New Developments in Lower Extremity Prostheses for Children

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The staff members of the Child Amputee Prosthetics Project (CAPP) at the University of California at Los Angeles are working constantly on improving and developing prostheses for the child with an amputation or anomaly. This article discusses two recent developments in the area of lower extremity prostheses: (1) a hip disarticulation type prosthesis for preschool age children, and (2) a child's size adjustable below knee leg.

The cooperation and assistance of the engineering and prosthetic consultants from the Prosthetics Devices Study at the University of California at Berkeley (UCB) have been invaluable in the development of our lower extremity program. James Foort, engineering consultant, and Leigh Wilson, certified prosthetist, were instrumental in much of the work on the hip disarticulation type prosthesis.

A HIP DISARTICULATION TYPE PROSTHESIS FOR PRE-SCHOOL AGE CHILDREN

A year old infant with a left hip disarticulation amputation was referred to CAPP for his prosthetic care. Rather than fitting this child with the more frequently used pylon type fitting, the staff attempted an articulated prosthesis using the basic bio-mechanical principles utilized in the Canadian type hip disarticulation prosthesis.[1]

Two major factors were taken into consideration in design and fabrication:

1. The components used in fabrication had to be very small. Scaling down adult components would be difficult and there would be no assurance the finished product would be satisfactory.
2. The prosthesis had to be made easily adjustable for lineal and circumference growth.

The Socket

A socket was made using the same UCB techniques described by Foort.[2] The cast was taken over the diapers. This was done to provide a padding for the ampuation site and to protect the socket from constant wetting.

A webbed strap and buckle attached to the waistband of the socket was provided for suspension. Later, snaps were put directly on the flexible waistband, but the mother preferred the webbed strap and buckle because it permitted easier removal when changing diapers. The webbed strap and buckle

[1] Radcliffe, Charles W. "The Biomechanics of the Canadian-Type Hip Disarticulation Prosthesis," *Artificial Limbs*, Prosthetics Research Board, National Academy of Science, National Research Council, Washington. Vol 4, No. 2, Autumn 1957, pp. 29-38.

[2] Foort, James. "Construction and Fitting of the Canadian-Type Hip Disarticulation Prosthesis," *Artificial Limbs*, Prosthetics Research Board, National Academy of Sciences, National Research Council, Washington. Vol. 4, No. 2, Autumn 1957, pp. 39-47.

also allowed better adjustment of the waistband as a more positive means of suspension without resorting to shoulder straps. The snaps also came off frequently.

The child has had three sockets during a fifteen month period. The original socket was replaced because of growth. The second socket received hard wear through increased activity and was too large when the child no longer wore diapers. He is presently wearing the third socket.

The Hip Joint

The child's size hip disarticulation hip joint available commercially was too large for the child when the first prosthesis was made so a small door hinge was used. Later, when the second socket was made, the commercially available hip joint was used. The door hinge seem to function satisfactorily in the initial prosthesis.

The Thigh-Knee-Shin Unit

The pre-school age child has a rapid rate of lineal growth. The cost of replacing a prosthesis each time the child outgrew it would be exorbitant. The engineers at UCB designed a thigh-knee-shin unit which could be adjusted easily for growth. (FIGURE 1)

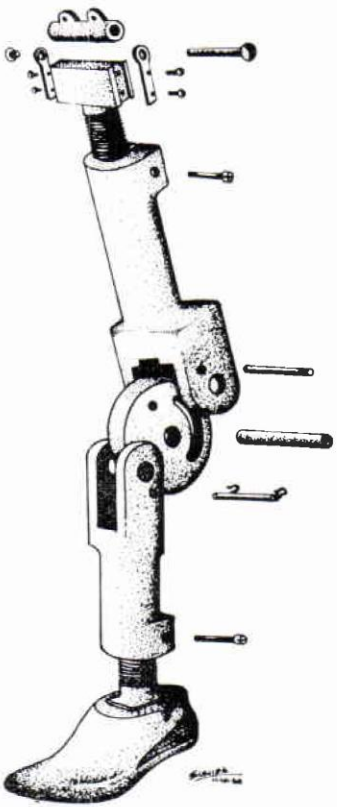

Figure 1. The thigh-knee-shin unit with hip joint and SACH foot attached.

The knee joint was designed to be as near "pinch proof" as possible to prevent harm to the child and clothing during rough play. The knee joint had no friction control in this case, but could be added if desired. The knee was left unlocked. If a patient were having difficulty controlling both the hip and knee joints, the knee could be stabilized by means of knee

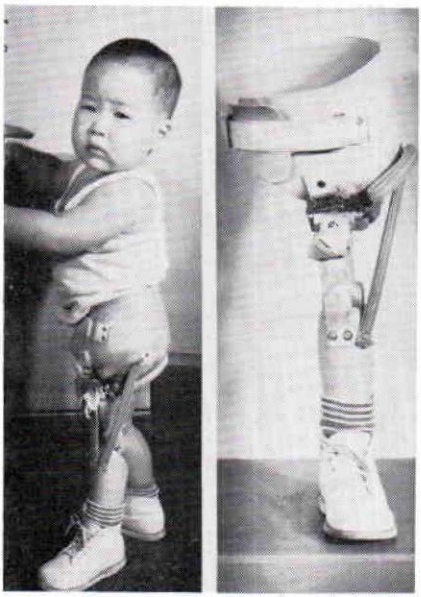

Figure 2. Nineteen-month-old child wearing the first unit of nylon.

flexion control strap. It is recommended that some flexion be allowed to acquaint the child with the potential flexion and extension of the knee joint. Allowing ten to fifteen degrees of flexion seemed adequate for stability and still allowed the child to experience the sensation of knee flexion. However, the knee control strap should be removed as soon as possible.

Threaded extensions projected from the knee joint into which threaded aluminum rods were inserted. This allowed for growth adjustments in both the shin and thigh sections. Collar type clamps on the knee joint extensions were used to keep the aluminum rods from rotating.

Two thigh-knee-shin units were made for testing. The first was made of nylon and the second of micarta. The child has worn both units. The nylon unit was worn first (FIGURE 2) and the micarta unit, which was a little larger, was used when the second socket change occured. (FIGURE 3)

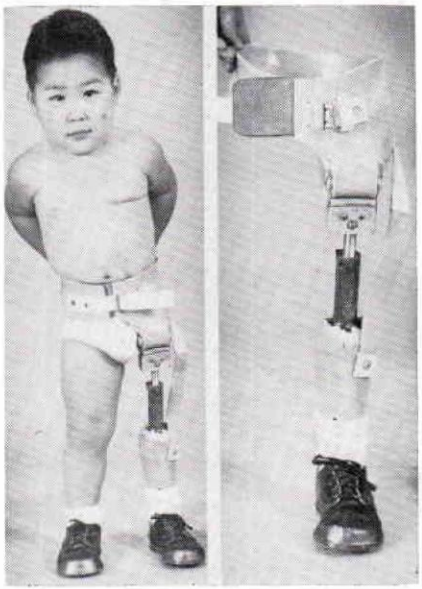

Figure 3. Child wearing second unit of Micarta.

Figure 4. Training activity to establish two-legged standing balance.

Both units worked equally well and were durable enough to withstand a great deal of scuffing, kicking, and general hard wear. No maintenance was required on the units. The micarta unit is less expensive to make than the nylon and may be preferred because of this. The same units may be re-used for other patients.

The Foot

The SACH foot was worn during the entire time with no difficulties encountered.

Control Straps and Alignment

The control strap and alignment for the prosthesis were essentially the same as with the Canadian type hip disarticulation prosthesis.[3]

Cosmetic Covering

A cosmetic covering was put over the shin section for cosmesis and to have a point of attachment for the control strap or straps. The thigh section was left uncovered as it was quite short and the family did not object to

[3] Ibid, pp. 48-51.

the unit being exposed. If a cosmetic covering were desired on the thigh section, it could be applied easily.

Adjustments for Growth

Adjustments for growth were made about once a month, taking about five minutes of the prosthetist's time. At no time did the patient have to walk with a prosthesis that was too short. Extension spacers were added to the cosmetic shin covering as growth adjustments were made. When about two inches of adjustment had been made in the shin section, the whole cosmetic covering was relaminated.

Training

The patient received his prosthesis at the age of one year, seven months. Since this child had never walked, it was necessary to give him an awareness of the prosthesis for standing balance as well as for walking. He received intensive daily gait training for two weeks with follow-up training sessions occuring three times a week until he was able to walk independently.

The primary goal in the initial phase of training was the establishment of basic skills needed for prosthesis control and walking. Balance, prosthesis control training, and reciprocation were stressed. The therapist assisted the child in the pelvic motions necessary for control of the prosthesis until the child could accomplish these motions independently. Play activities such as catching and throwing a ball, and hitting a balloon suspended from the ceiling were used to gain balance and to teach proper weight shifting on the prosthesis and the sound leg. The child established good balance and fair prosthesis control in three weeks and then attempted a few independent steps on his own. By eight weeks, he was walking, running, and jumping. He had learned to climb stairs and was not restricted in any of the climbing activities he attempted. (FIGURES 4, 5, 6) The child wore the prosthesis during all of his waking hours from the day it was received. Full time wearing was encouraged in order to accustom the child to the prosthesis and to check the fit of the socket for pressure areas.

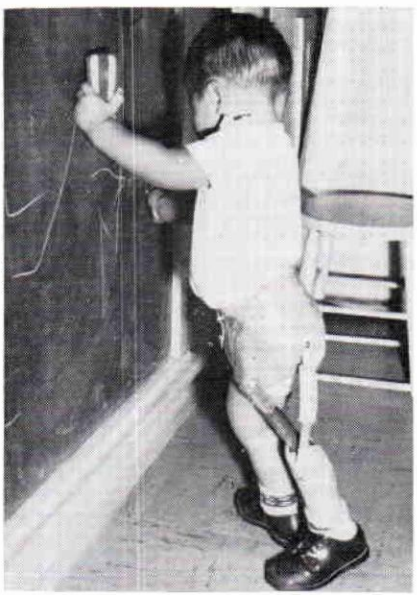

Figure 5. Training activity to establish body and prosthesis control in different positions.

Figure 6. Training activity to establish reciprocal walking pattern.

Conclusions

The hip disarticulation type prosthesis has proved feasible for the pre-school age child from a fabrication and training standpoint. The cost of fabrication and maintenance of the prosthesis has been reduced by the use of the adjustable thigh-knee-shin unit. It is worthy to note again that the thigh-knee-shin units may be re-used for other patients.

The prosthetists at CAPP are now modifying the thigh-knee-shin unit for use with the above knee amputee. A subject has been chosen to test the unit and fabrication of the prosthesis will begin shortly.

The adjustable thigh-knee-shin units are not available commercially at this time. Before approaching a manufacturer, CAPP would be willing to suggest sizes in which these units could be made so that the child could get a maximum period of wearing before changing to another unit.

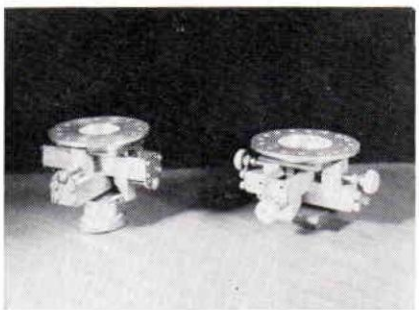

Figure 7. Left: child's adjustable below knee unit designed by Harry Campbell, C.P. Right: commercially available unit.

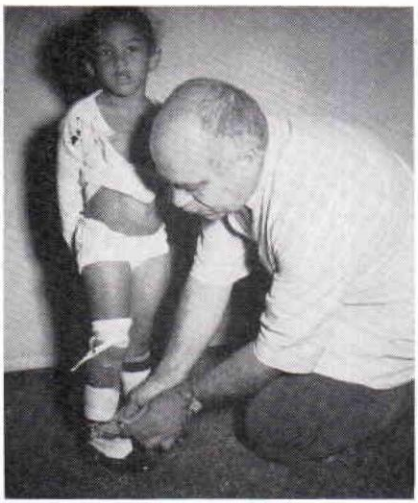

Figure 8. Adjustable below knee leg being used to gain optimum alignment.

THE CHILD'S ADJUSTABLE BELOW KNEE LEG

Many questions have arisen regarding the patellar tendon bearing type of below knee fitting in the growing child. Some of these questions are: "What are the effects of this type of fitting on bone growth? Will this type of fitting cause or increase deformity? How will the absence of knee joints in the prosthesis affect knee stability?"

In order to find answers to these questions and others, it would be necessary to fit a number of children and follow them over a period of several years.

Proper alignment of the prosthesis is important. Although a skilled prosthetist could align this prosthesis without the aid of an adjustable leg, it is desirable to use the adjustable below knee leg during the fitting stages to rule out as much error as possible.

A great majority of CAPP patients are too small to use the adult model of the adjustable leg. Harry Campbell, research prosthetist at CAPP, scaled down the adult type to meet the needs of the children. (FIGURE 7)

CAPP has five children between the ages of one year and six years wearing the patellar tendon bearing below knee prosthesis with cuff suspension. CAPP will continue to fit other children as they are referred to the Project. (FIGURES 8, 9, 10) Three of the children presently wearing this type of fitting have bilateral amputations. Two have below knee and Symes type amputations, the third has below knee and above knee amputations.

The child's size adjustable below knee leg is available commercially.

Figure 9. Twenty-four month old toddler with patellar tendon bearing prosthesis. Child was initially fitted at age of one year with same type of fitting.

Figure 10. Four-year-old bilatteral above knee, below knee amputee fitted with quadrilateral suction socket above knee prosthesis on the right, patellar tendon bearing prosthesis on the left.