

Case in Point

Microprocessor Knee and Power Foot Combination in a Transfemoral Amputee

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Advances in the functionality and materials of prosthetics and successful component integration enabled an Iraq War veteran to return to long-distance running and bicycling.

Rapid advances in technology have brought improvements in prosthetic components. In particular, prosthetic knees and ankle/foot complexes have made substantial advancements with the incorporation of computer technology. For example, microprocessor knees are relatively new; the X2 knee from Ottobock (Minneapolis, Minnesota) represents one of the latest and most advanced units and has just been upgraded.

Until recently, there have been no similarly functioning ankle/foot components except for the Proprio Foot from Össur (Foothill Ranch, California), which also provides powered dorsiflexion.

Also, recently BiOM introduced the BiOM T2 foot and ankle system with the added technology of powered plantarflexion to further normalize amputee prosthetic gait. Active patients who have successfully used a microprocessor knee,

such as the X2, have generally paired that technology with a variety of foot/ankle components, ranging from passive-elastic units to advanced-energy storing units.

To normalize gait and improve biomechanics even further in select above-knee amputees, experts in the field have suggested combining a microprocessor knee with a powered foot/ankle complex. One potential obstacle to this combination, however, concerns the possible conflict between the active components of the individual units, such as over- or underengagement of component sensors. This situation, theoretically, could compromise patient safety. BiOM, however, provides training to prosthetic providers to address possible component integration issues, including microprocessor conflict and methods to safely use the components together. Once the prosthetist received this training, the patient in this study was fitted with

the T2 foot and the X2 knee with excellent results and no perceived disadvantages.

CASE PRESENTATION

The patient was a 32-year-old man with a right transfemoral amputation due to trauma from a blast injury, which occurred during Marine service in Iraq. He also had a gunshot wound to his left leg, which resulted in severe injury, but this limb was salvaged and now has good residual function. Before the trauma, the patient was very athletic and involved in long-distance running and bicycling. Once he recovered from his acute injuries, the patient expressed a desire to return to his previous high level of activity and sport participation.

The patient's prior prosthetic experience involved many types of knees, both mechanical and microprocessor. These included the Rheo Knee (Össur), the C-Leg (Ottobock), and the X2 ankle/foot. He experienced limitations in walking up and down hills and walking through snow, sand, and mud. He also felt that placement of his

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foot was “inaccurate” in situations such as walking between crowded tables in a restaurant or down an aisle of occupied seats in a movie theater. Carrying objects, such as a milk carton in a grocery store, was also problematic, because the object had to be carried exclusively on his sound side.

The experiences of these limitations pushed him to look for other prosthetic options that would offer better performance in these situations. Ultimately, he received the T2 ankle/foot with the X2 microprocessor knee after using a different combination for 2 years. He felt substantial improvements in all the aforementioned limitations and has been using the X2 and T2 combination ever since. The prosthetist provided training in both instances. For distance running, the patient uses the Flex-Run (Össur) Foot.

The Trinity Amputation and Prosthesis Experience Scale (TAPES) and the Locomotor Capabilities Index in Amputees (LCI) were used to assess his adjustment to the prosthetic and performance, respectively, before and after use of the aforementioned combination.

The LCI is a validated measure of lower-extremity amputees’ ability to perform activities with a prosthesis.¹ The patient scored the maximum of 7 for all parameters of the LCI (a total of 28 parameters) while using his baseline prosthetic configuration of the X2 knee and the Triton foot (Ottobock). This score did not change when he used the X2/T2 combination (Figure 1; Table).

The TAPES Index is a validated



Figure 1. The BiOM T2 Foot and Ankle Prosthesis, Providing Dorsi- and Plantarflexion.

measure of psychological adjustment to prosthetic integration.² The measure consists of 12 items, rated 1 to 3 (1 = limited a lot; 2 = limited a little; and 3 = not limited at all). His total score was 25 using the X2 alone without the T2 but with the Triton foot. The patient reported that he was “limited a lot” on 2 activity measures (climbing several flights of stairs and running to catch a bus). This measure was reapplied after the patient used the T2 ankle/foot and X2 knee for several weeks. His new sum score was 36, the highest possible for

this measure, indicating no functional, social, or athletic restrictions.

Furthermore, the patient reported other improvements, including an almost complete elimination of long-standing back pain, present since amputation. He reported he was able to climb hills with increased speed and less fatigue. The patient also reported he could stand more comfortably and don his shoes more easily, because the T2 would “bend.” Other subjective activity improvements included the ability to easily pick an object off the floor, step up curbs, walk on uneven ground, perform a mountain-climber exercise, and go through small spaces. He reported he was able to do all these activities previously, but the X2/T2 combination made these tasks easier than before to accomplish (Figures 2A and 2B).

DISCUSSION

The subject of this case report is a physically active traumatic transfemoral amputee who had previous experience with several prosthetic components with the ultimate preference and use of the X2 microprocessor knee. Because of the patient’s desire for the most natural and energy-sparing gait he could achieve, a T2 foot and ankle system was added. Though objective measures of locomotion (LCI) did not change, he reported significant improvement in subjective measures of function and prosthetic acceptance (TAPES).

Reported objective advantages favoring the use of microprocessor prosthetic components most often

refer to the decrease in energy consumption during locomotion. Several small studies have compared powered with nonpowered, energy-storing, or passive-elastic components and demonstrated at

Table. Locomotor Capabilities Index in Amputees¹

Basic Activities
1. Get up from a chair
2. Walk in the house
3. Walk outside on even ground
4. Go up the stairs with a handrail
5. Go down the stairs with a handrail
6. Step up a sidewalk curb
7. Step down a sidewalk curb
Advanced Activities
1. Pick up an object from the floor (when you are standing up with your prosthesis)
2. Get up from the floor (eg, if you fall)
3. Walk outside on uneven ground (eg, grass, gravel, slope)
4. Walk outside in inclement weather (eg snow, rain, ice)
5. Go up a few steps (stairs) without a handrail
6. Go down a few steps (stairs) without a handrail
7. Walk while carrying an object
No—0; Yes, if someone helps me—1; Yes, if someone is near me—2; Yes, alone, with ambulation aids—3; Yes, alone without ambulation aids—4.

least modest energy savings. In a study of transtibial amputees, researchers compared oxygen consumption during locomotion in patients fitted with a passive-elastic ankle/foot with patients fitted with the powered T2.³ The researchers reported an average decrease in overall energy consumption of 8.4%. Plantarflexion and peak ankle-power production at push-off were both increased. The authors of this study conclude that the T2 ankle/foot allows achievement of greater biological realism. A 2010 review by Highsmith and colleagues concluded that the microprocessor knee C-Leg demonstrated increased efficacy in safety and energy efficiency compared with other prosthetic knees for transfemoral amputees.⁴

Subjectively, the study patient reported less fatigue when using the X2/T2 combination than when using the X2 knee without the T2 ankle/foot. It is currently unknown whether the combination provided additive energy savings, and this area would be a good course for future investigation.

The study patient reported several subjective improvements, including reduced back pain, a more natural gait, and improved mobility. Hammarlund and colleagues found a significant prevalence of postamputation lower-extremity back pain compared with preamputation symptoms.⁵ This pain resulted in at least moderate disability in all subjects during prosthetic use. Morgenroth and colleagues went on to speculate that abnormal lumbar spinal kinematics could be a contributing factor for back pain in transfemoral amputees.⁶ Though not specifically causative, the study found that those transfemoral amputees with

increased lumbar spine transverse plane motion experienced significantly more back pain than did similar amputees without lumbar spine transverse plane motion. An abnormal gait would promote more transverse plane motion than that seen in a normal gait. Normalizing prosthetic gait to best simulate the patient's preamputation biomechanical baseline could reduce transverse lumbar spine motion, reduce back and other mechanical pain, and ultimately, reduce overall disability.

Similarly, the patient in this study also reported increased ease with hills and stairs. Many studies exist that attest to the advantages of microprocessor knees in providing improvements such as decreased stumbles, increased ability to multitask, increased satisfaction with the prosthesis, and improved stair and stance functions, such as with the Genium (Ottobock).^{7,8} Whether the combination of a microprocessor knee with a powered ankle/foot would further improve these aspects is yet to be objectively investigated. The report of this study patient who used the combination suggests these types of advantages but certainly as a single case report does not provide definitive answers.

The patient achieved the highest possible score on the LCI before using the X2/T2 combination and thus demonstrated a ceiling effect that has been discussed in several studies.⁹ Furthermore, Larsson and colleagues noted that because of the ceiling effect, the LCI was more useful for amputees of low to moderate activity levels.¹⁰ The TAPES, however, showed an improvement in before and after measurements, and assessment with it was not hindered by a ceiling effect.



Figure 2A. Courtesy of BiOM.
Figure 2B. Courtesy of Ottobock.



CONCLUSION

The patient in this case report noted substantial subjective functional improvements when using the X2 compared with prior mechanical prosthetic knees paired with the T2 foot/ankle. The functional gains were further verified by significant improvement in the TAPES Index score, a validated measure of prosthetic integration. Specific subjective advantages included energy savings, almost complete resolution of back pain, and improved facility with hills, stairs, and crawl spaces. No perceived disadvantages were reported. ●

Author disclosures

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