An alternative surgical architecture to broaden accessibility of the Agonist-antagonist Myoneural Interface (AMI)

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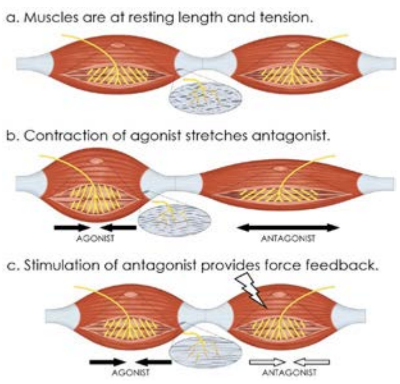
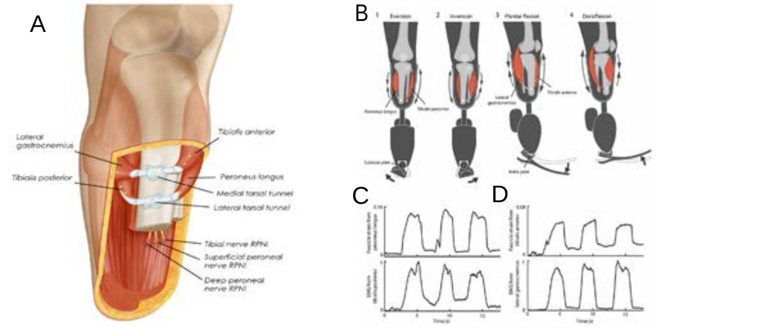
Background and Motivation

Agonist-antagonist Myoneural Interface (AMI)



The AMI has emerged as a methodology to reflect proprioceptive sensations of joint position, speed, and force from a neurally controlled prosthesis onto the nervous system. It is designed on the principle that native physiological mechanotransducers provide the best means of communicating proprioceptive information from a prosthesis to the nervous system. The fundamental AMI paradigm is shown above. One AMI is surgically constructed in the residuum for each prosthetic joint, by 1) rerouting native musculature, 2) connecting neurovascular island flaps, or 3) creating free muscle grafts.

Ewing Amputation Surgery



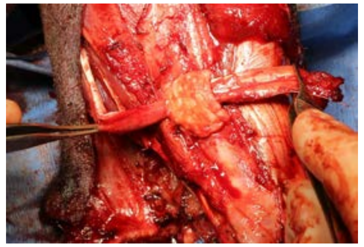
(A) The Ewing Amputation incorporates two AMIs into a primary transtibial amputation surgery. (B) One AMI, comprised of the tibialis posterior and the peroneus longus, is linked to inversion and eversion of the prosthetic subtalar. The other AMI, comprised of the lateral gastrocnemius and tibialis anterior, is linked to plantar and dorsiflexion of the prosthetic ankle. **The AMI muscles are connected through a tarsal tunnel, harvested from the amputated ankle joint.** (C) Inversion of phantom subtalar causes strain the peroneus longus, evidencing coupled motion within the AMI construct. (D) Plantar flexion of the phantom ankle causes strain in the tibialis anterior.

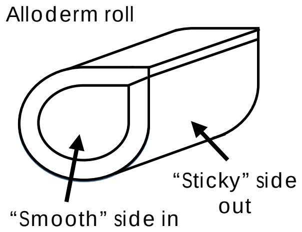
The Challenge

How do we create native AMIs in a patient who does not have usable tarsal tunnels, due to trauma or a prior amputation?

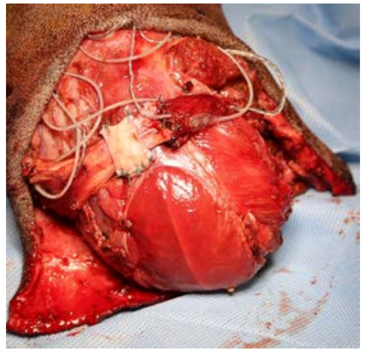
Methods

Alloderm as a Pulley



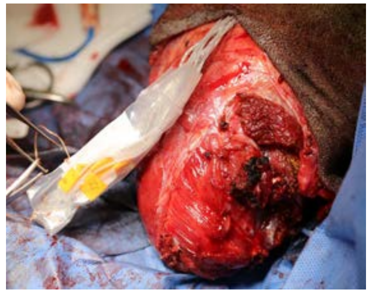


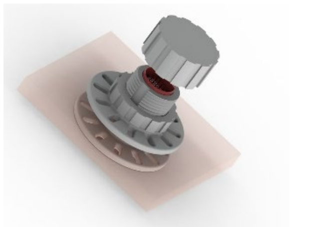
In a large goat model, one AMI was created at the time of primary transtibial amputation. The distal tendon of the *medial gastrocnemius* was passed through a rolled piece of Alloderm, and coapted to the distal *tibialis cranialis*. The Alloderm pulley was then sutured closed, and affixed directly to the surficial fascia via five sutures. Placement of the pulley was selected to preserve biological levels of tension in each muscle.



Implanted Electronics

Sonomicrometer crystals and intramuscular electrodes were placed within each muscle to measure fascicle strain, and electromyography, respectively.

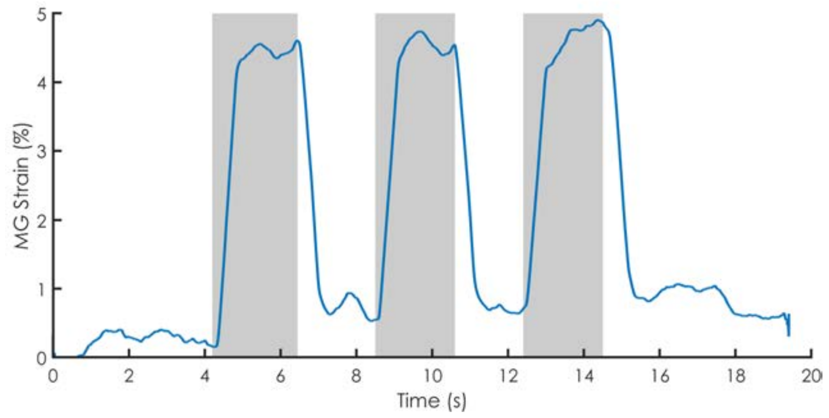




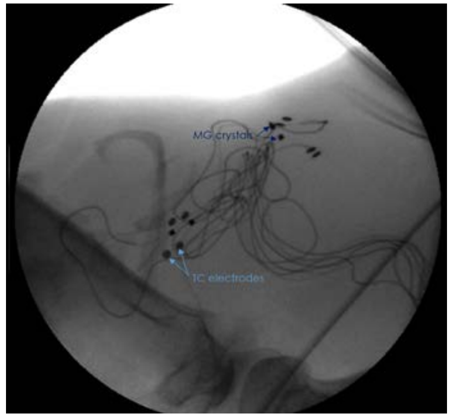
Leads were routed percutaneously through a custom-designed, 3D printed port in the animal's back.

Results

AMI Function

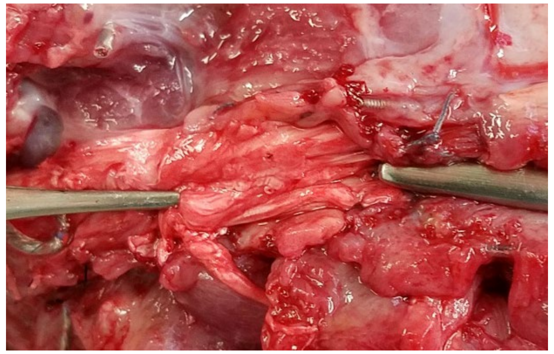


Sonomicrometry data showing stretch in the *medial gastrocnemius* during artificial stimulation of the *tibialis cranialis*. This antagonistic stretch is indicative of AMI excursion. Gray shading shows that stimulation is on (9mA, 400us, 30Hz).

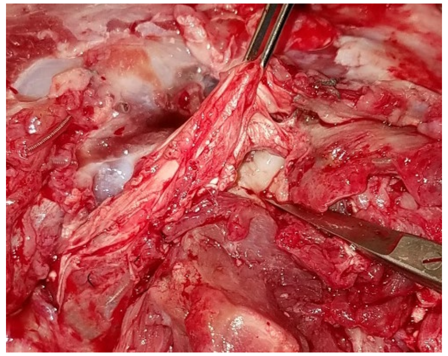


Coupled motion of the AMI muscles was also clearly visible in planar fluoroscopy.

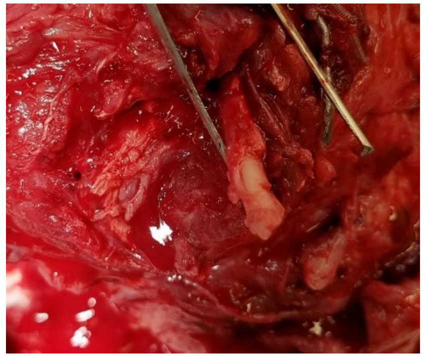
Surgical Outcome



The Alloderm pulley was localized, intact, approximately 3 cm proximal to the initial attachment point.



A clean, lubricious plane was identified between the internal surface of the Alloderm roll and the tendon.



A large osteophyte was also identified in the residual limb. This appeared to be unrelated to the Alloderm pulley.

Conclusion and Future Directions

These findings demonstrate that Alloderm may be used as a substitute for tarsal tunnels in the construction of native AMIs. This new architecture has the potential to broaden the patient population that would benefit from the AMI to include those with limited availability of distal tissues, including persons who have already undergone amputation.