Tracking Functional Development: A Case Report

Patient: 2800

I. Introduction

In the United States, approximately 133,000 amputation-related hospital discharges occur each year, with 31% occurring at the transfemoral level.[1] Assessing and improving mobility are among the primary concerns for new amputees. In a study of 25 transtibial and transfemoral amputees, Deans et al. found that there was a significant relationship between amputees' functional ability and their physical, psychological and social well-being.[2] This finding shows that an assessment of the patient's functional development throughout the recovery process is instrumental to his or her reintegration into the community. However, very little has been studied about the use of the prosthesis after discharge and if the attained function is maintained thereafter.

Technological advances within the field of prosthetics such as energy storing feet, microprocessor controlled knees, ankle rotators and shock absorbers have attempted to mitigate negative functional effects associated with prosthesis use. However, van der Linde et al.'s literature review highlighted a lack of unbiased information about the direct effects of these different components on patient functional ability. Only two significant comparative studies each were found on the effect on gait of prosthetic feet and on prosthetic knees.[3] The vast majority of clinical studies have used standardized gait assessment protocols with limited ecological validity, making them inappropriate to use in making a prosthetic prescription.[3] In conclusion, the authors suggest that research is needed to illustrate the long-term functional impact of both prosthetic training of lower limb amputees and the use of advanced prosthetic components.

Each phase of amputee rehabilitation has distinct challenges, goals and outcomes (Table 1). The aim of this case report is to show the functional development of one patient from prosthetic training stage to follow-up, quantitatively and qualitatively assessing her functional status at intervals.

Table 1. Phases of amputee rehabilitation [11]

Phase	Hallmark
Preoperative	Assess body condition, patient education, surgical level discussion, postoperative prosthetic plans.
Amputation Surgery & Reconstruction	Length, myoplastic closure, soft tissue coverage, nerve handling, rigid dressing.
Acute Post Surgical	Wound healing, pain control, proximal body motion, emotional support.
Pre-prosthetic	Shaping, shrinking, increase muscle strength, restore patient locus of control.
Prosthetic Prescription	Team consensus on prosthetic prescription and fabrication.
Prosthetic Training	Increased prosthesis wear and functional utilization.
Community Integration	Resumption of roles in family and community activities. Emotional equilibrium and healthy coping strategies. Recreational activities.
Vocational Rehabilitation	Assess and plan vocational activities for future. May need further training or job modification.
Follow-up	Lifelong prosthetic, functional, medical assessment and emotional support.

II. Case Presentation

The subject in this case is a patient at Dayton Artificial Limb Clinic in Beavercreek, Ohio. She is a 54 year old female with a right mid-transfemoral amputation, is 5 feet 9 inches tall and weighs 188 pounds. Her amputation in August 2008 was the result of a Methicillin-resistant Staphylococcus aureus (MRSA) infection contracted during her fifth knee-replacement surgery. Also of note, the patient fractured her pelvis and sacrum in a 2008 fall, has occasional seizures as a result of a 1989 head trauma, and recently had a cyst removed from her contralateral meniscus. Shortly after the amputation, she was fit with a prosthetic leg through another prosthetics company. The patient did not receive any therapy following this fitting, but rather was instructed on how to use the prosthesis and released. The patient experienced a great deal of pain in her pelvis and therefore wore this prosthesis infrequently. Instead, she used a walker and a wheelchair to navigate her one story home, where she lives alone. She also attends church service once a week, does her own grocery shopping, and is able to perform light household maintenance tasks independently. She is currently unemployed. She smokes half of a pack of cigarettes daily and drinks no alcohol.

In the prosthetic prescription stage, the predicted ambulatory status for the patient was determined by the referring physiatrist. She was classified as a K3, indicating her potential to achieve ambulation with variable cadence, negotiate most environmental barriers, and use a prosthesis beyond simple locomotion.[4] This recommendation was discussed with the patient, who reported an active lifestyle prior to amputation. Considering that Taylor et al. found that functional status prior to the development of limb symptoms was the best predictor of post-rehabilitation performance, a long-term prosthetic prescription including high activity components was created.[5] The prescription was to initially fit with the manual locking knee and to later progress and fit her with a microprocessor knee.

The patient began prosthetic training in July 2010 and presented with a hip flexion contracture, which was immediately and aggressively addressed since its presence has been shown to be one of the most significant predictors of poor prosthetic outcome.[6] Due to her mid-transfemoral amputation and history of hip fracture, the primary concern during prosthetic training with this patient was dynamic stability and fall prevention. The patient was fit with a manual locking knee during the first stage of prosthetic training. Usually recommended for geriatric patients, the manual locking knee maximizes dynamic stability. The prosthetist mounted a 15° Flexcon offset plate to the distal end of the socket, which reoriented her Trochanter-Knee-Ankle line to fall anterior to prosthetic knee center, maximizing stability. Since a manual locking knee was being used, the additional 15° of socket flexion that the Flexcon provides was the key feature of this component being utilized at this point. The Flexcon also provides anterior offset of the socket in relationship to the knee component. The magnitude of the anterior offset is calculated based on the degree of flexion in the plate (15°) and the approximate length of the patient's residual limb (8, 10, 12").

It was decided that the best course of action in terms of socket design was to fit a Vacuum Chamber Socket Design (VCSD) which is a total surface weight bearing transfemoral socket design. This type of socket is conducive for use with either passive or active vacuum fittings. For this particular case, a passive vacuum socket fitting was found to be the best option for the patient. This passive vacuum was obtained via use of the Elevated Vacuum Locking System (EVLS™), SealMate™ silicone locking liner and

Aura Locking Sheath along with the EV-MAN-VLV which is a combination air transfer manifold and slide operated release valve.

Upon evaluation of the patient for a silicone locking liner it was determined that the circumferences at 5cm (2”) proximal to the distal end and at the perineum were 55cm and 71.5 cm respectively. Due to the differential between these two measurements it was determined that an off-the-shelf size liner would not be adequate in this case. The patient was casted and measured for a custom SealMate™ silicone locking liner to accommodate the soft tissue of her residual limb properly.

Once fit with the custom liner a passive casting technique to capture the pelvic anatomy and residual limb soft tissue was employed. The cast was taken by applying casting pants or equal barrier to cover the patient’s skin and liner. The land marks identified for this casting procedure were the apex of the Greater Trochanter, Ischial Tuberosity, Adductor Longus Tendon and a coronal limb bisector which was used to align the European 4-hole bolt pattern with. Any other trigger points and/or bony areas were also noted. The casting procedure was performed while the patient was standing, however it could also be accomplished with the patient lying on the non-involved side with their residuum abducted with limb and soft tissue support.

To start the casting procedure a 5-7 layer splint of rigid 6” plaster bandage was made. The length of the splint was enough such that it could cover the Adductor Longus to the Ischial Tuberosity (IT) from anterior to posterior. Once the splint was applied it was only necessary to capture the natural anatomy of the perineum, definition of the IT is not desired in this casting method. The final socket posterior trim line will be more gluteal weight bearing than IT/Ramus containment. The shape capture of the inferior-medial aspect of the Gluteus Maximus is more important. Once the splint was in place the limb was circumferentially wrapped with 4” flexible plaster bandage followed by the same with 4” fast-setting rigid plaster bandage. The limb was wrapped in abduction to allow for easier access, once the rigid bandage was in place the limb was returned to the neutral position. Once set, the cast was removed and prepped for imaging for import into the CAD program.

A Provel D1 mechanical point digitizer was used to obtain a digital image (model) of the cast impression. The socket model was then imported into an industry specific CAD program for modifying. Following a blending procedure to remove any abnormalities, land marks were added every two inches below IT level. Next, the circumferences of the model were scaled down to 96% of their original measurement for a 4% circumferential reduction. Following reduction, the trim line was added to the model (see Figures 1 and 2). The trim line is used to help us plan where to apply our build-ups which mostly serve to supply relief for contraction of the hip flexors and adductors during the gait cycle.

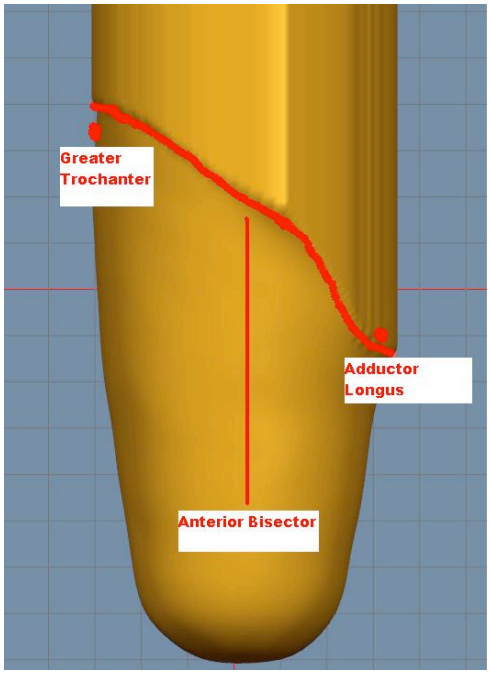

Figure 1. Anterior Trim Line

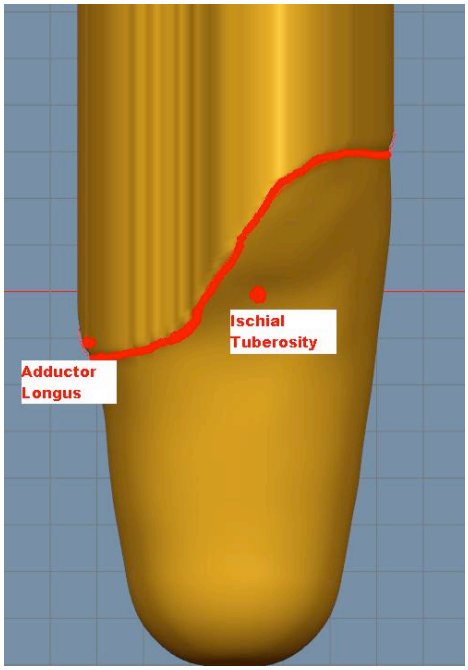

Figure 2. Posterior Trim Line

The initial build-up was adding 1/2 - 5/8" of relief from the mid-point of the proximal anterior at the trim line medially to the adductor region (Figure 3). This build-up runs medial to posterior around the region where the IT was marked (Figure 4). The build-up is applied at the trim line and 1-1.5" below it and is then blended/tapered distally to allow for a smooth transition. More or less of a build up can be applied based on patient muscle tone and tissue density in these regions.

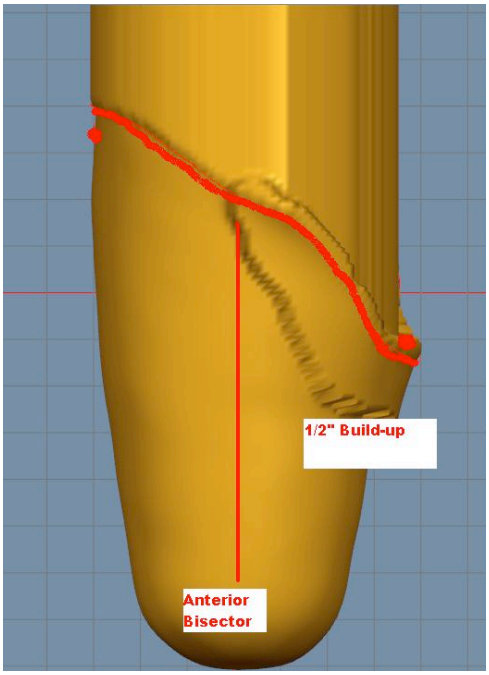

Figure 3. Anterior-Medial Build-Up

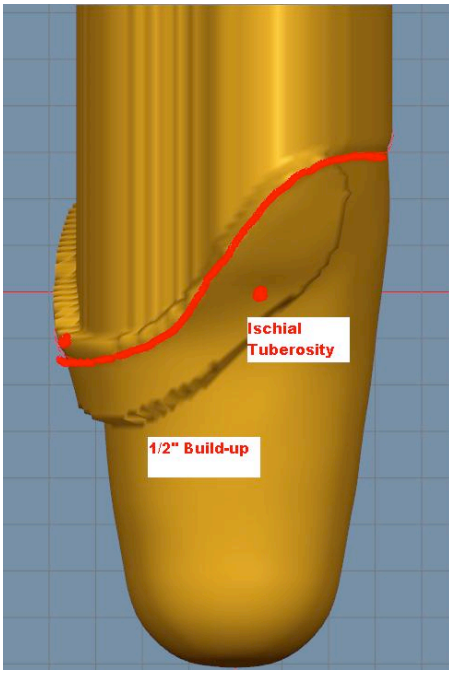

Figure 4. Post-Medial Build-Up

The reduction of circumferential measurements and the proximal build-up are essentially the only modifications that are needed. No other modifications or shaping of the socket model is needed due to the superior linkage and rotation control that the combination of the Aura Locking Sheath and vaccum provide.

The next step then was to add the necessary tooling to provide a void in the socket for the vacuum lock (EVLS™) which acts as a suspension aid, distal socket seal as well as connecting plate. Formation of the distal void is of the utmost importance to ensure a quality seat at all sealing points between the socket and EVLS™ lock. Use of the proper fabrication tooling (drill bits, guides and fixtures) is also important as to not compromise the sealing points of the lock.

The finished definitive socket is tested for seal quality by installing the EVLS™ lock and manifold, applying a vacuum source (up to 27 inHg) and ensuring the distal end of the socket is sealed. The proximal aspect of the socket will be sealed via the use of the Aura Locking Sheath and coverless SealMate™ locking liner.

Within 15 minutes of training with the new prosthesis, patient was able to push off of the prosthetic foot, coming over her toe, and she had better than expected swing phase symmetry, even with the locked prosthetic knee. She walked with her left hip retracted and her sound side adducted, due in part to two years using the walker. The initial gait abnormalities observed in the patient are common manifestations of a hip flexion contracture, including knee instability, lordosis, and uneven step length. The first gait interventions with the patient were having her walk more slowly, with more time spent in double support. This action reflects research done by Kendell et al., who recognized those two adjustments as the most effective ways to increase dynamic stability with a lower limb prosthetic device.[7]

The Locomotor Capabilities Index (LCI) was chosen as the functional outcome measure in this report. It measures a lower limb amputee's capabilities with a prosthesis during and after rehabilitation. It consists of 14 basic and advanced activities and a five-point ordinal scale. It has demonstrated good internal consistency, test-retest reliability and construct validity.[8] The LCI is widely used and recommended for clinical and research use with amputees.[9] The LCI is useful for setting goals and monitoring progress.[8] After her first prosthetic training appointment, the patient was administered an interview that included the LCI and Independent Activities of Daily Living Scale (IADL) assessments (Appendix ii). The IADL is an assessment that evaluates the amputee on his or her ability to perform 8 different daily activities. The patient is rated with either a 1 or a 0 on each activity.[10]

While considering her new prosthesis after her first prosthetic training, the patient scored a 17 of a possible 56 on the LCI, with 11 points on the general tasks and 6 points on the advanced tasks. On the IADL, she scored a 6 out of a possible 8 points. On her second prosthetic training visit, the Flexcon was replaced with an offset plate. This decision was made with the recommendation of the physical therapist, who stated that the flexion contracture was sufficiently reduced. After 4 sessions of prosthetic training in the clinic, the patient scored a 12 on the LCI, indicating that her judgment of her abilities with the prosthetic leg became more realistic with training. This is consistent with Gauthier-

Garnon et al.'s note that the LCI does not measure the amputee's actual performance, but rather their perceived capacity.[8] At this same appointment, the patient scored a 7 out of a possible 8 points on the IADL. This shows improvement from her initial score of 6 because this assessment measures the amputee's actual performance rather than their perceived capacity. After two months with the prosthesis, the patient scored a 19 on the LCI, with 17 points on the general tasks and 2 points on the advanced tasks. This shows an improvement of 7 points from her more realistic score of 12 after her first 4 sessions of prosthetic training.

Left: Three-quarter-inch carbon fiber offset plate. Right: Flexion contracture plate (Flexcon).

III. Discussion

The subject was able to achieve mobility much sooner than other patients who displayed the same type of hip flexion contracture. The widely-used physical therapy interventions for hip flexion contracture were utilized with this patient: backlying with neutral hip extension, lying prone with six inch diameter rolled towel placed under the patient at mid-femur, and stretching in the form of forward pelvis rotation while in approximate midstance. After low-load continuous stretching, more aggressive contract-relax exercises were employed to lengthen the hip flexor. These exercises reduced the angle of the hip by 5° after the first session. Use of sagittal isometric contract-relax treatment of a contracted muscle with an amputee was not found in the literature review. Traditionally, the flexion contracture can only be addressed therapeutically, but the recent development of the Flexcon offset plate allows the prosthetist to immediately reduce the negative effects of flexion contracture on gait, so the patient can begin gait training with the prosthesis much sooner. Therapeutic interventions continue, and as seen with this patient, the Flexcon plate is removed when the patient has improved range of motion at the hip.

IV. Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

IV. References

1. Gailey R, Allen K, Castles J et al. Review of secondary physical conditions associated with lower-limb amputation and long-term prosthesis use. *Journal of Rehabilitation Research and Development*. 2008; Vol. 45, No. 1: 15-30.
2. Deans S, McFadyen A, Rowe P. Physical activity and quality of life: A study of a lower-limb amputee population. *Prosthetics and Orthotics International*. June 2008; 32(2): 186-200.
3. Van der Linde H, Hofstad C, Geurts A et al. A systematic literature review of the effect of different prosthetic components on human functioning with a lower-limb prosthesis. *The Journal of Rehabilitation Research and Development*. July/August 2004; Vol. 41, No. 4:555-570.
4. Ip, David. Orthotic rehabilitation, assessment, and enablement. 1st edition. New York: Springer; 2007:647.
5. Taylor S, Kalbaugh C, Cass A et al. 'Successful Outcome' After Below-Knee Amputation: An Objective Definition and Influence of Clinical Variables. *The American Surgeon*. July 2008; Vol. 74:607-13.
6. Munin M, Guzman M, Boninger M et al. Predictive factors for successful early prosthetic ambulation among lower-limb amputees. *Journal of Rehabilitation Research and Development*. July/August 2001; Vol. 38 No. 4:379-84.
7. Kendell C, Lemaire ED, Dudek NL et al. Indicators of dynamic stability in transtibial prosthesis users. *Gait Posture*. March 2010; 31(3):375-9.
8. Gauthier-Garnon C, Grise M. Tools to Measure Outcome of People with a Lower Limb Amputation: Update on the PPA and LCI. *Journal of Prosthetics and Orthotics.* 2006; 18:1.
9. Condie E, Scott H, Treweek S. Lower Limb Prosthetic Outcome Measures: A Review of the Literature 1995 to 2005. *Journal of Prosthetics and Orthotics.* 2006; 18:13. \
10. Lawton, M.P., and Brody, E.M. "Assessment of older people: Self-maintaining and instrumental activities of daily living." Gerontologist 9:179-186, (1969).
11. Esquenazi, Alberto. Amputation rehabilitation and prosthetic restoration. From surgery to community reintegration. *Disability and Rehabilitation*. 2004; Vol. 26, No. 14/15:831-6.

Appendix i. Details of Patient's Prosthetic Components

Component	Manufacturer	Part #	Quantity
Vacuum Chamber Socket Design	Prosthetic Design, Inc.	AK-4	1
EVLS Locking Kit	Prosthetic Design, Inc.	EVLS-CAUC	1
Custom Seal-Mate Liner	Prosthetic Design, Inc.	SM-CUST	1
Vacuum Manifold with Release Valve	Prosthetic Design, Inc.	EV-MAN-VLV	1
Aura Locking Sheath	Evolution Industries, Inc.	HSSN-8-18-6	1
Manual Locking Knee	Otto Bock	3R41	1
Rotating Receiver	Otto Bock	4R51	1
30mm Pylon	Prosthetic Design, Inc.	P30	1
15° Flexcon	Prosthetic Design, Inc.	FC15-TD12CFI	1
Offset Plate	Prosthetic Design, Inc.	OP3/4-4C4TCF	1
Multiflex Foot Size 26cm	Endolite	519128	1