

SOME NONSTANDARD PROSTHESES FOR CHILDREN

Yoshio Setoguchi, M.D.¹

At the UCLA Child Amputee Prosthetics Project (CAPP), amputee patients are seen from birth until 21 years of age for complete rehabilitation management. Because of the restriction relative to the age of patients, the Project does not see as many patients who have acquired amputations as those who are born with limb deficiencies, but prosthetics devices developed for the more common congenital limb deficiencies involve fitting techniques that are applicable to patients with acquired amputations.

Three major areas of changes in prosthetics fitting are discussed here: modular upper-limb prostheses, partial-foot prostheses, and the flexible-wall socket with new applications.

MODULAR PROSTHESES

A review of the history of prosthetics research and development of the past few years shows that considerable emphasis has been placed on the concept of modular prostheses. It is also apparent that interest at most major prosthetics centers is concentrated on development of "cosmetic" prostheses that retain the basic functional characteristics of the previous "standard prostheses." The Child Amputee Prosthetics Project has also undertaken development in the area of "modular" prostheses or, as we prefer to call them, "unitized" prostheses. Since the major case load of both congenital and acquired amputees at our clinic consists primarily of children who have upper-limb involvement, it was natural for us to focus on this group of patients. In 1967 a study was undertaken for providing improved function for this group of infant children while providing better cosmesis.

When we analyzed the standard fitting techniques used for infant amputees (Fig. 1), it was obvious that fitting these children with

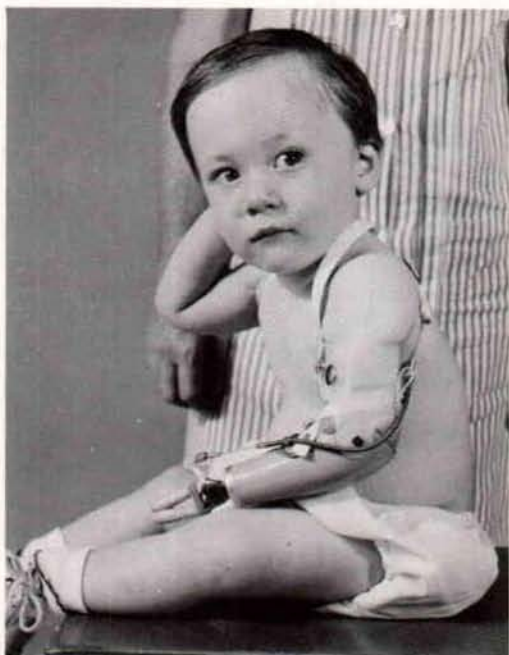


Fig. 1. Standard prosthesis and harness for a child with a below-elbow amputation.

scaled-down adult prostheses did not take into consideration the fact that the body proportions of infants are not miniaturizations of adults, and the activities and movement patterns were not the same as those of an adult. Adults may bend, lift, and reach, but never go through the contortions of an infant. It was felt that if the infant functions differently from the adult, and his body proportions are also different, his prosthetics requirements must be different.

A considerable amount of data was gathered relative to the growth, development, and activities of children. These observations, together with specific functional criteria, suggested a radically new approach in prosthetics design. The standard prosthesis is constructed on an exoskeletal concept, in which the supporting framework is the external shell and the interior is

¹Medical Director of the Child Amputee Prosthetics Project, University of California, Los Angeles. The Child Amputee Prosthetics Project is supported by a grant from the Department of Health, Education, and Welfare, Maternal and Child Health Service.

hollow to the point where the terminal device is attached. In contrast, the unitized prosthesis is hollow only in the socket area which fits over the patient's stump, and the remainder is constructed on an endoskeletal concept in which the basic structure is internal and other materials fill the space around it to complete the arm (Fig. 2).



Fig. 2. Experimental modular prosthesis.

Certain functional criteria were considered in the design and development of the prostheses. First and foremost was that for the child to actively incorporate the prosthesis into his use pattern, the prosthesis had to be light. Furthermore, the soft forearm was used for the function it would provide rather than for improved cosmesis.

Some of the major needs of infant below-elbow amputees are the ability to use the prosthesis for stabilizing and supporting objects, for clasping and also for crawling, for stabilizing himself, and for pushing himself up from the floor. To provide the infant with a prosthesis which would permit him to do these things, a soft-textured forearm with a frictional surface that would also enable him to hold a variety of shapes and textured objects in his arms was incorporated in the design. Such a prosthesis, then, would give the child much more function than he had enjoyed previously.

With this criteria in terms of materials and function as a basis for the development of a new prosthesis, a modular prosthesis was designed.

The basic socket configuration remains essentially unchanged, but because we were considering an entirely new prosthetic concept, various transparent thermoplastic materials, such as Lexan, were tried. The purpose of the clear socket was to allow the prosthetist and therapist to observe the actual stump-socket relationship as the patient uses the arm. The transparent socket concept remains a desirable feature, but because of problems with production (cost, as well as fabrication) and lack of strength once fabrication was accomplished, the clear plastic socket has not yet been successful clinically (Fig. 2).²

Because of the difficulty experienced with the clear plastics, we reverted to the polyester-laminate socket. To this socket is attached a flared cup of polyvinylchloride (PVC) or other thermoplastic material to fit over the end of the socket, to provide a receptacle approximately 1 in. long to receive a central tubing of PVC or Lexan (Figs. 3, 4, and 5). The tubing is cut to the

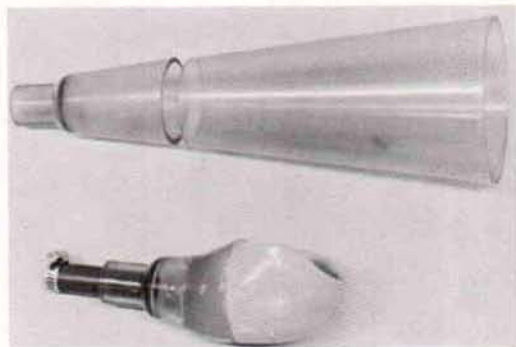


Fig. 3. Use of a flared plastic cup for attaching forearm section to the socket.

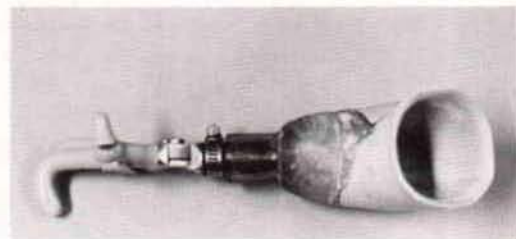


Fig. 4. Complete assembly using the flared tube technique.

²This work was carried out before the successful application of vacuum-forming techniques to prosthetics and orthotics. *Ed.*

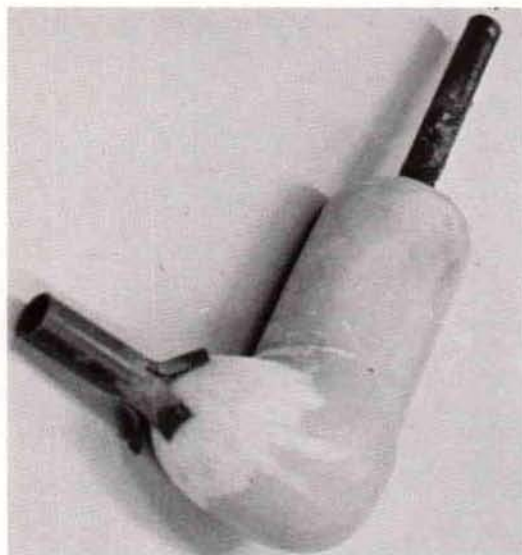


Fig. 5. Attachment of PVC forearm to socket. The PVC tube is threaded at the distal end to receive a terminal device.

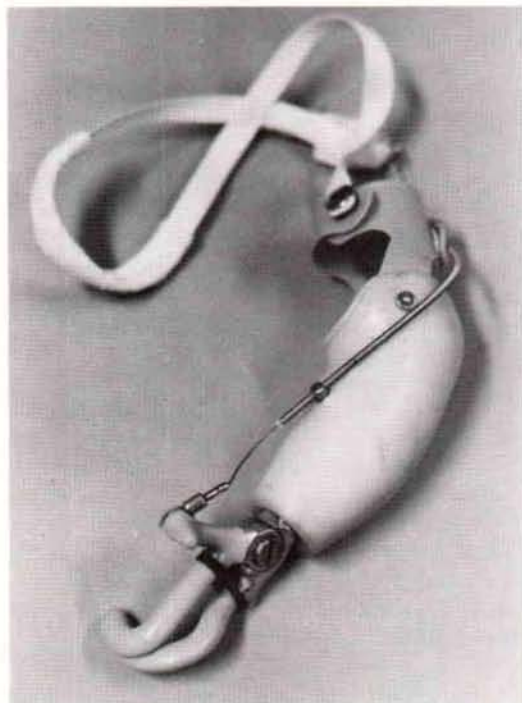


Fig. 6. Completed modular prosthesis for below-elbow case. Note the plastic cuff.

appropriate length and a ring clamp is attached to provide friction when the terminal device is attached. The forearm is then covered by a light-weight polyurethane foam. This material is shaped and covered by a PVC sleeve. To this is applied a standard ortholen or polyethylene full cuff (Fig. 6).

The unitized prosthesis is constructed largely of plastics that have sufficient strength and durability to survive approximately three years of wear. Plastics were used because of additional advantages such as light in weight, soft appearance, and minimal maintenance. Furthermore, the expense is less when components are produced in fairly large quantities.

For infant below-elbow amputees fitted with a nonactivated terminal device, a harness that would provide direct counterforce to supply vertical suspension of the prosthesis was necessary. The harness must not fall off the shoulder, cause undue axillary pressure, or require critical fit in the chest area. In addition, it should allow maximum shoulder motion (Fig. 7). To meet these requirements a modified chest-strap harness was designed. The harness consists of a chest strap, an over-the-shoulder strap, axillary cord, and swivel tab. The over-the-shoulder strap and axillary cord together form a suspension loop which fits on the amputated side. The swivel tab slides on the axillary cord permitting free arm movement. The swivel tab snaps to the cuff and is the only attachment point to the harness for suspension.

The end result of this development was a modular prosthesis which provided the infant amputee, below-elbow type, with a prosthesis which was light in weight, had a soft appearance, with a frictional sleeve surface, and a much simplified but more effective harness that required minimal, if any, maintenance.

Our clinical trials have shown that the infant amputees readily accept this type of prosthesis and use it immediately in their daily activities. The functional advantages of the modular prosthesis are compatible with their needs as physical and mental development occurs.

Because of the excellent acceptance of the below-elbow type of modular prosthesis, the Child Amputee Prosthetics Project has also developed a unitized prosthesis for infants who have above-elbow and shoulder-disarticulation amputations. Again, the criteria of light in

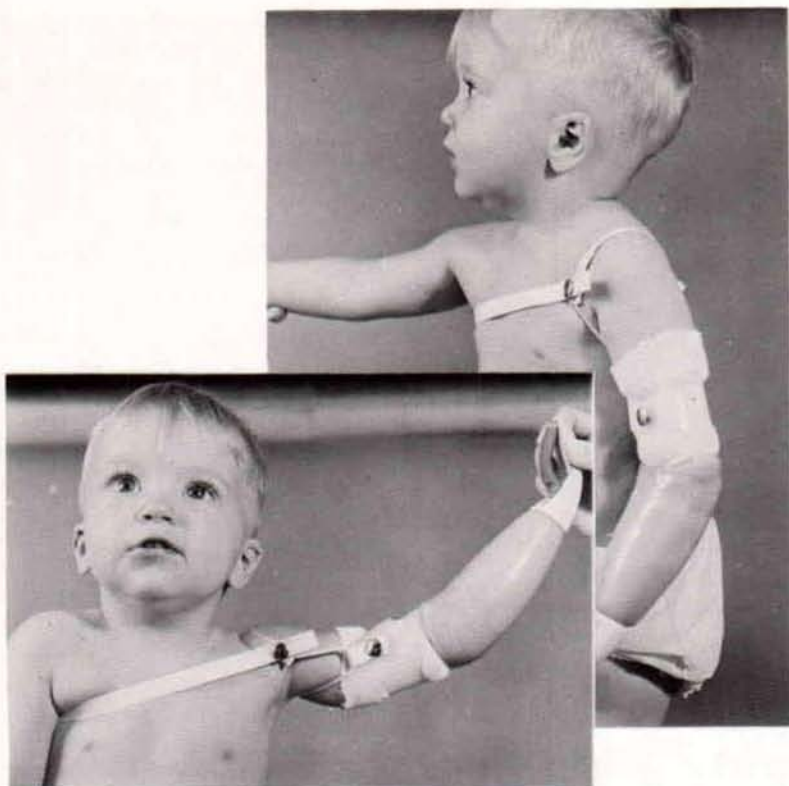


Fig. 7. Modified chest-strap harness for young below-elbow amputee.

weight, a soft appearance, and function for clasping and leaning were considered. The modular above-elbow and shoulder-disarticulation prostheses utilize a manually positioned, six-position elbow joint, three sizes of threaded PVC tubes, ring clamps, and a fixed 90 deg. angle (Fig. 6).

These parts can be combined in a variety of ways to attach the CAPP plastic wrist unit³ which is laminated to the socket for use as a turntable or a shoulder joint (Fig. 8). Preliminary results with this type of prosthesis show that the modular system is extremely versatile for the infant amputee who has a high-level amputation. Since there are no firm guidelines for prostheses segment lengths for young patients with extensive limb deficiencies, especially shoulder-disarticulation types, it is often necessary to estimate the lengths that will be needed. Once a conventional-type prosthesis is fabricated,

changes are not possible. With a modular type the therapist and prosthetist, after the prosthetist has made the socket, have an opportunity to work with the child using interchangeable endoskeletal arm segments prior to the time the prosthesis is covered (Figs. 9 and 10). This is very helpful because it is possible to find the best combination of segment lengths for the patient with a minimum cost.

Another advantage of the modular prosthesis for these youngsters is that when the child has grown linearly, or when functional needs change, it is possible to change segment lengths without providing an entire new prosthesis. These high-level modular prostheses seem to provide additional functional advantages. The prostheses are used for gross clasping, and some children use the soft textured cover to stabilize themselves in leaning and pushing. One side benefit from this type of prosthesis has been that the parents of children fitted with modular prostheses report a positive reaction to the general appearance of the prosthesis (Fig. 11).

³Manufactured by Hosmer/Dorrance, P.O. Box 37, Campbell, California 95008.

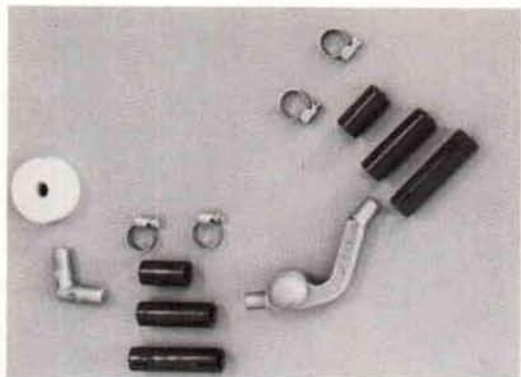


Fig. 8. Parts for assembly of modular prostheses for young above-elbow and shoulder-disarticulation amputees.

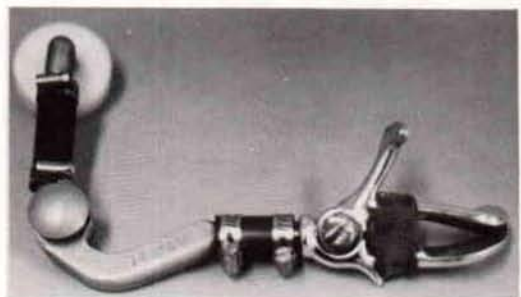


Fig. 9. Basic parts for the shoulder-disarticulation prosthesis assembled, but without socket and cosmetic treatment.

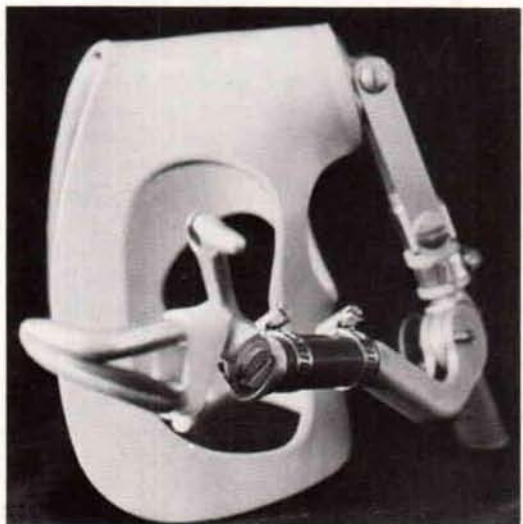


Fig. 10. Modular prosthesis for shoulder-disarticulation amputee before cosmetic treatment.



Fig. 11. A shoulder-disarticulation amputee with functional modular prosthesis.

PARTIAL-FOOT PROSTHESIS

Experience at UCLA with children who have partial-foot amputations indicates that some major problems besides those of normal wear are: outgrowing the prosthesis very frequently, mechanical breakdown, wear and tear on normal shoes, or a combination of all of these conditions. Children in almost all of their waking hours engage in strenuous activities, thus subjecting the partial-foot prosthesis to the most severe kinds of stress. It is not uncommon for these patients to require new prostheses in less than a year after the fitting, and this need places a considerable financial burden on either the parents or the funding agency. Therefore, a design study was undertaken to develop a partial-foot prosthesis which would reduce the costs of time and material and yet provide function and cosmesis equal to or superior to that of existing partial-foot prostheses.

The design criteria were: 1) fabrication should be by existing methods, utilizing materials normally available in prosthetics facilities, 2) fabrication time should be reduced by simplification of procedures, 3) function should be satisfactory, and 4) cosmesis should be improved as compared to hard-shelled or metal frame leather-type devices.

The prosthesis as developed is made of laminated RTV Silastic.⁴ Reinforcement is provided in several key areas to provide the strength necessary for optimal function. In the sole area a belting material as well as a strip of spring steel is added. Over the dorsum of the foot, and extending medially and laterally over the instep area, Dacron webbing is used for additional reinforcement (Fig. 12). Over this reinforcement a final



Fig. 12. Dacron tape in place on RTV Silastic laminate to provide reinforcement for prosthesis for amputation through the forefoot.

lamination is made using the same RTV Silastic material. In order to provide easier donning, a cut is made, usually on the medial side, and these two flaps are then closed using either a "zipper" or lacing. A stocking is worn over the prosthesis.

This fitting has provided excellent function (Fig. 13) for a variety of partial-foot patients, including transtarsal, Lisfranc type, and Chopart amputations. Both function and cosmesis appear to be considerably improved compared to conventional designs. Patients and parents have accepted this technique unanimously and positively. An improved gait pattern has also been evident in these patients.

FLEXIBLE-WALL SOCKET

Another area of major concern, particularly for the acquired amputee, was the patients who have Syme's amputations. Two methods of fitting had become relatively standard, and although both

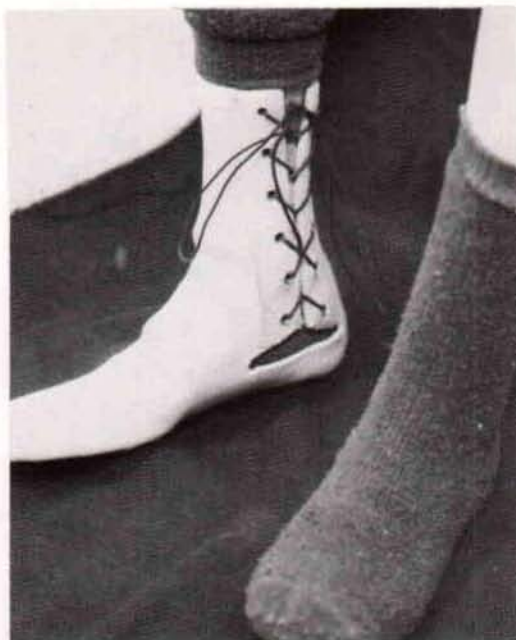


Fig. 13. Completed prosthesis for amputation through the forefoot.

were functionally adequate, appearance was poor. When the bulbous end of the Syme's amputation was not too different in circumference as compared to the narrow portion of the lower leg, a long below-knee prosthesis without a window was fabricated, and suspension provided by a suprapatellar cuff. Those patients who had a large bulbous distal end were fitted with a conventional Canadian-type Syme's prosthesis. Both designs leave much to be desired in terms of cosmesis. Particularly, the young girls were concerned about appearance. A new type of prosthesis was developed for this group of patients, using a technique that had been designed and developed previously for patients who have proximal femoral focal deficiencies (PFFD) and have been converted surgically to functional above-knee amputees (Fig. 14).

Since 1967 the Child Amputee Prosthetics Project has been fitting PFFD patients with a socket that has a flexible inner wall (Fig. 14). The flexible layers of the socket extend from the bottom of the socket to at least the level at which the bulbous end can pass through freely. This satisfies the function of the window in a standard

⁴Dow Corning Corporation, Midland, Michigan 48640.



Fig. 14. Socket for prosthesis for amputee with a proximal femoral focal deficiency, sectioned to show flexible inner liner.

Syme's prosthesis and provides room for expansion of the flexible wall as the bulbous end is inserted into the socket.

Once the stump is inserted fully, the flexible wall closes around it, giving a total-contact fit. Now it is possible to use the bulbous portion of the stump to provide suspension and thus make it possible to eliminate side joints and the pelvic belt. Because of the success of the flexible-wall socket when fitted to the PFFD patients, the concept of a flexible-wall socket was tried on a patient who had an acquired Syme's amputation (Figs. 15 and 16). The results have been very satisfactory. Suspension has been excellent and the patients feel more comfortable without the patellar cuff. Cosmesis is greatly enhanced by this design. This technique is not revolutionary or new in concept, and many other clinics have similar sockets, but we have made a modification in the fabrication of the inner lining. To avoid some



Fig. 15. Patient with Syme's amputation and prosthesis.

of the problems inherent with the use of RTV Silastic material, such as crumbling with aging and retention of odor from perspiration, we have used a completely elastic polyester resin for the fabrication of the inner lining. This material allows the parents or the child to clean the socket adequately without fear of damaging the inner lining.

This same bladder-wall or flexible-wall concept has now been applied to patients who have wrist-disarticulation stumps with bulbous ends. The concept of flexible-wall sockets that provide excellent suspension, while eliminating the need for windows or cuff or other type of harness suspension, has been a tremendous asset in providing functional prostheses with good cosmesis.



Fig. 16. Patient shown in Figure 15 in action.