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Introducing the Starfish Procedure

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Novel muscle transfer technique enables patients to have improved control of a myoelectric prosthesis

Significant advancements have been made in upper extremity prosthetics in recent years. Yet, the goal of independent digital control remains elusive, given the limitations of the human-prosthesis interface. Surface myoelectric signals must be detectable to power these prosthetics, and patients with partial or total hand amputations usually lack the requisite number of functioning, detectable muscles. As a result, patients often abandon use of current myoelectric hand prosthetics due to the unnatural and nonintuitive ways of controlling them.

The starfish hypothesis

Patients with partial hand amputations often still have innervated interosseous muscles. Their deep position in the hand, however, means that surface electrodes cannot detect signals generated by their contractions.

We wondered whether these muscles could serve as myoelectric signals for a patient with a partial hand amputation—if they could be transposed to the dorsum of the hand without injuring the associated neurovascular bundles. If so, would the result be a highly intuitive prosthesis since the interossei naturally initiate finger flexion? Could this concept be applied at an even more proximal level?

Naming the starfish

We first undertook a cadaver study to validate the ability to transpose the interossei while preserving the neurovascular bundles. In this study, we were able to mobilize all of the hand's intrinsic muscles as a group, up to the mid-forearm level, while maintaining their neurovascular pedicles.

When all interossei, along with the thenar and hypothenar musculature, were raised simultaneously with their pedicles, the resultant appearance was that of a starfish (Fig. 1). This appearance, coupled with the starfish's unique ability to regenerate lost limbs, led us to term this surgery the starfish procedure.

Fig. 1 *Image of a cadaver dissection of all of the hand intrinsic muscles with their neurovascular pedicles. It is noted to resemble the shape of a starfish.*
Courtesy of R. Glenn Gaston, MD, and Bryan J. Loeffler, MD

The starfish procedure

This procedure requires that the viability and functionality of the interosseous muscles must be confirmed prior to surgery (Fig. 2). This can be done either in the operating room at the time of initial injury or by a preoperative EMG. After viability and functionality are confirmed, the desired metacarpals are exposed and the terminal 3 cm of each metacarpal is resected to allow sufficient room for the prosthetic componentry and to make the prosthetic digits match the natural finger lengths.

Fig. 2 *Preoperative image of a right hand that has sustained a partial amputation with only the thumb remaining. All fingers have been amputated through the MP joints.*
Courtesy of R. Glenn Gaston, MD, and Bryan J. Loeffler, MD

The desired interossei are then elevated in a distal-to-proximal direction from the metacarpal and transferred dorsally on the metacarpal. The volar plate and flexor tendon sheath are then elevated and rotated dorsally to serve as an interposition between the transferred interossei (Fig. 3). This creates a buffer between the individual interosseous muscles, which minimizes cross-talk between the transferred muscles and allows cleaner signal detection.

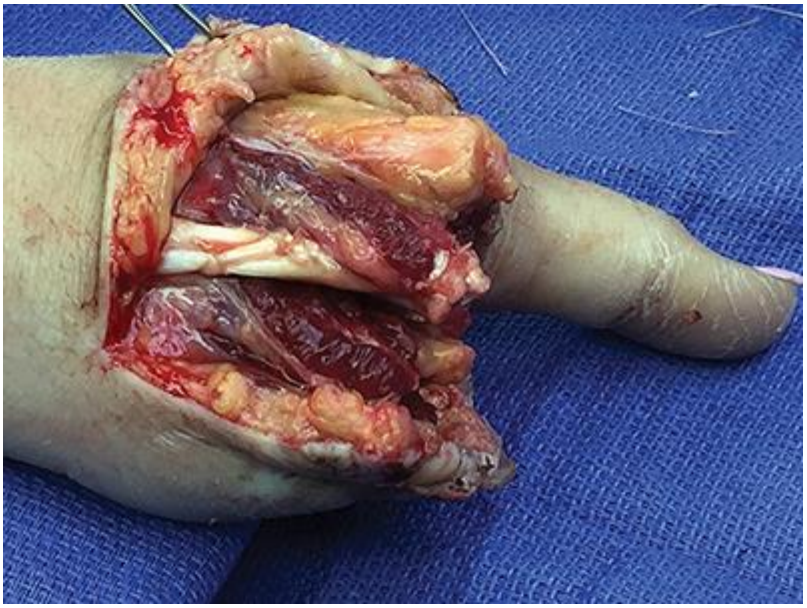

Fig. 3 *Intraoperative photograph demonstrating interossei transfers of the long and ring finger to the dorsal aspect of the hand to allow future signal detection for myoelectric prosthetic use. Courtesy of R. Glenn Gaston, MD, and Bryan J. Loeffler, MD*

With this technique, each preserved interosseous muscle will contract when the patient attempts to initiate flexion of the corresponding finger. The muscle contraction generates a myoelectric signal that can be detected by a surface electrode, which transmits the signal to the prosthetic digit. When the prosthetic digit receives that signal, it flexes—thus producing the patient's desired function. Because each transferred muscle corresponds to a single finger and each muscle has its own sensor and prosthetic finger, individual digital control is possible.

Results

At the OrthoCarolina Reconstructive Center for Lost Limbs, we have now performed seven starfish procedures for partial hand amputee patients who have lost two to four fingers. In all cases, robust palpable and detectable signals were detected immediately following surgery. Patients demonstrated the ability to naturally control each prosthetic finger in a highly intuitive manner even at the 2-week postoperative visit.

The first surgery was performed more than two years ago, and the patient is now capable of natural independent finger motion. He can perform acts as delicate as picking a flower and as robust as lifting a 20-lb dumbbell. He is the first patient to have individual digital control of a prosthetic following a partial hand amputation.

What's next?

The starfish procedure enables the transferred dorsal interossei muscles with flexor sheath interposition, in combination with a hypothenar signal, to provide independent signals to power individual digital control of a myoelectric hand prosthesis. This concept of salvaging muscles with their remaining nerve and blood supply from a mangled extremity and transferring them into a more proximal location during amputation has the potential to markedly enhance available signals for myoelectric detection and hence function.

This technique has the potential to create similar individual digital control for even more proximal level amputations, as demonstrated in our cadaveric study, including the possibility of a myoelectric hand with all five digits capable of independent control. The starfish procedure could potentially be performed at the level of a distal forearm amputation. The opportunity to salvage muscles that retain their nerve and blood supply and transfer them proximally into the residual limb to allow increased highly intuitive myoelectric signals has broad potential applications for improved prosthetic function.

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