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Case Report OMICS International

Gait Analysis in Three Patients after Limb Salvage with IDEO and Post-Transtibial Amputation with Prosthetic

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Abstract

Background: Severe lower extremity injuries require limb salvage, amputation and/or late amputation. Our purpose was to compare gait mechanics pre-amputation without a brace, pre-amputation with a brace and post-amputation with prosthesis.

Case descriptions and methods: Three subjects with severe lower extremity injuries underwent limb salvage and late transtibial amputation. Biomechanical gait assessment was performed without a brace, with a brace and after amputation with prosthesis.

Results: Case 1, peak dorsiflexion angle was 94% higher post-amputation compared to bracing and peak ankle torque and power were similar with bracing and post amputation. Case 2, the ankle torque was increased when testing with bracing, but there was no difference between bracing and post-amputation. Ankle power was 78% higher post-amputation. Case 3, the ankle power was 16% higher post-amputation compared to bracing.

Conclusion: In patients pursuing limb salvage where the limb is braceable, it functions similar to a transtibial amputation with prosthesis.

Keywords: Gait analysis; Limb salvage; Brace; Trans-tibia amputation; Prosthetic

Background

Severe combat-related lower extremity injuries include extensive bony and soft tissue involvement that requires multiple limb salvage procedures, primary amputation or late amputations. Limited data is currently available to determine when amputation or limb salvage would result in the best functional outcome following combat injury. The needed comparisons between groups are often limited due to the difficulties finding groups with very similar injury characteristics to compare objective outcomes data. Most combat-related amputations occur within three months of injury, approximately 10-15% are performed greater than three months after injury and pain, neurologic dysfunction and infection increase the likelihood of late amputation [1-3]. A recent study looking over 10 years of war from 2001-2011, found 72% of those who undergo late amputations were transtibial [4].

It is well understood that extremity injury negatively affects mobility, including the important functional task of walking [5-8]. In a large civilian study of severe lower extremity trauma, treatment approach (limb salvage or amputation) did not correlate with patient satisfaction, but physical function, psychological stress, clinical recovery, return to work and walking speed did correlate with satisfaction [9]. A service members' inability and/or perceived inability to return to their previous level of function may result in a desire to abandon limb salvage and proceed to late amputation [10].

While outcome data comparing amputation and limb salvage appears mixed [8,11], a direct comparison of gait mechanics within the same individual pre-and post-amputation could provide valuable insight into the level of function associated with each procedure. This approach removes confounding factors such as differences in injury mechanisms, severity or types. A recent case series by Schnall et al. demonstrated differences in increased self-selected walking velocity, decreased pain and greater ankle power following transtibial amputation after an attempt at limb salvage [12], potentially suggesting a beneficial effect of amputation.

An integrated return to run clinical pathway (RTR) [13], including intense rehabilitation, the Intrepid Dynamic Exoskeletal Orthosis (IDEO^{TM}) and gait retraining was developed to restore lost function and reduce amputation rates [13-17]. The IDEO^{TM} is a custom-made, orthotic device specifically designed to support the limb and allow improved mobility. Similarities can be seen between the IDEO^{TM} and energy storing and returning prosthetic feet which rely on a carbon fiber keel to store and return energy.

A prospective study in 84 Service Members demonstrated significant improvements in physical ability to include restoring walking speed to near-normal levels [18]. Outside of basic measures of walking speed little is known about how custom ankle foot orthoses (AFO) such as the IDEO affect gait mechanics in traumatically injured patients. Most AFO studies involve patients with neuromuscular disorders of non-traumatic origin [19-22] whose limitations and needs for bracing may be very different. A carbon fiber orthosis, like the IDEO^{TM}, may restore ankle function by increasing ankle torque producing capability and power lost due to injury [9,10].

The purpose of this evaluation was to compare gait mechanics collected from three individuals pre-amputation without an orthosis, pre-amputation with a custom orthosis, and post-amputation with an energy storing and returning prosthesis. We present a case series of Active Duty Soldiers who sustained severe lower extremity injuries in combat, underwent limb salvage and subsequently late transtibial amputation.

Case Description and Methods

Case 1

The patient is a 25-year-old male who sustained a sciatic nerve transection that resulted in chronic sciatic neuropathy despite repair and grafting following a gunshot wound to the right femur. He had no active range of motion (ROM) at the ankle and loss of distal sensation in the deep and superficial peroneal and sural nerve distributions. He had 6 months of physical therapy prior to referral to our institution. He then participated in the RTR with the IDEO^{TM} for 12 months [10,13-16]. His visual analogue scale for pain was 3/10 at rest and he was unable to ambulate without use an ankle-foot-orthosis, such as the IDEO^{TM}. He was unsatisfied with his level of function and elected to have a transtibial amputation 2 and ½ years following his injury.

Case 2

The patient is a 41-year-old male who was injured by an explosively formed penetrator blast, sustaining a right open tibia and left open calcaneus fractures. He developed complex regional pain syndrome in his right lower extremity, which was unrelieved by multiple modalities. His ankle dorsiflexion ROM and strength were 5° and 4/5, respectively. He had no active plantar flexion after 13 months of physical therapy at an outside facility and 5 months in RTR with the IDEO^{TM} [10,13-16]. His visual analogue scale for pain at rest was 8/10. He subsequently elected for a transtibial amputation 3 years following his injury.

Case 3

The patient is a 27-year-old male who was injured by an improvised explosive device blast, sustaining a common peroneal nerve injury and open left distal femur, comminuted tibia and foot fractures. He had chronic neuropathic pain, which was unrelieved by multiple treatment modalities. His maximum dorsiflexion was -10° with no dorsiflexion strength and global numbness of the foot. He underwent 14 months of physical therapy prior to joining the RTR, which he participated in for 6 months with the IDEO^{TM} [10,13-16]. His visual analogue scale for pain at rest was 3/10. He elected to have a transtibial amputation 3 years following his injury.

Patients were counseled by physical therapists, behavioral health professionals, prosthetics, pain service providers, current amputees and multiple orthopedic surgeons prior to amputation. Biomechanical gait assessment during the course of clinical care was performed as described previously [20].

Assessment was performed without the IDEO^{TM}, with the IDEO^{TM}, and four months after transtibial amputation, ensuring that they were able to fully and comfortably weight bear in their prosthesis. Data were recorded for both the involved and uninvolved extremity. Similarities and measurement differences greater than previously published minimum detectable change values are specifically identified and discussed [23,24].

Findings and Outcomes

Case 1

The patient was unable to walk without the IDEO^{TM} due to foot drop and loss of sensation in the involved extremity. Stance phase comprised 57% of the gait cycle in the IDEO^{TM}, which was similar to 4 months post-amputation, 59% (Table 1). Motion of the foot relative to the leg (referred to as ankle range of motion) was similar when testing with the IDEO^{TM} and 4 months post-amputation for the involved and uninvolved extremities (Table 2). Peak dorsiflexion angle was 94% higher post-amputation compared to with the IDEOTM (Figure 1A). Peak ankle moment and ankle power were similar when testing with the IDEO^{TM} and at the 4-month post-amputation testing session (Figure 1C, 1E).

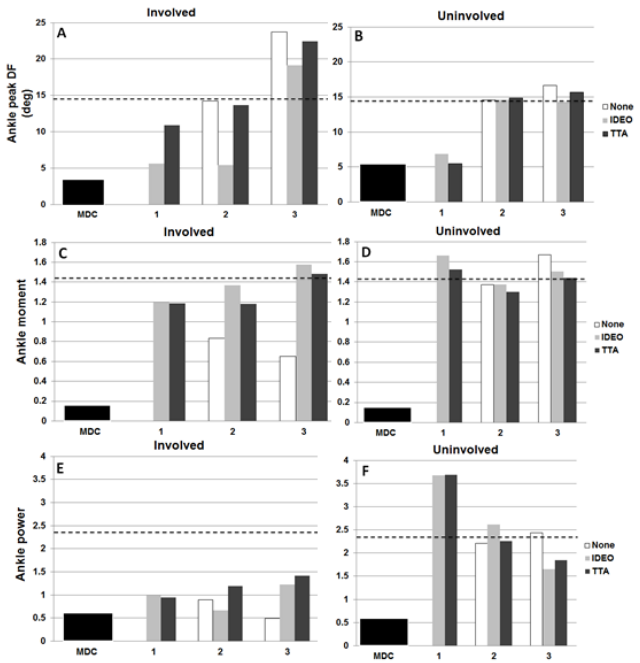

Figure 1: Peak ankle angle (A-B), ankle moment (C-D) and ankle power (E-F) of the involved and uninvolved limbs for all three patients.

The minimum detectable change (MDC) value is presented in black and the mean value for healthy controls is presented as a dashed line for visual reference [23,24]. DF, dorsiflexion; deg, degrees; none, no brace; IDEOTM, with brace; TTA, post-transtibial amputation with prosthetic at 4 months.

Case 2

The percent gait cycle in stance phase for the involved extremity was 67% without the IDEO^{TM}, 59% with the IDEO^{TM} and 63-65% post-amputation (Table 1). Compared to with the IDEO^{TM}, ankle range of motion was 224% higher without the IDEO^{TM} and 127% higher post-amputation, respectively (Table 2). Compared to testing with the IDEO^{TM}, peak dorsiflexion angle was 162% higher without the IDEO^{TM} and 151% higher post-amputation, respectively (Figure 1A).

The ankle joint moment was increased when testing with the IDEO™, but there was no difference between the IDEO™ and post-amputation (Figure 1C). For the uninvolved extremity, the ankle moment results were similar across all treatments (Figure 1D). Compared to testing with the IDEO™, ankle power was 78% higher post-amputation (Figure 1E).

Variables	No.	None	IDEO™	4mo
Involved	1	--	57.02	59.54
	2	67.56	59.75	63.62
	3	69.55	59.91	62.9
Uninvolved	1	--	63.75	64.01
	2	60.31	65.6	65.1
	3	61.22	66.57	65.61

Table 1: Percent of gait cycle in stance phase for each patient.

Case 3

The percent gait cycle in stance phase for the involved extremity was 69% without the IDEO™, 59% with the IDEO™ and 62% post-amputation (Table 1). There was a small decrease in dorsiflexion motion when tested without IDEO™ compared to testing with the IDEO™. Compared to testing without the IDEO™, ankle range of motion was 62% lower with the IDEO™ and 71% lower post-amputation (Table 2). The peak dorsiflexion angle was similar between all conditions (Figure 1A). The ankle moment was 142% higher with the IDEO™ than without (Figure 1B), and the IDEO™ was similar to the post-amputation condition (Figure 1C). The ankle moment was similar with the IDEO™ and post-amputation in the uninvolved extremity (Figure 1D). The ankle power was 149% higher with the IDEO™ versus without the IDEO™. The ankle power was 16% higher post-amputation compared to with the IDEO™ (Figures 1E and 1F).

Variables	No.	None	IDEO™	4mo
Involved	1	--	11.52	9.68
	2	17.35	5.29	12
	3	19.75	12.17	11.53
Uninvolved	1	--	38.63	28.02
	2	22.05	29.08	34.95
	3	23.57	23.08	25.62

Table 2: Motion of the foot relative to the lower limb each patient.

Discussion

Limb salvage patients may perceive their outcome as unsatisfactory and pursue late amputation [1-4]. All three of the limb salvage patients presented in this series pursued amputation either due to pain or dissatisfaction with their level of function. The data presented here provide a unique comparison of gait within the same individuals while using a custom orthosis (IDEO™) and following amputation with prosthetic.

The IDEO™ braces used at our institution are highly customized to each patient [14] and are provided when other conventional devices were not suitable. The device characteristics, to include stiffness and shape are varied empirically to match the patients available pain free range of motion, unique limb shape and the amount of energy storage to meet functional goals. As such, the data varies between individuals and appear to be associated with each individual's injury characteristics.

The IDEO™ provides support of the limb and allows loading necessary to perform many functional activities [10,14]. Due to loss of ankle strength and sensation, Case 1 was unable to walk without an AFO, but with the IDEO™ was a functional ambulator. For all cases, ankle moment with the IDEO™ was greater than without, approximated normal ankle function, and was no different than with prosthesis indicating adequate support was provided. The IDEO™ can, however, affect ankle motion. For example, Case 2 was provided a stiff device specifically to minimize pain during activity. Although it allowed improved function, this resulted in a decrease of ankle motion and power. Case 3, who sustained limb injury but could tolerate motion, demonstrated decreased range with the IDEO™ but the resulting ankle range and power were similar to the prosthesis. Case 1 who had an intact but non-functional ankle displayed similar energy return and range while wearing the IDEO™ and prosthesis. These data suggest the ability to create more normal ankle mechanics in individuals who have sustained significant limb trauma, particularly in individuals with available motion.

Bracing with a customized orthosis coupled with a regimented physical therapy program [13], results in patients having similar gait mechanics in this case series when compared to gait mechanics following a transtibial amputation. In a recent case series of three patients, comparing pre-and post-amputation gait mechanics, Schnall et al. showed following transtibial amputation patients had an increased self-selected walking velocity, decreased pain and greater ankle power [12]. However, the current study differs in that all patients were tested with a customized orthosis after formal rehabilitation. While there are various factors that affect patient outcomes, to include pain, sensation, etc., these were not specifically addressed in this study. However, it is important to note that our study does shed some light on the reasons for the initial success of the IDEO™ and the RTR as it appears to allow the limb to function rather similarly to a transtibial amputee with prosthesis.

The main drawbacks to the IDEO™ are: multiple adjustments may need to be made to the brace during use, the brace is custom made and may not be available to all patients, and it can be cumbersome with shoe wear.

Conclusions

In patients pursuing limb salvage where the limb is braceable, it functions similar to a transtibial amputation. As a result, consideration should be given to pursuing limb salvage, with the IDEO™ and RTR as similar gait mechanics may correlate with similar functional outcomes. This limited case series highlights the importance of factors affecting the decision to amputate, as limb function may be more similar than expected, but other factors, such as pain may lead to a decision to amputate.

In individuals with near normal range of motion and significant plantar flexion weakness, as in Case 3, limb function is similar with the IDEO™ or with a prosthesis following transtibial amputation. A much

broader range of patients with varying physical limitations have done well with the IDEO™ and RTR [13,18], which makes further research necessary to match patient selection and expectation to outcomes.

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