CASE STUDY: MULTIPLE-LIMB AMPUTEES FIT WITH POWERED PARTIAL HAND PROSTHESES

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INTRODUCTION

For people with digit amputations, prosthetic choices have been limited to cosmetic restorations usually made of silicone, opposition posts, or mechanical linkages. In a study in Australia, those with partial hand losses perceive themselves to be at a higher disability than those with unilateral transradial or transhumeral upper extremity amputations.[1] More than half of partial hand amputees are unable to return to their previous work.[2] Of those that did return to work, the majority did not find their prosthesis functional for work.[2] Articulating partial hand prostheses have been available since at least the mid 1970's, but have not largely been adopted due to limitations of fit or usefulness.[3,4]

Each year approximately 17,000 digit amputations are performed in the United States.[5] Between 2000 and 2010 it is estimated that within the Veterans' Administration there were 3000 digit amputations. There are roughly 400 warriors with digit amputations attributable to operation OIF/OEF, and an estimated 50 with bilateral thumb loss.

Improvement in the ability to carry out activities of daily living (ADL) using partial hand prostheses is evaluated in two case studies of subjects presenting with multiple-limb amputations. Impairment and disability are assessed using the *quick*DASH, the Jebsen-Taylor Hand Function Test, and the Box and Blocks Test during initial visits and at follow-up visits after delivery of their prosthetic devices. Both of the subjects represent unique challenges for prosthetic fitting and have revealed unique outcomes in their abilities to utilize their partial hand prosthesis in ADLs.

CASE STUDY 1

Subject Information

Subject is a 33-year-old male Marine who suffered multiple wounds due to an improvised explosive device (IED) blast in September 2010 while stationed in Iraq as part of Operation Iraqi Freedom (OIF). He was treated in Al Asad and then transported to Balad Military Medical Base before being admitted to the James A. Haley Veterans' Administration (JAHVA) Polytrauma Unit in October 2010. His injuries include traumatic brain injury (TBI), right transradial amputation, and left partial hand amputation where the 1st digit was partially amputated, and digits 2, 3, 4 were completely amputated (Fig. 1). Prosthetic care was provided by the VA while the subject was an inpatient.

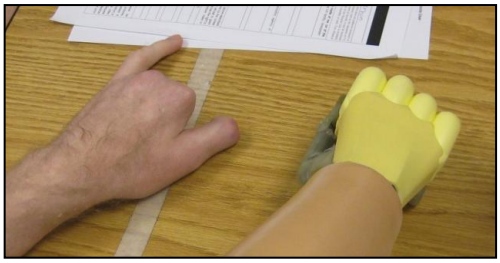

Figure 1: Subject 1 shown with right transradial prosthesis and left partial hand amputation.

Prosthetic History

The subject was initially fit for a right body-powered prosthesis constructed as a traditional hard laminate socket with a figure-8 harness, triceps cuff, flexible hinges and hook terminal device (TD). The subject quickly mastered the use of this prosthesis. In December 2010 he was provided with dual site externally-powered myoelectric prosthesis with an I-Limb (Touch Bionics) terminal device. Independent donning/doffing was not achieved by the subject due to the limitations of his left hand. Clinic reports indicate that the subject stated he was pleased with the myoelectric prosthesis, but he often came to appointments without the arm in place. The subject experienced limb volume loss resulting in difficulty maintaining sufficient contact to operate the controls effectively. Eventually, new sockets were made for both prostheses. The subject was provided with a custom silicone cosmetic cover for his myoelectric prosthesis. At the end of 2010 the decision was made for JAHVA to provide him with a partial hand prosthesis on his left side.

Treatment

At the time of the fitting for the left partial hand prosthesis, the subject was an inpatient at the JAHVA, and was 6 months post-injury. The limited thumb digit had a significant impact on his ability to grasp. Because of the bilateral involvement, it was deemed especially important to reestablish grasping functions. For this reason, we elected to provide a prosthesis incorporating prosthetic digits (ProDigits) manufactured by Touch Bionics. ProDigits are newly available self-contained prosthetic digits that are

individually powered and controlled to provide new fingers for partial hand patients. This is the initial experience JAHVA has using ProDigits. Individual devices can be configured to match the number of digits required for partial hand restoration.

Subject was cast for a partial hand prosthesis using silicone which was sent to Touch Bionics for fabrication. A flexible silicone socket resembling a sleeve with a carbon fiber frame was fabricated (Fig. 2). The sleeve extended from distal to the bicep cubital fold to the distal end of his residuum. A zipper was incorporated to enable donning and doffing. The carbon fiber frame fit over his residuum, distal to the wrist, leaving the thumb exposed. Electrodes were placed over the wrist flexors and extensors. EMG sites were also identified on the residual hand; however, the decision was made to utilize forearm sites to use consistent controls between the contralateral transradial prosthesis and the partial hand prosthesis. The prosthesis incorporated three ProDigit fingers (to replace digits 2-4). Because this was the first prosthesis provided by this hospital that integrated ProDigits, Touch Bionics flew in a certified prosthetist and occupational therapist to assist with fittings. Several modifications were made to the socket in order for the subject to independently don and doff the partial hand prosthesis by using his right transradial prosthesis. The first modification was the addition of a ring on the posterior zipper, this allowed him to hook the thumb of the I-Limb into the ring to zip or unzip. The second modification was relocating the positioning of the on/off switch in order for him to activate it without difficulty.

Figure 2: Partial hand prosthesis with ProDigits.

Specific activities that had presented a problem for this subject included activities of daily living (ADLs) such as cutting up food and toileting. During therapy independence in those activities was achieved (Fig. 3). Initially, Touch Bionics delivered the prosthesis without the addition of a thumb post. During their training session with the occupational therapist they deemed it beneficial for the subject to receive a digital restoration of the partial thumb to improve grasping. Subsequent testing was not performed with the thumb post in place; that addition came later. Results from the three tests are provided in Outcomes section of this paper.

Figure 3: Subject 1 performing a simulated meat cutting exercise during therapy shortly after delivery of prosthesis.

CASE STUDY 2

Subject Information

Subject 2 is a 50-year-old male Navy veteran who had bilateral transtibial amputations and a right partial hand amputation (Fig. 4) involving digits 2-5 secondary to heparin-induced thrombocytopenia following a massive myocardial infarction (MI) which occurred in March 2005. 2005, Two months after the MI, he underwent a heart transplant, requiring him to take immunosuppressant drugs which now cause hand tremors. Complicating prosthetic use, he suffers from right shoulder restricted range of motion (ROM) with pain at end range, but has functional ROM in his right wrist.

Figure 4: Subject 2 shown with right partial hand amputation.

The subject has recovered remarkably well from the heart transplant and is ambulatory with his lower extremity prostheses, using a cane when walking for extended periods of time. His most current goal is to be fit with an upper extremity partial hand prosthesis that will provide him with a functional grasp to aid in activities of daily living (ADL). He learned to use his thumb and palm very effectively when grasping or picking up certain objects, but most activities involving hand function are limited. The subject seeks to regain the ability to perform a wider range of tasks that involve the use of his hands.

Prosthetic History

Two months following his surgeries, the subject was fit with bilateral transtibial prostheses by the JAHVA; he later chose an outside provider for future prosthetic needs. He uses a pin suspension system and is ambulatory, using a cane for extensive periods of walking. He is able to independently don/doff his prostheses. The partial amputation of his right hand was followed by an extended period of sensitivity in the residuum which delayed prosthetic fitting. He learned to utilize his thumb and palm when performing ADLs, even so, he is severely limited in functional capabilities involving the hands. In early 2009, the sensitivity in his right hand improved and he was ready for prosthetic fitting. Commercially available options for functional prostheses that would fulfill his needs were scarce. He was fit with a passive custom silicone partial hand prosthesis. Later that same year he requested and was provided with a recreational upper extremity prosthesis which could be used to play golf. In 2010, the subject was fit with a body-powered partial hand prosthesis that utilized four mechanical fingers operated via wrist flexion. This device was eventually rejected by the subject. In 2011, JAHVA provided the subject with an externally-powered

myoelectric prosthesis equipped with ProDigits developed by Touch Bionics. See figure 5

Figure 5: Subject two wearing ProDigits

Treatment

This was the second partial hand prosthesis provided to a veteran by the JAHVA that incorporated ProDigits. Subject's residual limb was cast using silicone; the mold was shipped to Touch Bionics for prosthetic fabrication. A flexible silicone socket (similar to a sleeve) with a carbon fiber frame was fabricated. The flexibility of the socket accommodates the natural movement of the skeletal and musculotendinous structures and allows for wrist motion in all planes; this characteristic makes it possible to achieve maximum function with a prosthesis. The intimate fit helps achieve maximum suspension and facilitates maintaining good electrode to skin contact over myoelectric sites. The flexible portion of the socket extended from approximately the bicep cubital fold to the distal end of his residuum. The subject chose black silicone as opposed to something more flesh-colored for the flexible socket. A zipper was incorporated to facilitate donning and doffing. The carbon fiber frame fit over his residuum, distal to the wrist, leaving the thumb exposed. Electrodes were placed over the muscles controlling wrist ulnar and radial deviation; this helped preserve functional wrist flexion and extension. The prosthesis included four ProDigit fingers to take the place of missing digits 2-5. Open/close controls were set to operate with ulnar/radial deviation. Electrode gains required adjustment over time because his tremors would elicit inadvertent movements of the ProDigits during training.

OUTCOME MEASURES

Three measures were used to follow the subjects; the Box and Blocks Test, The Jebsen-Taylor Test of Hand Function, and the Disability of Arm, Shoulder and Hand Assessment (*Quick*DASH). The box and blocks is a test of manual dexterity. The test was originally developed to evaluate adults with cerebral palsy. The Jebsen-Taylor is a seven-part test which evaluates a broad range of everyday hand functions using common items such as paper clips, cans, pencils, etc. The *Quick*DASH is a shortened version of the DASH Outcome Measure, which uses 11 items to measure physical function and symptoms in people with any or multiple musculoskeletal disorders of the upper limb. Measurements were scheduled to be taken at three time points; with no partial hand prosthesis during the casting visit, after delivery and two days of occupational therapy with the new prosthesis, and 45 days post-delivery. Tables 1 & 2 provide test results for Subjects 1 and 2, respectively.

DISCUSSION

*quick*DASH

The *quick*DASH is a survey, and is reflective of the user's perceptions. The *quick*DASH score for Subject 1 indicates improvement between visit one and two subject 1. For comparison to Davidson's study, prior to provision of a prosthesis, Subject 1 has a score that falls between Bilateral Upper Extremity amputations (68 ±5) and Partial Hand Amputation (49 ±22). [1] His second score, after two days of occupational therapy post-delivery, reflects a large improvement; a lower score is better. After 45 days, the score shows a loss in improvement.

Subject 2 was not tested at 45 day post-delivery for unrelated medical reasons which delayed follow-up. He was tested while wearing his body-powered partial hand prosthesis that he rejected. The results show a loss in function with the body-powered, and no change between no prosthesis and the ProDigits at post-delivery visit 2. The subject has attend therapy sessions since visit 2 and reports that he is very pleased with the ProDigit prosthesis, stating

he wears the device 4-5 hours per day. He comes to visits wearing the prosthesis.

Table 1: Outcome Measures for Subject 1 at 3 time points.

Test	Subject 1 Outcome Measures		
	No Prosthesis	***2 Days Post Delivery***	***45 Days Post Delivery***
quickDASH (Score)	59	34	41
Box & Blocks (# Blocks)	35	8	22
Jebsen-Taylor	(time/fraction completed)		
▪ Writing	1:04 – 20/24	2:00 – 0/24	:48 – 24/24
▪ Turning Cards	0:07 – 5/5	0:22 – 4/5	0:23 – 5/5
▪ Small Objects	0:20 – 5/5	0:48 – 4/5	1:41 – 2/6
▪ Feeding	0:15 – 4/4	1:02 – 5/5	0:30 – 5/5
▪ Stacking Checkers	0:27 – 4/4	0:56 – 4/4	0:40 – 4/4
▪ Light Cans	0:04 – 5/5	0:40 – 5/5	0:45 – 5/5
▪ Heavy Cans	0:04 – 5/5	0:33 – 5/5	0:20 – 5/5

Table 2: Outcome Measures for Subject 2 at 3 time points.

Test	Subject 2 Outcome Measures		
	No Prosthesis	***Post Delivery Body Powered***	***2 Days Post Delivery (ProDigit)***
quickDASH (Score)	41	47	40
Box & Blocks (# Blocks)	37	16	29
Jebsen-Taylor	(time/fraction completed)		
▪ Writing	0:38 – 24/24	0:35– 24/24	:38 – 24/24
▪ Turning Cards	0:18– 5/5	0:48 – 5/5	0:18 – 5/5
▪ Small Objects	0:14 – 5/5	1:41 – 4/5	0:36 – 6/6
▪ Feeding	0:13 – 4/4	1:40 – 5/5	1:14 – 5/5
▪ Stacking Checkers	0:09 – 4/4	0:43 – 4/4	0:19 – 4/4
▪ Light Cans	0:05 – 5/5	0:18 – 5/5	0:21 – 5/5
▪ Heavy Cans	0:05 – 5/5	0:23 – 5/5	0:32 – 5/5

Box and Blocks Test and Jebsen-Taylor Hand Function Test

The Box and Blocks Test and Jebsen Taylor Hand Function Test are skill based tests. Dromerick *et al*. showed that immediately upon receipt of a prosthesis, function actually goes down.[6] The team indeed saw that also with both subjects. This may have been further exacerbated because this was a new prosthetic user with a traumatic brain injury. Secondly, we may be approaching a ceiling effect on some measures. According to the results of Hackel et al.,[7] this subject is approaching normative values for the light cans, heavy cans, and card turning tasks. Similarly the starting score on the box and blocks is relatively high. The partial thumb digit also played a role in the functional challenges during visit two. With the finger restoration, his thumb was now short by comparison, and he had more difficulty grasping with the prosthesis, than by using the thumb without a prosthesis. A decision was made to provide a passive restoration to the thumb to improve opposition.

Subject 2 has become very adept at manipulating objects such as those used in the Box and Blocks and Jebsen-Taylor without a prosthesis. The initial testing after delivery of his prosthesis indicates that he has to slow down to grasp and move the objects. His ability to perform actual day-to-day functions has improved, according to self-reporting. This important information is not reflected in the chosen tests.

CONCLUSION

New partial hand restoration for a two complex cases involving multiple-limb amputees was presented; one was further complicated by the presence of traumatic brain injury. The ProDigit is a promising device for the treatment of the partial hand amputee. In each case, the ProDigits prosthesis was very well received by the users. The functional testing for Subject 1 did not reflect the increase in functionality that the user described or articulated in the *quick*DASH instrument. In the case of Subject 2, the initial *quick*DASH score did not reflect what was observed (he successfully utilized the device). Hopefully, with continued follow up and monitoring, functional testing will reflect the users' perceptions. At least for these users, the functional tests selected (Box and Blocks Test and Jebsen Taylor Hand Function Test) may not be sensitive to functional changes related provision of a partial hand prosthesis.

ACKNOWLEDGEMENTS

This material is the result of work supported with resources and the use of facilities at the James A. Haley Veterans' Hospital, the Tampa Regional Amputation Center, and Prosthetics and Sensory Aids Service.

REFERENCES

[1] J. Davidson. "A comparison of upper limb amputees and patients with upper limb injuries using the Disability of the Arm, Shoulder and Hand (DASH)," *Disabil Rehab*, vol. 26, pp. 917-923, 2004.

[2] H. Burger, T. Maver, and C. Marincek, "Partial hand amputation and work," *Disabil Rehab*, vol. 29(17), pp. 1317-1321, 2007.

[3] T. Dick, D. Lamb, and W. Douglas, "A wrist-powered hand prosthesis," *J Bone Joint Surg B*, vol. 66(5), pp. 742-744, 1984.

[4] J. Shim, Y. Lee, J. Lee, J. Park, and J. Moon, "Wrist-driven prehension prosthesis for amputee patients with disarticulation of the thumb and index finger," *Arch Phys Med Rehab*, vol. 79(7), pp. 877-878, 1998.

[5] T. Dillingham, L. Pezzin, and E. MacKenzie, "Limb amputation and limb deficiency: epidemiology and recent trends in the United States," *South Med J*, vol. 95(8), pp. 875-883, 2002.

[6] A. Dromerick, *et al*., "Effect of training on upper-extremity prosthetic performance and motor learning: a single-case study," *Arch Phys Med Rehab*, vol. 89(6), pp. 1199-1204, 2008.

[7] M. Hackel, G. Wolfe, S. Bang, J. Canfield, "Changes in hand function in the aging adult as determined by the Jebsen Test of Hand Function," *Phys Therapy*, vol. 72(5), pp. 373-377, 1992.