SHORT COMMUNICATION

A Proposal of a Design for the Bionic Hand: Describing the Integration, Motor Controlling System, Stereognosis, and Proprioception Sensory Feedback Components

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Abstract

Despite recent advancements in bionic upper limb prostheses technology, the rejection rate by users remains unacceptably high. Various factors contribute to this issue, such as limited functionality, complex control mechanisms, and discomfort, with most of these concerns being documented solely through self-assessment surveys. In this article, we introduce our proposed four components for an integrated bionic hand aimed at making it closely resemble a natural hand. These components include an integrated intramedullary stem, a kineticomyographic motor control system, sensory feedback for stereognosis, and sensory feedback for proprioception.

Level of evidence: V

Keywords: Bionic hand, Integrated, Kineticomyography, Proprioception, Sensory feedback, Stereognosis

Main body

Integrated Intramedullary Stem: The use of osseointegrated arm implants, especially in cases of transradial amputations, plays a crucial role in enhancing the functionality of myoelectric hand prostheses and restoring the sense of body integrity. Osseointegration systems have also demonstrated their effectiveness in transhumeral and transfemoral amputations. In the forearm, they offer the distinct advantage of reducing the perceived weight of the bionic hand and providing a wider range of motion for activities such as supination and pronation. However, challenges arise when dealing with smaller radius and ulna bones in the forearm. These challenges necessitate the development of a new osseointegration design, primarily due to the narrow diameter of these bones. Furthermore, variations in the curvature of the radius and ulna bones affect the design of a universal nail. Additionally, addressing the complexities of the two-bone structure, radial head laxity, and simulating pivot movement presents another set of challenges that must be overcome in this context. The conventional osseointegration system consists of a threaded titanium implant (the fixture), a skin-penetrating cylindrical implant (the abutment), and a titanium screw (the abutment screw). A novel osseointegration system is introduced with modifications, including proximal screw fixation for rotational stability, a porous coating for better bony ingrowth, and a smaller middle area to enhance flexibility during implant insertion.

Kineticomyographic Motor Controlling System: The conventional method for bionic limb control is through electromyographic (EMG) signals.[1] a novel approach in the field of bionic limbs is the Kineticomyographic Motor Control System. This method offers a precise way to control artificial limbs by detecting the remaining muscle movement in the amputee's leg and forearm. It does so by sensing the specific magnetic field of the implanted magnets at the musculotendinous junction, which is the voluntary movement terminal.[2] additionally, this system introduces a new surgical procedure for implanting magnetic tags in prosthetic hands. This surgical approach involves a two-

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stage flexor-extensor tendon transfer, which increases the magnetic tags' range of motion and enhances limb movement independence, ultimately improving the signal-to-noise ratio.[3]

Stereognosis Sensory Feedback System: We are introducing an innovative concept aimed at developing stereognosis sensory perception for artificial limbs. This idea enables individuals with limb loss to feel and identify the shape and form of solid objects through the stimulation of their skin's tactile sensory receptors. We are currently in the process of patenting this project.[4] the stereognosis module consists of internal magnetic tags and external electromagnetic coils. These internal tags are placed beneath the skin, in the forearm's hypodermis. According to the skin's two-point discrimination, magnetic tags are organized in a matrix pattern on a surgical mesh sheet. The activation of specific magnetic tags in the subcutaneous tissue is synchronized with the pattern of coil activation. This activation stimulates the nerves, inducing the sense of stereognosis and transmitting it to the brain. Sensors within the limb, whether natural or artificial, detect the environmental stimuli, process the signals, and transfer this data to the designated electromagnetic coil matrix situated at the proximal site of the injury or amputation. Once again, specific magnetic tags in the subcutaneous tissue correspond with the pattern of coil activation. This stimulation engages the nerves, resulting in the perception of stereognosis. This innovative approach holds the potential to significantly improve sensory perception in artificial limbs, offering a more natural and intuitive experience for amputees.

Proprioception Sensory Feedback System: Proprioception is the body's internal sense of self-movement and spatial awareness, enabling coordinated actions and maintaining posture. In amputees, we are introducing proprioceptive sense by inserting inert magnets into residual or pathologic muscles. These magnetic tags are externally controlled by a scaled electromagnetic field, allowing the precise manipulation of muscle movements to trigger spino-muscular reflexes and maintain balance. The proprioception module consists of a single magnetic tag placed within a specific muscle, complemented by a row of external electromagnetic coils on the skin. The muscle tag is strategically positioned at the musculotendinous junction, while the external magnetic row aligns with the muscle's longitudinal axis, creating a magnetic field aligned with muscle movement. By controlling the magnetic intensity (for adjusting tag speed), duration, polarity (for pushing or pulling), and magnetic field length (for tag distance from the starting point), the muscle contracts or relaxes proportionally to the tag's movement. This stimulation activates the muscle spindle, generating neural signals that are transferred to the central nervous system. The proprioceptive sense ideally resides within the target limb, while stereognosis can be located in another adjacent site with an acceptable two-point discrimination size. For example, in a distal forearm-level amputation, which is a prevalent upper extremity amputation level, we have designated the internal surface of the arm for the insertion of stereognosis module magnets and that of the forearm for proprioception.

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