How Does the Smoothness of Joint Motions during Walking Change with Transfemoral Osseointegration?

Courtney M. Butowicz[1-3], Julian C. Acasio[1,2], Ashley B. Anderson[2,3], Brad D. Hendershot[1-3]
[1]Extremity Trauma and Amputation Center of Excellence, Defense Health Agency, Falls Church, VA, USA
[2]Walter Reed National Military Medical Center, Bethesda, MD, USA
[3]Uniformed Services University of the Health Sciences, Bethesda, MD, USA
Email: courtney.m.butowicz.civ@health.mil

Summary

Transfemoral osseointegration aims to improve mobility by mitigating socket-related complications. Here, we evaluated changes in the quality (smoothness) of movement after osseointegration using the normalized jerk cost of lower limb joints during walking (a measure of gait smoothness). Findings indicate changes in movement smoothness of the prosthetic hip during prosthetic stance occur between 12 and 24 months after osseointegration, likely resulting from re-learning to walk with a bone-anchored prosthesis.

Introduction

Surgically altered or missing anatomy after lower limb loss reduces sensory feedback, impairing movement control and often altering coordination strategies that manifest as abnormal gait mechanics. Moreover, traditional prosthetic sockets adversely affect sensory feedback, further exacerbating gait abnormalities. Osseointegration (OI) allows for the direct skeletal attachment of a prosthesis to bone, eliminating socket-related issues and improving sensory feedback, reducing gait compensations and abnormalities. Normalized jerk cost (JC) of joint motion during gait can explain underlying motor strategies and movement quality [1]. Thus, this study evaluated trunk, hip, knee, and ankle jerk costs pre-, 12-months, and 24-months post-OI. We hypothesized that normalized jerk cost would decrease over time as more smoothness would be associated with a higher degree of sensory feedback [2].

Methods

Eight male service members with unilateral transfemoral limb loss (age: 38±9yr, height: 1.78±0.12m, mass: 99.2±24.0kg, time since amputation: 90±54mon) underwent two staged OI using the OPRA^{TM} implant system, repeating a biomechanical gait evaluation (self-selected walking velocity [SSW]), before, 12, and 24 months after OI. Full-body kinematics were tracked (120Hz) via optical motion capture (Qualisys, Göteborg, SE), and angular jerk was determined as the 3rd derivative of three-dimensional joint angles. Normalized JC was calculated during stance for bilateral hip, knee, ankle, and trunk [3]. Repeated measures ANCOVA determined differences between visits with SSW as a covariate ($p<0.05$).

Results and Discussion

There was an interaction between visit and SSW (means: 1.24 m/s, 1.16 m/s, and 1.24 m/s for baseline, 12-and 24-months, respectively) for bilateral hip flexion and adduction JC ($p<0.027$); prosthetic-side hip JC increased between 12 and 24-months after OI ($p<0.02$), notably as walking speed increased. Contrary to our hypothesis, there were no differences in knee, ankle, or trunk JC between time points, regardless of stance limb ($p>0.09$).

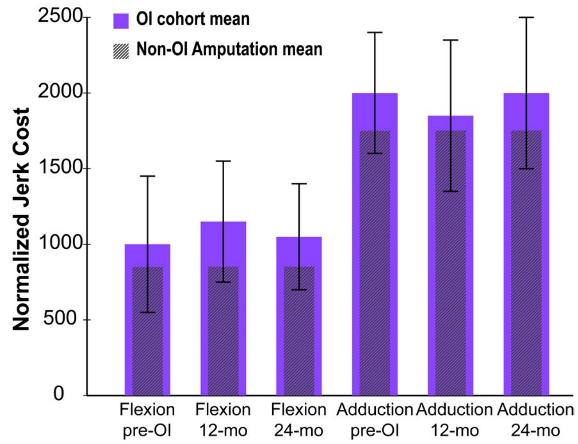

Figure 1: JC of prosthetic-side hip flexion (Flex) and adduction (Add) during prosthetic stance at each time point (pre, 12 months, and 24 months post-OI). Gray bars: means of 8 individuals with a non-OI transfemoral amputation, matched to the OI cohort by age, sex, SSW, and time since amputation to serve as a reference value.

Our data suggest that patients achieve smoother forward progression at the cost of mediolateral smoothness 24 months after OI. Yet, the decreased smoothness points relative to non-OI patients likely suggest that factors outside the prosthesis connection influencing function in this patient population must be considered (e.g., limb length, and activity level).

Conclusions

Direct skeletal attachment of a prosthesis increases tactile sensory perception and feedback during gait and improves proprioception of the foot/limb. Sensation is paired with improved prosthesis control that should improve gait mechanics and decrease abnormalities or compensations that increase the risk of secondary health conditions and reduced independence.

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