A Modular Below Elbow Prosthesis For Children

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INTRODUCTION

In the history of prosthetic design and development, the ability to extend the life of a child's prosthesis has only been partially solved. The ideal design would include the ability to increase both the prosthetic length and girth without having to completely replace the prosthesis. The parameters for length of the upper limb have been discussed in detail by Lustid and Keats[1], Wallis[2], and Meredith[3].

Exoskeletal lower limb prostheses utilizing SACH feet can be readily lengthened by incorporating an extension block between the ankle and the foot. Additional length compensation can be planned by making the prosthesis long at the outset and compensating for this added length by the addition of a lift on the opposite shoe. Then as growth occurs, the removal of the lift equalizes the length resulting from growth and augments the life of the prosthesis.

Girth changes can be achieved by removing the soft insert in the below-knee prosthesis and in addition building up or relieving the socket wall to accommodate shrinkage or swelling. The adding or removal of the residual limb socks could also aid in the process of girth compensation.

In the case of the upper limb prosthesis, the problem has proven not to be as simple or as easily solved.

The modular prosthesis developed by the U.C.L.A. Child Amputee Prosthetic Project was the first upper limb prosthesis that attempted to attend to the problem of linear growth through the use of modular components[4]. It failed to explain how they would attend to the other problem secondary to growth, that of changes in girth. In response to this need, the Prosthetics Department of the Kessler Institute for Rehabilitation in West Orange, New Jersey has developed an adjustable upper limb prosthesis that will accommodate both the circumferential and longitudinal growth of the child's residual limb. This article presents the concept, design and fabrication steps of this unique approach.

CONCEPT

The rationale of this prosthesis is to accommodate length and girth changes due to the normal development of a child, both on the amputated and non-amputated side, since both must be considered routinely by the physician and the prosthetist as the child matures. Changes in the girth and length of the residual limb requires prosthetic alterations during the life of the prosthesis. Longitudinal growth in the contralateral arm requires extension of the prosthetic arm.

The prosthesis presented in this article allows an overall increase in the forearm portion of two-and-one-half centimeter (2.5 cm.). This significant lengthening is achieved without the need of adding any external component to the wrist unit. It is a modular component design that is fabricated as part of the original prosthesis. It allows changes in length to be carried out simply without replacement of the endoskeletal components.

Conventional methods for extending the life of a child's prosthesis have been to either fit the patient initially with extra ply socks, to incorporate a socket within a socket (triple wall), or a combination of the two. As the child grows, the ply of socks can be reduced and eventually the inner socket can be removed. Continued growth of the residual limb cannot be accommodated by the prosthesis, so usually a new prosthesis is required.

There are compromises that have to be accepted with this approach. Extra ply socks in hot climates will not enhance wearing comfort. A triple wall socket will add additional weight to the prosthesis. Also, the outer socket is just a larger replica of the inner socket and may not exactly reflect actual growth changes in the residual limb. All standard approaches to accommodate residual limb growth can be incorporated into this modular prosthesis. However, one of the unique features about this prosthesis is that the original socket can easily be removed and a new custom molded socket can be attached to the existing superstructure. This can be done simply by heating the proximal portion of the forearm and allowing it to expand and shape itself over the new, enlarged socket.

The prosthesis can also function as a temporary prosthesis by using the endoskeletal components to connect the socket to the wrist unit[5]. The temporary prosthesis (Fig. 1) would provide the recent traumatic amputee with a functional prosthesis until volume changes in the residual limb have been stabilized.

In summary then, the concept is to allow the prosthetist to lengthen and increase girth of the prosthesis. It is possible using this design to augment the life expectancy of a pediatric prosthesis during the growth years.

DESIGN

This is a modular, polypropylene, below-elbow prosthesis with supracondylar suspension attached to a figure 9 harness. Polypropylene has been used in the past in a limited capacity for the fabrication of certain upper limb prostheses. We have selected polypropylene as the choice material in the fabrication of the below elbow prosthesis because it can be easily thermoformed over a plaster model and offers a hard, durable surface that is easy to clean. This material is more malleable and less brittle than polyester or acrylic resins and also provides a surface resistant to high impact surface fractures. Another advantage is that polypropylene is inert at ambient temperatures which would eliminate the risk of dermatological allergic reactions at the socket interface.

Since polypropylene can readily be thermoformed, socket relief adjustments can be performed simply by removing the socket and heating the particular area enough to form the proper relief.

The prosthesis is composed of the following modular components (Fig. 2):

- Polypropylene forearm
- Polypropylene socket
- DELRIN* socket receptacle with ½-20 internal threads
- A nylon ½-20 threaded rod
- A DELRIN* friction wrist unit
- A DELRIN* retainer for cable housing
- A DELRIN* and polyethylene cross bar assembly

The average weight of the prosthesis assembled, but without the terminal device,

*DELRIN—E.I. DuPont De Nemours trade name for polyacetal resin.

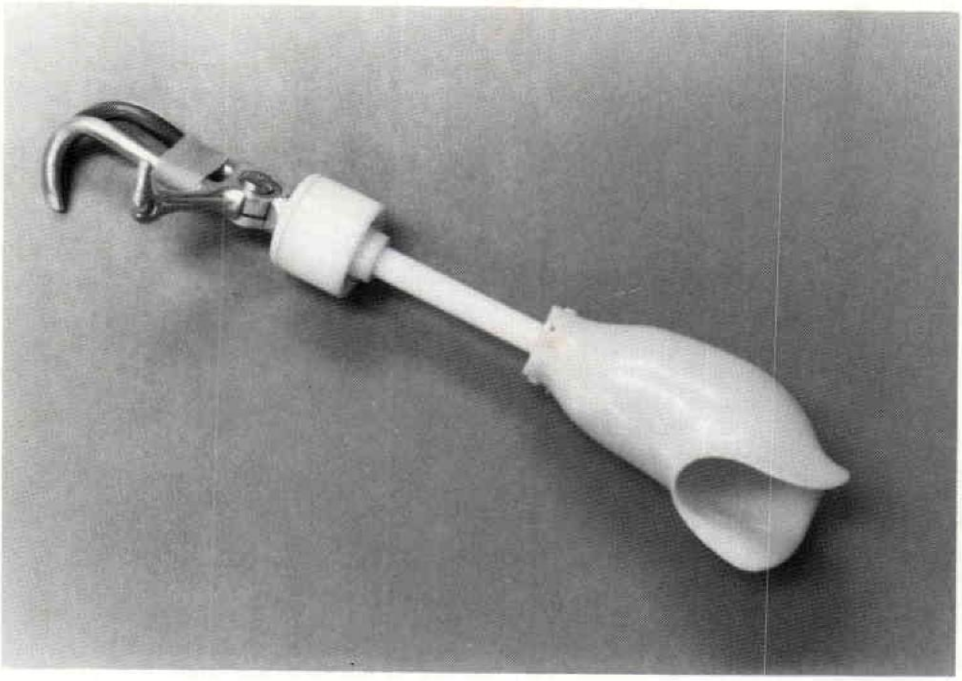

Fig. 1—Temporary below elbow prosthesis using nylon rod and Delrin wrist unit.

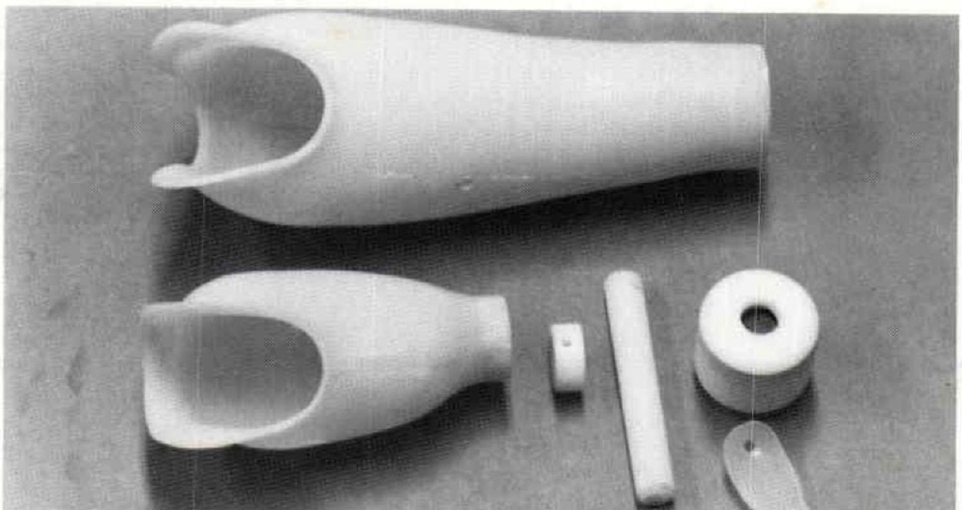

Fig. 2—Component parts for the Modular Below Elbow Prosthesis.

is between 140-165 grams. The forearm weight can be as light as 47 grams; the socket 36 grams; the wrist unit 32 grams.

There is an endoskeletal nylon ½-20 threaded rod which is connected to a friction wrist unit and a socket receptacle at the distal portion of the socket. These endoskeletal components provide the prosthesis with structural integrity. In addition, they allow the lengthening adjustments of up to 2.5 centimeters.

The polypropylene forearm provides a protective, rugged cover for the endoskeletal components since it is primarily fabricated for use by the pediatric age group. In addition, the cover provides attachment points for the control assembly components.

ALIGNMENT

The casting of the residual limb is carried out with the development of the positive mold in the usual manner. Anterior and lateral mid lines are drawn on the plaster model representing the long axes of the residual limb in both the frontal and sagittal planes (Fig. 3). A hole is made at the distal end of the mold where the two lines intersect and an alignment receptacle is inserted. A mock wrist unit attached to a temporary rod is then positioned in the receptacle (Fig. 4). The required length of the prosthesis is established by sliding the wrist unit to the proper position on the rod. The method of alignment is similar to the method used by Otto Bock Industries for aligning below-elbow myoelectric prostheses. Further alignment adjustments, if necessary, can be carried out by changing the angle of the receptacle.

FABRICATION

Once the alignment is achieved, the temporary rod and the mock wrist unit are removed. One-eighth inch thick polypropylene is draped and vacuum-formed over the receptacle and model. Care must be taken at this point to assure that the seam is on the anterior surface of the model. The ridge created on the socket during the vacuum forming process is sanded flush with the surface and is then burnished with a heat gun.

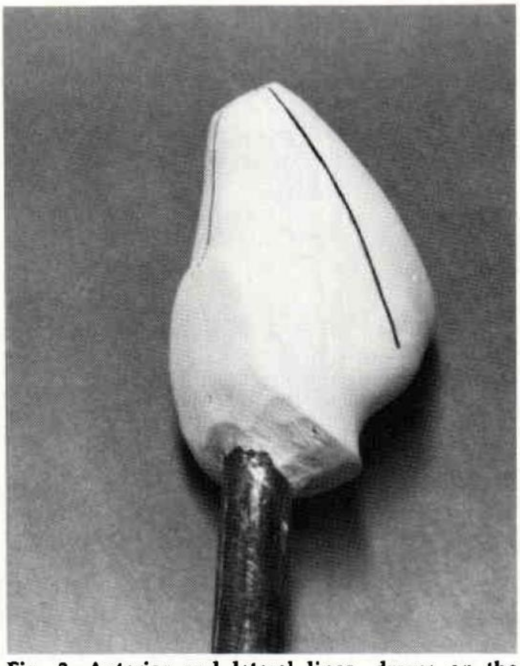

Fig. 3—Anterior and lateral lines, drawn on the positive impression model, are used to establish the alignment of the prosthesis.

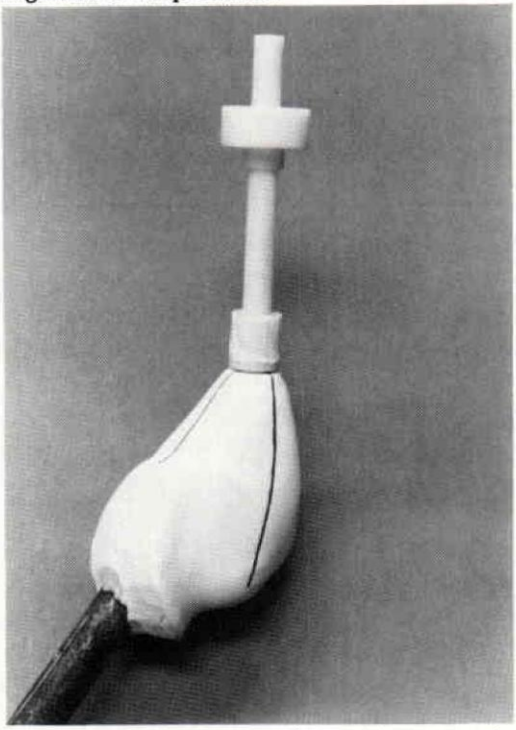

Fig. 4—Alignment receptacle positioner on the positive impression model, with the alignment rod and mock wrist positioned in place.

The mock wrist unit and rod are once again inserted into the receptacle and a forearm is shaped using clay. When the proper shape of the forearm is obtained, the rod is removed and a plaster model of the forearm is made using an alginate impression. Once dried, a one-eighth inch polypropylene sheet is draped and vacuum formed over the model making sure the seam this time is on the posterior surface. The seam is smoothed in the manner previously described. The forearm section and socket are removed from the plaster models.

ASSEMBLY

The alignment receptacle is then removed from the socket and replaced by the definitive socket receptacle. The receptacle has a ½-20 internal thread and is securely fastened to the distal portion of the socket. A nylon ½-20 threaded rod is screwed into the socket receptacle and is fastened so that no further rotation takes place.

The proximal posterior portion of the forearm is lowered three centimeters to allow enough expansion for it to fit easily over the socket.

After the forearm is in place, the friction wrist unit is inserted into the distal portion of the forearm and is threaded onto the rod until the desired length is obtained.

Assembly is then completed by fastening the forearm to the proximal medial lateral portion of the socket using two nylon screws for fixation. The proper terminal device is then attached (Fig. 5).

DISCUSSION

The prosthesis, once prepared, is used by the child after proper training.

As growth occurs in the contralateral limb, the prosthesis is returned to the library for lengthening which is achieved by adjusting the length of the threaded rod gradually up to its maximum (Fig. 6).

Continued residual limb growth that cannot be accomodated by minor socket adjustment can be achieved by replacing the inner socket without any alterations to the external appearance of the prosthesis (Fig. 7). The increased size is achieved following a second casting for the fabrication of the new inner socket (Fig. 8).

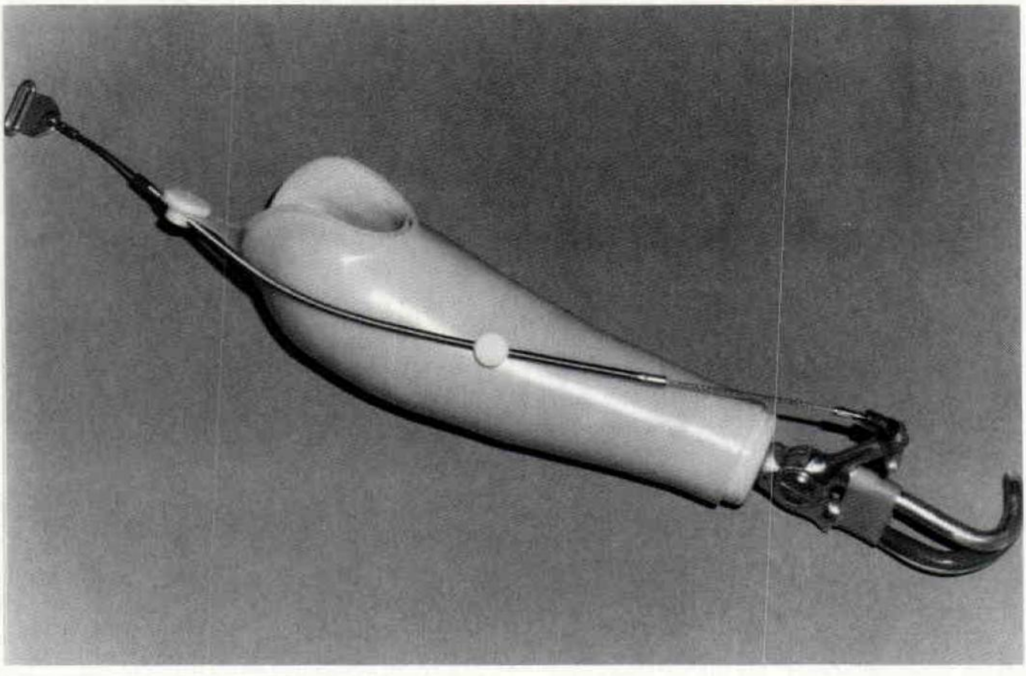

Fig. 5—Modular Below Elbow Prosthesis completely assembled.

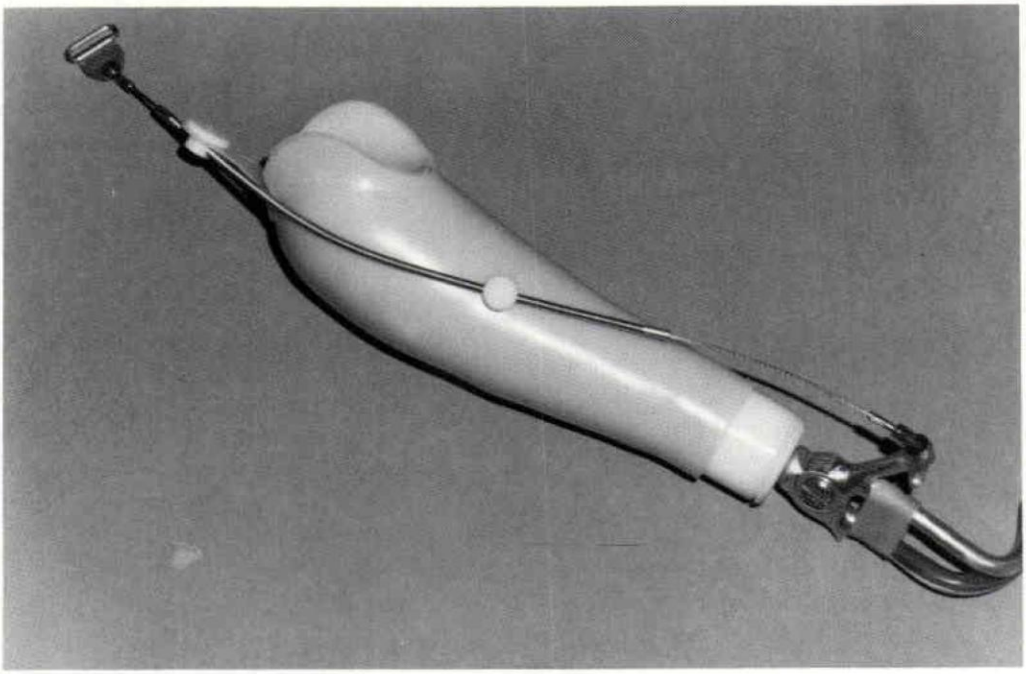

Fig. 6—Modular Below Elbow Prosthesis with the adjustable wrist unit in the extended position.

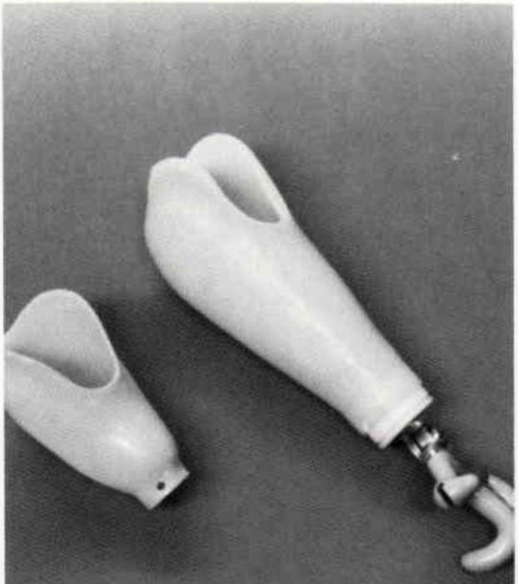

Fig. 7—The new, enlarged socket has been installed within the forearm, using all of the original endoskeletal components. The original socket is also shown.

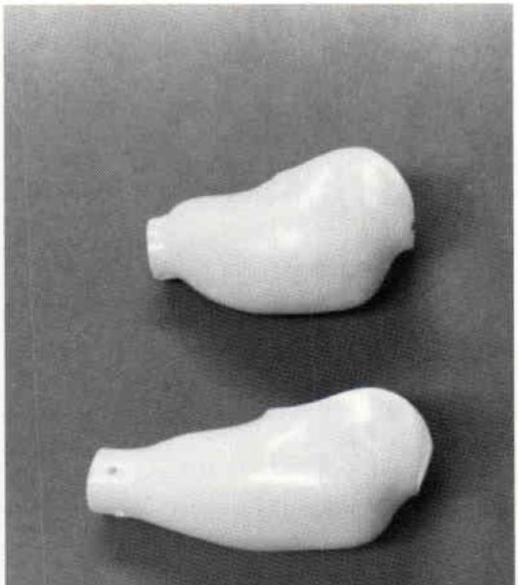

Fig. 8—The original socket that the child has outgrown is shown at the top. The new, enlarged socket that will be attached to the existing superstructure of the prosthesis is shown at the bottom.

All the above changes can, in our view, significantly extend the life of the average pediatric below-elbow prosthesis. The required changes can be carried out economically and with minimal alteration to the superstructure of the prosthesis.

SUMMARY

A new concept in below-elbow prosthetics is presented that is modular and allows increase in length and girth which significantly extends the life of the pediatric age prosthesis.

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