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Reconstructive

Functional Chimeric Double-barrel Fibula and Reinnervated Peroneus Brevis Osteomyocutaneous Flap for One-stage Forearm Reconstruction

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Summary: Reconstructing a mangled limb is complex and requires expertise in both bone and soft-tissue reconstruction, particularly when there is significant muscle loss. Typically, multistage surgery is necessary, starting with soft-tissue coverage, followed by bone grafting and tendon transfers. Sometimes, microsurgical techniques such as vascularized bone grafts and free functional muscle transfers are necessary, especially when there is a bone defect of over 6 cm; the soft-tissue environment is infected, scarred, or poorly vascularized; or there are extensive musculotendinous injuries. We treated a 34-year-old man who had a crushed left forearm resulting in an 18×8 cm open wound, 5-cm radius and 7-cm ulna bone defects, loss of the extensor pollicis longus and brevis muscles, and extensive injuries to the other musculotendinous structures of the forearm. To accomplish a one-stage reconstruction, we used a chimeric fibula osteomyocutaneous flap that included a 20×10 cm skin flap, peroneus brevis muscle with its motor nerve, and two segments of fibula. The proximal and distal fibula segments were used for ulnar and radial bone reconstruction, respectively, preserving forearm supination and pronation. The peroneus brevis tendon was sutured to the extensor pollicis longus tendon, and its motor nerve was coaptated with the posterior interosseous nerve to restore thumb extension. The skin flap provided complete coverage of all exposed bone and tendon structures. At the 12-month follow-up, the patient regained full extension of the thumb, and there were no difficulties with forearm supination and pronation or with foot eversion and plantar flexion at the donor leg.
(Plast Reconstr Surg Glob Open 2023; 11:e5182; doi: 10.1097/GOX.0000000000005182; Published online 9 August 2023.)

INTRODUCTION

Initially introduced for traumatic bony defects in the lower extremity, the free vascularized fibula has since been used for upper extremity reconstruction.[1–3] The size and shape of the fibula closely resemble those of the diaphysis of the radius and ulna, making it an ideal donor for reconstructing significant bone loss in the forearm.[4] For segmental defects of both the radius and ulna, a "double barrel" vascularized fibula for simultaneous reconstruction, instead of one-bone forearm reconstruction, has been suggested to preserve forearm rotation.[5,6]

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Received for publication May 9, 2023; accepted June 27, 2023.

DOI: 10.1097/GOX.0000000000005182

However, reconstructing a severely damaged forearm often requires not only bone but also soft-tissue reconstruction. Traditionally, this has been done in multiple stages, but the functional results have been disappointing due to severe adhesion between the musculotendinous units. To address this issue, a one-stage chimeric fibular flap was developed for upper extremity reconstruction.[7] Additionally, success has been achieved by using the lateral soleus or flexor hallucis longus as functional muscles.[8,9]

The use of peroneus brevis as a functional muscle was initially experimented in a rabbit model.[10] Later, its clinical application was successfully introduced as a third component in the fibula osteomyocutaneous flap to reconstruct the radius and flexor carpi radialis, following a better understanding of the anatomic location

Disclosure statements are at the end of this article, following the correspondence information.

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of the branching point and motor entry point of the superficial peroneal nerve to the peroneus longus and brevis muscles.[11,12] In this study, we present the first case where a chimeric fibula osteomyocutaneous flap was used, including a large skin paddle, a reinnervated peroneus brevis muscle, and a double-barrel vascularized fibula, to achieve skin, extensor pollicis longus, and both radial and ulnar bone reconstruction in a single stage.

CASE REPORT

A 34-year-old man sustained a severe crushing injury to his left forearm, resulting in comminuted open fractures of the radius and ulna, as well as loss of wrist and digit extension, and weakness of wrist and digit flexion. Emergency treatments, including external skeletal fixation and repair of all the extensors at zone VIII and flexor digitorum superficialis of the index and middle fingers at zone V, were performed. Unfortunately, the crushed soft tissue showed progressive necrosis, revealing the devitalized bone fragments. After serial debridement, the forearm had an 18×8 cm open wound, 5-cm radius, and 7-cm ulna bone defects, and muscle loss of the extensor pollicis longus/brevis and extensor indicis proprius. (**See figure, Supplementary Digital Content 1,** which displays (a) radiography showing bone defects in the radius and ulna. (b) The distal stump of the severed extensor hallucis longus is identified. (c) The stump of the posterior interosseous nerve is identified. (d) Creation of the arteriovenous loop prior to transfer of the chimeric fibular flap, **http://links.lww.com/PRSGO/C714**.)

On posttraumatic day 52, we planned to address all the injuries at once. First, we created an arteriovenous loop from the branch of the ulnar artery to the cephalic vein at the elbow level using a 25-cm-long saphenous vein graft. The loop was placed through a subcutaneous tunnel to reach the forearm wound. Next, we harvested the left fibula osteomyocutaneous flap carrying the peroneus brevis muscle (Fig. 1). The distal musculotendinous portion

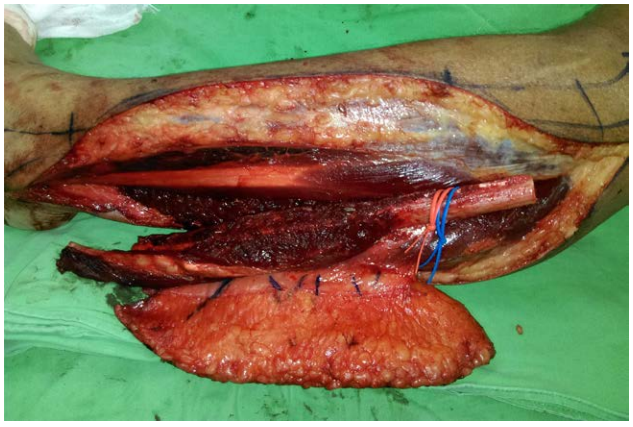

Fig. 1. Chimeric fibula-peroneus brevis osteomyocutaneous flap.

Takeaways

Question: Functional reconstruction of the forearm with two bone defects and muscle loss.

Findings: A chimeric osteomyocutaneous flap with a double-barrel fibula to reconstruct the radius and ulna and a reinnervated peroneus brevis muscle to restore the extensor pollicis longus function was introduced.

Meaning: We present a novel technique to accomplish double bone reconstruction with simultaneous functional muscle transfer to the mangled forearm.

was transected at the lateral malleolar level, and the distal tendon stump was sutured to the peroneus longus tendon for synergistic foot eversion and plantar flexion. The proximal muscle portion was dissected off the peroneus longus, and its motor nerve was included and divided at its branching point from the superficial peroneal nerve.

The fibula was osteomized to create two segments. The proximal segment was fixed to the ulna, and the distal segment was fixed to the radius using plates and screws. The peroneus brevis tendon was sutured to the extensor pollicis longus tendon at the wrist, metacarpophalangeal, and interphalangeal joints in maximal extension and adjusted according to the tenodesis effect. The motor nerve was coaptated to the posterior interosseous nerve, with the anastomosis site as close to the muscle as possible. The created arteriovenous loop was divided and anastomosed to the flap pedicle. The operation was completed after the skin flap was inset (Fig. 2).

The patient had an uneventful recovery, and experienced no complications at the donor site. There were no difficulties with foot movement, including plantar flexion and eversion. At the 6-month follow-up, partial extension of the left thumb's metacarpophalangeal and interphalangeal joints had been regained, and by the 12-month follow-up, full extension had been achieved, along with restoration of forearm pronation and supination (Figs. 3 and 4). (**See Video 1 [online]**, which displays the 4-year follow-up, at which the patient demonstrated a full range of motion in forearm supination and pronation.) (**See Video 2 [online]**, which displays the 4-year follow-up, at which the patient demonstrated full extension of the thumb and visible muscular contraction under the skin of the fibular flap.)

DISCUSSION

Preserving functional limbs after trauma or tumor removal is challenging and requires both soft-tissue and bone reconstruction. A multistage approach is typical, starting with good soft-tissue coverage and a cement spacer after removing damaged bone. Then, the spacer is removed, and a bone graft is implanted.[13] For larger or complicated defects, vascularized bone grafts may be recommended.[2,3] If there is muscle loss, simpler options like local muscle transfers should be tried first, but free

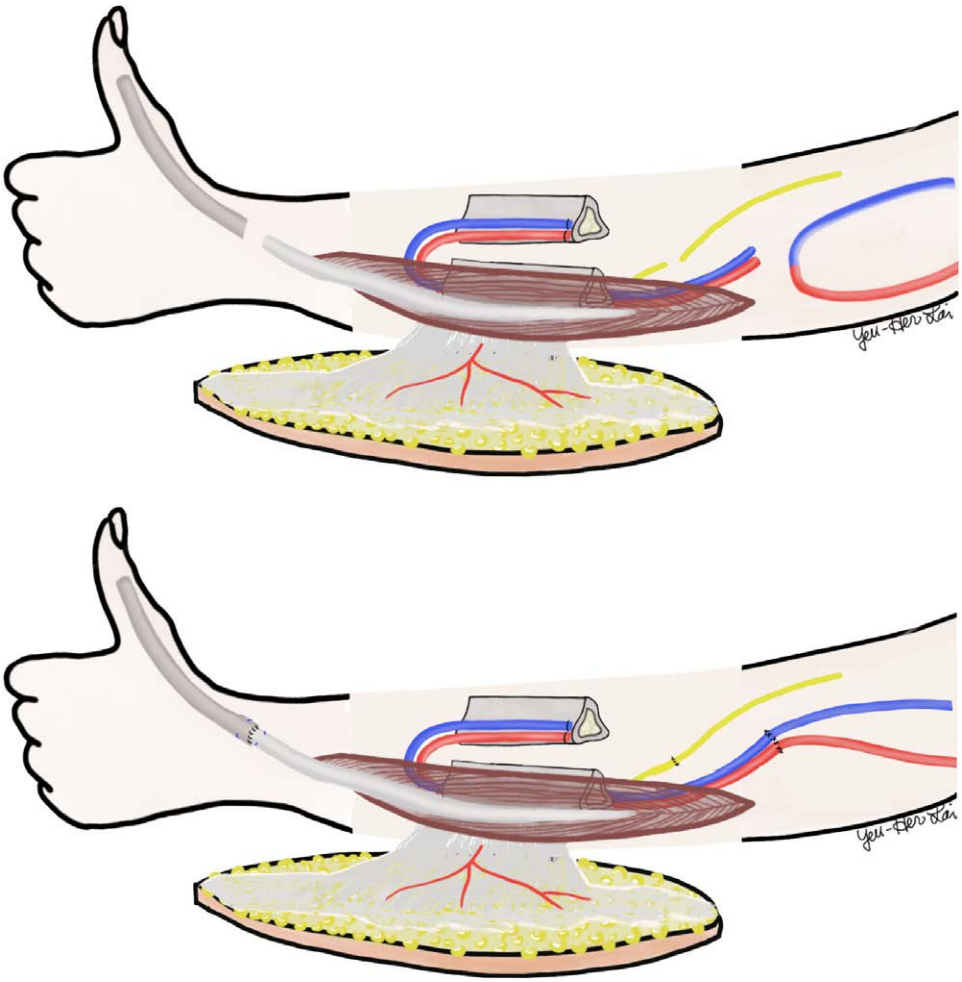

Fig. 2. Illustration of the reconstruction.

Fig. 3. At the 12-month follow-up, full extension of the left thumb's metacarpophalangeal and interphalangeal joints had been regained.

functional muscle transfers may be required for severe tissue damage.[14]

In our case, the forearm sustained significant damage with open wounds, segmental loss of bones, and loss of muscle function. Although multistaged surgery is an option, the extent of the damage can hinder recovery. One-stage reconstruction using a chimeric fibula flap with reinnervated muscle would be ideal but is sophisticated. There are only four similar cases reported. In 1992, Chuang et al used the fibula for a 16-cm radial bone defect and reinnervated lateral soleus muscle for extensor pollicis longus and extensor digitorum communis muscle loss.[8] In 2002, Schoeller et al used the fibula for a 14-cm humeral bone defect and reinnervated flexor hallucis longus muscle for brachial muscle loss.[9] In 2013, Giessler and Schmidt used a 15-cm-long fibula for a radial bone defect and reinnervated peroneus brevis muscle for the flexor carpi radialis muscle loss.[12] In 2015, Blanc et al used a 15-cm-long fibula to bridge the proximal ulna to distal radius to achieve one-bone forearm reconstruction for the segmental loss of both the radius and ulna.[15] The reinnervated soleus muscle was used for wrist and finger extension. However, none of these performed simultaneous reconstruction of the radius and ulna with a double-barrel fibula like we did. We have further expanded its use in the forearm reconstruction with preservation of forearm rotation and restoration of thumb extension by using a functional

Fig. 4. Radiographic images after 26 months.

chimeric double-barrel fibula and reinnervated peroneus brevis osteomyocutaneous flap.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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