

Multi-Segmental Osteocutaneous Free Fibula Flap for Three-Dimensional Post-Traumatic Thumb and Wrist Reconstruction

Jack D. Sudduth, Shireen Dogar, Narges L. Horriat, Marc E. Walker*

Division of Plastic and Reconstructive Surgery, Department of Surgery, University of Mississippi Medical Center, Jackson, MS, USA

Email: *mwalker6@umc.edu

How to cite this paper: Sudduth, J.D., Dogar, S., Horriat, N.L. and Walker, M.E. (2023) Multi-Segmental Osteocutaneous Free Fibula Flap for Three-Dimensional Post-Traumatic Thumb and Wrist Reconstruction. *Modern Plastic Surgery*, 13, 23-31. <https://doi.org/10.4236/mps.2023.131003>

Received: November 1, 2022

Accepted: January 13, 2023

Published: January 16, 2023

Copyright © 2023 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Thumb reconstruction following a traumatic injury challenge depends on the extent of the injury. Ideally, reconstruction should restore thumb length and position and retain thumb stability, mobility, and strength, while preserving sensation and aesthetics. Achieving these outcomes can be especially challenging in severe cases of soft tissue and bony loss. The authors present a case of a 20-year-old right-hand dominant female involved in a motor vehicle accident who sustained severe crush injuries and burns to her right hand. Her injuries included soft tissue and bony defects extending from the thumb to the distal radius, namely avulsion of the thumb and significant loss of the distal radial and carpal column, resulting in severe wrist instability. We employed a three-segment vascularized osteocutaneous fibula flap to reconstruct the thumb and wrist to restore bony construct, carpal support, and soft tissue coverage. Thumb motion could not be achieved, but this technique offered a sensate, functional post for opposition and the appearance of an anatomic hand. Because of this surgery, the patient was enabled to graduate from college and pursue full-time employment. The authors hope that this report will add to the fund of knowledge and surgeon armamentarium for similar devastating injuries demanding thumb and wrist reconstruction.

Keywords

Thumb Reconstruction, Wrist Reconstruction, Microvascular Reconstruction, Free Fibula Flap, Thumb Amputation

1. Introduction

Thumb and wrist reconstruction in the setting of traumatic amputation requires

complex surgical planning, beginning with early and aggressive debridement [1]. Of the options available for reconstruction, the vascularized free fibula flap (FFF) has been described as the best overall choice for traumatic injuries [2] [3] [4]. Taylor *et al.* first reported successful free vascularized bone transfer in 1975 [5]. In 1986, Wei *et al.* expanded the idea of vascularized bone transfer to include an osteocutaneous flap to provide additional skin coverage when needed [6]. Since then, there have been various applications of the free vascularized osteocutaneous fibula flap, the most notable of which has been the reconstruction of long, segmental bone defects [3].

FFF is used following tumor resection in most case reports of thumb and wrist reconstruction [7] [8]. Reconstruction following oncologic resection for tumor ablation is designed based on bony and soft tissue defects that are surgically planned according to necessary oncologic margins. However, traumatic injuries can be more challenging as anatomic structures are not preserved compared to surgically planned cases. Instead, reconstruction is planned based on what remains intact following traumatic tissue loss in these cases. The size of the bony defect, the number of bony segments needed, the presence of soft tissue loss, and the amount of soft tissue coverage required are variable and often unpredictable, often requiring more complex reconstructive decision-making [9] [10].

The FFF is the best reconstructive option for significant bony defects with concomitant soft tissue loss. The bone can be divided into segments that bridge multiple defects—providing three-dimensional reconstruction—and the skin paddle can be tailored for broad soft tissue coverage [11]. Pederson notes that contaminated wounds are best covered with muscle or other vascularized soft tissue, which increases infection resistance due to hypervascularity [1]. Additionally, FFF provides better healing quality and a higher incorporation rate than non-vascularized grafts due to its innate promotion of osteogenesis [2] [3] [4] [12] [13]. Dailiana *et al.* and Humail *et al.* report that the FFF is useful for defects involving the distal radius and hand, as the architecture of the fibula matches that of the proximal carpal row [13] [14]. Problems with the FFF include infection, nonunion, secondary fracture, joint instability, and arthritis, yet, even so, the benefits of FFF still outweigh those of other bone grafts [15]. Thus, this case report describes a multi-segmental osteocutaneous free fibula flap for post-traumatic three-dimensional thumb and wrist reconstruction.

2. Case Report

A 20-year-old, right-hand-dominant female with no past medical history presented to the emergency department following a motor vehicle accident. At the time of presentation, she sustained significant avulsion of the right dorsal radial skin with surrounding full-thickness thermal injury, complete loss of the radial aspect of the distal radius at the radial styloid and scaphoid fossae, displacement of the scapho-trapezio-trapezoid complex and carpometacarpal joint, bony loss of 75% of the thumb proximal phalanx and metacarpal, and an open index me-

tacarpal base fracture (**Figures 1(a)-(c)**). The radial dorsal tips of each distal interphalangeal joint demonstrated full-thickness abrasions, but the remaining skin contained good capillary refill and normal sensation throughout. The flexor digitorum superficialis and profundus were intact to all digits, as were all extensors. The flexor pollicis longus remained intact, and the thumb tip demonstrated sensate volar skin. The thumb extensors and abductors were avulsed, abraded, and unable to be salvaged.

The patient was taken emergently to the operating room for debridement of all devitalized tissue, removal of foreign debris, reduction of fractures, and evaluation of remaining soft tissue and its viability. The distal radioulnar joint was found to be preserved on supination and pronation. However, a significant loss of radial height and radial buttress effect led to severe carpal instability and radial subluxation. After complete debridement, the index finger metacarpophalangeal joint was pinned percutaneously with Kirchner wires, the distal radioulnar dislocation was reduced, and the radiocarpal joint was stabilized with an external fixator (**Figure 2**). Finally, the wound was temporized with a loose approximation of remaining skin, and a negative pressure dressing was placed over the remaining open wounds.

Given the patient's injuries, much consideration was taken in determining a reconstructive course that would allow for a maximal functional and aesthetic outcome. Ultimately, we planned a complex reconstruction of the thumb and distal radius with a multi-segment osteocutaneous free fibula flap. Osteotomies were measured and planned to achieve optimal shape and position of the thumb using contralateral radiographs and digital planning using 3D CT imaging (**Figure 3**). Before reconstruction, we irrigated and debrided any residual devitalized tissue and ensured a clean and healthy wound bed (**Figure 4**). A free fibula flap was then marked and harvested from the ipsilateral leg (**Figure 5(a) & Figure 5(b)**). Three segments of vascularized bone based on the peroneal artery pedicle were created using these osteotomies, starting distally with a 2 cm segment for the proximal phalanx, followed by a 4 cm segment for the thumb metacarpal and a 3.5 cm segment for the reconstruction of the radial carpal column. An additional 3 cm segment of bone graft was harvested from the fibula to restore the radial styloid as a buttress for the carpus (**Figure 6**).

The neo-thumb was secured with plates into an anatomic position onto the remaining native bony segments, and the new carpal construct (most proximal segment) was secured to the ulnar carpus with two compression screws. The bone graft was secured to the remnant radius to serve as a radial buttress to prevent radial translation of the carpus. Vascular anastomoses were made from the flap pedicle to the radial artery and a superficial vein. The skin paddle was used to cover the bony construct and all vital structures, while a split-thickness skin graft was used to cover the remaining soft tissue defect (**Figure 7**). The vascularized skin flap and native muscle covered all bone, hardware, and neurovascular structures. An implantable doppler was placed around the artery for flap monitoring.



Figure 1. (a) Right radial wrist demonstrating intact volar thumb soft tissue; (b) Right radial wrist on presentation with debris and cross contamination; (c) Radiograph of right hand on presentation demonstrating significant loss of distal radius and destruction of thumb metacarpal and radial carpal bones.



Figure 2. Status post initial debridement, external fixation for stability of hand and wrist, partial soft tissue closure.

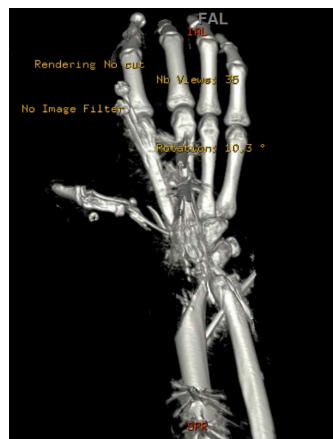


Figure 3. Computed tomography 3D reconstruction of right hand.

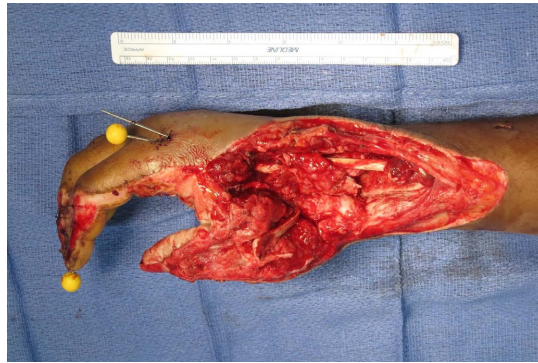


Figure 4. After irrigation and debridement, demonstrating a healthy wound bed.



Figure 5. (a) Free fibula flap marking and skin paddle design from ipsilateral lower leg; (b) Free fibula flap after dissection.



Figure 6. Intraoperative fluoroscopic lateral view after bony reconstruction with free fibula flap.

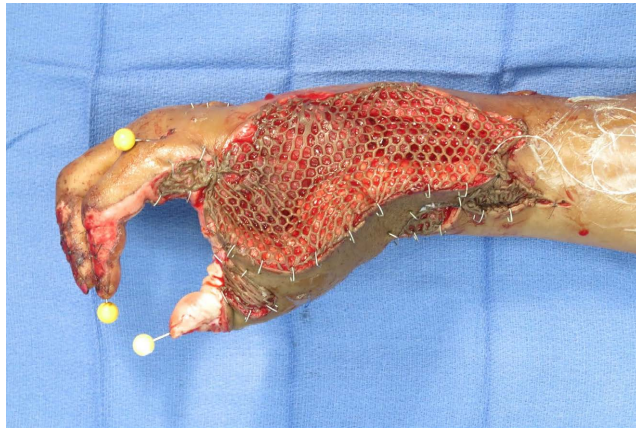


Figure 7. Closure and coverage after microvascular anastomosis to the proximal radial artery and inset and fixation of osteocutaneous construct.

Over the subsequent days, the skin paddle suffered from venous congestion; however, the bone and muscle remained vascularized. Despite multiple attempts at salvaging the skin paddle, this was eventually taken back to the operating room and debrided. A salvage groin flap was employed to provide skin coverage and protect the bony construct of the wrist, which was ultimately successful. After the flap was separated and allowed time to heal, the patient underwent extensive hand therapy. At her one year follow-up appointment, she maintained a sensate and functional thumb with an index-thumb pinch. She graduated from college, returned to driving, and began working full-time.

3. Discussion

The importance of the thumb is well-documented in the surgical literature. According to the AMA Guides to the Evaluation of Permanent Impairment, thumb amputation results in 40% loss of hand function, while amputation of the index or long finger accounts for only 20% loss of hand function [16]. The thumb's vital role in hand function is attributed to its unique ability to flex across the palm's width [17]. It maintains this extensive range of motion because the thumb only has two phalanges, a short metacarpal, and a saddle-shaped carpometacarpal joint. When trauma and destructive changes are introduced to this joint, it inevitably affects the posture and function of the entire hand. For carpometacarpal joint destruction, stability of the thumb is more critical than functional movement [17]. Addressing the complexities of thumb injuries is paramount to restoring the hand's functionality and improving the patient's quality of life.

Hand trauma occurs frequently and represents a significant portion of non-fatal injuries requiring medical intervention. The global incidence of hand trauma has been unchanged since 1990, with thumb amputation accounting for the most significant burden of disability internationally [18]. With the high incidence and morbidity associated with thumb trauma, it is essential to define reconstructive objectives. Pet *et al.* state that reconstructive goals should seek to

restore thumb length, strength, position, stability, mobility, sensation, and aesthetics [19]. Reconstructive methods are based on two thumb injury classifications: defects and amputations. The primary objective of thumb defect reconstruction is to resurface or replace damaged components, whereas the reconstructive goal for thumb amputation is to restore with replantation, and often these objectives of reconstruction overlap. For example, a thumb amputation with a substantial volar pulp defect may require replantation and flap coverage for skin resurfacing [20].

A functional thumb should be stable enough to perform pulp-to-pulp or tripod pinch for fine object manipulation and hand-digital cylinder grasp for larger objects. These functional demands require a post for opposition that rests outside the plane of the palm. There needs to be sufficient length to oppose the remaining digits, mobility of all joints involved in opposition, adequate sensation for pulp pinch, and acceptable aesthetic appearance when reconstructing the thumb.

A recent case report by Graham *et al.* demonstrated a similar approach to thumb reconstruction. [21] Their patient had disruption of the thumb's metacarpophalangeal joint and were able to successfully restore the joint's form a function with preserved sensation using a vascularized FFF. In the current case, the authors describe a traumatic injury extending proximally from the thumb to the distal radius. This injury created a combination of functional demands, including the restoration of 1) wrist stability, 2) thumb length, 3) thumb position, and 4) aesthetic appearance. A multi-segmental free fibula flap construct was designed to recreate the functional position of the thumb and stability of the wrist. While full functionality of the thumb could not be preserved, this reconstructive approach allowed for an anatomic-appearing hand with a sensate thumb and restoration of index-thumb pinch and opposition. Given the severity of the injury, the overall outcome of the reconstruction was considered successful as we achieved stable bony construct and soft tissue coverage and avoided more proximal surgical amputation of the hand.

4. Conclusion

A free fibula flap is a viable option for post-traumatic total thumb and wrist reconstruction. This technique allows for a sensate post for opposition and a normal hand aesthetic.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Informed consent was obtained from all patients to be included in the study. Additional informed consent was obtained from all patients for which identifying information is included in this article.

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national)

and with the Helsinki Declaration of 1975, as revised in 2008 (5).

References

- [1] Pederson, W.C. (2001) Upper Extremity Microsurgery. *Plastic and Reconstructive Surgery*, **107**, 1524-1537. <https://doi.org/10.1097/00006534-200105000-00034>
- [2] Simsek, T., Engin, M.S., Demir, A., *et al.* (2012) Reconstruction of Hand Injuries with Multiple Metacarpal Defects Using Free Fibular Osteoseptocutaneous Flap. *Microsurgery*, **32**, 520-526. <https://doi.org/10.1002/micr.21977>
- [3] Daniel, R.K. and Weiland, A.J. (1982) Free Tissue Transfers for Upper Extremity Reconstruction. *Journal of Hand Surgery—American Volume*, **7**, 66-76. [https://doi.org/10.1016/S0363-5023\(82\)80017-8](https://doi.org/10.1016/S0363-5023(82)80017-8)
- [4] Korompilias, A.V. and Soucacos, P.N. (2009) Vascularized Bone Grafts in Trauma and Reconstructive Microsurgery, Part 1. *Microsurgery*, **29**, 337-341. <https://doi.org/10.1002/micr.20673>
- [5] Taylor, G.I., Miller, G.D. and Ham, F.J. (1975) The Free Vascularized Bone Graft. A Clinical Extension of Microvascular Techniques. *Plastic and Reconstructive Surgery*, **55**, 533-544. <https://doi.org/10.1097/00006534-197505000-00002>
- [6] Wei, F.C., Chen, H.C., Chuang, C.C. and Noordhoff, M.S. (1986) Fibular Osteoseptocutaneous Flap: Anatomic Study and Clinical Application. *Plastic and Reconstructive Surgery*, **78**, 191-200. <https://doi.org/10.1097/00006534-198608000-00008>
- [7] Anderson, I.B., Gilmour, A., Rahman, K.M.A., *et al.* (2013) Thumb Reconstruction Using a Free Osseocutaneous Fibular Flap Following Excision of an Epithelioid Haemangioendothelioma. *European Journal of Plastic Surgery*, **36**, 391-394. <https://doi.org/10.1007/s00238-013-0811-x>
- [8] Hein, C., Watkins, B. and Zuckerman, L.M. (2016) Thumb Reconstruction with Arthrodesis to the Second Metacarpal Following Sarcoma Excision. *Case Reports in Orthopedics*, **2016**, Article ID: 8061036. <https://doi.org/10.1155/2016/8061036>
- [9] Yajima, H., Tamai, S., Ono, H., *et al.* (1999) Free Vascularized Fibula Grafts in Surgery of the Upper Limb. *Journal of Reconstructive Microsurgery*, **15**, 515-521. <https://doi.org/10.1055/s-2007-1000131>
- [10] Akin, S., Ozgenel, Y. and Ozcan, M. (2002) Osteocutaneous Posterior Interosseous Flap for Reconstruction of the Metacarpal Bone and Soft-Tissue Defects in the Hand. *Plastic and Reconstructive Surgery*, **109**, 982-987. <https://doi.org/10.1097/00006534-200203000-00028>
- [11] Lee, H.B., Tark, K.C., Kang, S.Y., *et al.* (2000) Reconstruction of Composite Metacarpal Defects Using a Fibula Free Flap. *Plastic and Reconstructive Surgery*, **105**, 1448-1452. <https://doi.org/10.1097/00006534-200004040-00029>
- [12] Yuceturk, A., Tuncay, C., Isiklar, U. and Tandogan, R. (1998) Vascularised Bone Graft Applications in Upper Extremity Problems. *Microsurgery*, **18**, 160-162. [https://doi.org/10.1002/\(SICI\)1098-2752\(1998\)18:3<160::AID-MICR5>3.0.CO;2-P](https://doi.org/10.1002/(SICI)1098-2752(1998)18:3<160::AID-MICR5>3.0.CO;2-P)
- [13] Humail, S.M., Ghulam, M.K. and Zaidi, I.H. (2014) Reconstruction of the Distal Radius with Non-Vascularised Fibular Graft after Resection of Giant Cell Tumour of Bone. *Journal of Orthopaedic Surgery (Hong Kong)*, **22**, 356-359. <https://doi.org/10.1177/230949901402200318>
- [14] Dailiana, Z.H., Malizos, K.N. and Urbaniak, J.R. (2005) Vascularized Periosteal Flaps of Distal Forearm and Hand. *The Journal of Trauma*, **58**, 76-82. <https://doi.org/10.1097/01.TA.0000124269.37054.0A>
- [15] Legname, M., Barbary, S. and Dautel, G. (2011) Distal Radius Reconstruction Using

- a Split Vascularized Fibula. Two Cases Following Giant Cell Tumor Resection. *Orthopaedics & Traumatology: Surgery & Research*, **97**, 762-765.
<https://doi.org/10.1016/j.otsr.2011.06.010>
- [16] Rondinelli, R.D., Genovese, E., Katz, R.T., *et al.* (2022) The Upper Extremities. AMA Guides to the Evaluation of Permanent Impairment. Sixth Edition, American Medical Association, Chicago. <https://doi.org/10.1001/978-1-64016-212-9>
- [17] Flatt, A.E. (2002) Our Thumbs. *Proceedings (Baylor University. Medical Center)*, **15**, 380-387. <https://doi.org/10.1080/08998280.2002.11927870>
- [18] Crowe, C.S., Massenburg, B.B., Morrison, S.D., *et al.* (2020) Global Trends of Hand and Wrist Trauma: A Systematic Analysis of Fracture and Digit Amputation Using the Global Burden of Disease 2017 Study. *Injury Prevention*, **26**, i115-i124.
<https://doi.org/10.1136/injuryprev-2019-043495>
- [19] Pet, M.A., Ko, J.H. and Vedder, N.B. (2014) Reconstruction of the Traumatized Thumb. *Plastic and Reconstructive Surgery*, **134**, 1235-1245.
<https://doi.org/10.1097/PRS.0000000000000716>
- [20] Tosti, R., Treiser, M.D. and Eberlin, K.R. (2020) Contralateral Heterotopic Thumb-to-Thumb Replantation with Free Ulnar Forearm Fasciocutaneous Flap and Targeted Muscle Reinnervation. *Journal of Hand Surgery—American Volume*, **45**, 71e1-71e5.
<https://doi.org/10.1016/j.jhssa.2019.03.004>
- [21] Graham, E.M., Hilton, J. anderson, S. and Mendenhall, S.D. (2022) Free Fibula Flap Thumb Salvage after a Gunshot Wound: Case Report Emphasizing the Orthoplastic Approach. *Orthoplastic Surgery*, **7**, 19-24.
<https://doi.org/10.1016/j.orthop.2021.12.001>