional members of the clinic team as on the type of fabrication and components used.

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