Free Flap Functional Muscle Transfers

Ryan M. Garcia, MD[a,*], David S. Ruch, MD[b]

KEYWORDS

- Free • Functional • Muscle • Flap • Transfer

KEY POINTS

- Free functional muscle transfers remain a powerful upper extremity reconstructive option when other local transfers are unavailable.
- Selection of the donor motor nerve remains challenging, particularly following brachial plexus injuries.
- The gracilis muscle is most commonly used as the donor given its functional capacity, ease of harvest, and disguised donor site.
- Variable outcomes have been reported following free functional muscle transfers that are related to donor motor nerve availability and reinnervation.

INTRODUCTION

Upper extremity functional muscle loss secondary to brachial plexus injuries, ischemic muscle loss, traumatic injuries, oncologic resections, or congenital absences can be life altering and may severely limit a patient's ability to perform activities of daily living. More commonly, upper extremity functional losses are reconstructed with local muscle and tendon transfers.[1] Alternatively, upper extremity functional losses also can be treated by performing a neurotization procedure that entails using some or all fascicles of an intact donor motor nerve and transferring the afferent signal to a distal recipient nerve with a viable, available muscle.[2] Less commonly, patients who are not candidates for a tendon, local pedicled muscle, or nerve transfer may be considered for a functional free muscle transfer to restore elbow flexion, finger and wrist flexion, and/or finger and wrist extension.

Functional free muscle transfers were first explored in dogs and reported by Tamai and colleagues in 1970.[3] Terzis and colleagues[4] later showed in a rabbit model that only one-fourth of the rectus muscle function was retained after free muscle transfer and replantation. These findings were later challenged in 1986 by Stevanovic and colleagues[5] in a canine study that demonstrated 70% of the transplanted muscle function could be achieved following the free muscle transfer. Regarding upper extremity functional muscle transfers, Manktelow and McKee[6] were the first to report on 2 cases (1 gracilis muscle, 1 pectoralis major muscle) to restore finger flexion after traumatic injuries in what were reported to be excellent outcomes. Ikuta and colleagues[7] shortly thereafter reported a free gracilis muscle transfer to restore elbow flexion in a patient with brachial plexopathy.

PATIENT SELECTION

Stevanovic and Sharpe[8] provided a number of guidelines for appropriate patient selection before performing a free functional muscle transfer. First, patient motivation must be assessed. Patients need to have an acceptable expectation and need to be compliant with the planned postoperative course, which entails extensive and complex

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[a] OrthoCarolina, Division of Hand Surgery, Hand Center, 1915 Randolph Road, 2nd Floor, Charlotte, NC 28207, USA; [b] Department of Orthopedic Surgery, Duke University Medical Center, 2301 Erwin Road, Durham, NC 27705, USA
* Corresponding author.
E-mail address: ryan.garcia@orthocarolina.com

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physical therapy rehabilitation. These investigators also recommended an age consideration of 45 years or younger for patients considering this complex reconstruction. Despite this arbitrary age consideration, others have reported excellent outcomes in patients much older.[9] Less has been reported on free flap reconstructions in skeletally immature patients[10–12] and the long-term outcomes in this subgroup of patients remains unknown. Although Terzis and Kostopoulos[13] did show improved outcomes in patients younger than 15 years following free muscle transfer for elbow flexion, these patients should be informed on the potential for asymmetrical growth of the transplanted muscle when compared with the growing skeleton, which could lead to future joint contractures and weakened muscle strength. Stevanovic and Sharpe[8] also highlighted that patients with medical comorbidities compromising vascular microcirculation and nerve reinnervation, such as diabetes, peripheral vascular disease, autoimmune diseases, and smoking, should be contraindicated for free functional muscle transfers.

HIERARCHY OF FUNCTIONAL RESTORATION

The hierarchy of functional restoration for the upper extremity remains elbow flexion,[1] finger flexion, and finger extension allowing patients to improve their ability to perform vital activities of daily living. Ideally, the general tendon transfer principle of using a single muscle to provide a single function applies to free functional muscle transfers. Despite this, when there is a paucity of donor motor nerves to power multiple free functional muscles in a single limb, then a single muscle may be used to accomplish multiple functions. Hattori and colleagues and Doi and colleagues,[14–17] in a series of articles, reported the use of a double free muscle transfer in which 1 muscle was used to provide both elbow flexion and wrist extension while the second muscle transfer was responsible for finger flexion. These investigators reported good-to-excellent outcomes in most patients, which included both children[14] and adults.[15–17] In the series of patients with long-term follow-up, 25 (96%) of 26 patients were determined to have good-to-excellent elbow flexion and 17 (65%) of 26 had good-to-excellent hand prehension capabilities.[16] Most investigators use the British Medical Research Council Grading System to report preoperative and postoperative outcomes and are referenced throughout this article.

RECIPIENT SITE

Many of the established tendon transfer principles also apply to the use of free functional muscle transfers. These principles include the following: the use of a single muscle/tendon to provide a single function, confirming that the joint involved in the transfer is as supple as possible having maximized passive range of motion capabilities, the muscle should be oriented to provide a straight line of pull to maximize the muscle effect on the joint, an adequate muscle antagonist should be present, optimization of the synergistic effects of distal joints whenever possible, and the soft tissue bed should be adequate to support the muscle while also allowing the tendon to glide. Stevanovic and Sharpe[8] further expand these requirements for free functional muscle transfers to include an adequate donor motor nerve and available vessels for microsurgical anastomosis. The available donor motor nerve should be expendable, have a maximized number of axons, and should be of adequate length (often increased with nerve grafts) to allow a tension-free coaptation.

Additional surgical interventions may be necessary before the free functional muscle transfer. Patients who do not demonstrate adequate passive range of motion may require a joint capsulotomy/capsulectomy and contracture release or extensive tenolysis followed by an extended period of aggressive physical therapy. The soft tissue bed also can be optimized to allow eventual tendon gliding. This may require resection of scar tissue and soft tissue rearrangement procedures before the microsurgical reconstruction.

DONOR MOTOR NERVES

The donor motor nerves available for neurotization can be challenging, particularly in patients with complete brachial plexus injuries. In contrast, patients who undergo a functional free muscle transfer after a Volkmann contracture, traumatic injury, or oncologic resection often have various local donor motor nerves readily available. When possible, it is preferred to choose the donor nerve with the same or similar function as the anticipated free muscle transfer. In scenarios in which the donor motor nerve is chosen from a very distant site, it is advised that the nerve is established and allowed to mature before the free functional muscle transfer. Terzis and Kostopoulos[13] demonstrated this principle in a large series of patients who underwent free muscle transfers after post-traumatic brachial plexopathies to restore elbow function and hand function.[18] The distant donor motor nerve was chosen, nerve grafts coapted, and tunneled to the “banked” recipient site during the first stage of the reconstruction. The second stage consists of transferring the free functional muscle, which typically occurs 6 to 9 months later