PROSTHETIC MANAGEMENT OF A CHILD WITH A PHOCOMELIC DEFICIENCY

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INTRODUCTION

The subject of this case study is an 8 year old girl who has a phocomelic deficiency of her left upper extremity. Her phocomelic hand consists of 3 digits including a thumb and has limited strength and range of motion. She also has an unusually prominent and mobile "spiked" clavicle and no scapula. All other limbs and systems are unaffected and she is a bright, energetic little girl.

HISTORY

Initial Prosthesis

Prosthetic fitting began for Katy at 6 months of age. She received a passive shoulder disarticulation prosthesis. This was done to aid in sitting balance and establish a wearing pattern for future, more complex prosthetic fitting. The socket was a hemi-thoracic frame-type laminated hard socket in which the "spiked" clavicle and phocomelic hand protruded through openings in the socket. The prosthetic components were: an Otto Bock 12S5 flexion/ abduction friction shoulder joint, a Steeper children's 1½" passive elbow and a Centri crawling hand and glove.

Katy wore the device for most of her waking hours.

First Powered Prosthesis

At 1¾ years of age, Katy was fitted with her first powered prosthesis. Only the hand was activated. A similar socket design to the passive device was used, with some modifications. Now, there were control issues to consider.

The new laminated frame-type socket required modifications in order to accommodate the additional weight of a powered fitting. Due to Katy's small size and "spiked" clavicle, the amount of suitable area available for vertical loading was very limited. To increase comfort, the upper portion of the hard socket was lined with a softer laminated silicone material. This served to better distribute weight over the narrow trapezius (weight-bearing) region just proximal to her clavicle.

Control of the electric hand had to be simple and direct, considering her young age. After much experimenting, it was decided to use the thumb on Katy's phocomelic hand to push a single-acting micro-switch. This would control the VASI 0-3 electric hand via a Steeper voluntary opening circuit. The micro-switch was positioned on the outside of the socket where Katy's thumb rested. A precisely crafted cradle of acrylic laminated material was fitted to the microswitch's lever. This cradle ensured support and feel for Katy's thumb to successfully depress the switch. The prosthesis was powered by a 6 Volt 180mAh Nicad battery pack (5 AAA cells) installed within the humeral section.

This system worked quite well and Katy became increasingly bimanual.

Second Powered, more Complex Prosthesis

Seven months later, at 2½ years of age, Katy's mother decided to add weights to the prosthesis in preparation for the addition of an electric elbow in the next fitting. Again, Katy accepted the change well. Katy's mom had been a strong advocate for powered prosthetic fitting from the beginning. She felt that the powered elbow would enhance Katy's function and thereby help her to incorporate the prosthesis into her self-image. Katy's mother has provided the continuous support, training and inspiration necessary for a successful outcome.

We were faced with a new challenge. The primary problem with the addition of an electric elbow was one of control. Katy's phocomelic hand was not strong or mobile enough to access another pair of inputs. Myoelectric control was out of the question as mounting the electrodes over the pectoralis and trapezius muscle groups would have resulted in too much inadvertant elbow activation due to Katy's constant movement within the socket. Force Sensing Resistors (FSR's) required more strength than Katy had. The only option possible was Capactive Touch Control, requiring only slight touch for activation. After much coaxing, it was determined that Katy could consistently and deliberating articulate her clavicular "spike".

Once the control strategy was decided upon, the hardware needed to be designed and fabricated. There was nothing on the market to link the CTC's to the VASI 3-8 electric elbow (the only elbow appropriately sized). A special CTC board needed to be designed. Initially, a miniaturized version of Bloorview MacMillan Centre's wheelchair touch-plate control was developed by our interfaces program. On the board, each channel had its own potentiometer and LED. The LED's were crucial in being able to monitor each channel individually to determine if the channel was being activated.

Two CTC buttons were mounted on a narrow, curved laminated strip that bridged over, but did not touch, Katy's "spiked" clavicle. By moving her "spike" posteriorly, she accessed one of the CTC buttons and was able to extend the elbow. Conversely, by moving her "spike" forward she could make contact with the other CTC button and flex the elbow. Bridging the laminated strip in one piece over her clavicle prevented clothing from disrupting contact with the buttons. The buttons were Otto Bock's round gold-plated electrode contacts.

Hand control continued to be the single-acting microswitch operating a voluntary opening VASI 0-3 electric hand. This prosthesis was powered by a 6 Volt 450mAh internal battery pack installed within the humeral section.

The incorporation of silicone into the socket of the previous prosthesis had been successful and was repeated for this one. The Otto Bock 12S5-shoulder joint was also used again. A cosmetically shaped laminated shoulder joint cover was installed, even though it limited the joint's range of motion slightly.

Functional Status

Katy wore the device for 8 hours a day except on very hot days. She used it for all age-appropriate activities. Her control of the elbow was spontaneous and subtle. There were no extraneous movements as would often be seen with any other mechanical switch option, i.e. pull or push switch etc. Her control of the electric hand was also quite smooth.

Frequency of Repairs

There were problems with breakdown of the Otto Bock shoulder joint and the switch-mounting lever where Katy's thumb rested. The breakdown of the switch-mounting lever was simply caused by wear and tear on the components and required several replacements over the lifetime of the prosthesis. In the case of the Otto Bock shoulder joint, it would lose the friction after several months and fall apart necessitating reassembly of the prosthesis and repair of any broken wires caused by the failure of the shoulder joint.

Third Powered Prosthesis featuring Additional Complexity and Improved Component Design

By the time Katy was 5 years old she had become an excellent user of her prosthesis. It was decided that she should advance to 2-site hand control and have a VASI 2-6 hand. Again, control was an issue. The logical choice was to replace the problematic push-switch with two CTC buttons, one for hand closing and the other for hand opening. Very precise positioning of the buttons on either side of her phocomelic hand allowed Katy to control the VASI 2-6 electric hand. She did this by shifting her hand back and forth approximately ¼ inch touching one button with her thumb and the other with her third digit. As before, a special board was designed and fabricated at the Bloorview MacMillan Centre, this time, it contained 4 channels. It was fabricated by our Electronics Department.

This CTC board also featured a series of LED's and potentiometers, each one, corresponding to a CTC button. The board was housed in the humeral section of the prosthesis and could be easily accessed by removing a specially laminated cover. The LED's were even more important now for troubleshooting since we had 4 channels to deal with. They were very helpful in determining the correct placement of the CTC buttons. For example, if a particular LED was always lit up, the CTC was obviously positioned too close to Katy and needed to be repositioned.

In order to address the shoulder joint problem, a different design was adopted. The Steeper children's 1¾" passive elbow was used as the shoulder joint. To mount this shoulder joint to the prosthesis, a reinforced laminated bulkhead was attached to the socket frame. The bulkhead and joint combination were carefully shaped to preserve symmetry. A custom shoulder flexion/extension stop pin was installed in order to prevent excessive flexing of the wiring bundle that passed through the shoulder joint to the humeral section. A corresponding curved groove was carved into the bulkhead allowing 90 degrees forward flexion and 10 degrees posteriorly. Shoulder abduction was limited to 90 degrees laterally. The 0-degree adduction stop had to be very strong in order to protect Katy's fingers from being pinched between the humeral section and the frame. This is a constant concern as Katy often "roughhouses it" with her 3 siblings and playmates. The abduction/adduction stops were achieved with precise shaping of the upper edges of the humeral lamination which stop medially against the bulkhead and laterally against a step on the Steeper joint surface.

Both of these changes in component design alleviated the previous repair problems. This prosthesis was virtually maintenance free.

The socket design and battery capacity were the same as the second powered prosthesis. The only other difference was the addition of the VASI OMNI wrist. It boosted the functional capability of the prosthesis by allowing 30 degrees of passive wrist motion in all directions. Katy very readily and automatically used the flexibility of the wrist to position the hand as needed.

Current Prosthesis

Katy's current prosthesis is identical in design and components to the previous one. The only change is the size of the hemi-thoracic frame and the humeral and forearm sections, she simply outgrew them. The hand and elbow were overhauled and reused. The same CTC board was also reused. The only new components were the shoulder joint and the OMNI wrist. They are more subject to wear and tear and don't lend themselves to refurbishing.

SUMMARY

Katy is an excellent user of her prosthesis, despite the high level of her deficiency. The latest control strategy takes advantage of four very distinct movements which translates into four separate functions. This simple, direct system has enabled her to achieve a high degree of spontaneity and function in the use of her prosthesis.

Katy is proof that a high-level limb deficient child can effectively wear and use a complex externally powered prosthetic device. When the clinic team, parents, child and supporting technical expertise unite, a successful outcome can be realized.

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