Chunlin Hou · Shimin Chang · Juyu Tang
Zhigang Cai *Editors*

Practical Microsurgery Cases

Repair, Replantation and Reconstruction

SSTP

Springer

Practical Microsurgery Cases

Chunlin Hou • Shimin Chang • Juyu Tang
Zhigang Cai
Editors

Practical Microsurgery Cases

Repair, Replantation and Reconstruction

Springer

Editors
Chunlin Hou
Department of Orthopedic Surgery
Changzheng Hospital
Second Military Medical University
Shanghai
China

Shimin Chang
Department of Orthopedic Surgery
Yangpu Hospital
Tongji University School of Medicine
Shanghai
China

Juyu Tang
Department of Hand and Microsurgery
Xiangya Hospital
Central South University
Changsha
China

Zhigang Cai
Department of Oral and Maxillofacial Surgery
Peking University School
and Hospital of Stomatology
Beijing
China

ISBN 978-981-15-9715-2 ISBN 978-981-15-9716-9 (eBook)
https://doi.org/10.1007/978-981-15-9716-9

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

The use of the operating microscope created many new possibilities in surgery. Initially, most work was done in digital replantation and, somewhat later, in transfers of toes for reconstruction of amputated thumbs. Microvascular surgery, however, appeared to be a great technique suitable for more applications [1–3]. Anatomic research of the blood supply of skin, fascia, nerve, muscle, and bone identified flaps could be carried by pedicle vessels. Transfer of these flaps and revascularization by microvascular anastomoses of the arteries and veins set the stage for free flaps. With free flap surgery, single-stage and complex reconstructions could be achieved, which then led to earlier mobilization and better restoration of function with a shorter hospital stay. Today, microsurgical technique is fully matured, and microvascular free tissue transfer is an essential part of reconstructive surgery.

Microsurgery was born in China [4–17]. In the early growing stage of microsurgery, four great achievements were performed by Chinese surgeons. The first successful distal forearm replantation in the world in January 1963 by Dr. Zhong-Wei Chen and coworkers in Shanghai Sixth People's Hospital, the first successful second toe-to-thumb transplantation in February 1966 by Drs. Dong-Yue Yang and Yu-Dong Gu in Shanghai Huashan Hospital, the third free flap (lower-abdomen flap nourished by superficial epigastric artery and vein) transfer in the world in March 1973, also by Drs. Yang and Gu, and the first neurovascular pectoralis major (abdomen part) free transfer in July 1973 by Dr. Zhong-Wei Chen's group.

However, there were very restricted scientific exchanges with the Western world before China's Open Policy in the 1980s. Some western surgeons or groups visited China occasionally and introduced Chinese achievements sporadically in western English journals. In the last 20 years of the twentieth century, the exchanges were still limited because of the lack of financial support and barrier of foreign language. Only a small number of Chinese surgeons had the opportunity to attend international meetings and present their works, and still only a small number of authors could publish their papers in English in the Western medical journals, or in the English edition of *Chinese Medical Journal*, which was the only English periodical pressed by *Chinese Medical Association* before the 2000s. Therefore, many original works by Chinese investigators in microsurgery are unknown to the world.

In the twenty-first new century, microsurgery has been practiced widely and extensively throughout the country, in both university hospitals in big cities and county hospitals in rural areas [18–21]. The aim of this English compilation is to introduce some novel or sophisticated microsurgical techniques and applications in the pattern of illustrative case presentations, including almost all the spectrum of microsurgery, from head and neck, upper limb and hand, to lower limb and foot, for example, digit replantation, toe-to-hand transplantation, peripheral nerve injuries, surgical flaps, bone and joint, and tumor resection and microsurgical reconstruction.

References

1. Buncke HJ, Chang DW. History of microsurgery. Semin Plast Surg. 2003;17:5–16.
2. Buncke HJ. Forty years of microsurgery: what's next? J Hand Surg [Am]. 1995;20(3 Pt2):S34–45.
3. Buncke HJ. Replantation surgery in China: report of the American Replantation Mission to China. Plast Reconstr Surg. 1973;52(5):476–89.
4. Chang SM, Hou CL, Xu DC. An overview of skin flap surgery in the mainland China: 20 years' achievements (1981 to 2000). J Reconstr Microsurg. 2009;25(6):361–7.
5. Chen CW, Chien YC, Pao YS, Lin CT. Further experience in the restoration of amputated limbs: report of 2 cases. Chin Med J (Engl). 1965;84:225–31
6. Chen CW, Chien YC, Pao YS. Salvage of the forearm following complete traumatic amputation: report of a case. Chin Med J (Engl). 1963;82:633–8
7. Chen ZW, Bao YS. Microsurgery in China. Clin Plast Surg. 1980;7(4):437–74
8. Chen ZW, Ni AM. Microsurgery in China. Microsurgery. 1994;15(5):293–6.
9. Chen ZW, Yang DY, Chang DS. Microsurgery. New York: Springer-Verlag; 1982.
10. Chen ZW. Free muscle transplantation by microvascular anastomoses: report of a case. ChinMed J (Engl). 1976;2:47–50
11. Dongyue Y, Yudong G. Thumb reconstruction utilizing second toe transplantation by microvascular anastomosis: report of 78 cases. Chin Med J (Engl). 1979;92:295–309
12. Hou CL, Chang SM, Zhang F. The seventh congress of the Chinese Society of Microsurgery. Microsurgery. 2003;23(6):539–46.
13. Hou CL, Chang SM. History of Chinese society and state of practice in China. Microsurgery 2008;28(1):2–3
14. McDowell F. Editorial: Get in there and replant. Plast Reconstr Surg. 1973;52(5):562–7.
15. Pu LL1, Lineaweaver WC. Asia mentor redux. Ann Plast Surg. 2009;63(1):5–7.
16. Yang DY, Gu YD. Free flap transfer with vascular anastomosis for repair of a cheek defect after cancer resection [in Chinese]. Natl Med J China (Zhonghua Yi Xue Za Zhi). 1974;54:163–5
17. Yang DY, Gu YD. Free second toe transplantation to thumb: a report of 40 cases [in Chinese]. Chin J Surg (Zhonghua Wai Ke Za Zhi). 1977;15:13–6
18. Zhang F. Introduction to the Chinese Society issue. Microsurgery. 2008;28(1):1.
19. Zhang J, Chen ZW. Retrospective of the replantation of severed limbs in the People's Republic of China: current status and prospects. Microsurgery. 2002;22(1):39–43.
20. Zhao D. Introduction: Microsurgery in China. Microsurgery. 2013;33(8):591–2.
21. Zhong SZ, Kong JM. Microsurgical anatomy in China. Surg Radiol Anat. 1989;11:115–23.

Shanghai, China Chunlin Hou
Shanghai, China Shimin Chang
Changsha, China Juyu Tang
Beijing, China Zhigang Cai

Contents

Contributors

Zhigang Cai Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Shimin Chang Department of Orthopedic Surgery, Yangpu Hospital, Tongji University School of Medicine, Shanghai, China

Huihao Chen Department of Orthopedic Surgery, Changzheng Hospital, Second Military Medical University, Shanghai, China

Yunfeng Chen Department of Orthopaedic Surgery, Shanghai Sixth People's Hospital, Shanghai Jiaotong University, Shanghai, China

Zhi Wu Chen Department of Plastic Reconstructive Surgery, Ningbo First Hospital, Ningbo, China

Qiqiang Dong Department of Hand and Foot Surgery, Zhengzhou Renji Hospital, Zhengzhou, Henan, China

Yiyun Du Clinical Division, Department of Hand Microsurgery, Shunde Peace Surgery Hospital, Foshan City, Guangdong Province, China

Zengyang Gao Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China

Qiaohong Guo Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China

Mingfei He Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China

Chunlin Hou Department of Orthopedic Surgery, Changzheng Hospital, Second Military Medical University, Shanghai, China

Jianxi Hou Department of Hand and Foot Surgery, Zhengzhou Renji Hospital, Zhengzhou, Henan, China

Ruixing Hou Department of Hand and Foot Surgery, Ruihua Hospital Affiliated to Soochow University, Suzhou, Jiangsu, China

Jian Xin Huang Department of Hand and Foot Surgery, Tian Jin Baodi Hospital, Tianjin, China

Wang Yang Jian Department of Plastic Reconstructive Surgery, Ningbo First Hospital, Ningbo, China

Chuanlei Ji Department of Orthopedic Surgery, Xi Jing Hospital, Air Force Medical University, Xi'an, China

Jihui Ju Department of Hand and Foot Surgery, Ruihua Hospital Affiliated to Soochow University, Suzhou, Jiangsu, China

Yifan Kang Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Yanwen Lei Clinical Division, Department of Hand Microsurgery, Shunde Peace Surgery Hospital, Foshan City, Guangdong Province, China

Jie Liang Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Zhirong Liang Clinical Division, Department of Hand Microsurgery, Shunde Peace Surgery Hospital, Foshan City, Guangdong Province, China

Jianning Li Department of Hand and Foot Surgery, Ruihua Hospital Affiliated to Soochow University, Suzhou, Jiangsu, ChinaJing Li Department of Orthopedic Surgery, Xi Jing Hospital, Air Force Medical University, Xi'an, China

Jun Li Department of Oral and Maxillofacial-Head and Neck Oncology, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine, Shanghai, China

Liang Li Clinical Division, Department of Hand Microsurgery, Shunde Peace Surgery Hospital, Foshan City, Guangdong Province, China

Haodong Lin Department of Orthopedic Surgery, Shanghai General Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China

Jian Lin Chongming Research Center for Wound Prevention and Treatment of Shanghai, Chongming Branch of Xinhua Hospital (Chongming) Affiliated to Medical College, Shanghai Jiaotong University, Shanghai, China

Shijun Li Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Rui Liu Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

Ying Liu Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Yu Jie Liu The Hand Surgery Center of CPLA, 971st Hospital of the CPLA Navy, Qingdao, China

Zan Li Department of Oncology Plastic Surgery, Hunan Cancer Hospital, Changsha, China

Zimeng Li Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Xuchao Luo Department of Orthpaedic Surgery, Traditional Chinese Medicine Hospital Affiliated to Southwest Medical University, Luzhou, Sichuan, China

Mingming Lv Department of Oral and Maxillofacial-Head and Neck Oncology, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine, Shanghai, China

Xiaoming Lv Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Changliang Ou Department of Orthpaedic Surgery, Traditional Chinese Medicine Hospital Affiliated to Southwest Medical University, Luzhou, Sichuan, China

Ding Pan Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

Shaokun Pei Department of Orthopaedic Surgery, The 4th People's Hospital of Shaan'xi, Xi'an, China

Liming Qing Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

Yan Xiang Rui Department of Hand and Foot Surgery, Tian Jin Baodi Hospital, Tianjin, China

Xiaofeng Shan Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Xinzhong Shao Department of Hand Surgery, Third Hospital of Hebei Medical University, Shijiazhuang, Hebei, China

Yi Shen Department of Oral and Maxillofacial-Head and Neck Oncology, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine, Shanghai, China

Dajiang Song Department of Oncology Plastic Surgery, Hunan Cancer Hospital, Changsha, China

Jialin Song Department of Orthopaedic Surgery, Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai, China

Jiazeng Su Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Jian Sun Department of Oral and Maxillofacial-Head and Neck Oncology, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine, Shanghai, China

Juyu Tang Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

Xiu Jun Tang Department of Burn and Plastic Surgery, Guizhou Provincial People's Hospital, Guiyang, China

Shanhua Wang Department of Orthopaedic Surgery, Shanghai Sixth People's Hospital, Shanghai Jiaotong University, Shanghai, China

Wei Wang Department of Hand Surgery, The People's Liberation Army No. 906 Hospital, Haidian, China

Xiang Wang Department of Hand Surgery, The People's Liberation Army No. 906 Hospital, Haidian, China

Zhenlin Wang Department of Hand Surgery, The People's Liberation Army No. 906 Hospital, Haidian, China

Zhi Jiang Wang Chongming Research Center for Wound Prevention and Treatment of Shanghai, Chongming Branch of Xinhua Hospital (Chongming) Affiliated to Medical College, Shanghai Jiaotong University, Shanghai, China

Peng Wei Department of Plastic Reconstructive Surgery, Ningbo First Hospital, Ningbo, China

Li Zhi Wu Chongming Research Center for Wound Prevention and Treatment of Shanghai, Chongming Branch of Xinhua Hospital (Chongming) Affiliated to Medical College, Shanghai Jiaotong University, Shanghai, China

Panfeng Wu Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

Wenjie Wu Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Xiang Wu Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China

Zhaosen Wu Department of Hand and Foot Surgery, Zhengzhou Renji Hospital, Zhengzhou, Henan, China

Lifeng Xia Department of Orthopaedic Surgery, The 4th People's Hospital of Shaan'xi, Xi'an, China

Shuqiang Xie Department of Hand and Foot Surgery, Zhengzhou Renji Hospital, Zhengzhou, Henan, China

Zhenjun Xie Department of Hand and Foot Surgery, Henan Provincial People's Hospital, Zhengzhou, China

Chaofan Yang Department of Hand and Foot Surgery, Zhengzhou Renji Hospital, Zhengzhou, Henan, China

Zhao Yang Department of Orthopedic Surgery, Xijing Hospital, Air Force Military Medical University, Xi'an, Shaanxi Province, China

Guangyan Yu Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Bingfang Zeng Department of Orthopaedic Surgery, Shanghai Sixth People's Hospital, Shanghai Jiaotong University, Shanghai, China

Jianhua Zhang Department of Hand and Foot Surgery, Henan Provincial People's Hospital, Zhengzhou, China

Jingliang Zhang Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China

Kai Zhang Department of Microsurgery and Orthopedic Trauma, No. 988 Hospital of Joint Logistic Support Force, Zhengzhou, Henan Province, China

Tian Hao Zhang Chongming Research Center for Wound Prevention and Treatment of Shanghai, Chongming Branch of Xinhua Hospital (Chongming) Affiliated to Medical College, Shanghai Jiaotong University, Shanghai, China

Wenlong Zhang Department of Hand Surgery, Tianjin Union Medical Center, Tianjin, China

Xu Zhang Department of Hand Surgery, Third Hospital of Hebei Medical University, Shijiazhuang, Hebei, China

Xun Zhang Department of Microsurgery and Orthopedic Trauma, No. 988 Hospital of Joint Logistic Support Force, Zhengzhou, Henan Province, China

Yabin Zhang Department of Orthopaedic Surgery, The 4th People's Hospital of Shaan'xi, Xi'an, China

Zhongren Zhang Department of Orthopaedic Surgery, Shanghai Sixth People's Hospital, Shanghai Jiaotong University, Shanghai, China

Dewei Zhao Department of Orthopedics, Affiliated Zhongshan Hospital of Dalian University, Dalian, Liaoning, China

Guangyue Zhao Department of Orthopedic Surgery, Xijing Hospital, Air Force Military Medical University, Xi'an, Shaanxi Province, China

Lei Zheng Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Xianyou Zheng Department of Orthopaedic Surgery, Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai, China

Mingwu Zhou Department of Microsurgery and Orthopedic Trauma, No. 988 Hospital of Joint Logistic Support Force, Zhengzhou, Henan Province, China

Xiao Zhou Department of Oncology Plastic Surgery, Hunan Cancer Hospital, Changsha, China

Yonggang Zhu Department of Orthopedic Surgery, Xijing Hospital, Air Force Military Medical University, Xi'an, Shaanxi Province, China

Jiwei Zou Department of Orthopedic Surgery, Xijing Hospital, Air Force Military Medical University, Xi'an, Shaanxi Province, China

Yonggen Zou Department of Orthpaedic Surgery, Traditional Chinese Medicine Hospital Affiliated to Southwest Medical University, Luzhou, Sichuan, China

Part I

Upper Limbs and Hands

1 Successful Replantation of the Distal Phalanx of the Little Finger in a Newborn: A Case Report

Yanwen Lei, Liang Li, Jingliang Zhang, Zhirong Liang, and Yiyun Du

1.1 Case Presentation

The infant was a 0.5-hour-old boy, with a bodyweight of 3.32 kg. The infant encountered an accidental truncation of the left little finger when the umbilical cord was cut during cesarean section at 10 a.m. on March 9, 2013, in a hospital; the distal interphalangeal joint of the left little finger was completely amputated for half an hour, and then was urgently sent to the Hand Microsurgery Department of our hospital for consultation. Physical examination results: Development was normal, crying was loud, heartbeat and breathing were normal, and no deformities of limbs were found. The space plane of the distal interphalangeal joint of the left little finger was completely amputated, the two cross-sections were even, the articular surfaces were exposed, the isolated finger was intact, and pallor and active hemorrhage was observed near the broken end (Fig. 1.1a, b).

After active preparations, the infant underwent debridement and replantation of the left little finger under general anesthesia at 90 min after injury. During the operation, the infant was routinely sterilized and debrided. Since the two articular surfaces were relatively intact, in order to preserve the joints and length of the finger, phalangeal shortening was not performed, and the articular surfaces were preserved. After direct alignment, manual internal fixation was performed with 0.45 × 16 RW syringe cannula (no finer

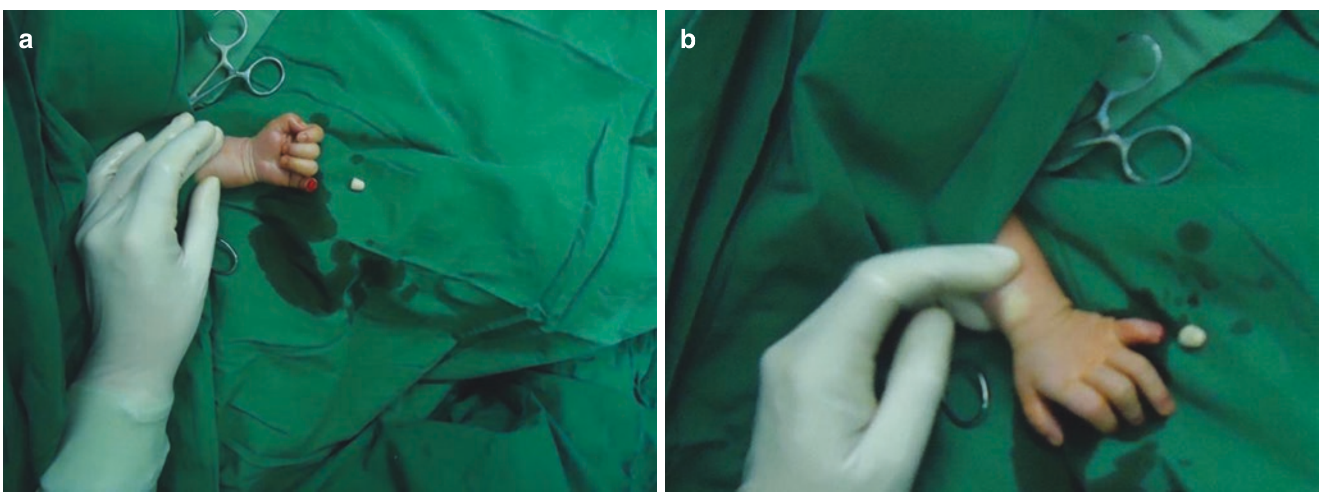


Fig. 1.1 (**a**, **b**) Left small finger defect wound of the infant

Y. Lei · L. Li · Z. Liang · Y. Du
Clinical Division, Department of Hand Microsurgery, Shunde Peace Surgery Hospital, Foshan City, Guangdong Province, China

J. Zhang (✉)
Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China
e-mail: jingliang.zhang@hmmedicalgroup.com

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_1

Kirschner wire was available). The periarticular tissue and articular capsule were sutured with 6–0 absorbable suture. The extensor and flexor tendons were repaired by figure-of-eight suture. Under 16× operating microscope, the blood vessels and nerves of the two broken ends were searched and freed, two dorsal finger veins with a diameter of 0.15 mm were anastomosed by three stitches with 12–0 noninvasive microsurgical sutures, and then the dorsal skin was sutured. Similar noninvasive microsurgical sutures were used to anastomose the radial digital artery with a diameter of 0.15 mm by four stitches, the ulnar digital artery with a diameter of 0.1 mm was anastomosed by three stitches, the bilateral digital nerves were anastomosed, and then the palm-side skins were sutured. The operation lasted for 150 min. Blood circulation was rebuilt after loosening the tourniquet. The color of the finger pulp was ruddy and full (Fig. 1.2). The warm ischemia time of the isolated finger was approximately 4 h.

Fig. 1.2 After replantation, the left little finger had blood circulation

Postoperative measures: The infant underwent immobilization of the left upper limb with macromolecular splints and then was sent to neonatal intensive care unit (ICU) for special care and nursing after finger replantation. Timely oxygen supply, hibernation, and general nutritional support were given, and prevention of infection, anti-spasm, and anticoagulant treatments were performed. On postoperative day 2, the replanted finger had gradually increased tension, and the complexion was dark. It was considered that venous reflux was slightly poor, intermittent stitch removal of the wound, cotton swab local intermittent massage, and other measures were taken, to promote venous reflux. After the above-mentioned treatments, on postoperative day 4, the skin color of the finger restored to ruddy, the tension was moderate, the venous reflux was improved, and the blood circulation of the finger became stable. On postoperative day 10, the infant underwent stitch removal. Within 2 weeks, the internal fixation cannulas were removed (Fig. 1.3a, b). The infant was discharged after 14 days of hospitalization, and at this time, the wound in the operation

Fig. 1.3 (**a**, **b**) At 13 days after replantation, dorsal and palmar conditions of the left little finger

area healed well, the appearance was normal, the blood circulation of replanted finger was good, and the isolated finger body well survived.

The infant was followed up for 5 months. The dorsal side and nails of the left little finger grew well. When needling and objects touching the pulp of the little finger, there were signs of sensory nerve recovery such as finger escape and grip reflex, and there was no difference in reflex time from the unaffected right little finger (Fig. 1.4). At 8 months after the operation, the body weight of the infant reached 9.1 kg, the growth and development of the replanted little finger were the same as that of the unaffected right little finger, the color was normal, and the finger pulp was full. It was observed that the left hand was flexible, there was no abnormality in flexion and extension, and the functional recovery was satisfied (Figs. 1.5 and 1.6). According to the criteria of functional evaluation after replantation of the isolated finger, the result was excellent [1].

Fig. 1.4 Follow-up at 5 months after surgery revealed that the back and nail of the left little finger grew well

1.2 Discussion

At present, the youngest successful case of finger replantation reported in the literature is the replantation of the distal phalanx of the index and middle fingers in a 5-month-old infant [2]. However, the successful replantation of the finger in newborns has not been reported in Chinese and foreign literature. This case in the present report is the first case of replantation of the finger in newborns. In this case, the infant was still in the fetal stage at the moment of finger severance caused by accidental injury during cesarean section (the umbilical cord has not been cut off). The little finger was isolated on the plane of distal interphalangeal joint, the isolated finger body was small, only in a "soybean" size, the diameters of the vessels of broken ends were only 0.10–0.15 mm, the walls were thin, and vascular anastomosis was very difficult. Furthermore, since the condition of injury was special, the family members of the infant were anxious. It was not only difficult in replantation, but the stress was also was very high. In order to preserve joint function, and not shorten finger length, no routine phalangeal shortening and joint fusion were performed during the operation; this made the blood vessel tension higher and further increased the difficulty and risk of replantation.

According to the experience and understanding of the surgeon, finger replantation in newborns is a new challenge for both the surgeon and the postoperative care nurses. The keys to ensuring the success of the operation are as follows: (1) Surgeons must have more advanced microsurgery skills and better psychological diathesis. (2) Since the diameters of blood vessels were small (0.10–0.15 mm), the vascular walls were thin, the tensions were high, there were no more choices, every vascular anastomosis should be completed accurately and in high quality at one time. (3) Due to the specificity that the infant was a newborn infant and had received general anesthesia for nearly 3 h, special careful and timely nursing was needed after the operation, oxygen

Fig. 1.5 Follow-up at 5 months after surgery revealed the comparison of both hands, the left little finger grew well without atrophy

Fig. 1.6 Follow-up at 5 months after surgery revealed the appearance of the palmar side of the left little finger

supply, sputum suctioning, remaining adequate blood volume and general nutritional support were the important treatment measures after the operation. In order to prevent vascular crisis caused by the restlessness of the infant, to ensure the smooth implementation of routine treatments and dressing change after the operation, adequate and effective immobilization and hibernation treatment are very necessary. (4) In the entire process of microsurgery special care, the blood circulation changes in the replanted finger should be closely observed. When abnormal signs of blood circulation occurred, timely and effective treatment was carried out until it became stable.

Some scholars consider that in situ suturing and replantation of the distal phalanx of the finger may also make the finger survive, and successful cases have been reported [3, 4]. However, it is necessary to do so in the absence of microsurgical techniques or replantation conditions or the isolated tissue is small, its contingency is great, but it has less controllability. The present successful case revealed that China has the leading level of microsurgery technology in the world, the technique of small vessel anastomosis is skilled, distal phalanx replantation and microvascular anastomosis are maturing day by day, all kinds of finger replantation can be successfully carried out with good assurance, and in situ suture and replantation should never be preferred. In the present case, the minimum diameter of vessels of the isolated finger in the infant was 0.1 mm; however, after 150 min of careful operation, blood circulation of the finger body was successful in one time, the skin color was ruddy, and capillary reaction was rapid. The infant was followed up, and no finger atrophy was found, sensation and movement were restored, and finger function achieved well recovery: The replantation score of the finger was excellent according to scoring criteria. This fully verifies the leading level of microsurgery technology in China. At 8 months after the operation, the infant was followed up. It was found that the appearance and function of the left little finger were not different from those of the unaffected right little finger.

References

1. Zhu S, Wang H. Discussion on the criteria for evaluating the function of replantation of severed fingers. Chin J Microsurg. 1989;12:116–7.
2. Chen F, Li J, Wang Z, et al. Successful replantation of the distal phalanx of the middle finger in a five-month-old infant: a case report. Chin J Microsurg. 2001;24:115.
3. Luo X, Liang Z, Liu H. Analysis of fingertip replantation and modified in situ suture. Chin J Microsurg. 1999;22:227.
4. Zhang C, Xia Y. Report of 20 cases of button-type suture in the absence of replantation conditions. J Pract Hand Surg. 2001;15:121.

2 Replantation of Amputated Finger Composite Tissue Mass

Jian Xin Huang and Yan Xiang Rui

2.1 Case Presentation

A 22-year-old female patient was injured by an electric knife on her right finger, causing pain and bleeding in the middle and end of the index finger for 2 h. Physical examination at admission: the right index finger, the radial half of the middle and distal phalanges was severed, the wound margin was neat, the distal and proximal interphalangeal joints were exposed, the attachment area of the central bundle of the extensor tendon and the radial tendon bundle of extensor tendon were exposed, and most of the radial half of the middle and distal phalanges were severed (Figs. 2.1 and 2.2).

Fig. 2.1 Disconnected tissue mass

2.1.1 Choice of Treatment

This patient's right index finger shows that the remaining and severed finger tissue block of the middle and last ruler is relatively complete and suitable for in situ replantation. The first stage is the reconstruction of bone joint structure and anastomosis repair of tendons, blood vessels, nerves, nail bed, and other important tissue structures. After the surgery, the broken tissue block survived successfully. After a follow-up year, X-ray examination showed that the right hand indicated that the middle and last phalanges healed well, the interphalangeal joint position was normal, the finger flexural function recovered well, the two points recognized 5 mm, and the nail shape was smooth and full.

2.2 Operative Technique

1. Debridement of wounds and tissues: The wounds were washed with disinfection soap, saline, and 0.05% diluted iodophor disinfectant. The cut tissues were soaked with 0.05% diluted iodophor disinfectant for 5 min and then rinsed with physiological saline. Under the microscope, the inactive skin margin was removed. Removal of pollutants on the surface of bone and tendon tissue were cleared, and the blood vessels and nerves on the margin of tissue mass were preserved. After the saline was washed again, the tissue mass and the broken end of the blood vessel at the remnant of the index finger were pruned and marked for reserve under the microscope.
2. Reconfirmation of the injury: The structure of the tissue mass was confirmed under a magnifying glass. The radial

J. X. Huang (✉) · Y. X. Rui
Department of Hand and Foot Surgery, Tian Jin Baodi Hospital, Tianjin, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_2

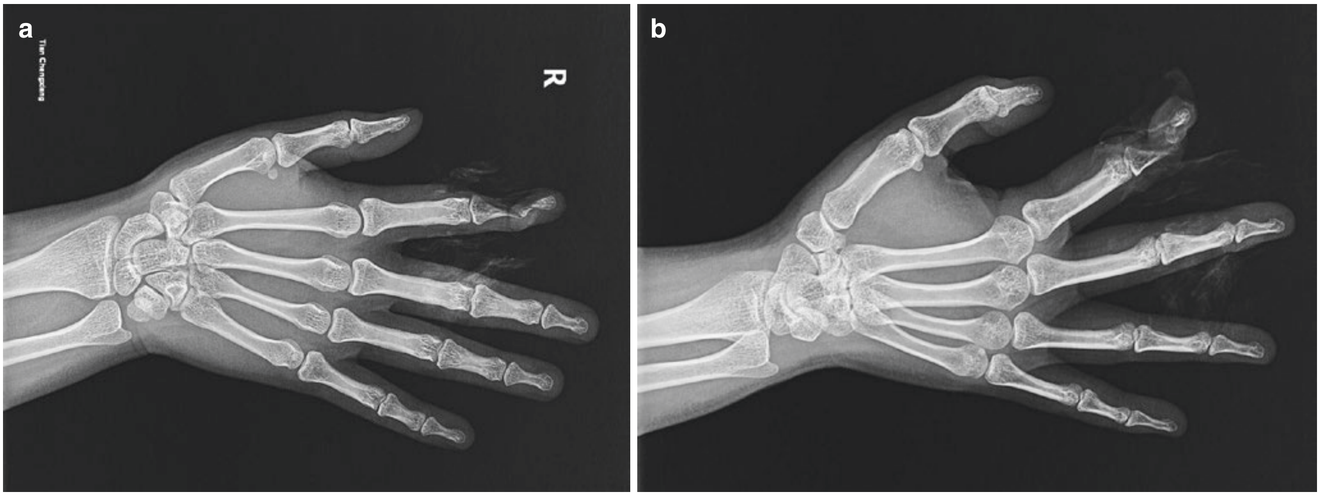


Fig. 2.2 (**a**) Posttraumatic positive X-ray. (**b**) Posttraumatic oblique position X-ray

half of the phalanx in the middle segment of the index finger was widened gradually from near to far, and most of the phalanx head and the base of the distal segment were widened; most of the attachment area of flexor digitorum profundus tendon and 2 cm long tendon; the radial and radial half attachment area of extensor digitorum tendon, the central attachment area of extensor digitorum tendon; about 2 cm long. Subcutaneous veins about 1 mm diameter were visible at the distal and proximal ends of the nerve and vascular bundles and tissue masses.

3. Bone scaffold fixation: Peel off part of periosteum carefully, hold and fix with point reduction forceps, drill holes in tapping protection sleeve, and screw two cortical bone screw into vertical fracture line to fix middle phalanx fracture. Because of the thinness of the remaining two fragments of the distal phalanx, 2 K wires were screwed into the ulnar dismembered tissue of the residual finger to fix the fracture of the distal phalanx (Figs. 2.3 and 2.4).
4. Tendon anastomosis: The proximal part of the flexor digitorum profundus tendon was sutured by 3–0 tendon modified Kessler and 5–0 tendon line continuous clavicular suture. The distal part was sutured by 4–0 tendon line "+" with the residual tendon. The body was repaired with 5–0 noninvasive line "+" to restore the integrity of the flexor tendon. After adjusting the tendon tension during the operation, the patient was repaired with 5–0 noninvasive suture with the body of the unbroken extensor tendon.
5. Establishment of blood supply: End-to-end anastomosis of the radial proper artery of the index finger in the tissue mass was performed with 10–0 PROLENE suture under the microscope. After loosening the tourniquet, the color of the tissue mass was ruddy. One vein with smooth dorsal proximal circulation was selected to anastomose with the dorsal digital vein.

Fig. 2.3 After fixation

6. Nerve anastomosis: End-to-end anastomosis of the adventitia small gap was used to anastomose the distal and proximal ends of the proper nerve of the finger, and one dorsal branch of the digital nerve was anastomosed.
7. Postoperative management:
   (a) Postoperative "three anti" therapy: low-molecular-weight heparin anticoagulation for 1 week, antibiotics for 24 h, selective application of papaverine to spasmolysis according to the change in condition, and smooth survival of tissue mass (Figs. 2.5 and 2.6).
   (b) Restrictive exercises of flexion and extension of the interphalangeal joint were started 2 weeks after the operation. Internal fixation of fixed distal phalanges was removed 4 weeks after the operation to increase the flexion and extension of the interphalangeal joint.

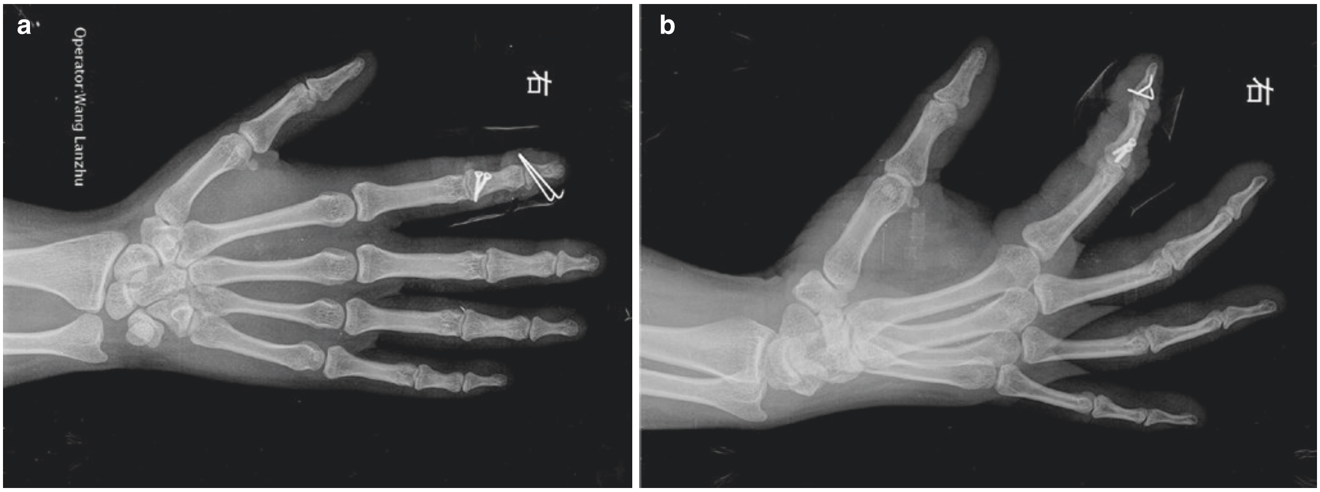


Fig. 2.4 (**a**) Radiographs after fixation. (**b**) Radiographs after fixation

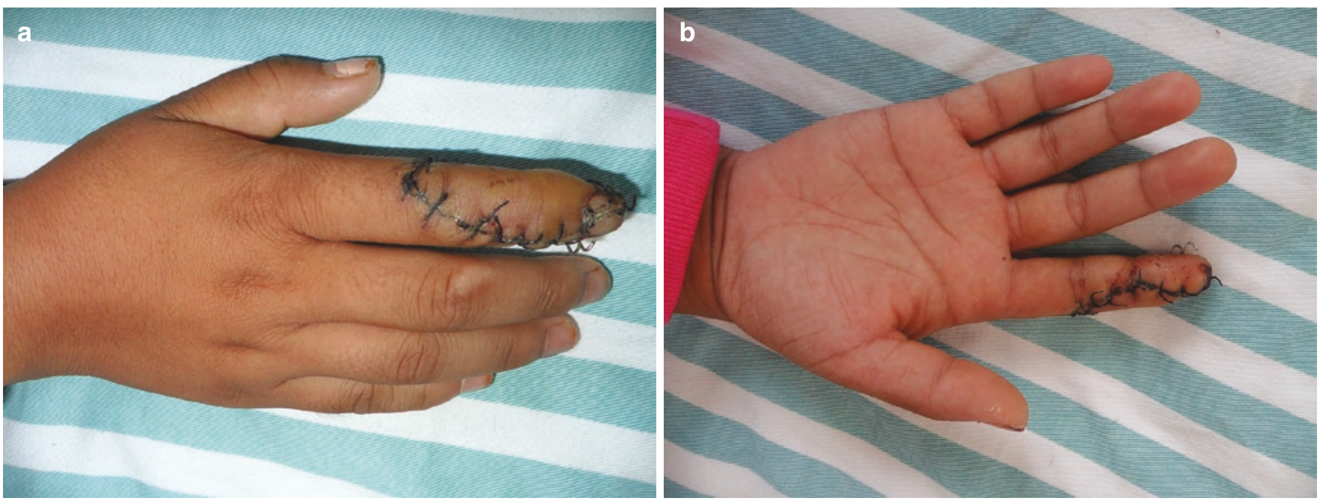


Fig. 2.5 (**a**, **b**) 1 week after the operation

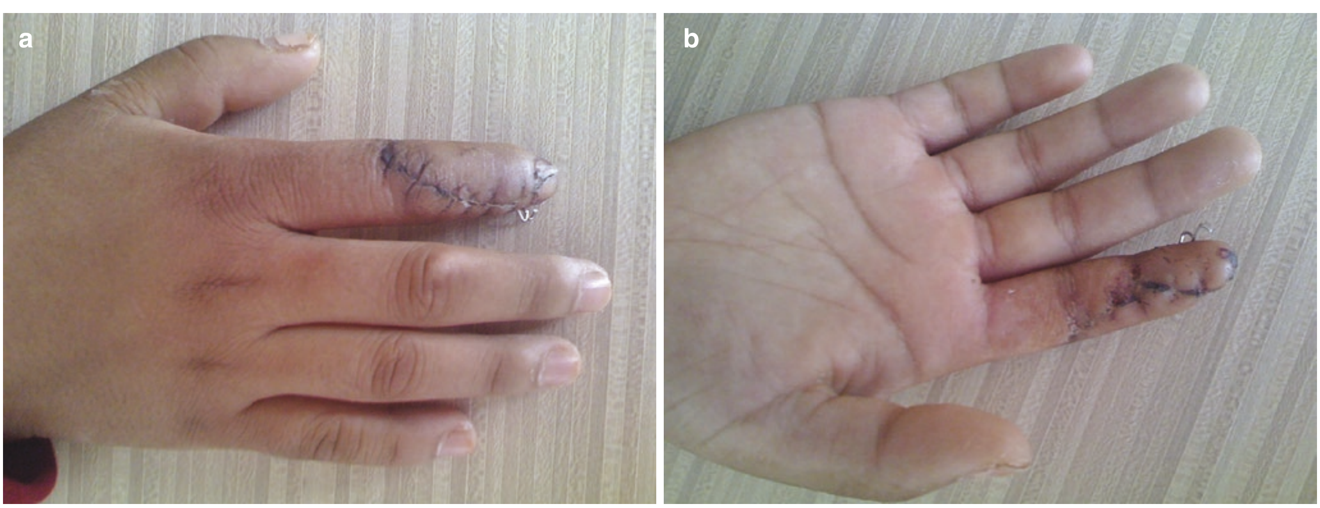


Fig. 2.6 (**a**, **b**) 2 weeks after the operation

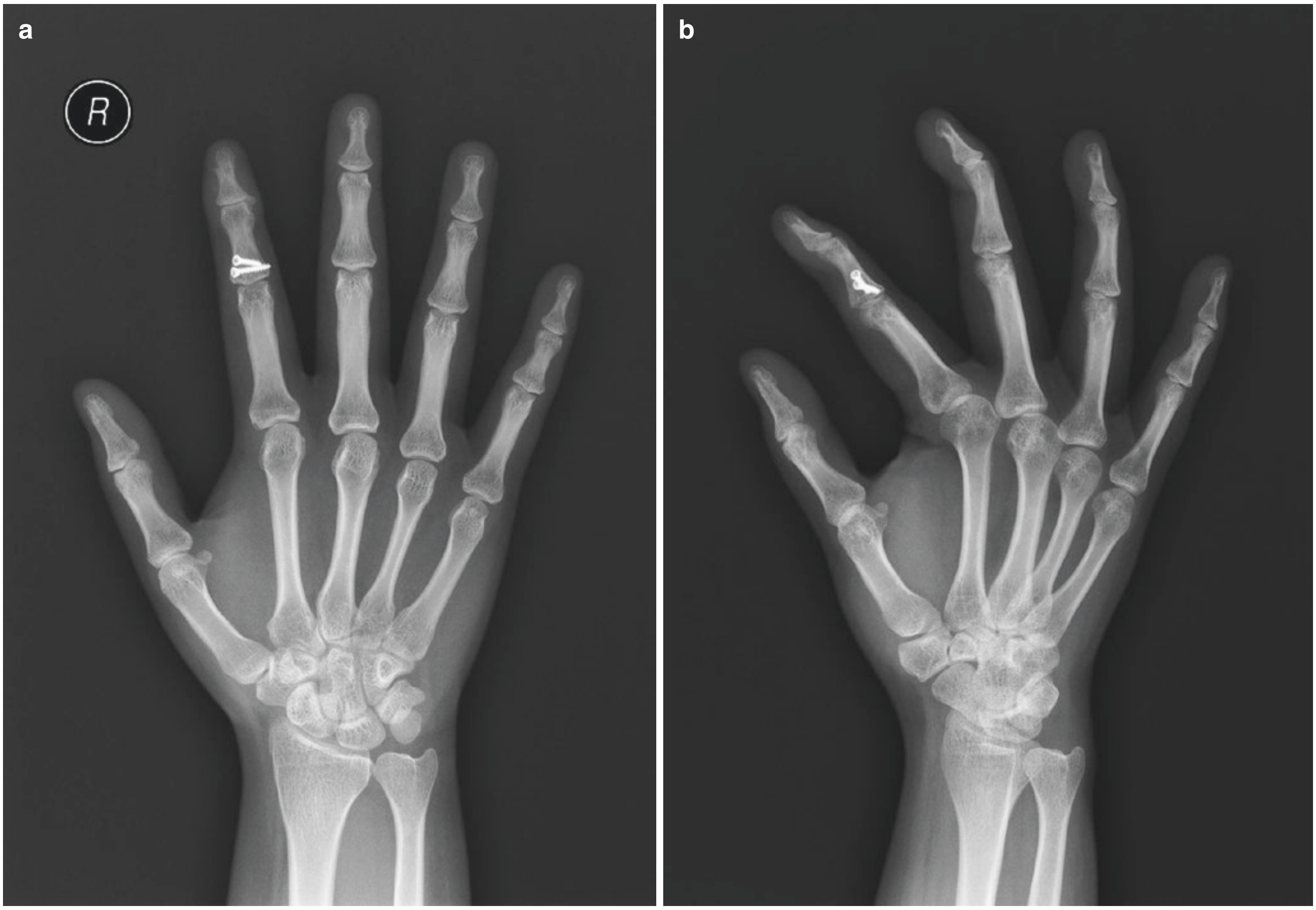


Fig. 2.7 (**a**, **b**) 6 months after the operation

The screw for fixing middle phalanges was removed half a year after the operation, and the function recovered well (Figs. 2.7 and 2.8).

2.3 Clinical Implication

1. Microscopic wound debridement: Most of the severed composite tissue blocks are sharp punch wounds with small volume, and accurate wound debridement is the key to successful operation. The first debridement under a magnifying glass and second debridement under a microscope can not only maximize the protection of the important structural broken ends exposed on the section but also make the pollutants and inactivated tissues of the wound as clear as possible and reduce the incidence of wound infection.
2. Search for blood vessels in tissue mass: Composite tissue blocks are small and have a strong ability to tolerate hypoxia. A small amount of blood supply can establish collateral circulation and make the tissue blocks survive. In order to avoid injury or loss of blood vessels, we should first debride and mark the blood vessels near and far from the finger wound, pay attention to retaining all visible arterial branches, and then search for blood vessels at the corresponding position of the composite tissue block [1].
3. Rebuilding blood circulation: Excellent quality of vascular anastomosis is a prerequisite for the survival of tissue replantation. Because of the uncertain anatomical position and irregular anatomical level of the tissue, it is difficult to anastomose the blood vessels. First, we kiss the arteries, and then choose the best vein to kiss according to the situation of venous bleeding.
4. Guarantee the length of nerves and blood vessels: In the replantation of composite tissue blocks involving joints, insufficient length of blood vessels and nerves is often encountered after debridement. After direct anastomosis, blood vessels are too tight to affect the blood supply. However, the existence of residual finger continuity cannot be solved by shortening phalanges [2]. Appropriate dissociation of neurovascular bundles and flexion of interphalangeal joints in healthy proximal tissues can be used to solve the problem.

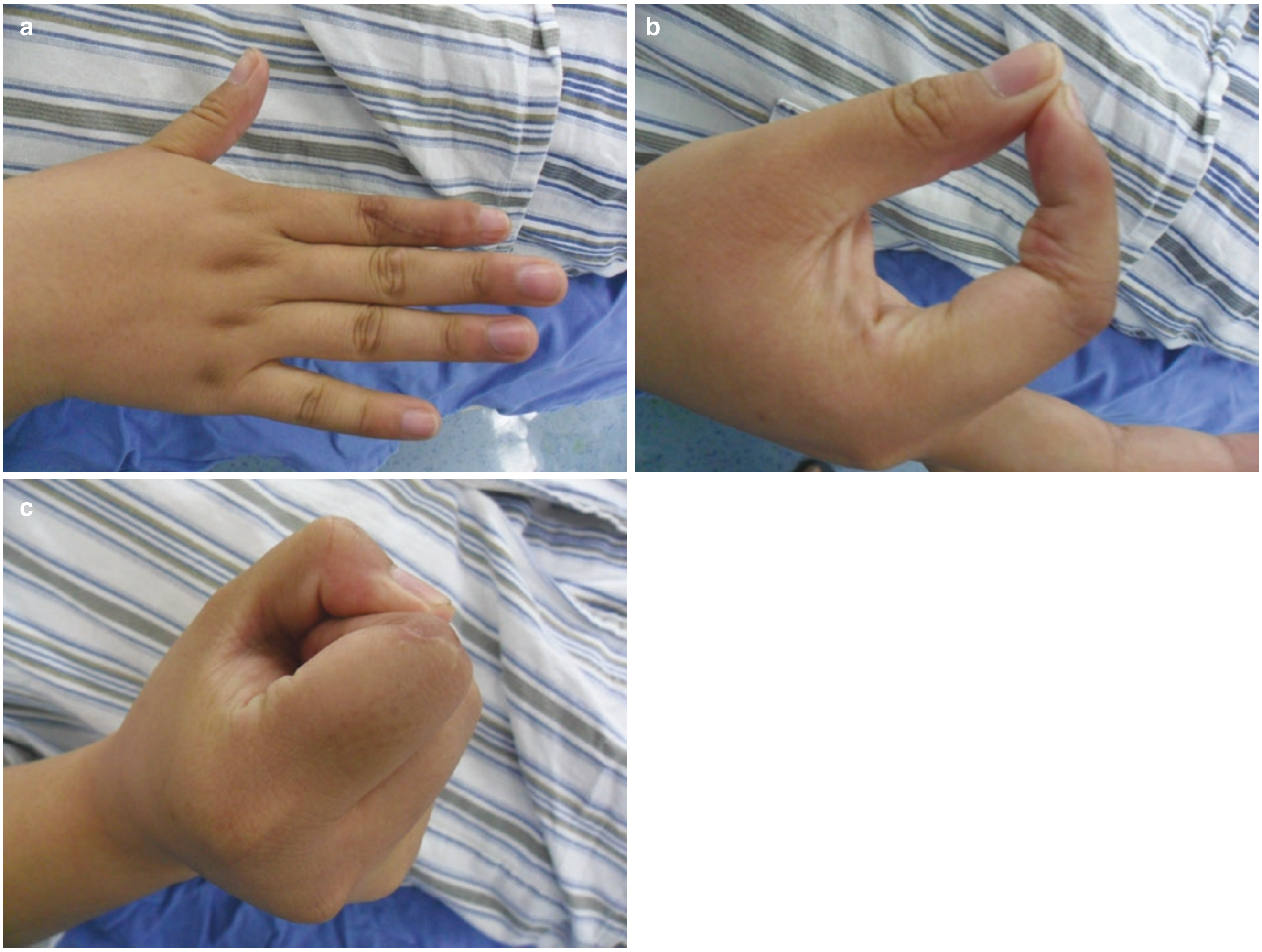


Fig. 2.8 (**a**) Extension of interphalangeal joint. (**b**) Interphalangeal joint opposite finger position. (**c**) Flexion position of interphalangeal joint

References

1. Yuan HP, Wang HS, Yuan Y, et al. Venous arterialization refers to replantation of composite tissue blocks in vitro. Chin J Hand Surg. 2014;30:148–9.
2. Feng W, Xing DM, Ren D, et al. Replantation of amputated composite tissue mass of fingers. Chin J Hand Surg. 2012;28:227–9.

3 Replantation of Four Amputated Fingers in a 23-Month-Old Child

Zhi Wu Chen, Wang Yang Jian, and Peng Wei

3.1 Case Presentation

A 23-month-old female child accidentally fell while inside a factory, and 2–5 fingers (Tamai IV area) of her right dominant hand were completely cut off by a high-speed cutting machine gear (Fig. 3.1a, b). The amputated fingers were refrigerated immediately after the injury.

3.2 Course of Treatment

The child was sent to our hospital for emergency treatment 2.5 h later. Physical examination: the 2–5 fingers of the right hand were completely amputated at the level of the proximal section. The amputated fingers were intact and had no ecchymoses. The wound edge was neat and the wound was only slightly polluted. After thorough preoperative preparation, the patient underwent 2–5 finger replantation under general anesthesia 4 hours after the injury (Fig. 3.2a, b). Four fingers recovered blood supply after 11.5 hours of operation (Fig. 3.3a, b). Conventional antibiotics were administrated to prevent infection as well as other symptomatic treatments including an anticoagulant, vasodilator drugs, spasmolysis, and blood transfusion.

On the third day after admission, an arterial crisis occurred in the ring finger (Fig. 3.4). No significant relief was observed after conservative treatments such as suture removal and papaverine intramuscular injection. Emergency examination in the operation room found vein thrombosis at the anastomosis of the bilateral digital artery. The radial defect was about 1.5 cm and the ulnar defect was about 2.0 cm. After resection of the embolic segment, a segment of about 2.0 cm of the superficial palmar vein in the forearm was inverted and transplanted to repair the radial artery of the ring finger. The two ends were anastomosed with the 6-stitch-2-fixed-point method using 11-0 Nylon thread. After this operation, symptomatic treatments were continued, namely, antibiotics to prevent infection, anticoagulant and vasodilator drugs, spasmolysis, and dressing changes. The blood supply of the ring finger was completely normal on the seventh day after surgery (Fig. 3.4).

On the 17th day of admission, the replanted 2–5 fingers demonstrated normal blood supply and survived smoothly. The patient was discharged after the stitches were removed. Follow-up radiographs 4 weeks after the operation showed that the fracture had healed. The Kirschner wire was removed and the grip in the right hand of the patient was good.

After one and a half years of follow-up, the child's 2–5 finger function was normal (Fig. 3.5a, b).

3.3 Operative Technique

For multifinger replantation in pediatric patients, it is difficult to perform lengthy operations due to the small size of blood vessels in children, the diameter of which is usually 0.3–0.5 mm. In such cases, surgery requires accurate anastomosis of the blood vessels as quickly as possible. The operation in the case we report was performed using a balloon tourniquet, with 15-minute deflation every 80 minutes. Replantation was performed after the following: internal fixation of the fracture according to a neurovascular marker in the debridement, anastomosis of the extensor and flexor tendons, anastomosis of the arteriae digitales propriae on one side, anastomosis of the palmar digital vein, anastomosis of the digital artery on the other side, anastomosis of the digital nerve, anastomosis of the palmar skin, anastomosis of the dorsal digital vein, and anastomosis of the dorsal digital skin. A total of 11 digital dorsal veins, eight arteriae digitales propriae, and eight digital nerves were anastomosed under a 10× magnification microscope. Only two veins were anastomosed in the index finger, and veins and arteries in the other fingers were anastomosed at the ratio of 2:3. The vascular anastomosis was carried out using the 6-stitich-2-fixed-point method, and an epineurium suture with six stitches was

Z. W. Chen · W. Yang Jian · P. Wei (✉)
Department of Plastic Reconstructive Surgery, Ningbo First Hospital, Ningbo, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_3

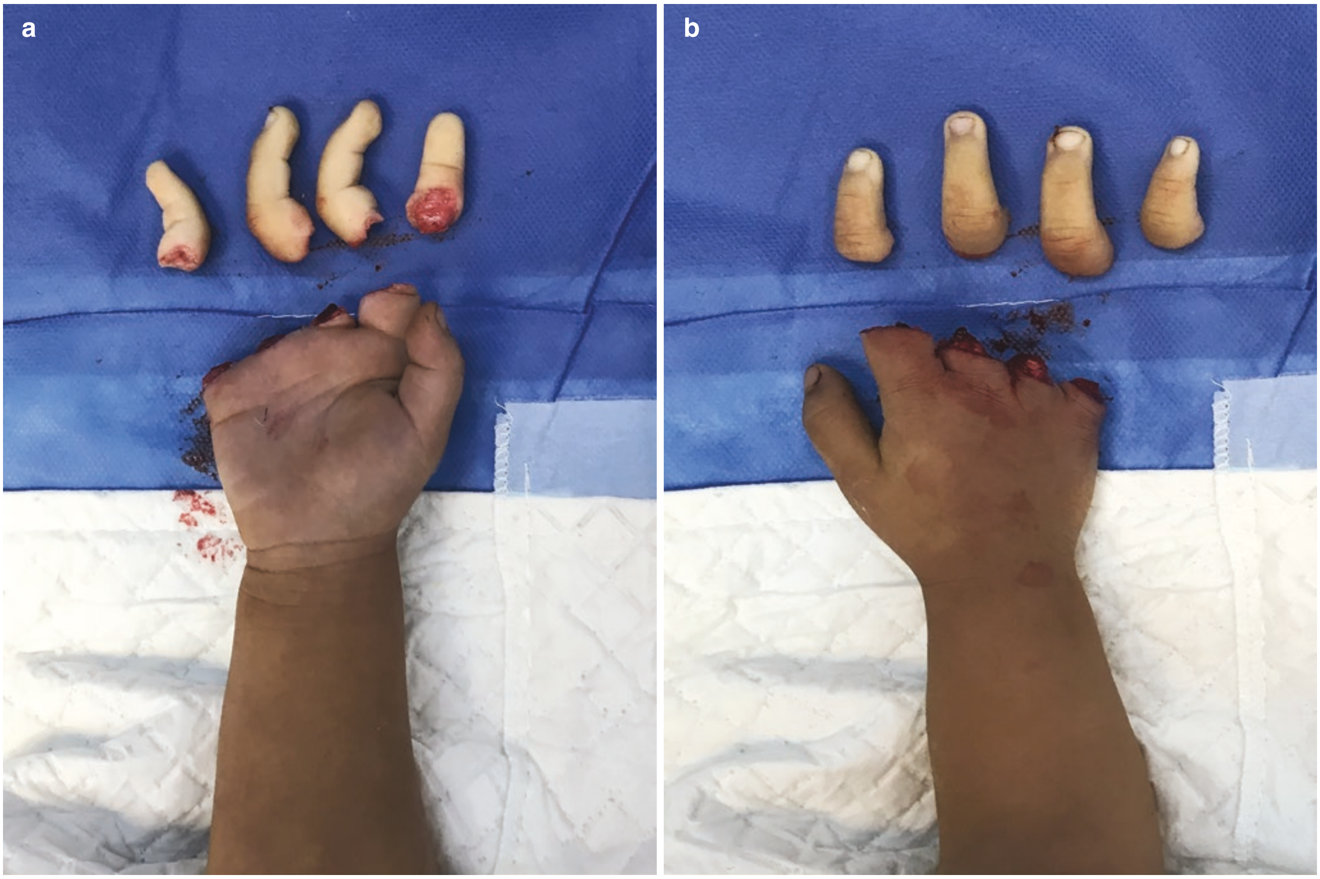


Fig. 3.1 The amputation of the metacarpophalangeal joint in the 2–5 fingers of the right hand of the child before operation. (**a**) palmer view, (**b**) dorsal view

employed for anastomosis of the nerve. The extensor tendon was repaired using an "8"-shaped suture, and the flexor tendon was repaired with a Kessler suture. Bone fixation during replantation should be done in a relatively simple and fast manner so as to reduce damage to muscles and soft tissues. Thus, a 0.8-cm Kirschner wire was used for lateral needle insertion and cross-internal fixation. The switch joint should be avoided during interval fixation with a Kirschner wire while staying away from the epiphysis to reduce damage to it. The wire can be removed 3–4 weeks after surgery to allow for early functional exercise.

Accurate vascular anastomosis is the key to replantation survival. Therefore, thorough vascular debridement is a crucial first step. The standard for thorough vascular debridement is the following: intact and smooth endangium without blood clot, no peeling of adventitia, and pulsating blood spurting at the proximal end. A proper margin and needle spacing should be considered during vascular anastomosis with a smooth anastomotic orifice and gentle eversion of endangium for successful one-time anastomosis. Otherwise, vascular crisis can occur after the operation. Due to the underdevelopment of body temperature regulation in children, their motor and peripheral vascular motor neuromodulation function is incomplete, resulting in weak body temperature regulation. Consequently, the body temperature of children can easily fluctuate with the surrounding temperature. Moreover, the blood vessels in children's fingers are small in diameter with thin vessel walls, and the sympathetic nerves of the limbs are dominant, often causing blood vessel shrinkage and proneness to hypothermia and vasospasm. In addition, operations such as injection, surgery, and dressing change by medical staff can easily lead to fear of medicine and emotional instability in pediatric patients. Vasospasm caused by crying after replantation of amputated fingers in children is a special complication that differs from adult cases. In the case we report, we performed surgical exploration immediately after the occurrence of arterial crisis. Transparent thrombosis was found at the anastomotic site of the radial digital artery, which was about 1.5-cm long. A 1.8-cm-long embolic artery was resected, and a 2.0-cm superficial vein of the carpal palm of the forearm was transplanted. The forearm fat layer in children is thicker, and superficial veins are often difficult to locate. In this case, an incision of about 1 cm was made at the possible direction of

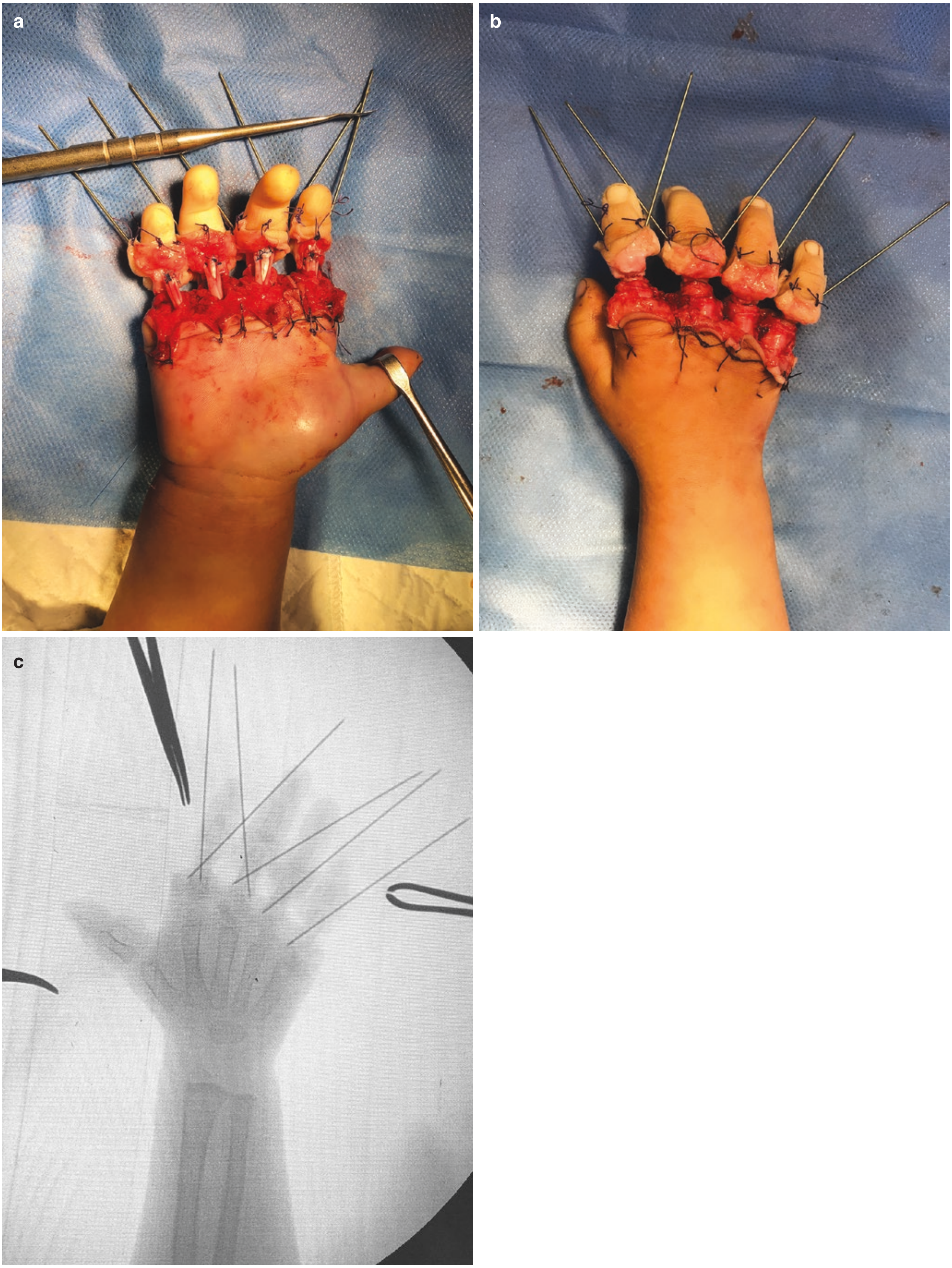


Fig. 3.2 After reducing the proximal phalanx fracture, the 2–5 fingers were cross-fixed with an 0.8-mm Kirschner wire. (**a**) palmer view, (**b**) dorsal view, (**c**) fluoroscopy

Fig. 3.3 Four fingers blood supply recovery after the operation. (**a**) palmer view, (**b**) dorsal view

the forearm distal volar superficial vein. After locating the superficial vein, it was explored, and about 2.5 cm of the skin was cut along the vein, after which the superficial vein for transplantation was cut out. The length of the graft vein cannot be too long; otherwise, sputum or embolism can occur. Vascular grafting solves the contradiction between complete resection of the diseased vessel segment and retaining the length of the phalanx as much as possible to avoid excessive anastomotic tension and improve the patency rate of the anastomosis.

3.4 Clinical Implications

The survival rate of replanted amputated fingers depends on a variety of factors. The quality and quantity of vascular anastomosis are the most basic [1]. Compared to adults, young children have higher recovery potential and adaptability as well as better functional recovery. Although sutures of children's veins are more difficult, relevant literature suggests always trying to repair amputated fingers in children younger than 6 years old [2]. Adequate venous anastomosis can prevent venous congestion and edema, insufficient arterial blood supply, and the accumulation of metabolites [3]. Anastomosis of as many veins as possible is conducive to the success of replantation [4, 5]. During the operation, we planned to anastomose vessels at a ratio of 2:3 (artery: vein). However, only two veins in the index finger were found during the operation. On the sixth day after the operation, the finger showed bruising and swelling. After removing the local suture, a small incision was made on the lateral side of the fingertip in combination with a local wet compress of a heparin cotton ball, to improve venous insufficiency. Nevertheless, we believed that the swelling caused by the infection hindered the reflux of the vein, which demonstrated venous crisis. We used cefoperazone sulbactam to control the infection, and the symptoms improved after 3 days.

Although the function of the hand cannot be fully restored after replantation, the operation can retain the appearance of the hand and reduce the psychological impact on the child. Indeed, replantation is recommended even with multi-finger amputation. In addition to a smooth operation, timely detection, and the successful treatment of complications, careful postoperative care is critical to ensure the treatment effect.

Fig. 3.4 Arterial crisis occurred in the ring finger (**a**), the blood supply was completely normal 1 week after vascular transplantation (**b**, **c**)

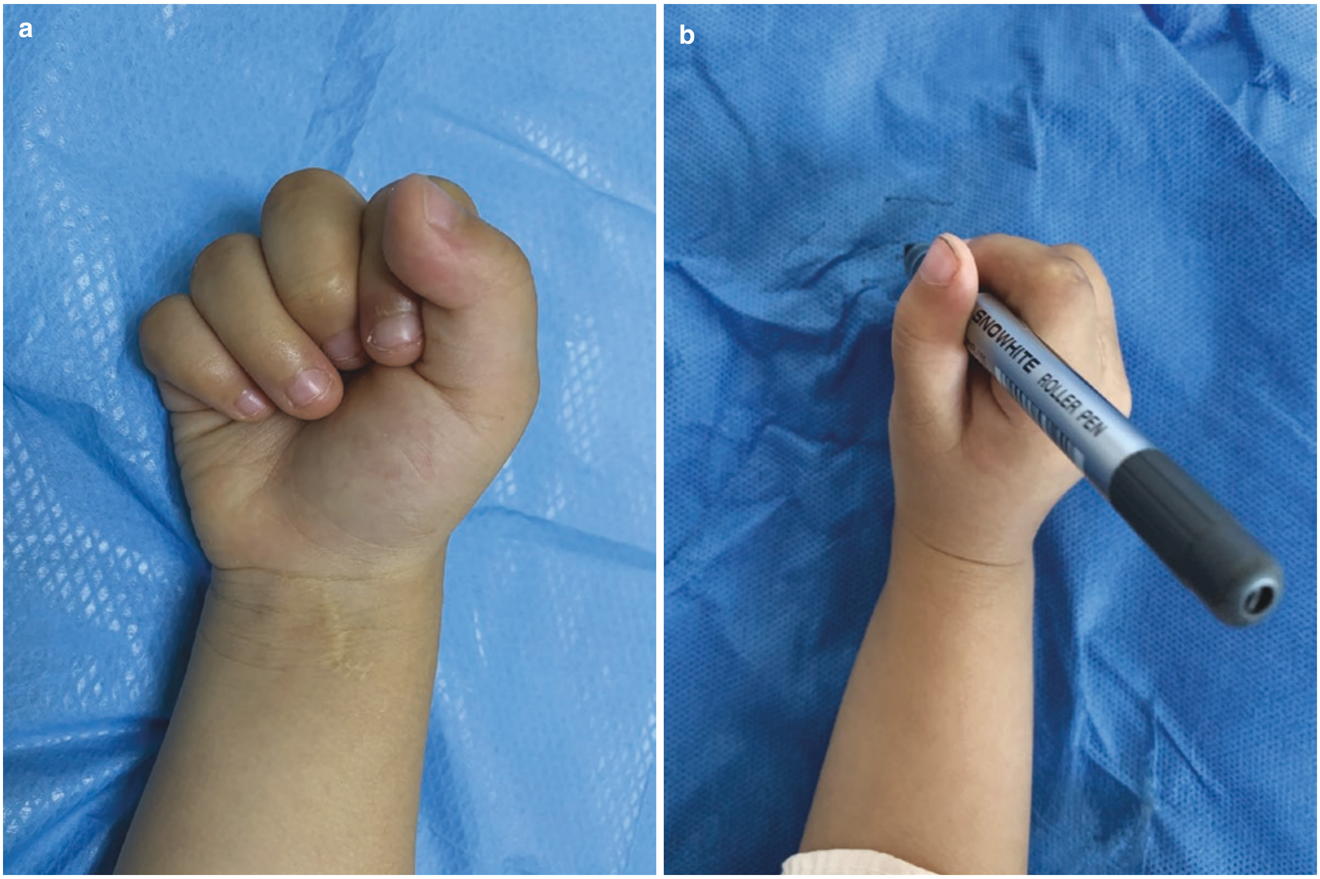


Fig. 3.5 One and a half years after the operation, the right hand of the child was followed up with a good appearance (**a**) and good grip function (**b**)

References

1. Efanov J, Rizis D, Landes G, et al. Impact of the number of veins repaired in short-term digital replantation survival rate. J Plast Reconstr Aesthet Surg. 2016;69(5):640–5.
2. Yildirim S, Calikapan G, Akoz T. Reconstructive microsurgery in pediatric population-a series of 25 patients. Microsurgery. 2008;28(2):99–107.
3. Shaterian A, Rajaii R, Kanack M, et al. Predictors of digit survival following replantation: quantitative review and meta-analysis. J Hand Microsurg. 2018;10(02):66–73.
4. Woo SH, Cheon HJ, Kim YW, et al. Delayed and suspended replantation for complete amputation of digits and hands. J Hand Surg. 2015;40(5):883–9.
5. Hou JX, Xie SQ, Zhang HF, et al. Replantation of hand multi-level severances with 17 segments. Injury Extra. 2014;45(6):41–4.

4 Replantation of Severed Fingers in Children

Jian Lin and Zhi Jiang Wang

4.1 Case Presentation

An 18-month-old boy was injured by a powder grinder of a distal section in vitro of the right ring finger, suffered from pain, bleeding, and was admitted in 1.5 h. Physical examination: The general situation was good; the vital signs were stable. About 0.8 cm × 0.5 cm of the skin near the palm side of the fourth finger on the right hand was avulsed, with tendon and bone exposure, irregular edges, the distal finger section amputated, and bleeding. There was about a 2-cm-long neurovascular bundle tip connecting to the palm of the finger which looked like a "horsetail," and there was congestion under the nail. The blood supply of the rest fingers was good. The surgery was carried out successfully under general anesthesia. After the tourniquet is relaxed, the finger should be ruddy and with moderate tension. The patient was brought to the ward safely after the operation with the replanted finger fixed with a sterile cotton bandage and padded with broken cotton yarn. Then the conventional treatment was given to him, and the replanted severed finger successfully survived 10 days later. The replanted finger's function and growth are good after regular 6 months' follow-up and functional exercise guidance (Fig. 4.1).

4.2 Choice of Treatment

Due to the children's finger blood vessel is small and anastomosis is very difficult, difficult management, high requirements of surgical techniques, especially the distal avulsion [1–3]. However, once the replantation is successful, the function of severed fingers would be better than that of adults, and there is no other treatment to replace them at present. Therefore, replantation still will be our choice [4, 5].

J. Lin (✉) · Z. J. Wang
Chongming Research Center for Wound Prevention and Treatment of Shanghai, Chongming Branch of Xinhua Hospital (Chongming) Affiliated to Medical College, Shanghai Jiaotong University, Shanghai, China

4.3 Operative Technique

(1) Infection must be prevented. The necrotic tissue should be removed under general anesthesia under a ×12 microscope, which is helpful for finding blood vessels and nerves carefully, that should be marked and for standby application; (2) the end of the fracture should be shortened appropriately. The distal phalanx base joint should be retained and the tendon should be flexed as far as possible to maintain the integrity of the distal interphalangeal joint. Fix the fracture with a single Gram's needle (0.8–1 mm) longitudinally; and (3) the younger the child is, the smaller the diameter of the blood vessel, and the thinner the blood vessel wall will be. It is difficult to operate when the distal vascular diameter is approximately 0.15–0.3 mm, at the same time the vascular strength is poor under the age of 3. Noninvasive thread 11–0 or 12–0 could be used, under tourniquet control for anastomosis, "stable, accurate and precise, skillful" small vascular anastomosis technique is also very important; and (4) the tightness of the skin should be appropriate to avoid the oppression on vascular anastomosis site [6].

4.4 Clinical Implications

(1) Demands and expectations of parents are generally high, which means detailed preoperative talk and education must be emphasized; (2) the mechanism of injury and wound conditions must be understood and judged by an experienced physician who would make the prognosis and decision whether to perform the operation; and (3) nursing is most important. The parents must cooperate with the treatment actively, which would make their children do the best to achieve good medical progress to obtain the best curative effect; and (4) injury, fear, preoperative and postoperative pain, postoperative brake position that the patients must face to would bring psychological tension, fear, crying, touch, and other complex conditions what would affect the blood supply of the replanted finger which would lead to vascular

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_4

Fig. 4.1 (1) The severed finger. (2) The situation after operation. (3) and (4) 26 months after the operation. Adapted from Lin J, Zheng HP, Xu YQ, et al. Special type of finger replantation. Springer, 2018; with permission

spasm. A warm therapeutic environment and personalized care should be provided to the patients; (5) the margin should be accurate and uniform, lift the knot gently to prevent anastomotic varus. Stable, light, and fast are required for the operation; (6) the blood vessels should not be distorted, under pressure, and there is no leakage of blood. In addition, if the right edge of the artery cannot be found, the proximal arteriovenous defect or the dorsal hand vein can be transplanted to the finger; (7) the epiphysis should be protected and avoid injury, which will affect the growth of the replanted finger; (8) some enzymes and blood-brain barrier development are not perfect in children, that means drugs could easily pass through the blood–brain barrier and arrive in the central nervous system to produce toxic side effects. So, individualized doses, small doses and avoiding multidrug combinations should be the principle; (9) as sensation has not yet been fully restored to the replanted finger, the secondary injury should be paid attention to, such as scalds, frostbite, and wounds; and (10) survival should not be the only standard for success, which should be also associated with good appearance and function. Children should be encouraged to use the finger for function recovery [6].

References

1. Cheng GL, Pan ZD, Xu PC. Severed finger replantation in children. Natl Med J China. 1982;62(5):303–4.
2. Kleinert HE, Kadsan ML, Romero JL. Small blood vessel anastomosis for salvage of severely injured upper extremity. J Bone Joint Surg Am. 1963;45:788.
3. Komatsu S, Tamai S. Successful replantation of a completely cutoff thumb: case report. Plast Reconstr Surg. 1968;42:374–7.
4. Wang CQ, Fan QS, Cai JF. Severed finger replantation in children. Chin J Orthopaed. 1983;3(6):349–51.
5. Lin J, Wang ZJ, Wu LZ, et al. Replantation of severed distal segment of children's distal of finger 9 cases. Chin J Microsurg. 2015;38(5):468–9.
6. Lin J, Zheng HP, Xu YQ, et al. Special type of finger replantation. Springer; 2018.

Replantation of Single hand's Multiplane Severances with 17 Segments

5

Jianxi Hou, Shuqiang Xie, Qiqiang Dong, Zhaosen Wu, and Chaofan Yang

5.1 Case Introduction

An 18-year-old girl suffered a cutting injury in her right hand during work. We found all the fingers and the palm were severed into 17 segments by 6 planes when she arrived at the emergency room of our hospital 3 h after the injury. The thumb was found severing into three segments by nail root, proximal, and distal parts of the thumb proximal segment, respectively. The index finger was severed in the middle and proximal segments, respectively. The middle finger severed in the middle segment, proximal segment, and nail root, respectively. The ring finger severed in the nail root, proximal, and distal part of proximal interphalangeal joint, respectively. The little finger severed in the middle segment and middle part of the proximal segment, respectively. The second to fifth metacarpal bones severed in the distal, middle, and proximal ends, respectively, with sharp edges, among which there was exclusively 2-cm-wide skin are connected at the middle part of the palm (Fig. 5.1).

5.2 Treatment Choices

Routine treatment may abandon replanting due to the severity of the injury, and the replantation of multifinger and multisegment would take so much time, but the risk of failure increases exponentially or may choose to replant just limited fingers to recover basic functions of the hand. However, after analyzing the case, we realized that the sections of the severed fingers and palm were neat, soft tissue contusion was not serious, and severed time was short. Therefore, we believed that replantation was possible with reasonable grouping cooperation.

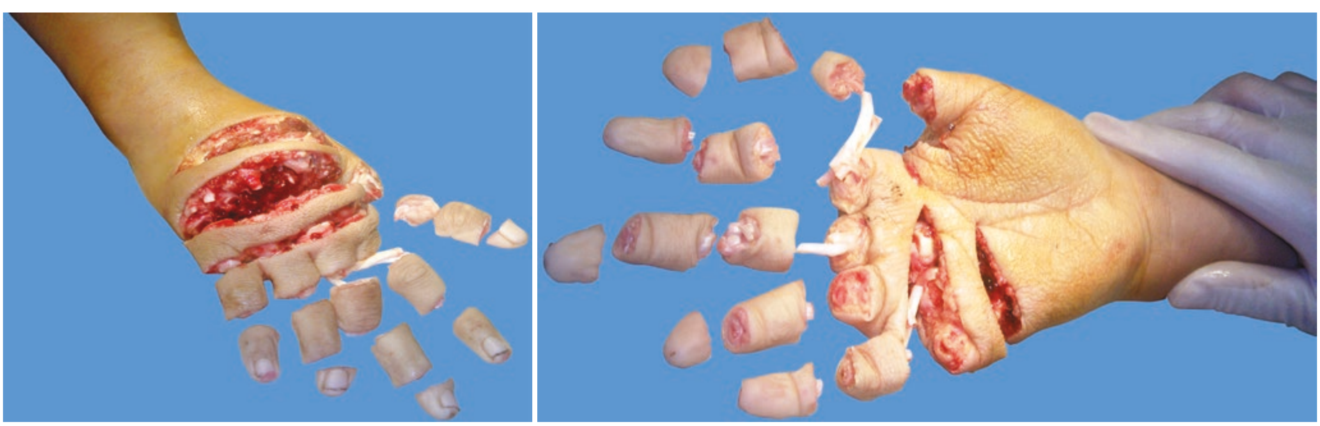


Fig. 5.1 Preoperative appearance (Adapted from Hou JX, Xie SQ, Zhang HF, et al. Replantation of hand multi-level severances with 17 segments. Injury Extra, 2014, 45(6):41–44; with permission)

J. Hou (✉) · S. Xie · Q. Dong · Z. Wu · C. Yang
Department of Hand and Foot Surgery, Zhengzhou Renji Hospital, Zhengzhou, Henan, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_5

We chose to replant all segments of fingers and palm in one stage by collaborative groups. Eventually, all fingers survived, and the patient returned to normal work and life with satisfactory functions.

5.3 Operation Techniques

The surgery was performed under brachial plexus anesthesia. After carefully identifying the attribution of all the segments, we divided them into four surgical groups.

Group 1 and group 2 were assigned to replant the segments from the first to fifth fingers. After thorough debridement without blood flow, we dissociated and marked blood vessels, nerves, and tendons under medical surgery microscope. Then, we transfixed all segments of phalanges in corresponding orders after some of which were shortened properly according to the length of the marked blood vessels. We anastomosed extensor tendons, a deep flexor tendon, 2–3 veins, and 1–2 arteries each segment successively. In all, 10–0, 12–0, and 9–0 non-invasive sutures were applied, respectively, while vessels of proximal segments, distal segments, and digital nerves were anastomosed.

Group 3 was assigned to replant the segments from the palm. Metacarpus was transfixed and then common palmar digital arteries, common palmar digital nerves, dorsal hand veins, Flexor, and extensor tendons were identified after thorough debridement. Palm blood circulation was successfully reestablished.

Group 4 was assigned to replant all fingers to the palm in the order of thumb, index, middle, ring, and little finger.

The surgery lasted 21 hours. The blood circulation of the severed right hand was reestablished. There was anastomosis of 33 arteries, including 3 arteria digitalis communis and 10 arteriae digitales propriaes, 56 veins, including 4 dorsal metacarpal, 10 dorsal digital, and 4 palmar digital veins, and 32 nerves. All vessel anastomosis applied three or four fixed mattress-eversion-suture technique. The hand was fixed with a plaster slab, and medications including anti-inflammation, anticoagulation, and anti-angiospasm were given continuously (Figs. 5.2–5.5).

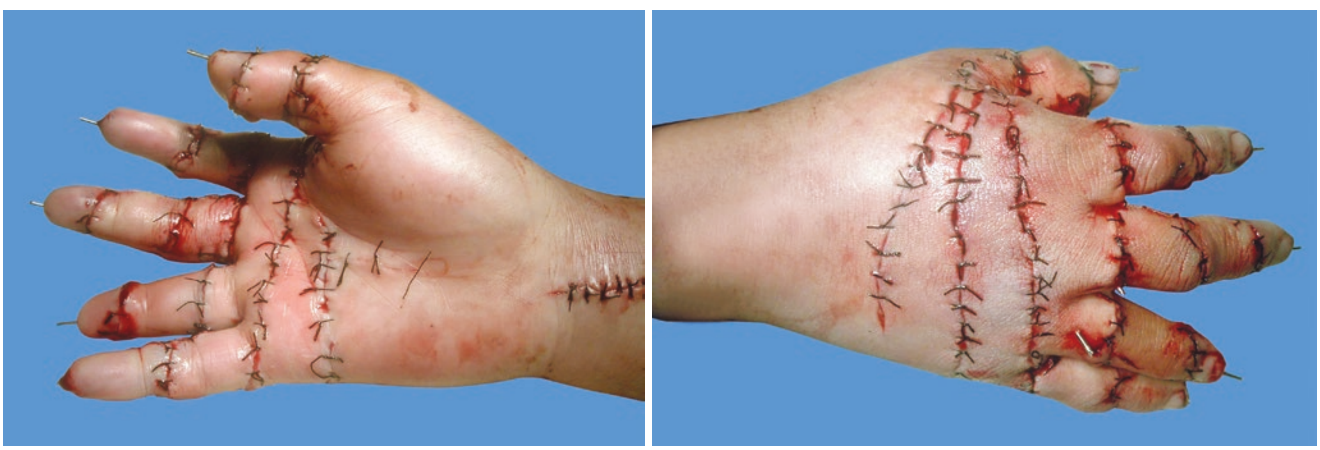


Fig. 5.2 Postoperative appearance (Adapted from Hou JX, Xie SQ, Zhang HF, et al. Replantation of hand multi-level severances with 17 segments. Injury Extra, 2014, 45(6):41–44; with permission)

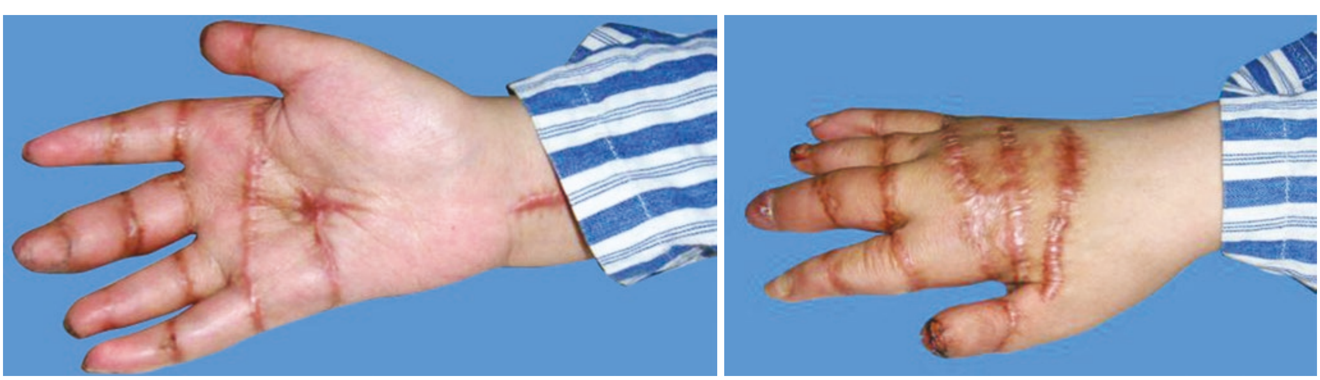


Fig. 5.3 All segments of all fingers were survived (Adapted from Hou JX, Xie SQ, Zhang HF, et al. Replantation of hand multi-level severances with 17 segments. Injury Extra, 2014, 45(6):41–44; with permission)

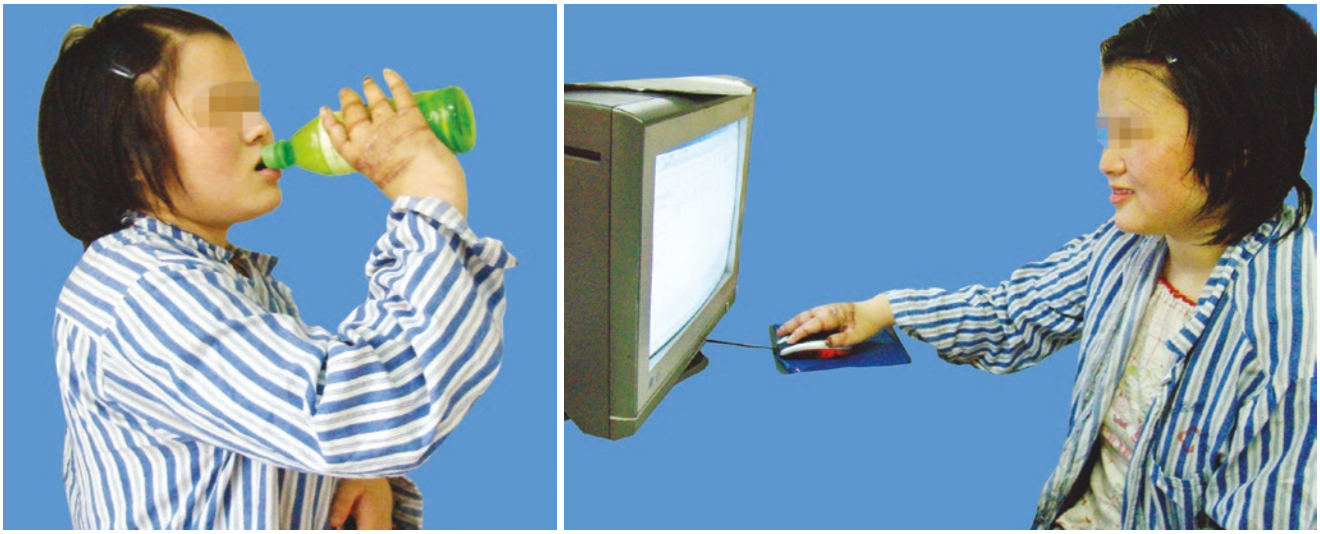


Fig. 5.4 Functional recovery (Adapted from Hou JX, Xie SQ, Zhang HF, et al. Replantation of hand multi-level severances with 17 segments. Injury Extra, 2014, 45(6):41–44; with permission)

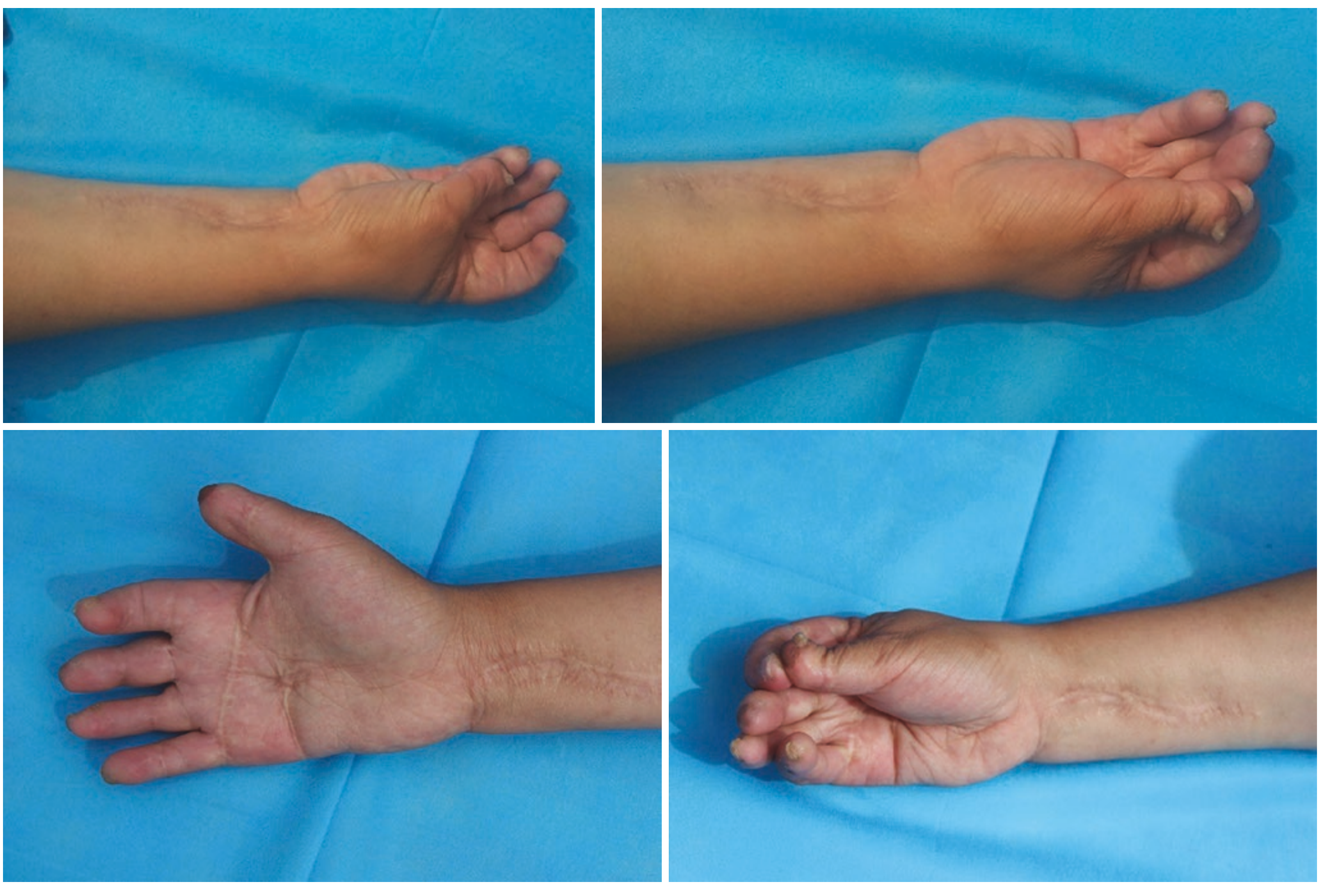


Fig. 5.5 5-year follow-up (Adapted from Hou JX, Xie SQ, Zhang HF, et al. Replantation of hand multi-level severances with 17 segments. Injury Extra, 2014, 45(6):41–44; with permission)

5.4 Discussion and Tips

When dealing with amputation injuries such as multifingers or multisegments, it is wise to divide your surgery team into groups reasonably [1]. Three or four fixed mattress-eversion-suture technique can avoid varus of vascular walls, reducing the risk of thrombosis and ensuring the survival of all replanted segments [2]. Early postoperative rehabilitation training is important for long-term functional recovery [3].

References

1. Kelsey F, Michael M, Elizabeth B, et al. Leadership and teamwork in trauma and resuscitation. West J Emerg Med. 2016;17(5):549–56.
2. Wu ZS, Hou JX, Xie SQ, et al. Application of three and four point mattress eversion vascular anastomosis in replantation of severed fingers (limbs). Chin J Microsurg. 2019;42(001):75–7.
3. Hou JX, Xie SQ, Zhang HF, et al. Replantation of hand multi-level severances with 17 segments. Injury Extra. 2014;45(6):41–4.

6 Replantation of the Severed Upper Arm of a 9-Month-Old Infant

Jianxi Hou, Shuqiang Xie, Qiqiang Dong, Zhaosen Wu, and Chaofan Yang

6.1 Case Introduction

A 9-month-old infant whose left arm was cut off completely by an electric saw at the lower one-third part of the upper arm. The patient had a pale complexion, and her vital signs showed"T:35.4 °C; P:147 times/min; R:28times/min; Bp:89/58 mmHg". There were no abnormalities in cardiopulmonary and abdominal examinations (Fig. 6.1).

6.2 Treatment Choices

Intravenous channels were established immediately for fluid replacement, blood transfusion, and correction of shock based on our experience. After stabilizing the vital signs, we realized that the severed limb had almost no extra damage except for some contusion and severe contamination of the wound surface. We believed in children's regenerative ability, although the baby's limb replantation is much more difficult than that of adults. Therefore, we did the replantation with reasonable grouping.

The injured arm, which eventually survived, maintained good blood circulation after the operation and successfully went through the dangerous period. The wound was primary healing and the plaster dismantled after 4 weeks. Rehabilitation training and guidance were given systematically for 2 weeks before discharge.

After 5-year follow-up, the replanted limb was just about 2 cm shorter than the contralateral side and had a satisfactory appearance despite scars. The forearm and hand had normal skin sensation and could sweat like other limbs. Two-point discrimination of the hand reached excellent 4 mm and elbow flexion reached 135°. Both the pronation and supination of the forearm reached 80°. Wrist flexion reached 50° and back extension reached 40°. Active flexion of metacarpophalangeal joints reached 90° and proximal interphalangeal reached 60°. Adduction and abduction reached 30° and 35°, respectively. This case reached an excellent grade according to the standard functional evaluation issued by the Hand Surgery Association of Chinese Medical Association [1].

6.3 Operation Techniques

The operation was performed under general anesthesia. Carpet debridement of the two sides of the wound was done by two groups at the same time.

Group 1 was assigned to debride the proximal limb to eliminate necrotic tissue and mark basilic vein, cephalic vein, brachial artery as well as accompanying veins, median nerve, ulnar nerve, radial nerve, medial brachial cutaneous nerve, lateral antebrachial cutaneous nerve, and some other subcutaneous veins. Then, the humerus was shortened by 0.5 cm according to the length of vessels and nerves.

Group 2 was assigned to debride the distal limb. After debriding, we fixed the humerus with crossed Kirschner wires and sutured the triceps, brachialis, and biceps tendon. Then, the radial artery and the accompanying veins were anastomosed with 9-0 noninvasive sutures. We saw smooth blood flow through the anastomoses after loosening the vascular clamp. And then median nerve, ulnar nerve, radial nerve, medial brachial cutaneous nerve, and lateral antebrachial cutaneous nerve were anastomosed in turns. At last, we anastomosed cephalic vein, basilic vein, and a few subcutaneous veins. The skin was sutured after checking all the anastomoses again and doing hemostasis thoroughly. The elbow joint was flexed with plaster at a flexion position of 70° (Figs. 6.2 and 6.3).

Postoperative treatments: (1) Medications including anti-inflammation, anticoagulation, and anti-angiospasm were given continuously after strictly calculating the dose. Blood volume was replenished reasonably and balance of electrolyte and acid-base was maintained. (2) We observed the

J. Hou (✉) · S. Xie · Q. Dong · Z. Wu · C. Yang
Department of Hand and Foot Surgery, Zhengzhou Renji Hospital, Zhengzhou, Henan, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_6

Fig. 6.1 Preoperative appearance

Fig. 6.2 2 weeks postoperative appearance

Fig. 6.3 The limb survived

changes in vital signs and circulation of the affected limb closely and changed the dressing of the wound regularly to prevent infection. (3) The patient was maintained in sub-hibernation state. (4) Regular blood biochemical examination was performed in case of acute renal failure and other complications (Fig. 6.4).

6.4 Discussion and Tips

With the continuous development and improvement in microsurgical technology, the rate of successful amputated limb replantation is increasing [1]. Adults' limb replantation cases have been reported, while infants' are rarely [2].

We get some key points from this successful replantation: (1) Prolonged operations require excellent anesthesia, but the risk of anesthesia will increase with the prolongation of operation time. The organs of infants are not developed, and adults and infants have poor compensatory functions in general. So fluid infusion, blood transfusion, and medication must be calculated rigorously to keep vital signs stable. (2) Debridement should be done thoroughly by a senior doctor to reduce infection risk, which is the key to succeed. (3) Microscopic anastomosis of blood vessels and nerves lays a good foundation for limb survival and functional recovery, which in this case was performed perfectly. (4) Hibernation therapy can be used properly after operation to reduce crying and prevent vascular crisis or anastomotic leakage of vessels. (5) Rehabilitation should be valued because it is important to the recovery of injured limb. (6) Infantile is a special period with strong regeneration ability. The recovery of sensory and motor function after replantation is much better compared to adults [3].

Fig. 6.4 5-year follow-up

Fig. 6.4 (continued)

References

1. Pan DD, Gu YD, Shi D, et al. Evaluation of upper limb function of the society of hand surgery, Chinese Medical Association. Chin J Hand Surg. 2000;03:4–9.
2. Taman E, Alfeky H, Omran A, et al. Maximising the outcomes of proximal upper limb replantation. Int J Surg. 2018;55:S116.
3. Hou JX, Dong QQ, Xie SQ, et al. Successful replantation of severed arm in a 9-month-old infant. Chin J Hand Surg. 2014;30(02):106.

7 Replantation with Vessel Anastomosis for Treatment of Hand Degloving Injuries

Jihui Ju, Jianning Li, and Ruixing Hou

7.1 Case Presentation

A 43-year-old female suffered a degloving injury of her left hand in a printing machine during her work. She was admitted to our hospital 2 h after the injury. The skin was avulsed from the distal forearm to the fingertip (Fig. 7.1). The bone, joint, tendon, nerves of the thumb and fingers, and the intrinsic muscle remained relatively intact. Complete debridement was performed under axillary block anesthesia in the emergency room. Relative intact of the degloved skin was found. The dorsal skin and palmar skin were bruised. The proper digital arteries of the index, middle, ring, and small finger were amputated at the level of the distal interphalangeal joint, and their nerves were extracted at the wrist level. The proper digital arteries of the thumb were amputated at the level of the fingertip.

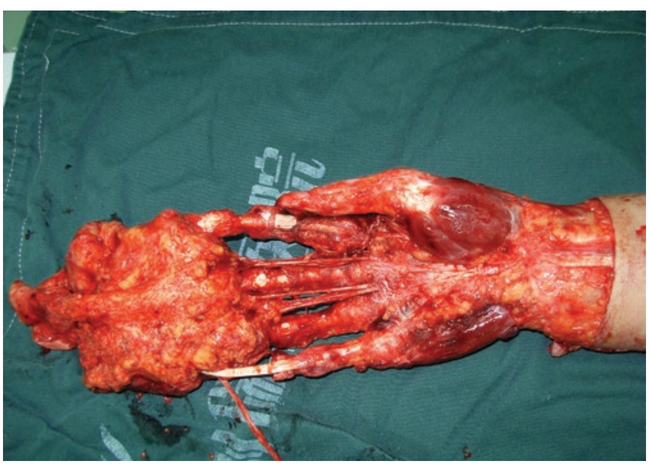


Fig. 7.1 Condition of the whole hand degloving injury

7.2 Choice of Treatment

The whole hand degloving injury is a type of skin and soft tissue avulsion. It may occur if the patient withdraws the hand violently and reflexively when his hand encountered foreign violence or roller crush injury. The character of this injury is the uneven wound edge with a severe bruise. The amputated level of the degloved skin, arteries, veins, tendons, bones, and joints were different. At the same time, the vessel endangium was severely bruised. Sometimes the arteries and nerves were extracted. The common treatment is to embed the injured hand into the abdominal subcutaneous tissue. The flap was separated 3–4 weeks after the operation, or the hand-wound with good granulation tissue was repaired by the skin graft. However, the appearance and function of the repaired hand were unsatisfactory. If the degloved skin could be replanted, the survival skin would encourage a better recovery of the appearance and function than other methods. For this case of hand degloving injury with relative intact of degloved skin, although digital arteries and palmar main veins were ruptured, the arteries and veins could be anastomosed to reconstruct the blood supply for the degloved skin, resulting in the successful replantation of the injured skin.

There are some advantages of replantation for treatment of hand degloving injuries: (1) maximize the usage of the degloved skin to repair the hand-wound; (2) The injury is treated by one operation with short duration of therapy; (3) Because of the usage of the original skin, the texture of the repaired hand skin is good. The appearance and function of the repaired hand are satisfactory. This method does not need other skin from the donor site and is accepted by the patient easily. In view of these advantages, replantation is suggested to repair the hand degloving injury preferentially.

J. Ju (✉) · J. Li · R. Hou
Department of Hand and Foot Surgery, Ruihua Hospital Affiliated to Soochow University, Suzhou, Jiangsu, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_7

7.3 Operative Technique

Complete debridement of degloved skin was performed and then was done again under an operating microscope. Then, the arteries, nerves, and dorsal and palmar veins were examined and marked. The injury condition of the skin was judged. The proximal stump of the injured hand was debrided, and the amputated stump of arteries, nerves, and dorsal and palmar veins were examined and marked. Hemostasis was performed carefully for the wound. After the tourniquet was released, hemostasis was done again, and no errhysis was found in the digital distal phalanx. All of the common digital arteries were ruptured at the level of the middle palm. The amputated stump of the superficial palmar arch was not found. Only superficial branch of the ulnar artery was detected. All the intercapital veins were ruptured. Three veins in the degloved skin at the junction of the finger and dorsum were found and marked. After complete debridement, the degloved skin was reattached to the original thumb and fingers. The proper digital arteries and nerves were repaired at first and the common digital arteries and nerves were done. Three veins at the junction of the finger and dorsum were then anastomosed. The edge of degloved skin was pulled to the dorsum and palm. Superficial veins, six in the palmar subcutaneous tissue and three in the dorsal subcutaneous tissue, were anastomosed. Totally, six dorsal veins and five palmar veins were anastomosed as well as the amputated proper and common digital arteries. The blood supply of the index, middle, ring, and small finger and the dorsal and palmar skin were recovered. In order to avoid ischemia necrosis of the digital bone, dendritic vein grafts from the volar aspect of the forearm were used to bridge the superficial branch of ulnar artery and the common digital arteries (Fig. 7.2). The dorsal and palmar skin received suitable compression bandaging. The blood supply of the thumb and fingers was good (Fig. 7.3).

Fig. 7.2 Vein graft from the volar aspect of the forearm for the bridge of the superficial palmar arch

Fig. 7.3 The appearance after operation

Fig. 7.4 Thumb, the four fingers, and the dorsal and palmar skin survived after replantation

A plaster splint was applied to the dorsal surface to support the fingers, hand, and wrist after the operation. Anticonvulsant, anticoagulant drug, and anti-inflammatory drug were routinely administered. The blood circulation of the thumb and fingers was observed closely. The dressing was firstly changed 3–5 days after the operation, and then pressure dressing was continuous. The replanted skin, thumb, and all four fingers survived 12 days after the operation (Fig. 7.4). Drainage occurred in the distal phalanx of the index finger 3 months after the operation. X-ray results suggested the bone of the distal phalanx was absorbed. So the distal phalanx of the index finger was amputated. The patient was followed up 2 years after the operation. The texture of the dorsal and palmar skin was good. The appearance of the thumb and the fingers was satisfactory (Fig. 7.5). The abduction and opposition function of the thumb was recovered. The extension and flexion function of the fingers were satisfied by the patient (Fig. 7.6). The digital sensation was S2-S3.

Fig. 7.5 The appearance of the injured hand 2 years after the operation

Fig. 7.6 The function of the injured hand 2 years after the operation

7.4 Clinical Implications

The replantation focuses on the complete debridement. Because if infection occurs, it would affect the skin survival and vascular patency. So the degloved skin was needed to be debrided completely [1, 2]. If necessary, the incision may be made for debridement. For ones with severe pollution, debridement must be performed under an operating microscope.

The wound should achieve good hemostasis during the operation. A drainage device with good patency is placed under the subcutaneous tissue. Suitable compression bandaging was done on the dorsal and palmar skin to avoid the formation of subcutaneous hematoma, which could affect the skin survival or lead to infection incidence [3]. If necessary, some longitudinal incisions could be made on the dorsal and palmar skin for drainage.

If there are many veins at the edge of the degloved dorsal and palmar skin, the veins should be anastomosed as many as possible for the reconstruction of vein drainage of the degloved skin [4]. It is a necessary measure for the dorsal and palmar skin survival [5].

The injury condition of the degloved skin should be judged carefully [6]. The one with a severe bruise could not be replanted [7–9]. The necrosis of the skin could lead to digital necrosis.

For the case with rupture of the superficial palmar arch, the superficial palmar arch should be reconstructed. If necessary, dendritic vein grafts from the volar aspect of the forearm were used for the reconstruction of blood supply.

When harvesting the vein graft, the vein drainage of the donor site should be concerned. It is not necessary to harvest the main veins. It is better to harvest it from the volar aspect of the forearm.

If the formation of a subcutaneous hematoma at the dorsum and the palm is found, some sutures of the edge could be removed, and the hematoma should be removed by gentle extrusion.

The dorsal and palmar skin received suitable compression bandaging, which could not affect the anastomosed vessels.

References

1. Hou RX, Wang HW, Ju JH, et al. Repair of degloving injury of the entire hand by bilateral combined transfer of wrap-around flap and multi-petal pedal flaps based on a single pedicle. Chin J Hand Surg. 2009;25(1):32–4.
2. Wang XN, Han BP, Chen KJ, Kan SL. Treatment of degloving injuries of the hand. Chin J Hand Surg. 2006;22(2):67–9.
3. Pradier JP, Oberlin C, Bey E. Acute deep hand burns covered by a pocket flap-graft:long-term outcome based on nine cases. J Burns Wounds. 2007;16:1–32.
4. Wang CS, Wang AG, Ma L, Han Y, Shi CL. Vein anastomosis and negative pressure drainage for treatment of whole hand palmar degloving injury. Chin J Reparative Reconstruct Surg. 2010;24(5):632–3.
5. Cui CL, Yin WG, Zhang XY, et al. Experimental study on the survival mechanism of pure venous flap in rabbit ear. Chin J Clin Anat. 2005;23(2):180–2.
6. Shou KS. Surgical selections of skin avulsion of the hands. Chin J Hand Surg. 2006;22(2):65–6.
7. Wang XN, Kan SL. Experimental study on microsurgical replantation of large degloving injury of rabbit hind leg. Chin J Microsurg. 2010;33(1):51–3.
8. Pan F, Tian WC. Classification and sequential management of hand avulsion injuries. Chin J Hand Surg. 2008;24(3):144–7.
9. Thomas BP, Tsai T. Primary reconstruction of a degloved hand using multiple toe transfers on a single pedicle and a reversed radial artery flap. J Reconstr Microsurg. 2004;20:3–6.

Transpositional Replantation of Severed Fingers

8

Jian Lin and Tian Hao Zhang

8.1 Case Presentation

The left hand of a 38-year-old female was injured by an injection molding machine and she was admitted within an hour. Physical examination: The general situation was good, and the vital signs were stable. We found only the thumb and the proximal–distal parts of the ring and little fingers were still residual. The wound was bleeding, irregular with multiple fractures, with tendon, blood vessel, and broken nerve ends exposure. There was no blood supply for the residual fingers, so they were shifted and replanted to metacarpal and radial alignment after satisfactory debridement under anesthesia and fixed with 1.0-mm Kirschner wire. After that, the tendons, blood vessels, and nerves were also anastomosed one by one. The surgery was successful since the replanted fingers were ruddy, with moderate tension and after the tourniquet relaxed. The patient was brought to the ward safely after the operation with the replanted finger fixed with a sterile cotton bandage and padded with broken cotton yarn. Then, the conventional treatment was given to her, and the replanted severed finger successfully survived 2 weeks later. The replanted finger's function and growth are good after regular follow-up and functional exercise guidance. (Fig. 8.1).

8.2 Choice of Treatment

Destructive fragmentation of the hand is a serious compound injury; generally, it would be impossible to undergo in situ replantations. Therefore, most of them choose prosthesis, and some patients also received free composite tissue (toe) transplantation to repair the wound and reconstruct the function of the hand, but neither the appearance nor the function would be satisfactory [1–3]. We choose the relatively complete tissue to reconstruct the function of the hand, and this kind of "waste" reuse would alleviate patients' suffering and burden.

8.3 Operative Technique

(1) Complete debridement and retain the useful tissues as far as possible to avoid the shortage. Find the arteries, veins, and nerves and mark them for use. (2) The bone can be fixed with Kirschner wire, wire wrapped in a "figure of 8" shape and screws. In our experience, the longitudinal fixation of the needle is simple and reliable which would shorten the operating time, and it would even affect joint activity after surgery and it could be the first choice. (3) The tension of the tendon should be appropriate, without corners and wrinkles, using a 3–0 noninvasive suturing needle. The tendon bed could be repaired with deep fascia so that the tendon can be isolated from the bone which would help avoid bone–tendon adhesion. (4) Vascular anastomosis: The proximal vein is easy to find also the finger vein. Select a suitable diameter and make an end-to-end anastomosis with 10–12 stitches. For artery, the ulnar or radial artery should be selected to be anastomosed with the total artery or the finger artery of the replanted finger. The end-to-side method could be used to solve the problem when there is a wide gag. In addition, when the arteriovenous blood vessel cannot be directly anastomosed, the remaining vein or forearm vein could be transferred to reconstruct the arteriovenous vessel. (5) Nerve repair: We should pay special attention to nerve repair. Both sides of the nerves should be anastomosed as far as possible, and early functional exercise the sooner the better. Once the nerve defect cannot be directly identified, a healthy residual nerve or the transplanted gastrocnemius nerve can be used to reconstruct the finger function.

J. Lin (✉) · T. H. Zhang
Chongming Research Center for Wound Prevention and Treatment of Shanghai, Chongming Branch of Xinhua Hospital (Chongming) Affiliated to Medical College, Shanghai Jiaotong University, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_8

Fig. 8.1 (1) The lateral view of the hand. (2) The X-ray before surgery. (3) The situation of the radial side after transpositional replantation. (4) The X-ray after surgery. (5, 6) The open function of the fingers 15 months later. (Adapted from Lin J, Zheng HP, Xu YQ, et al. Spcial type of finger replantation. Springer, 2018; with permission)

8.4 Clinical Implications [4–11]

(1) The mechanism of injury and wound conditions must be understood and judged by an experienced physician who would make the prognosis and decision whether to perform the operation. (2) In such a situation, the finger may be compressed and polluted seriously. What we should do in the emergency department is not only to remove dead tissues completely but also not to excise normal tissue too much, which is very important both in preventing infection and in ensuring the success of the operation. (3) The vein close to the dorsal part should be paid attention to be damaged when the fingers are connected. (4) The margin should be accurate and uniform and lift the knot gently to prevent anastomotic varus. Stable, light, and fast are required for the operation. (5) The size of the finger and blood vessels will be a problem in transposition. The very suitable varieties of vascular anastomosis methods should be chosen according to the anatomical characteristics, especially at the site of vascular anastomosis. At the same time, strengthened anticoagulant use is necessary to prevent a blood circulation crisis. (6) Nursing is most important. The patients must cooperate with the treatment actively, which would make them do their best to achieve good medical progress so as to obtain the best curative effect. (7) Survival should not be the only standard for success which should be also associated with good appearance and function. Children should be encouraged to use the finger for functional recovery.

References

1. Cai YM, Lin CZ, Qu XY, et al. To summarize the clinical special type of replantation. Chin J Microsurg. 2004;27(3):219–20.
2. Cheng GL, Pan DD, Zhang NP, Fang GR. Digital replantation in children: a long-term follow-up study. J Hand Surg Am. 1998;23(4):635–46.
3. Cheng GL. Review and prospect of finger replantation. Chin J Hand Surg. 2000;16(2):65–7.
4. Chen JZ, Wu KJ, Zhang YW, et al. Palmar wrist severed finger replantation ectopic lesion emergency hand reconstruction. Chin J Microsurg. 2000b;23(1):54.
5. Chen XM, Feng CC, Liu MW, et al. First phase shift finger blast injury 8 cases of thumb reconstruction. Peoples Mil Surg. 1996;11:62.
6. Gong ZF, Gao WY, Zhi L, et al. 28 reports of transposition replantation of severed fingers. J Wenzhou Med Coll. 1997;27(3):135–6.
7. Liao JW, Zhang ZW, Zhuang JC, et al. A case of double forearm stump finger ectopic replantation and reconstruct hand function. Chin J Hand Surg. 2009;25(2):88.
8. Zhou JH, Wang FP, Li GQ. 2 cases of ectopic joint replantation using left palm. Chin J Pract Hand Surg. 2011;25(1):71.
9. Zhang FH, Hu YX, Jiang X. Clinical observation of 10 cases of forearm stump finger ectopic replantation and reconstruct hand function. Zhejiang Clin Med J. 2014;3:377–8.
10. Lin J, Zhang TH, Wang ZJ. Emergency repair and reconstruction of smashed wounds in hands. Chin J Hand Surg. 2018;34(3):206–8.
11. Lin J, Zheng HP, Xu YQ, et al. Spcial type of finger replantation. Springer; 2018.

9 Salvage of the Damaged Hand by the Emergency Reconstruction with Heterotopic Replantation of Discarded Fingers

Juyu Tang and Panfeng Wu

9.1 Case Presentation

The patient, a 29-year-old woman, was admitted to the hospital for 2 h with a severe crush-avulsion amputated injury to the right hand caused by a machine accident. The wrist and palm of the right hand were damaged, and the distal finger was complete and connected with the proximal end by avulsion tendons (Fig. 9.1), but the thumb and index fingers can be selected for replantation at the forearm bones to restore pinch function (Fig. 9.2). During 19 months follow-up, the function of the right hand was partly restored, and the patient could complete daily functions such as writing and wringing the towel, etc. (Fig. 9.3).

Fig. 9.1 Preoperative view of damaged left hand

9.2 Choice of Treatment

Preoperative physical examination showed that the palm and wrist of the patient were completely damaged, but the thumb, index finger, middle finger, ring finger, and small finger were intact, with residual fingers available. We conducted hand reconstruction using heterotopic replantation of the amputated index finger and thumb. The bone union healed well with a satisfactory outcome. The interphalangeal and metacarpophalangeal joint of the fingers after the heterotopic replantation had a good holding activity. This is a worthwhile procedure, and the patient is satisfied with the results. The major disadvantage of this method is the poor appearance of the reconstructed hand.

9.3 Operative Technique

For patients with palmar and total palmar lesions, according to the condition of the distal part of the disused severed finger, two or three available fingers were selected to be fixed at the distal part of carpal bone or ulna and radius, respectively. The separation angle between the two replanted fingers should be adjusted between 20 and 30 degrees, and the frontal surface (inclined angle) of the two fingers should intersect between 90 and 120 degrees so that the palm of the finger can rotate 15 degrees to form good contraposition. In order to preserve the function of the thumb and index finger, a replantation combination of fingers was considered. The proximal arterial anastomosis was selected according to the external diameter of the donor finger artery. Common collocation methods are that radial artery is connected with the main thumb artery, or the ulnar artery is connected the first common finger artery. When conditions permit, many veins are anastomosed to ensure smooth circulation and vein collocation. Distally, the dorsal metacarpal vein, cephalic vein, or branch are anastomosed with the proximal cephalic vein and its branches and the branch of the basilic vein, respectively.

J. Tang (✉) · P. Wu
Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_9

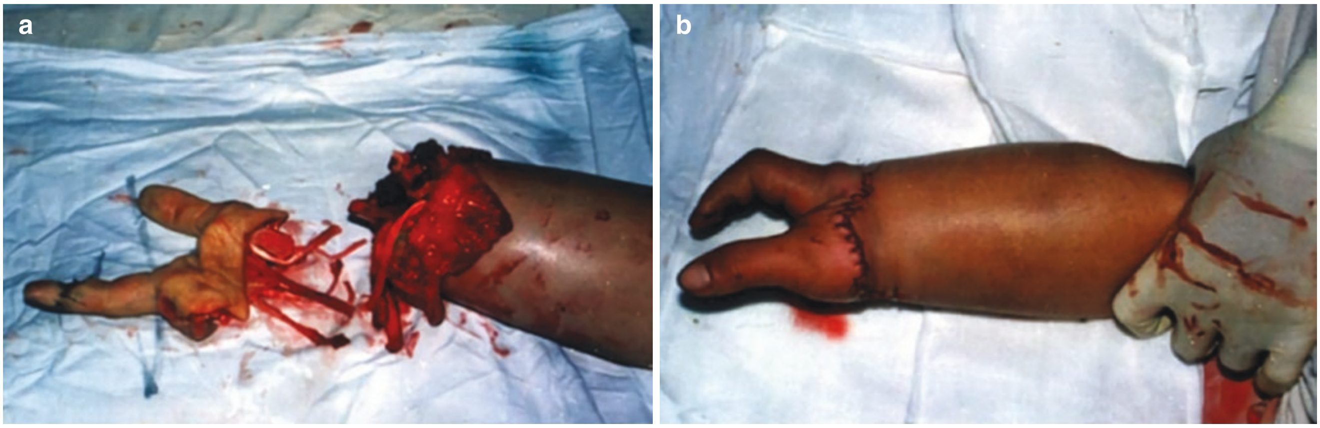


Fig. 9.2 (**a**) Thumb and index finger were dissected and the blood vessels, nerves and tendons of the fingers and the wrist were dissected. (**b**) Heterotopic replantation of thumb and index finger on the distal left forearm during operation

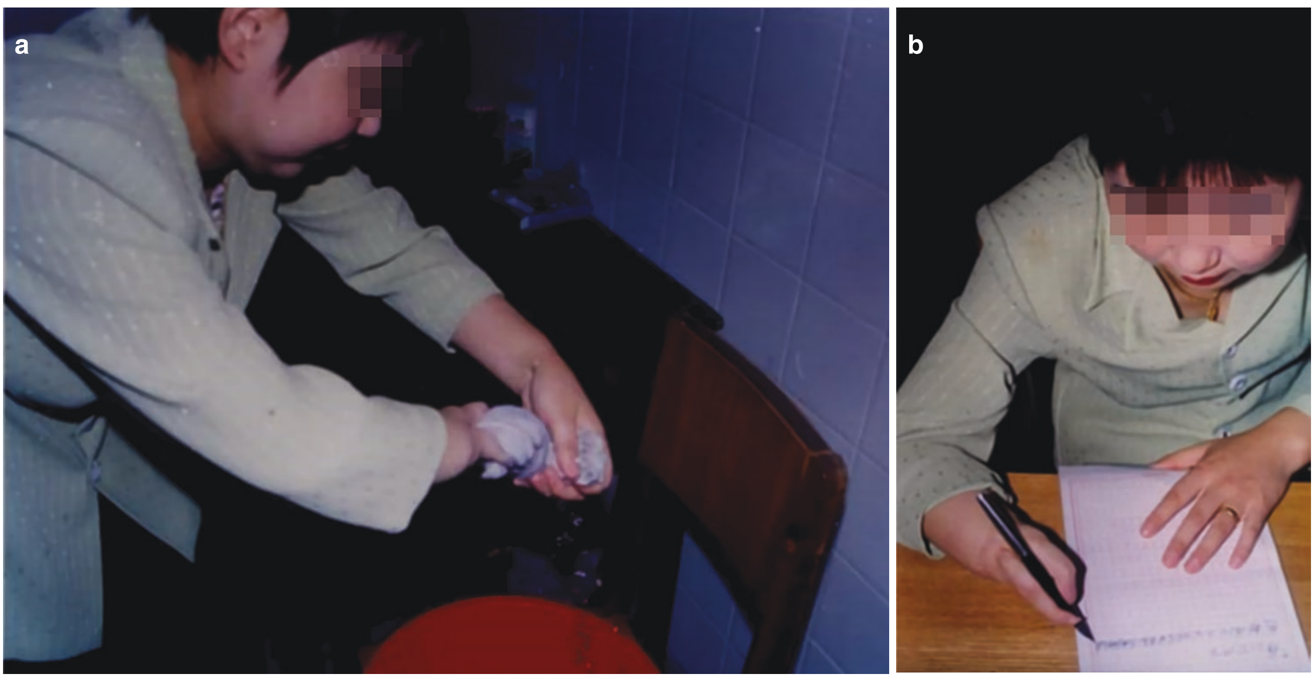


Fig. 9.3 (**a**, **b**) After 2 years of follow-up, the patient was able to write and twist towels

9.4 Clinical Implication

In 1917, Krukenberg [1] initiated the forearm splitting operation, which separated the muscles of the remnant of the forearm and attached them to the ulna and radius, respectively, to form forks to produce clamping action, thus restoring part of the hand function. With the development of microsurgery, Yu [1] has made great progress in the history of hand reconstruction with the use of artificial bone or the transplantation of toes on the stumps of the forearm to reconstruct part of the hand. For the first time, Cheng G L [2] succeeded in reconstructing the left hand by using the remaining index finger and thumb after the left hand was damaged. For traumatic wrist and palm tissue contusion or defect; proximal ulna and radius without multiple fractures; forearm soft tissue without serious contusion; blood vessels, nerves, muscles without avulsion injury; and more than 3 better-preserved fingers such as thumb, index finger, or others which connected at the distal end by a thumb web or finger web; and ectopic replantation of the severed finger in the distal forearm can be performed in emergency to reconstruct part of the hand function. This emergency hand reconstruction is not only a kind of replantation operation but also a kind of hand function reconstruction operation [3, 4].

We should pay attention to the following problems during the operation: (1) In the operation, we should follow the principle of function priority, thumb is the most important, followed by index finger, and middle finger. According to the size of the thumb web and the position of finger to palm, we can take the choice of removing index finger and retaining middle finger, which is conducive to the rehabilitation of hand function after the operation. (2) Damaging hand injuries are complex and diverse, with extremely poor local tissue conditions. If the operation is very difficult, we should not stand back from the difficulty, but should make full use of the remaining finger and hand compound tissue block, try to replant, obtain a functional finger is very important to the patient. (3) It is a prominent contradiction that the diameter of the blood vessel is too different in this operation. The proximal artery was anastomosed according to the external diameter of the donor finger artery. The common collocation methods are: The radial artery was connected to the main thumb artery, and the ulnar artery was connected and the first common finger artery. The vascular defect can be reconstructed with vascular transplantation. When the diameter of the vessel is different, methods such as fish mouth, cut angle, end-to-side, intussusception, and so on can be used to treat it. (4) Attach importance to the functional exercise of replanted viable fingers. According to the requirements of the surgical design, reasonable early functional exercise is beneficial to the maximum recovery of hand function.

References

1. Yu ZJ, Huang YC, Yu S, Sui SP. Thumb reconstruction in a bilateral upper extremity amputee: an alternative to the Krukenburg procedure. J Hand Surg Am. 1999;24(1):194–7.
2. Zhang GL, Chen KM, Zhang JH, Wang SY. Hand reconstruction using heterotopic replantation of amputated index and little fingers. Chin J Traumatol. 2011;14(5):316–8.
3. Bakhach J, Katrana F, Panconi B, et al. Temporary ectopic digital implantation: a clinical series of eight digits. J Hand Surg Eur Vol. 2008;33(6):717–22.
4. Li J, Ni GH, Guo Z, et al. Salvage of amputated thumbs by temporary ectopic implantation. Microsurgery. 2008;28(7):559–64.

10 Salvage of an Amputated Upper Extremity with Ectopic Implantation Followed by Replantation at the Second Stage

Juyu Tang, Panfeng Wu, and Rui Liu

10.1 Case Presentation

The patient, a male, 39 years old, was sent to the hospital due to a completely severed left upper arm from machine crushing. Physical examination showed a large area of skin contusion at the distal end of the left upper arm and irregular wound margin at the broken end (Fig. 10.1)

10.2 Choice of Treatment

After completing preoperative preparation, the limb was thoroughly debrided. After completely removing the necrotic skin during the operation, intact structure of the left hand and intact deep muscle of the left forearm were presented, median nerve and ulnar nerve of the left forearm were pretty intact, and the condition of limb preservation was preliminarily determined (Fig. 10.2) We considered to give the left upper limb abdominal foster replantation for the patient at stage one. When the patient's condition was stable, the patient's limb was replanted to his left limb stump.

10.3 Operative Technique

On stage one, left upper arm replantation was performed. The inferior epigastric artery and ulnar artery were anastomosed, and the left great saphenous vein was inverted from the left thigh and anastomosed with the great saphenous vein, and the superficial epigastric vein and the expensive vein were anastomosed (Fig. 10.3) Postoperative limb blood supply was restored. After 5 weeks, the limb was replanted

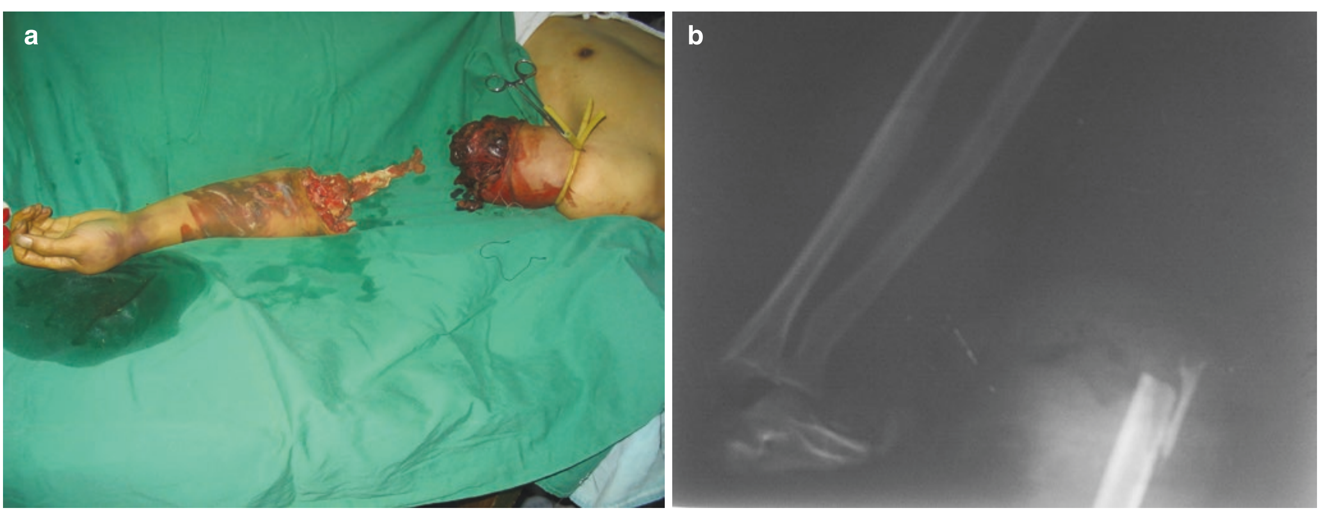


Fig. 10.1 (**a**) Preoperative view of amputated limbs. (**b**) Preoperative X-ray

J. Tang (✉) · P. Wu · R. Liu
Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_10

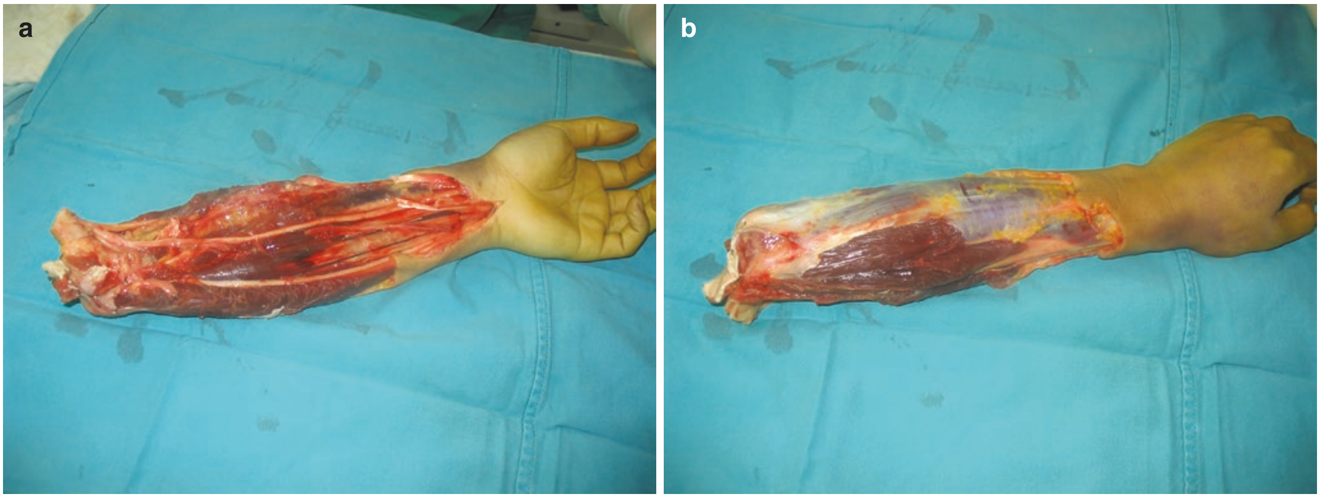


Fig. 10.2 (**a**, **b**) Volar and dorsal forearm condition after thorough debridement

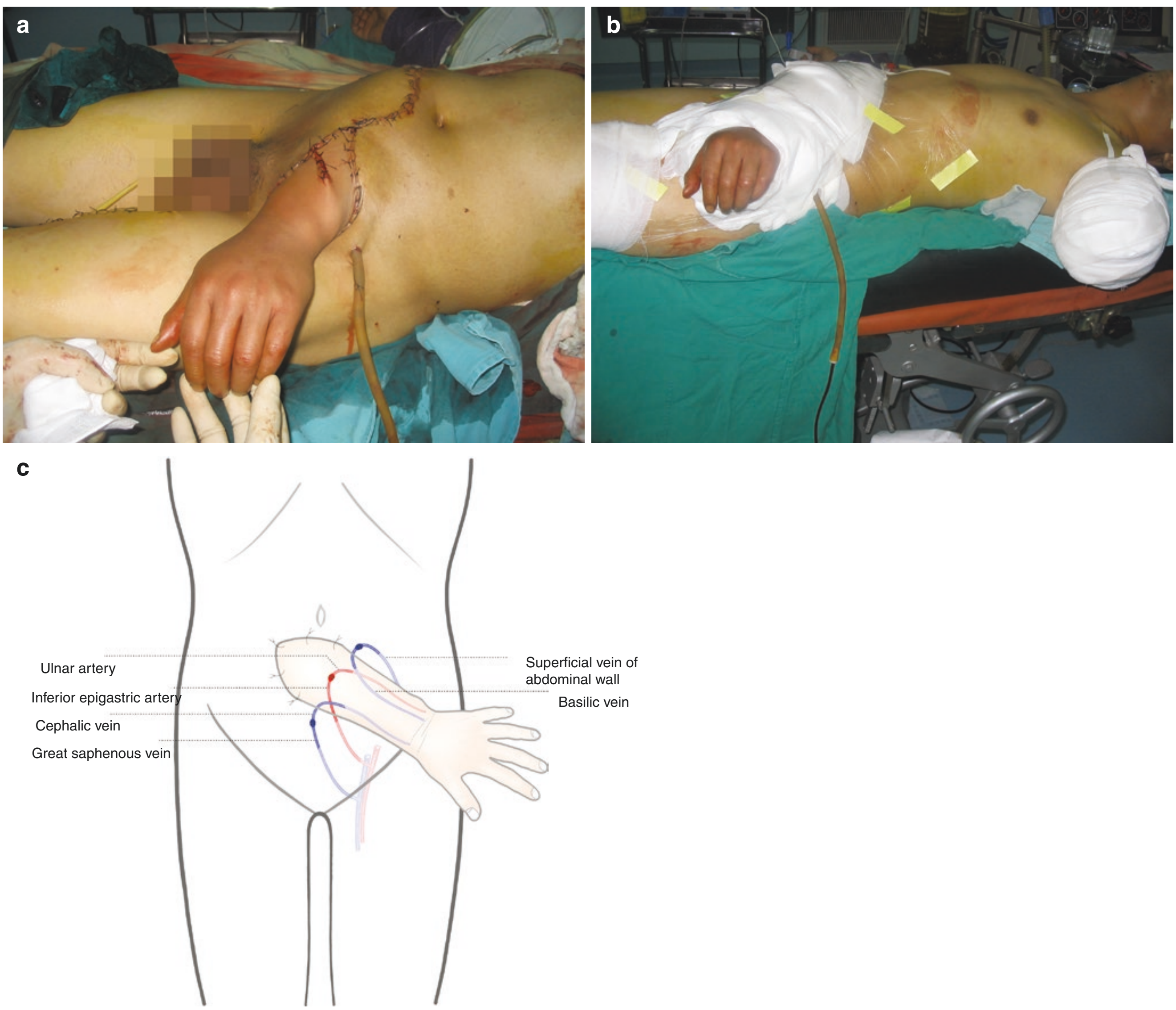


Fig. 10.3 (**a**) Ectopic replantation of amputated limbs in abdomen. (**b**) Direct dressing of left upper arm stump after thorough debridement (**c**) Sketch map of blood reconstruction

to the left arm, fixed left humerus with steel plate, during which operation, the great saphenous vein was inverted to bridge the ulnar artery and the brachial artery, anastomosed the great saphenous vein anastomosed with brachial vein with cephalic vein to reconstruct limb venous reflux. The superficial abdominal vein and the superficial perineal vein of the abdominal flap carried on the dorsal forearm were anastomosed with the branch of the great saphenous vein, and the muscle branch of the biceps brachii and the tenth intercostal artery in the flap were anastomosed. Remove the pedicled latissimus dorsi musculocutaneous flap, and transfer to cover the palmar wound surface of the left forearm. The median nerve, ulnar nerve, medial brachial cutaneous nerve, and lateral forearm cutaneous nerve were directly anastomosed, and 7-cm sural nerve was taken to reconstruct the radial nerve defect (Fig. 10.4).The left limb survived well after the operation, but necrosis of the skin and soft tissue appeared on the back of the elbow, and elbow joint and steel plate were exposed (Fig. 10.5). After the thorough expansion of the wound, the right medial calf flap was designed to repair the wound (Fig. 10.6). During the operation, the biceps muscle branch of the humerus and the posterior tibial artery and one associated vein branch were anastomosed. And another great saphenous vein was used to bridge the gastrocnemius muscle branch and the brachial vein (Fig. 10.7). During follow-up in half a year after the operation, the humerus fracture was healed, part of the sensation restored in the left limb, and the muscle strength of the wrist joint and fingers restored to grade 3 (Fig. 10.8). After 2 years of follow-up, the sensation of the left hand restored to S3+, part of thenar portion restored certain functions, and part of the grasping function of the hand was restored. The muscle strength of the wrist and fingers did not restore (Fig. 10.9).

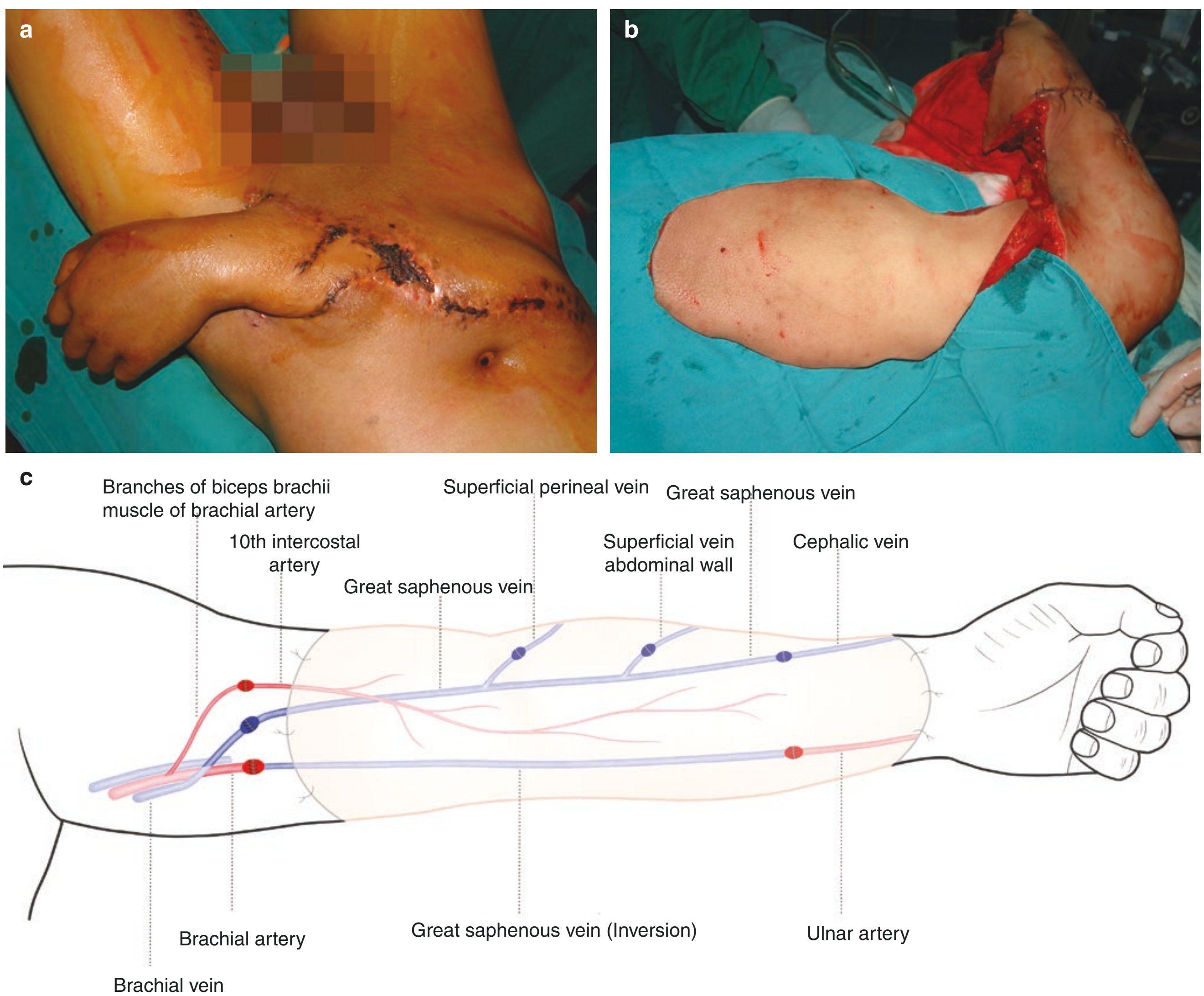


Fig. 10.4 (**a**) The amputated limbs survived well 5 weeks after operation. (**b**) The amputated limb was replanted in the left upper arm and the palmar forearm wound was covered with pedicled latissimus dorsi myocutaneous flap. (**c**) Sketch map of blood reconstruction

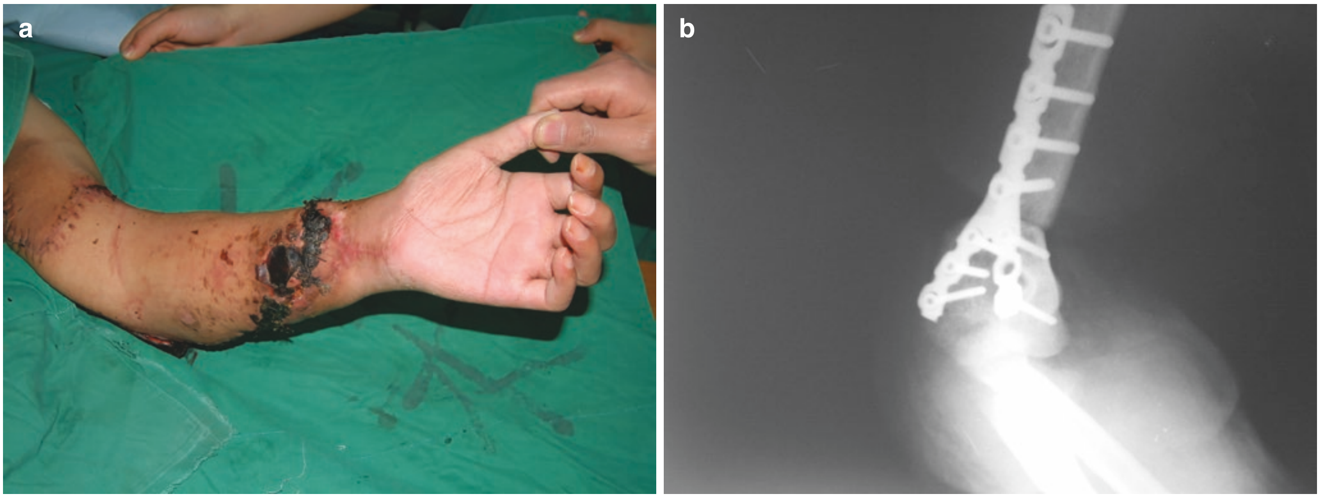


Fig. 10.5 (**a**) The amputated limbs survived well 4 weeks after operation. (**b**) Postoperative X-ray

Fig. 10.6 (**a**) Postoperative skin necrosis, plate exposure and elbow joint exposure. (**b**) Repair of wound with medial leg skin flap. (**c**, **d**) Repair of skin flap during operation

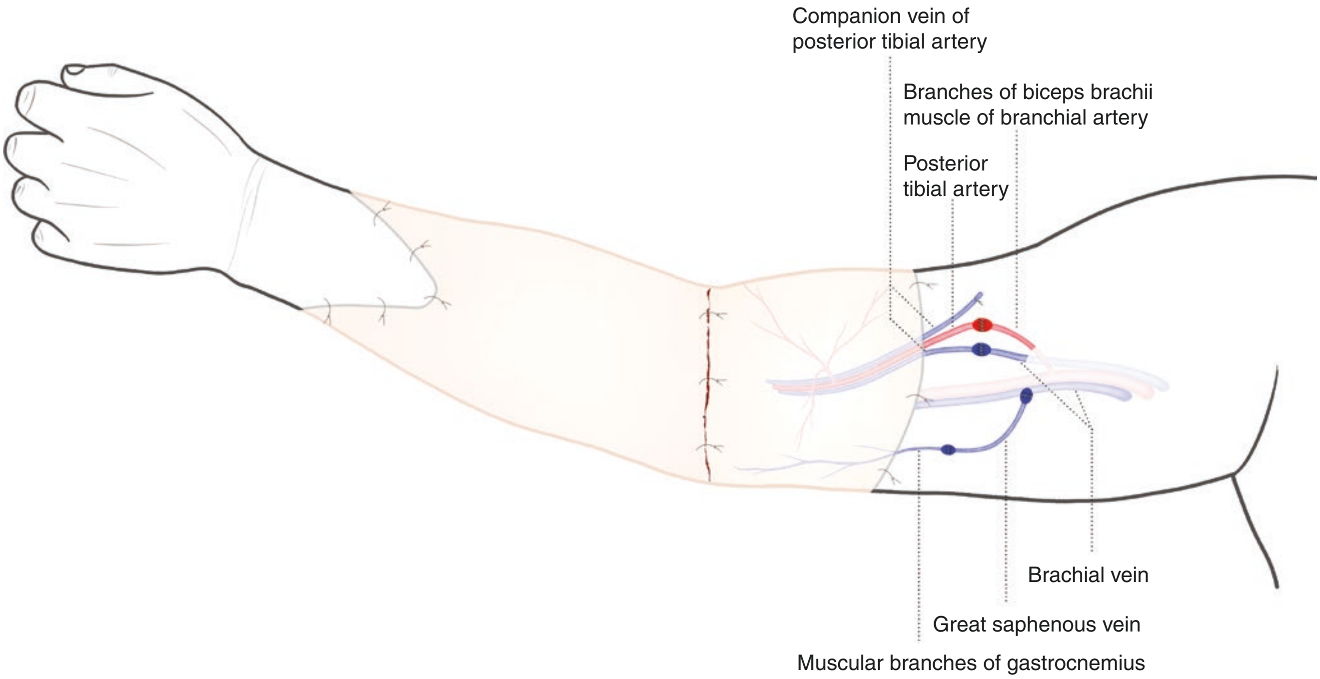


Fig. 10.7 Sketch map of blood reconstruction

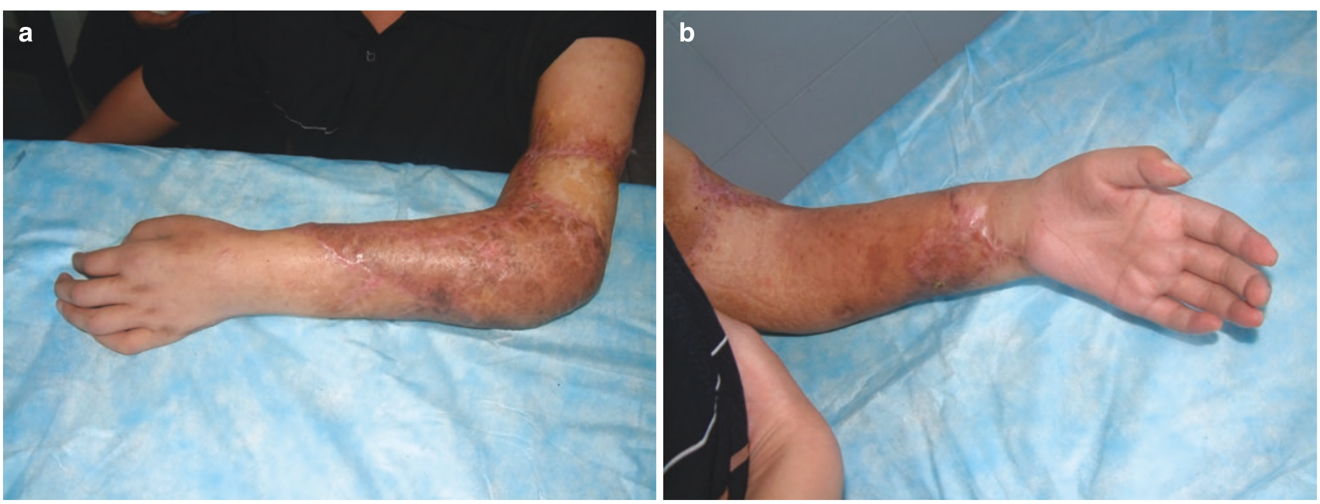


Fig. 10.8 (**a**, **b**, **d**) The limb and skin flaps survived well after half a year follow-up (**c**) the fracture healed completely after half a year follow-up

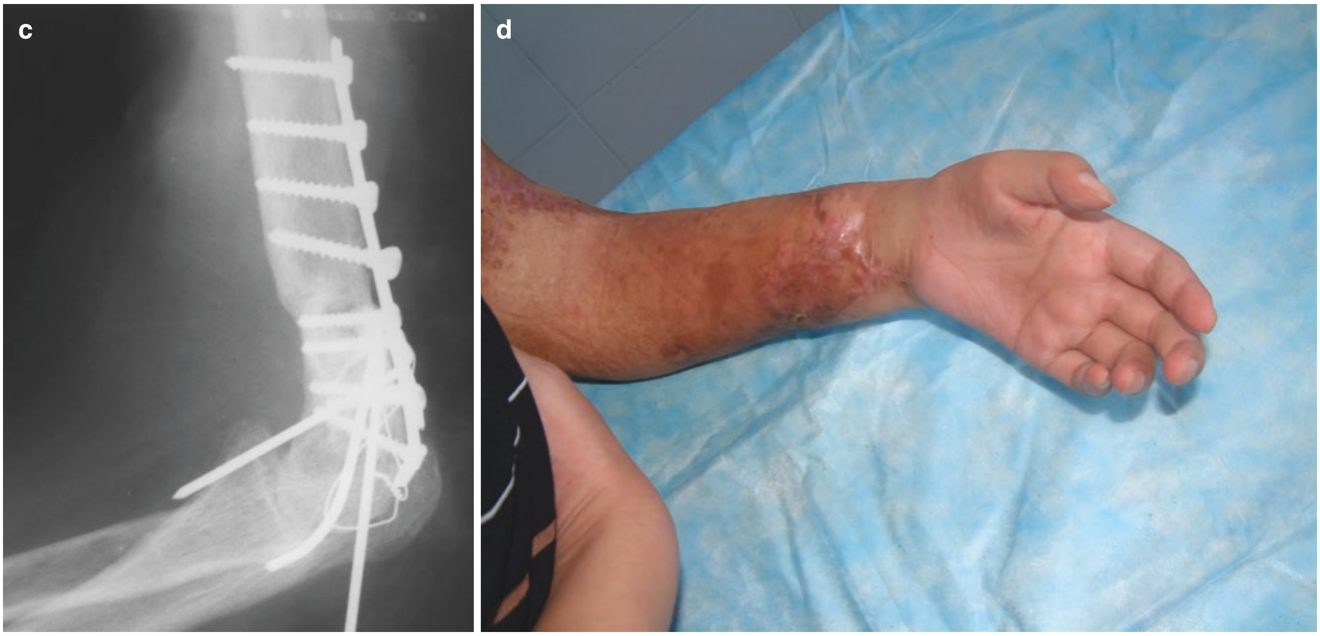


Fig. 10.8 (continued)

Fig. 10.9 (**a**) After 2 years of follow-up, sensation of the left hand restored to S3+. (**b**) Part of thenar portion restored certain functions. (**c**) Part of the grasping function of the hand restored

10.4 Clinical Implication

Limb foster replantation is a special replantation technique [1]. This technique is mainly suitable for situations where one-stage replantation is not possible, such as extensive distal limb damage or damage to important organs (brain, lung, and liver) [2]. It can anastomose damaged organs to blood vessels from other parts of the body and provide a rapid temporary heterotopic limb foster for severed limbs. Secondary limb replantation can be performed when the patient's condition and severed limb condition are stable. Temporary ectopic implantation is a valuable technique for salvaging amputation cases resulting from severe crushing injuries. There is yet no consensus on the indications of this surgical technique. Limb foster replantation was first reported by Godina [3] in 1986. At that time, he fostered the limbs on the upper part of the anterolateral thoracic side for 65 days, reconstructed the blood supply of the limbs by anastomosing the dorsal thoracic artery and ulnar artery, and anastomosing the dorsal thoracic vein and the cephalic vein. The two-point discrimination of limbs recovered to 23 mm after the operation. Later, many scholars reported the limb foster replantation. The severed limbs include digits [4, 5], hands [6], forearms [7], feet [8], and forearms [9]; the foster site includes the front and the outer thighs, the inner leg, the right forearm, and the inner thigh; the shortest foster time was 9 days, and the longest is 319 days; the recovery after surgery differed by conditions. Therefore, the surgical indications of ectopic limb foster replantation below should be strictly followed: (1) Patients in their right mind. (2) A strong desire for limb salvage. (3) Difficulty in determining the exact necrosis boundary of damaged limbs. (4) In situ replantation requires extra time or complicated reconstruction which would prolong the ischemia duration and increase surgical risks. (5) Both aesthetics and function are expected. In the process of foster and replantation of ectopic limb, attention should be paid to the following points: (1) The surgical indications should be strictly followed. (2) Thorough operation design and plan should be completed. (3) Shorten the ischemic time of amputated limbs as much as possible. (4) Rebuild as many nerves and motor muscles as possible. (5) Ensure a good rehabilitation exercise after surgery.

References

1. Higgins JP. Ectopic banking of amputated parts: a clinical review. J Hand Surg Am. 2011;36(11):1868–76.
2. Williams ZF, Bools LM, Adams A, Clancy TV, Hope WW. Early versus delayed amputation in the setting of severe lower extremity trauma. Am Surg. 2015;81(6):564–8.
3. Godina M, Bajec J, Baraga A. Salvage of the mutilated upper extremity with temporary ectopic implantation of the undamaged part. Plast Reconstr Surg. 1986;78(3):295–9.
4. Hallock GG. Transient single-digit ectopic implantation. J Reconstr Microsurg. 1992;8(4):309–11.
5. Graf P, Gröner R, Hörl W, Schaff J, Biemer E. Temporary ectopic implantation for salvage of amputated digits. Br J Plast Surg. 1996;49(3):174–7.
6. Cavadas PC, Landin L, Thione A. Secondary ectopic transfer for replantation salvage after severe wound infection. Microsurgery. 2011;31(4):288–92.
7. Kayikçioğlu A, Ağaoğlu G, Nasir S, Keçik A. Crossover replantation and fillet flap coverage of the stump after ectopic implantation: a case of bilateral leg amputation. Plast Reconstr Surg. 2000;106(4):868–73.
8. Wang JN, Wang SY, Wang ZJ, Liu D, Zhao GQ, Zhang F. Temporary ectopic implantation for salvage of amputated lower extremities: case reports. Microsurgery. 2005;25(5):385–9.
9. Cavadas PC, Landin L, Navarro-Monzones A, Soler-Nomdedeu S. Salvage of impending replant failure by temporary ectopic replantation: a case report. J Hand Surg Am. 2006;31(3):463–7.

11 Emergency Repairs of Degloving Injuries in Three Fingers

Jianhua Zhang and Zhenjun Xie

11.1 Case Presentation

A young male patient suffered a crush injury by machine and was diagnosed as (1) degloving and amputation injury in right index finger accompanied with tissue destruction in the proximal segment; (2) degloving and incomplete amputation injury in right middle finger; and (3) degloving and amputation injury with finger destruction in the right little finger (Fig. 11.1a,b).

11.2 Choice of Treatment and Operative Technique

For complex degloving and amputation injury of fingers, replantation of degloving fingers is the optimal treatment method [1]. However, when replantation is not possible, the transplantation of flaps is preferred. In this case, a thin and pliable soft tissue coverage was needed in the index finger. There are several options in clinical practice [2–6], such as anterolateral thigh flap (ALT) free flap, pedicled sural flap, or great toe wraparound flap. For most cases, the great toe wraparound flap is the preferred choice because this method can maintain a satisfactory appearance and function of the reconstructed fingers.

Various surgical technologies were employed due to the different conditions of each injured finger. Replantation was applied to the middle finger due to relatively intact soft tissue structure (Fig. 11.1c). For the index finger, the structure of intermediate and proximal digits of the index finger remained intact after debridement; however, replantation in situ is difficult because of the massive skin and vascular defect in intermediate digits. Due to the intact structure in the metacarpophalangeal and interphalangeal joint in the right little finger and the fact that the little finger is shorter than the index finger, the distal part of the index finger was transplanted on the remaining of the little finger (Fig. 11.1d). Then, a complex method was used to reconstruct the skin defect of the index finger, that is, harvesting the trifoliate flaps including big toe wraparound flap, second toe flap, and plantar metatarsal flap. The second toe flap and plantar metatarsal flap of the trilobite flap were reconfigured to reconstruct the defect in the proximal palm side of the index finger where a big great wraparound flap cannot cover (Fig. 11.1e–i).

Meanwhile, a free lateral supramalleolar flap was applied to the donor site by vascular retrograde anastomosis (The descending branch of the lateral supramalleolar artery was anastomosed with the distal end of the first metatarsal dorsal artery (FMDA) bundle). And the donor site of the free flap was covered by a thick skin flap from the hypogastric region. The donor site of the plantar metatarsal flap of the foot was sutured directly (Fig. 11.1n,o).

In 1-year follow-up, the patient's writing and walking function were well restored (Fig. 11.1j–o).

11.3 Clinical Implications

Treatment of a fingertip degloving injury continues to be a challenging problem [1, 5]. Replantation of the degloving finger is the optimal method [1]. When replantation is not possible, the replantation of a great toe wraparound flap is preferred [5, 6]. For the degloving injury of the whole finger, the skin defect of the dorsal side of the finger can be repaired by the combination of the big toe wraparound flap and the dorsal foot flap. However, the key point is that the length of the metatarsal side of the toe wraparound flap is not enough to cover the length of the palm side of the finger. We adopted a great toe wraparound flap, the second toe flap, and the plantar metatarsal flap of trilobite flap to repair the whole wound, and the surgical outcome was satisfying. The appearance and function of the hand were well restored.

J. Zhang · Z. Xie (✉)
Department of Hand and Foot Surgery, Henan Provincial People's Hospital, Zhengzhou, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_11

Fig. 11.1 (**a**) Preoperative palm-side view. (**b**) Appearance of the Severely injured fingers. (**c**) Transplantation of the distal index finger to the remaining of the little finger after debridement. (**d**) Massive degloving injury and skin defect of the index finger. (**e**) Surgical sketch of the trifoliate flaps including big toe wraparound flap. (**f**) Surgical sketch of planta. (**g**) The trifoliate flaps including big toe wraparound flap. (**h**) Reconfiguration of trefoil local flaps. (**i**) Postoperative palm-side view. (**j**) Palm-side view 1 year after the operation. (**k**) Grip function of post-operative fingers. (**l**) Writing with the injured hand. (**m**) X-ray image of the affected hand. (**n**) Dorsal view of the foot. (**o**) Plantar view of the foot

Fig. 11.1 (continued)

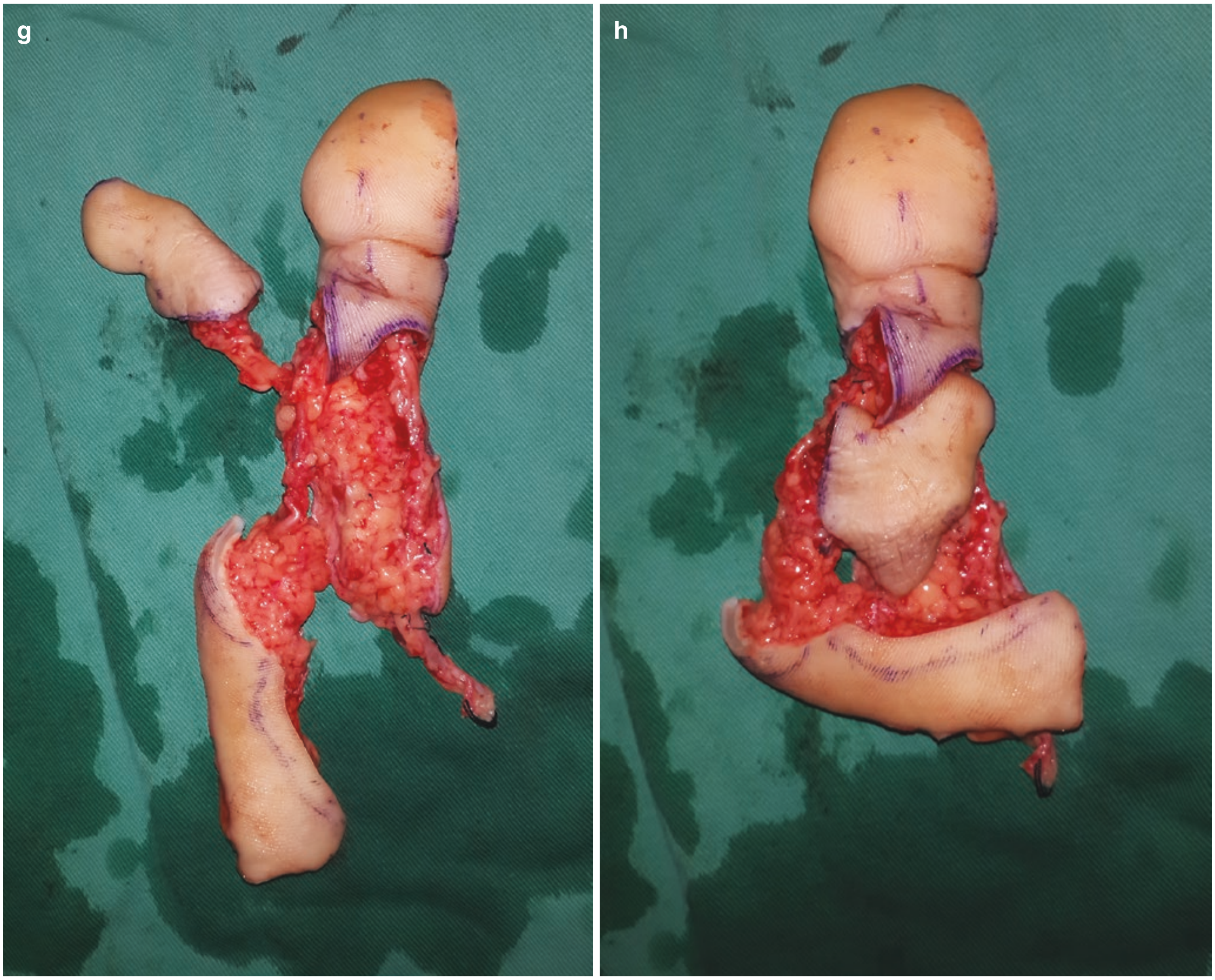


Fig. 11.1 (continued)

Fig. 11.1 (continued)

Fig. 11.1 (continued)

The donor area of the plantar metatarsal flap on the foot was sutured directly without additional damage to the foot. A free flap repair was performed at the donor site of the big toe wraparound flap. The foot appearance and function were also well retained.

References

1. Kerschhagl M, Larcher L, Mattiassich G, Prantl L. Replantation of a circumferentially degloved thumb in an occupational crush injury - a case report and review of the literature. Clin Hemorheol Microcirc. 2019;71(4):403–14. https://doi.org/10.3233/CH-199004.
2. Lin CT, Chen SG, Chen TM, Dai NT, Chang SC. Free fasciocutaneous flaps for reconstruction of complete circumferential degloving injury of digits. Microsurgery. 2013;33(3):191–7. https://doi.org/10.1002/micr.22064.
3. Zhang L, Pan Y, Tian G, Tian W, Guo X, Wang M. Thumb reconstruction with modified free wrap-around flap. Zhongguo xiu fu chong jian wai ke za zhi= Zhongguo xiufu chongjian waike zazhi= Chin J Reparat Reconstr Surg. 2010;24(3):309–14.
4. Chen C, Tang P, Zhang L, Wang B. Treatment of fingertip degloving injury using the bilaterally innervated sensory cross-finger flap. Ann Plast Surg. 2014;73(6):645–51. https://doi.org/10.1097/SAP.0b013e31828d7258.
5. Songcharoen P, Thanapipatsiri S, Mahaisavariya B, Chotigavanich C. Thumb reconstruction with a big toe microvascular wrap-around flap: a report of fifteen cases. Ann Acad Med Singap. 1995;24(4 Suppl):46–50.
6. Wang ZT, Sun WH. Cosmetic reconstruction of the digits in the hand by composite tissue grafting. Clin Plast Surg. 2014;41(3):407–27. https://doi.org/10.1016/j.cps.2014.03.001.

Reconstruction for Forearm Deformities with Ulnar Shortening Induced by Capitulum Ulnae Giant Chondroma

12

Jingliang Zhang and Xiang Wu

12.1 Case Presentation

The patient is a 16-year-old man and was admitted to our hospital due to a gradually enlarged mass at the right wrist for more than 10 years. Examination results: General situations were good. On the ulnar side of the right wrist, a large mass approximately 6.0 × 5.0 cm in size could be seen, with hard texture but without tenderness. The mass was not movable, and no varicose veins and ulceration were found in the skin and soft tissues on the surface of the mass (Fig. 12.1). The blood supply of each finger of the right hand felt good, and the motion of fingers was good. Active and passive movement of the right wrist joint were limited: 20°-0-30°. The right forearm was approximately 3 cm shorter than the healthy left forearm. The ulnar deviation was approximately 30° in the natural position. X-ray: The high-density shadow of an irregular mass was observed at the distal end of the right ulna (Fig. 12.2). Osteochondroma was considered. Diagnosis: Osteochondroma of distal right ulna, radius curvature, and shortening deformity.

Fig. 12.1 The patient at admission

12.2 Choice of Treatment

Since the distal part of ulna was bound to suffer from bone defect after resection of the tumor, which was hard to deal with, as a result, many hospitals refused to accept the patient for treatment. In addition, the destruction of the epiphysis of the capitulum ulnae caused by tumor retarded the growth of the ulna, this restricted the development of the radius in turn, causing curvature and shortening deformity of the radius. In order to solve the abovementioned problems, we chose the following procedures: (1) Bone transplantation to reconstruct the distal ulna, but it should be carried out after radius deformity correction. (2) Correction of radius deformity, which requires breaking down the radius and bone lengthening.

12.3 Operative Technique

The operation was confirmed to be completed in the second stage.

1. The first stage of operation: The right forearm was incised, and osteochondroma at the distal right ulna was resected carefully (Fig. 12.3), then middle radius osteot-

J. Zhang (✉) · X. Wu
Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China
e-mail: jingliang.zhang@hmmedicalgroup.com

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_12

omy and lengthening were carried out with an external fixator (Fig. 12.4a, b) .

2. The second stage of operation: At 1 month after bone lengthening 1–2 mm every day, the second-stage bone lengthening was performed (the bone was lengthened for approximately 1.5 cm). According to the length of ulna defect now, a contralateral fibular flap of a slightly shorter length (avoiding contact with the carpal bone) was designed and excised and transplanted to the forearm ulna for reconstructing the capitulum ulnae (Fig. 12.5a, b), plate internal fixation was given, then ulnar vessels of forearm were anastomosed. Holes were drilled in the radial side of the reconstructed distal ulna and the ulnar side of the distal radius, respectively, and then the corresponding length of the palmar longus tendon was obtained, inserted through the two holes, and sutured to reconstruct the distal radial and ulnar ligament. One-year follow-up X-ray shows the bones of the arm heal (Fig. 12.6), and the 2-year follow-up showed the function and appearance of the forearm are very good (Fig. 12.7a–d).

Fig. 12.2 X-ray: the high-density shadow of an irregular mass was observed at the distal end of the right ulna

Fig. 12.3 The osteochondroma at the distal right ulna was resected carefully

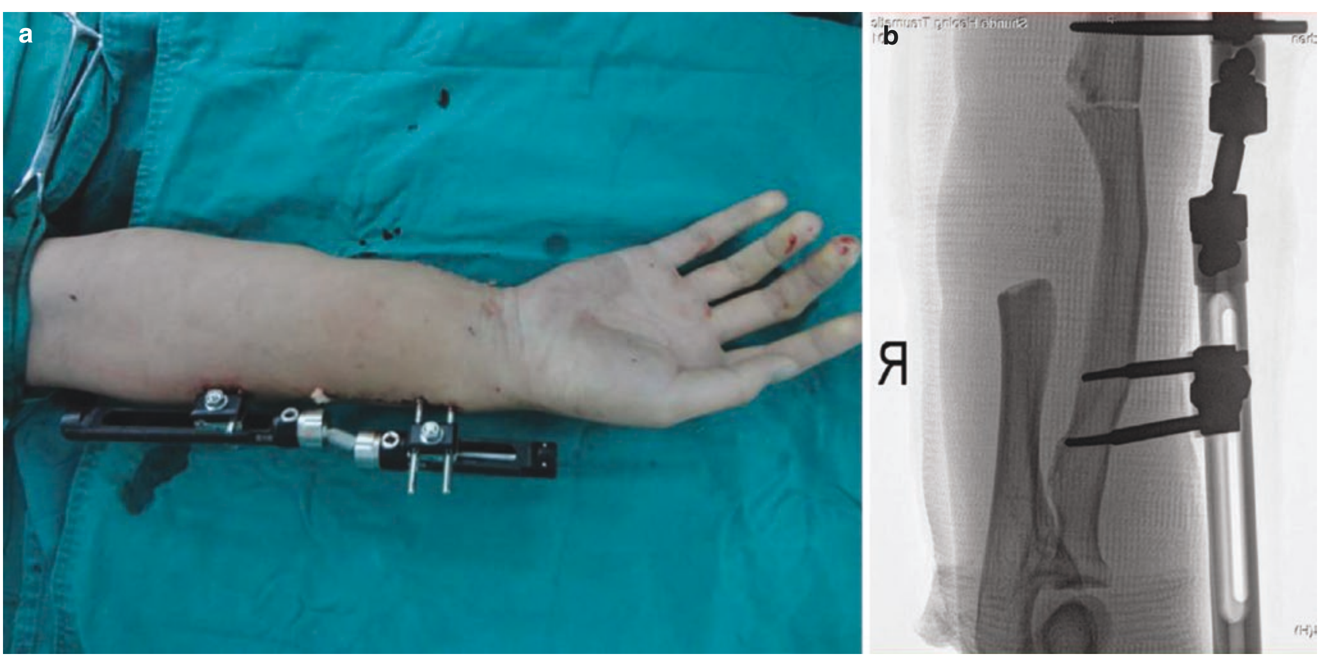


Fig. 12.4 The middle radius osteotomy and lengthening were carried out with an external fixator (**a**, **b**)

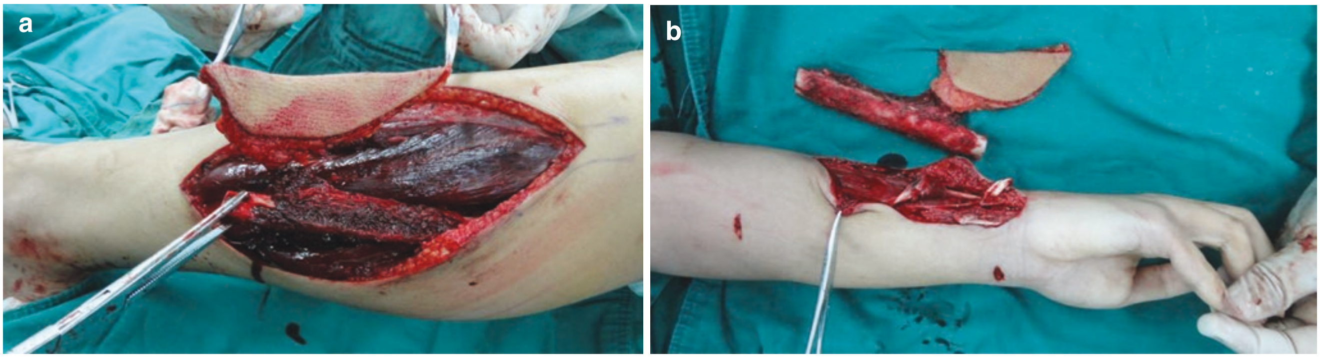


Fig. 12.5 A contralateral fibular flap was designed and excised (**a**) and transplanted to the forearm ulna for reconstructing the capitulum ulnae (**b**)

Fig. 12.6 One-year-follow-up of the X-ray show

12.3.1 Applied Anatomy

The forearm is composed of both radial and ulnar bones, the two are connected by forming two joints with distal and proximal parts of the two bones. The two bones coordinately grow, mutually stabilize and move; therefore, diseases in one bone often affect the other, causing forearm dysfunction.

12.4 Clinical Implications

1. Tumors should be thoroughly removed and removed from the normal diaphysis. Since the tumor segment of bone is enlarged, the ulnar nerve, ulnar blood vessel, and ulnar flexor carpal tendon are pressed to a flat shape and closely adhered to the tumor body, careful dissection is needed during resection. The operation should be conducted under an endoscope if necessary to avoid damage. The TFCC (triangular fibrocartilage complex) should also be dissected and persisted carefully.
2. The patient's tumors have been growing rapidly for 10 years, in the same period the patient himself was also in rapid development. While he was 16 years old at the time of the operation, there was no more space for his growth; therefore, it could be repaired according to the current length of the defect. Even if the bones further grow, it also removes the distal end of the reconstructed ulna from the carpal bone, which avoids collision with each other. Therefore, if the patient is younger, fibula transplantation should be delayed several years in order to avoid growth mismatch.
3. The connection between ulna and radius should be avoided during operation, and the two bones should be mutually separated to avoid the formation of bone bridges.
4. The operation rules of bone lengthening should be strictly followed to avoid complications [1].

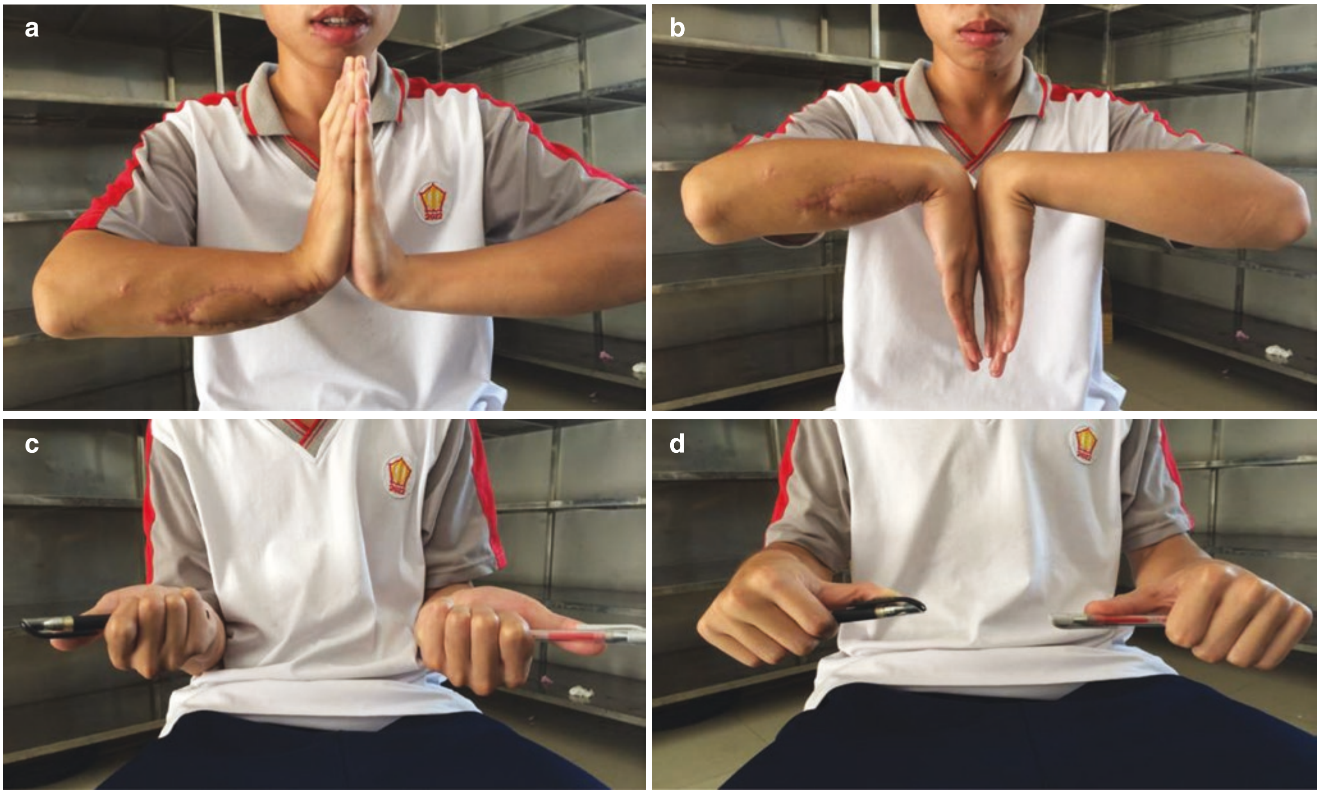


Fig. 12.7 Two-year follow-up shows the function and appearance of the forearm are very good (**a**, **b**, **c**, **d**)

Reference

1. Guo Y, Xing G, Dong Y. Observation of curative effect with tumour resection and ulnar lengthening about a shorted ulna resulting from osteochondroma. Clin J Misdiagnose. 2015;28(7):98–100.

13 Plastic Reconstruction of the Thumb through Transplanting Separated Second Toe with Full Dorsal Toenail Flaps Exchange between the First and the Second Toes

Jingliang Zhang and Zengyang Gao

13.1 Case Presentation

A 32-year-old woman was hospitalized in an emergency due to pain and bleeding of the right thumb for 1.5 h induced by machine crushing. Examination results: General situations were good. The right thumb was completely amputated from the proximal basement. The distal end of the isolated finger was incomplete, suffering destructive fragmentation without replanting possibility. The diagnosis was right thumb injury and III-degree absence (Fig. 13.1).

Fig. 13.1 The right thumb was completely amputated from the proximal basement and incomplete

13.2 Choice of Treatment

As we know, reconstruction of the thumb through transplanting separated second toe leads to a relatively good function of the thumb and small injury of the foot donor area. However, the reconstructed thumbnail is small and the finger is slender; furthermore, the thumb exhibits camel neck deformity, and thus the appearance is poor [1]. While thumb reconstruction through transplanting separated first toe will produce a better appearance when compared to using separated second toe, the reconstructed thumb is relatively thick and will lead to severe injury to the foot donor area and has an influence on the shape of the donor area [2]. In order to make full use of the advantages of the two surgical methods and reduce its disadvantages, we designed and adopted the first intention combined plastic reconstruction of the thumb through transplanting separated second toe with full dorsal toenail flaps exchange between the first and the second toes. The advantages are as follows: (1) The appearance of reconstructed thumbnails with second toe grafting was significantly improved, and the dorsal thumb was comparable to the healthy thumb. (2) The deformities of the camel neck and underextension were significantly improved. (3) From the results obtained, it was less expensive than other methods of reconstruction and did not increase damage to the donor area. (4) Comparing the method of thumb reconstruction with the second toenail joint tendon system wrapped by the thumbnail flap, in this method, the donor sites on the plantar and bilateral sides of the thumb were intact, no traces of scar were left, the innate nerve of the base of the hallux was preserved, walking was not affected, and trauma was less. (5) The dorsal side of the thumb as the donor site could be covered with the second toenail flap, the design was ingenious, as a donor site, and the appearance of the hallux was less affected.

J. Zhang (✉) · Z. Gao
Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China
e-mail: jingliang.zhang@hmmedicalgroup.com

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_13

13.3 Operative Technique

1. Preparations for recipient site: Thorough debridement was performed, sagittal incision of the skin at the stump of the thumb was made, and the skins were folded toward both sides. The vessels, nerves, and tendons to be anastomosed were marked.
2. Design and incision of full dorsal great toenail flap were designed and cut with the dorsal and lateral junctions of the whole great toe (Fig. 13.2) and the circumference of the para-toenail (a small triangular flap was cut at the front and near the nail root) as the boundaries. The proximal boundary was determined according to the length of the thumb to be reconstructed. Vessel pedicles were incised for the use as the first dorsal metatarsal artery, and the skin toenail flap with continuous vessels and nerves of the tibial side of the second toe was obtained for future use. The fibular plantar nerve of the hallux was reserved in the donor site.
3. Design and incision of full dorsal hallux toenail flap with continuous skin at the second toe.

   Skin toenail flaps were designed with the junctions at the dorsal and lateral sides of the second toe and the circumference of the para-toenail 1–2 mm to the nail (more anterior skin should be removed) as the boundaries. The proximal end of the flap was not cut off in order to keep the continuity of the dorsal skin of the foot, forming a pedicled toenail flap (Fig. 13.3).
4. The second toe without the dorsal skin toenail flap was conventionally incised, and the temporal vascular nerve and the full dorsal skin toenail flap of the hallux shared the same pedicle (from the first dorsal vessel).
5. The toenail flaps from the second toe and the hallux were combined and shaped, and the formed thumb was transplanted.

Fig. 13.2 Design and incision of full dorsal nail flap of great

Fig. 13.3 Design and incision of full dorsal hallux toenail flap with continuous skin at the second toe

   The full dorsal toenail flap of the hallux was covered on the dorsal side of the cut second toe and sutured around, forming a reconstructed thumb with a shape and thickness similar to those of the thumb; then, the pedicle was cut and the reconstructed thumb was transplanted to the hand recipient site, and tissues were anastomosed. After trimming the second metatarsal stump and the first and third interosseous ligaments, the second toe full dorsal toenail flap was placed over the donor site at the dorsal hallux and sutured (Fig. 13.4).
6. Two-year-follow-up of the function and appearance of the reconstructed thumb is very good (Fig. 13.5a, b), and the donor site is good (Fig. 13.6a, b).

13.3.1 Applied Anatomy

Design and incision were carried out based on the anatomical feature that the first and second toes were simultaneously supplied with blood by the first dorsal vessel.

13.4 Clinical Implications

1. When cutting the hallux toenail flap, small triangular flaps should be designed on the top and the proximal sides of the nail. The top triangular flap was embedded on the top of the second toe to make the region from the finger pulp to the fingertip of the reconstructed thumb more gentle (the second toe is more blunt). The triangular flaps from both sides of the hallux were embedded on both sides of the second toe to reduce the camel-neck deformation.

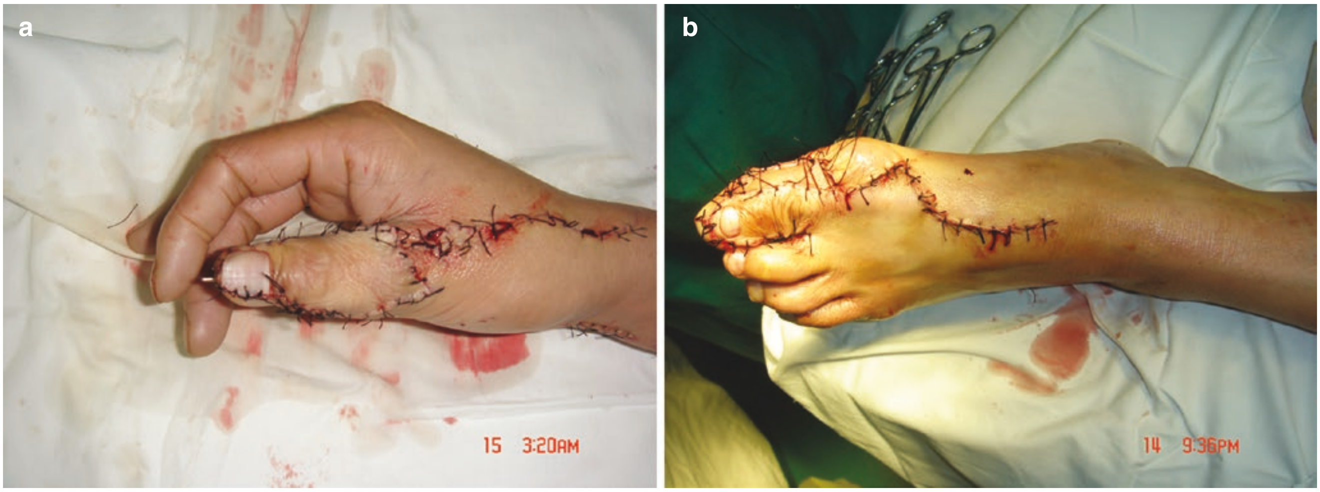


Fig. 13.4 Post-op:the reconstructed thumb and the donor site (**a**, **b**)

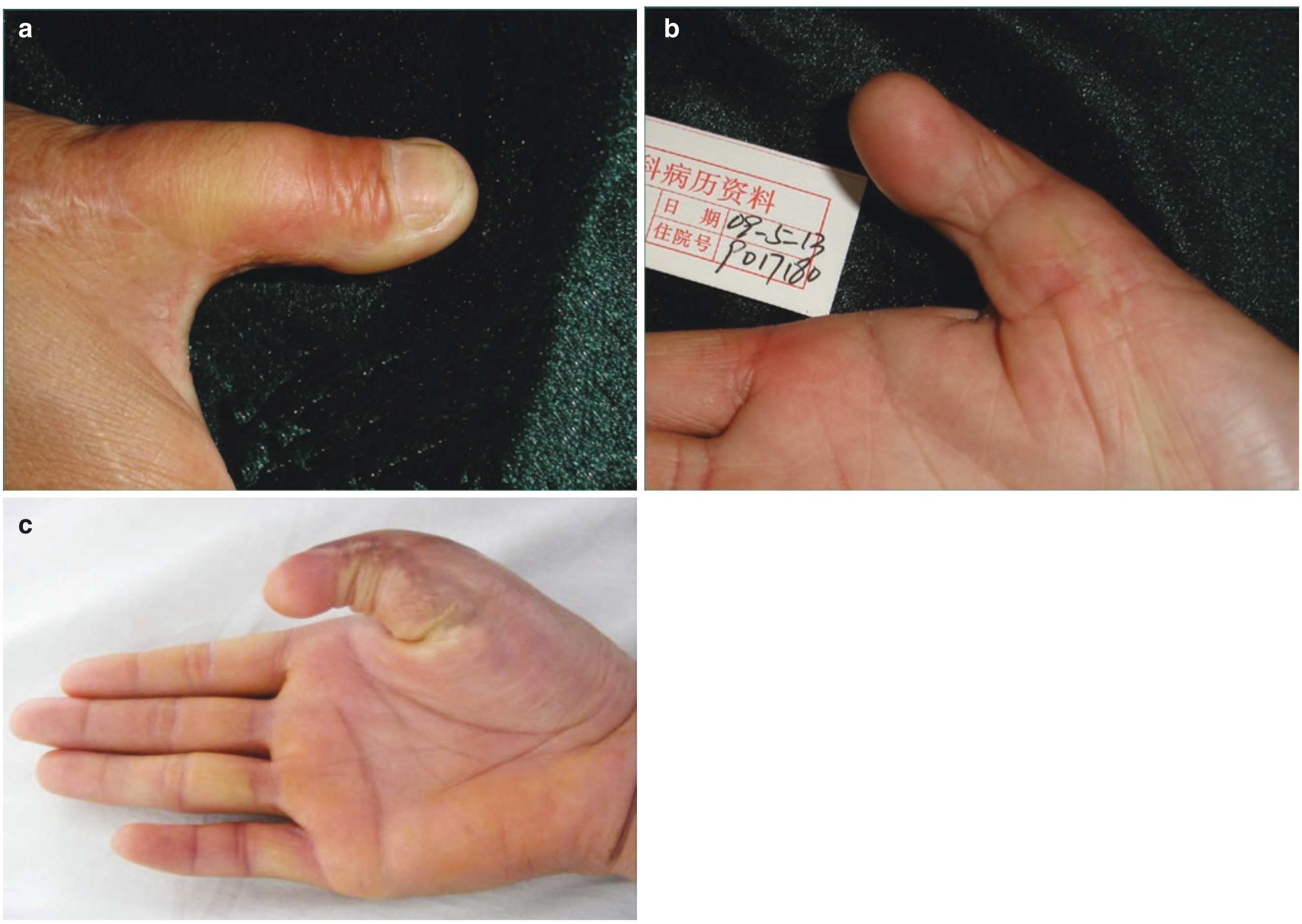


Fig. 13.5 Two-year-follow-up and the function and appearance of reconstructed thumb are very good (**a**–**c**)

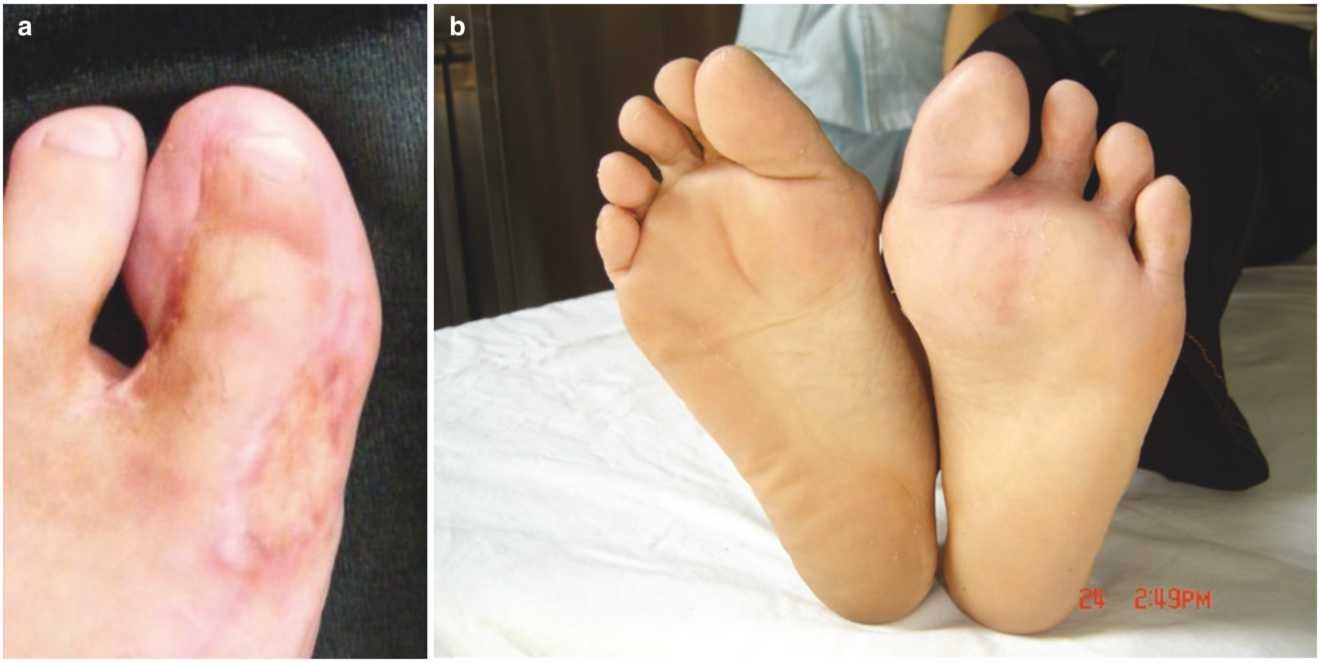


Fig. 13.6 Two-year-follow-up of the donor site is good (**a**, **b**)

2. When the hallux nail was incised, if the width of the nail was not significantly different from that of the healthy hallux, it could be completely incised. If the difference was large, a longitudinal nail bed could be made near the nail groove, which was then carefully stitched together.
3. When the hallux flap and the second toe were combined, the flap should be slightly moved to the distal side, which could also reduce the roundness and bluntness of the second toe.
4. Because the distal interphalangeal joints are often below the toenail, they can be fused together.
5. To reduce the risk and ensure the blood supply of the two toenail flaps, when incising, the proper toe artery on one side could be incised together, while the nerves remained in the original site, to retain the feeling of the bottom of the toe.
6. Sometimes, the second toenail flap could not completely cover the dorsal side of the hallux, skin grafting should be planted on the temporal side of the hallux as far as possible to avoid the friction of the shoes in the future.

References

1. Zhang J, Ren Z, Wang C. The thumb (finger) reconstruction by transferring the free second toe inlaid with the composite pedicle flap from fibular side of the great toe. Chin J Microsurg. 2001;24(4):252–3. https://doi.org/10.3760/cma.j.issn.1001-2036.2001.04.004.
2. Xie Z, Xiao J, Pang D. Clinic summary of thumb (finger) reconstruction with combining tissues. Chin J Microsurg. 2004;27(03):217–9. https://doi.org/10.3760/cma.j.issn.1001-2036.2004.03.024.

14 Tissues Mass Replantation of the Index and Middle Fingers

Wenlong Zhang

14.1 Case Presentation

A 34-year-old woman suffered a ground injury of her index and middle fingers and resulted in tissue defect of distal phalanges and deformity. The size of the index finger was 8 mm × 12 mm × 20 mm and the middle finger was 12 mm × 18 mm × 22 mm. Replantation of the fingers was required.

14.2 Operative Technique

Tissue mass replantation was performed under brachial plexus block anesthesia. All surgical procedures were performed under an 8× microscope. Simultaneously, wound debridement and search arteries and veins were executed under the microscope. Anterograde replantation was used to suture the dorsal deck to restore the position of the tissue mass. One artery was anastomosed in the index finger, and one artery and one vein were anastomosed in the middle finger, and then skin wounds were sutured. The blood supply of the replantation tissue patches was abundant, and the capillary reaction was quick. Postoperation, anticoagulation, anti-inflammatory, and antispasticity therapy were given for 7 days. The wound suture was removed 14 days after surgery. The two tissue blocks survived successfully. After 2.5 years of follow-up, the function of the fingers recovered well, and the sensation of the index finger abdomen recovered S4, and the static two-point discrimination was 4 mm. The middle finger abdominal sensation recovered S4, and the static two-point discrimination sensation was 3 mm (Fig. 14.1–14.8).

14.3 Clinical Implication

The distal phallus of the finger has a special structure, which contains abundant tactile corpuscle, longitudinal fiber septum, and abundant cuticle [1–3]. The dorsal nail bed deck is an irreplaceable accessory for the flexible function of the fingers [4–7]. There have been significant for restoring the function and appearance of the patient through replantation in situ when conditions permit [8, 9]. Meanwhile, it is also a practical test of the basic skills of precision repair to hand surgeons.

Notes: (1) the key to the replantation of the terminal tissue block is the blood circulation reconstruction, careful debridement, and searching the arteries and venous under the microscope should be executed. If there is no vein in the distal tissue mass, the venous loop can be reconstructed by means of mobile venous diversion. (2) Finger end abdomen contains rich nerve endings and tactile corpuscle; mark the nerve endings under the microscope for the reconstruction of tissue block feeling, which would reduce the degree of replantation tissue atrophy. (3) In the replantation process, the deck can be used as a reduction template when the flat nail bed is sutured and the bone cannot be extra suture or fixation.

W. Zhang (✉)
Department of Hand Surgery, Tianjin Union Medical Center, Tianjin, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_14

Fig. 14.1 Preoperation palm side view, the distal abdominal tissue mass of the index and middle fingers amputated and deformed, and the wound surface was neat

Fig. 14.2 Preoperation dorsal side view, the distal abdominal tissue mass of the index, and middle fingers amputated and deformed with part of the nail bed, deck, and distal phalange bone

Fig. 14.3 Volar view immediately after surgery, the blood supply of the replantation tissue patches were abundant, and the capillary reaction was quick

Fig. 14.4 Dorsal view immediately after surgery, the nail bed is ruddy in color, and the capillary reaction is normal

Fig. 14.5 Follow-up 2.5 years, the distal pulp of the index and middle fingers are full, and the shape is satisfactory

Fig. 14.7 Follow-up 2.5 years, the flexion function of interphalangeal joint function is normal

Fig. 14.6 Follow-up 2.5 years, the deck of the index and middle fingers are normal and the shape is satisfactory

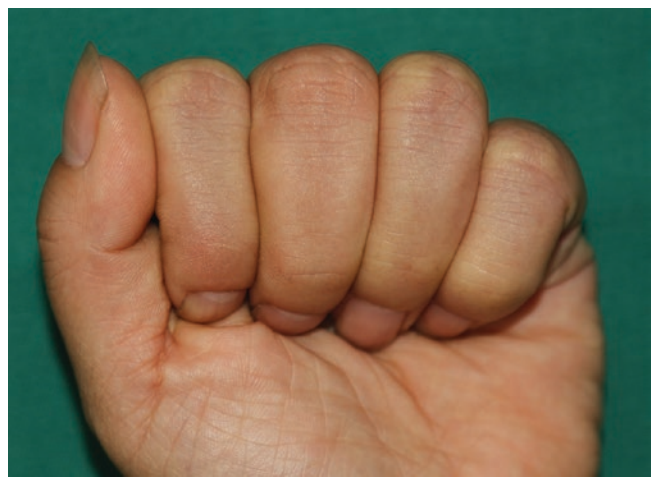


Fig. 14.8 Follow-up 2.5 years, the hand function is normal

References

1. Moscatelli A, Bianchi M, Serio A, et al. The change in fingertip contact area as a novel proprioceptive Cue. Curr Biol. 2016;26(9):1159–63. https://doi.org/10.1016/j.cub.2016.02.052.
2. Condon M, Birznieks I, Hudson K, et al. Differential sensitivity to surface compliance by tactile afferents in the human finger pad. J Neurophysiol. 2014;111(6):1308–17. https://doi.org/10.1152/jn.00589.2013.
3. Somer DD, Perić D, de Souza Neto EA, et al. A multi-scale computational assessment of channel gating assumptions within the meissnercorpuscle. J Biomech. 2015;48(1):73–80. https://doi.org/10.1016/j.jbiomech.2014.11.003.
4. Zhou X, Wang L, Mi J, et al. Thumb fingertip reconstruction with palmar V-Y flaps combined with bone and nail bed grafts following amputation. Arch Orthop Trauma Surg. 2015;135(4):589–94. https://doi.org/10.1007/s00402-015-2163-4.

5. Xing S, Shen Z, Jia W, et al. Aesthetic and functional results from nailfold recession following fingertip amputations. J Hand Surg [Am]. 2015;40(1):1–7. https://doi.org/10.1016/j.jhsa.2014.09.010.
6. Jeon BJ, Yang JW, Roh SY, et al. Lateral nail fold incision technique for venous anastomosis in fingertip replantation. Ann Plast Surg. 2016;76(1):67–71. https://doi.org/10.1097/SAP.0000000000000297.
7. Yang J, Wang T, Yu C, et al. Reconstruction of large area defect of the nail bed by cross finger fascial flap combined with split-thickness toe nail bed graft: a new surgical method. Medicine (Baltimore). 2017;96(6):e6048. https://doi.org/10.1097/MD.0000000000006048.
8. Sindhu K, DeFroda SF, Harris AP, et al. Management of partial fingertip amputation in adults: operative and non operative treatment. Injury. 2017;48(12):2643–9. https://doi.org/10.1016/j.injury.2017.10.042.
9. Peterson SL, Peterson EL, Wheatley MJ. Management of fingertip amputations. J Hand Surg [Am]. 2014;39(10):2093–101. https://doi.org/10.1016/j.jhsa.2014.04.025.

15 The Use of a Third Metacarpal Base Vascularized Osteoarticular Graft for Treatment of Metacarpophalangeal Joint Traumatic Defects

Xinzhong Shao and Xu Zhang

15.1 Case Reports

A 35-year-old man sustained a saw injury to the left thumb. There was an articular defect at the distal articular surface. Preoperative X-rays showed an articular defect at the base of the proximal phalanx on anteroposterior and lateral views.

15.2 Treatment Options

The metacarpophalangeal (MCP) joints are important for finger function because their average active range of motion accounts for 36% of total finger motion [1]. Intra-articular injuries to the MCP joints can lead to posttraumatic arthritis and functional disability as a result of joint pain and loss of motion [2, 3]. Although patients may benefit from the painless stability provided by thumb MCP joint arthrodesis, preservation of motion remains a laudable goal, even at the thumb MCP joint.

Several salvage procedures have been described for MCP joint reconstruction. Boulas et al. [4] reconstructed 5 MCP joint defects using a free metatarsophalangeal osteochondral autograft and observed a mean motion arc of 74°. However, those authors also noted joint space narrowing resulting from avascular cartilage necrosis in all cases. Menon [5] obtained excellent short-term results with the use of an autogenous osteoarticular graft taken from the metatarsal, but the author observed graft degeneration after 2 years. Malinin and Ouellette [6] indicated that nutrition for the articular cartilage is supplied by the subchondral bone and that interruption of the vascularized subchondral bone could lead to cartilage degeneration, although these changes would not be apparent in the short term and would be detected only after long periods of time. Seradge et al. [7] reported that the use of autogenous perichondrium produced an average MCP joint motion arc of 22° and a treatment failure rate of 19%. Engkvist et al. [8] reported a high incidence of joint pain and no functional improvement after perichondrial arthroplasty. Zappaterra et al. [9] reconstructed MCP joints using an autograft of costal cartilage and found that patients obtained a mean arch of motion of 37°. Jung et al. [10] used an autologous bone graft from the iliac crest for MCP joint reconstruction after tumor resection and found that this technique resulted in limited joint movement and the rapid development of osteoarthritis. Prosthetic arthroplasty can be an alternative, but it has a risk of implant failure [11]. Metacarpophalangeal joint arthrodesis represents an alternative procedure but results in loss of joint motion and risks excessive bone shortening and nonunion [12]. The outcomes of studies have been shown to vary according to the patient's age, occupation, original injuries, and daily activities; the medical examiners assigned to the case; and the length of the follow-up period [13, 14].

15.3 Anatomy

James et al. [13] found that nutrient arteries penetrate into the dorsum of the base of the third metacarpal. Those nutrient arteries arise from the distal and middle dorsal carpal arches, which run distally to the second to fourth DMAs (Fig. 15.1a, b). The first DMA originates from the radial artery (in 93% of cases), which connects to the dorsal carpal arches, although the first DMA has also been shown to originate from the distal dorsal carpal arch [14]. This anatomical organization is the basis for the development of a reverse DMA-based vascularized osteoarticular graft. Moreover, this flap technique can be modified according to anatomic variations. For example, the middle dorsal carpal arch is routinely present in all cases, whereas the distal dorsal arch is present in only 73% of the population. Thus, in a patient with no distal dorsal arch, the flap can be designed to obtain its blood supply from the DMAs of the middle dorsal carpal arch.

The third metacarpal has a widened proximal base, and the surface that articulates with the capitate is convex anteriorly and concave dorsally and extends to the styloid process

X. Shao (✉) · X. Zhang
Department of Hand Surgery, Third Hospital of Hebei Medical University, Shijiazhuang, Hebei, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_15

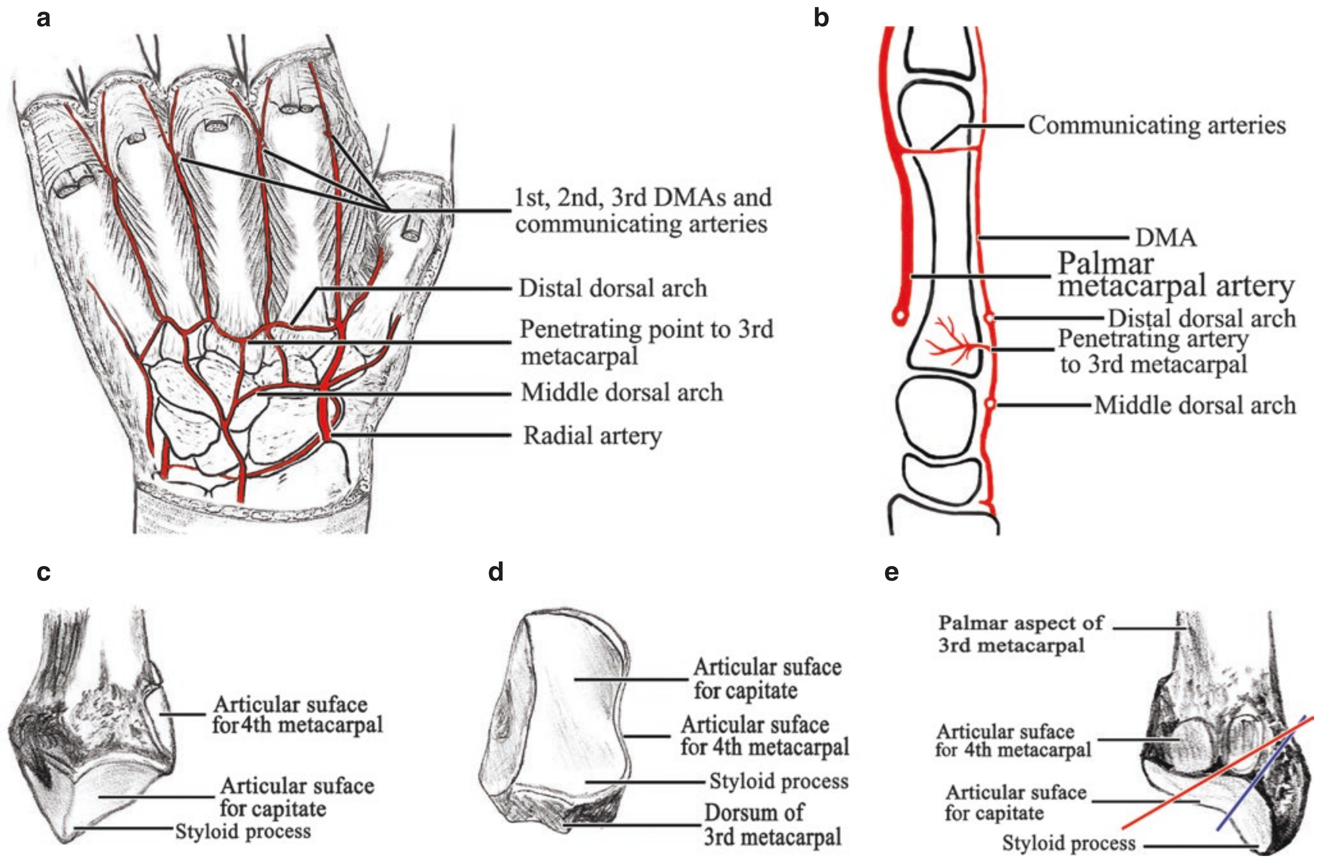


Fig. 15.1 (**a**) Anatomy of the dorsal metacarpal arteries (DMAs), dorsal arches, and penetrating point of the nutrient arteries at the base of the third metacarpal. (**b**) The third metacarpal and the arteries in the sagittal plane. (**c**) Volar view of the base of the third metacarpal. (**d**) Basal view. (**e**) Ulnar view. We performed an osteotomy through the blue line to obtain a convex articular surface and through the red line to obtain a concave articular surface

on the dorsolateral aspect of the metacarpal base4 (Fig. 15.1c–e). This unique contour is the basis for investigating the feasibility of using a portion of this articular surface for MCP joint reconstruction. The convex and concave surfaces are useful for reconstructing the metacarpal head and the base of the proximal phalanx, respectively.

15.4 Surgical Technique

Perioperative X-rays are obtained for assessing the articular defects. Perioperative CT scan is performed for old injuries, to more accurately assess the extent of the defects. (Fig. 15.2a–d) Nevertheless, intraoperative assessment is critical in determining whether to perform the tissue transfer.

The first, second, and third DMAs are selected for the vascular pedicle, mainly because of their reach, reliable position, and size, as they display less anatomical variation and a greater vascular caliber than the fourth and fifth DMAs. The DMAs are located preoperatively using a Doppler probe, and the surgery is performed under brachial plexus anesthesia with tourniquet control.

A lazy S- or L-shaped incision is made over the DMA that is selected as the vascular pedicle. At the wrist, the incision is curved transversely over the capitatemetacarpal joint (Fig. 15.3a). The DMA is identified and its accompanying two veins according to where they course along the dorsal interosseous fascia. In some cases, to ensure sufficient exposure, the insertion of the extensor carpi radialis brevis tendon is partially released and retracted laterally (Fig. 15.3b). If a large bone flap is required to simultaneously reconstruct a condylar defect, the extensor carpi radialis brevis insertion is completely released and sutured to the extensor carpi radialis longus. The periosteum of the third metacarpal is incised transversely at the level of the previous epiphysis, distal to the nutrient arteries. The metacarpal is cut at an angle using a sagittal saw (Fig. 15.3c). The angle is typically between 30° and 70°, which is determined according to the recipient site defect (Fig. 15.1e). During the osteotomy and elevating the osteoarticular graft, great care is taken not to injure the nutrient arteries (Fig. 15.3d). The DMA is included in the fascia over the full width of the muscle, involving the segment of the distal carpal arch in addition to 5–7 mm of the surrounding soft tissues, and the accompanying veins in the pedicle and they are dissected proximal to the graft. If the graft is pedicled on the first DMA, the involved segment of the radial artery is also harvested to maintain continuity of the pedicle. Then, the pedicle is dissected distally to a pivot point until the required length is achieved. The pivot point is chosen at a point along

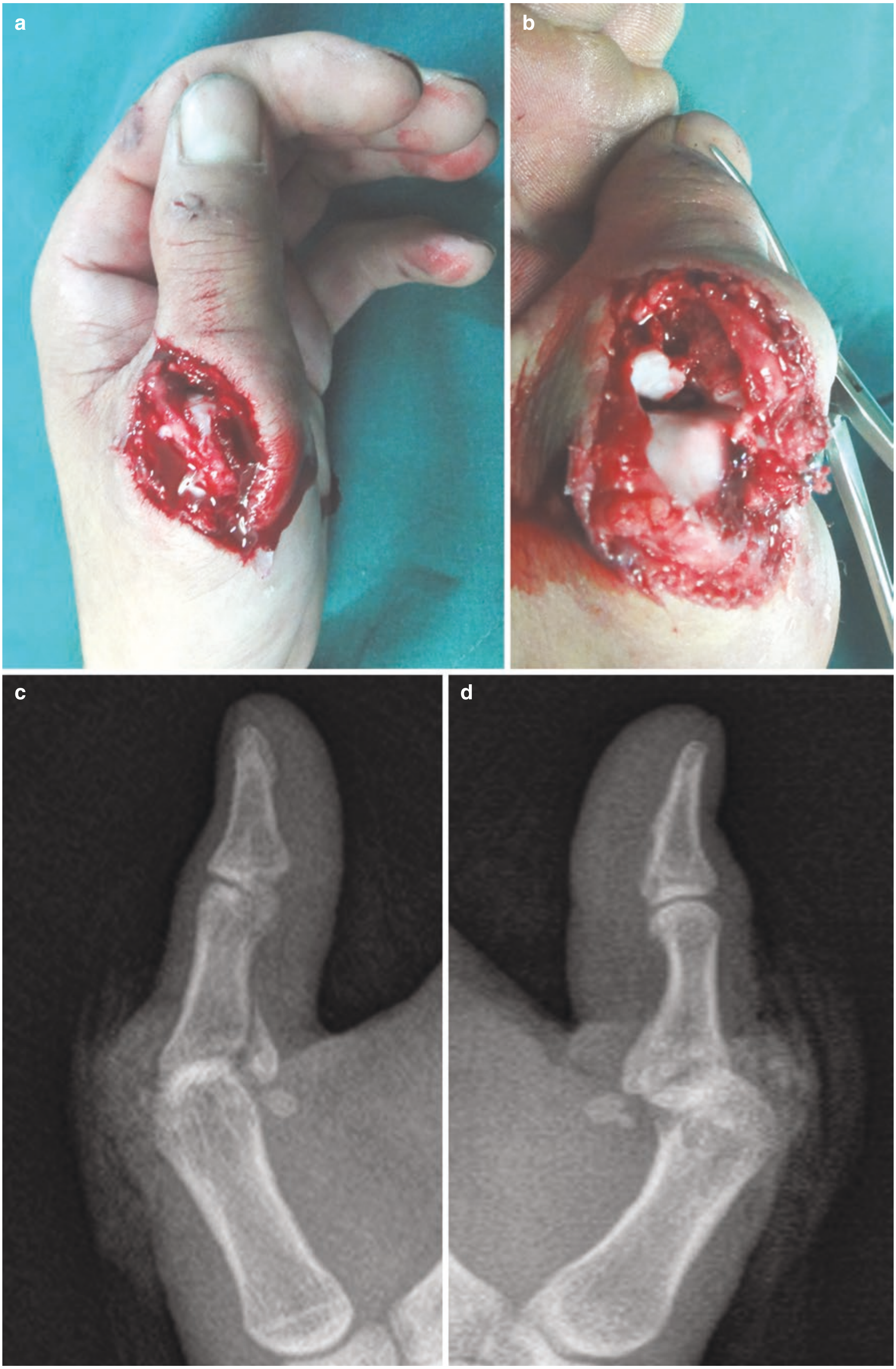


Fig. 15.2 The injury of case 1 with pictures (**a**, **b**) and x-ray films (**c**, **d**)

Fig. 15.3 (**a**) Incision design at the dorsum of the left hand. (**b**) 1, 2, and 3 show the first, second, and third DMAs and the accompanying veins. The arrow shows the point at which the nutrient arteries penetrate into the base of the third metacarpal. The arrowhead shows the extensor carpi radialis brevis and its insertion. (**c**) Osteotomy is complete. (**d**) Vascularized osteoarticular graft harvesting is completed

the portion of the DMA that is proximal to the communicating artery of the palmar metacarpal artery (Fig. 15.4). Thereafter, the tourniquet is released to check for graft bleeding. The graft is transferred to the defective joint through a subcutaneous tunnel. The graft and the defect are fashioned to fit together using a rongeur. The graft is fixed using 0.8- to 1.2-mm K-wires buried beneath the skin (Fig. 15.5a, b).

After surgery, the MCP joints and wrist are immobilized with a splint. The involved MCP joint of the finger or thumb is placed in 70° and 0° flexion, respectively. Two days after surgery, motion exercises of the interphalangeal joints are performed to decrease tendon adhesion. Two to 3 weeks after surgery, the splint and K-wire immobilizing the MCP joint are removed. Joint motion exercises are initiated. (Fig. 15.5c–e). Good thumb motion is observed 41 months after surgery (Fig. 15.6).

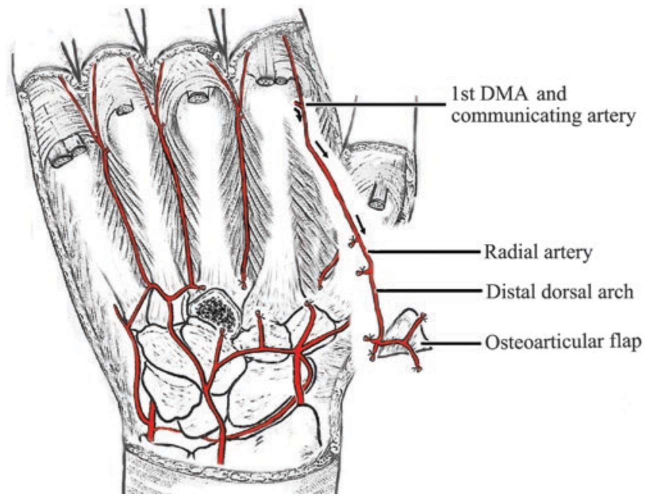


Fig. 15.4 Blood supply to the vascularized osteoarticular graft

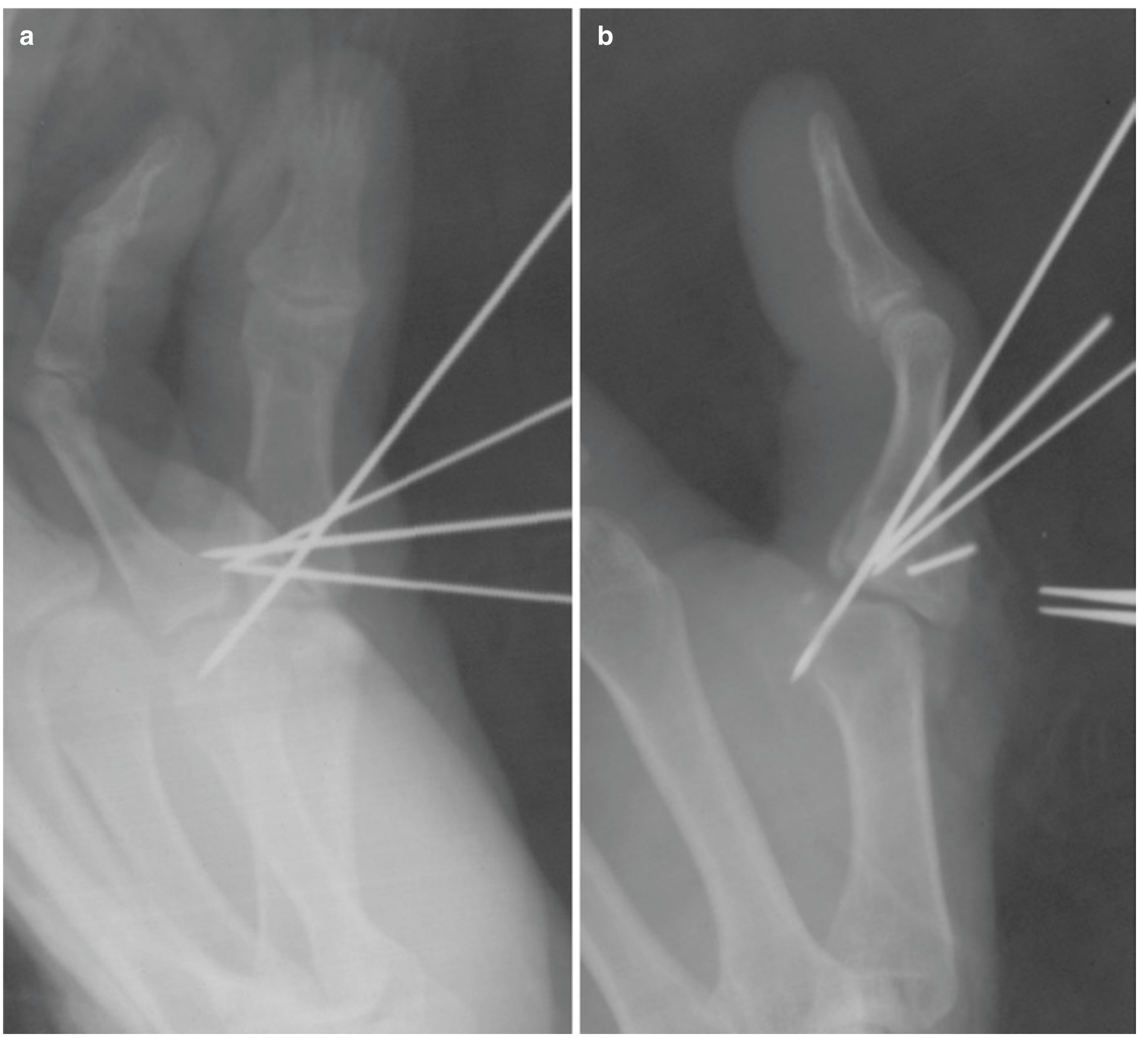


Fig. 15.5 (**a**) The radiograph shows flap fixation (anteroposterior view). (**b**) Lateral view. (**c**) The lateral image shows the thumb metacarpophalangeal (MCP) joint 41 months after surgery, with solid bone consolidation. (**d**) A sagittal computed tomography image shows bone healing at the donor joint. (**e**) Coronal imaging

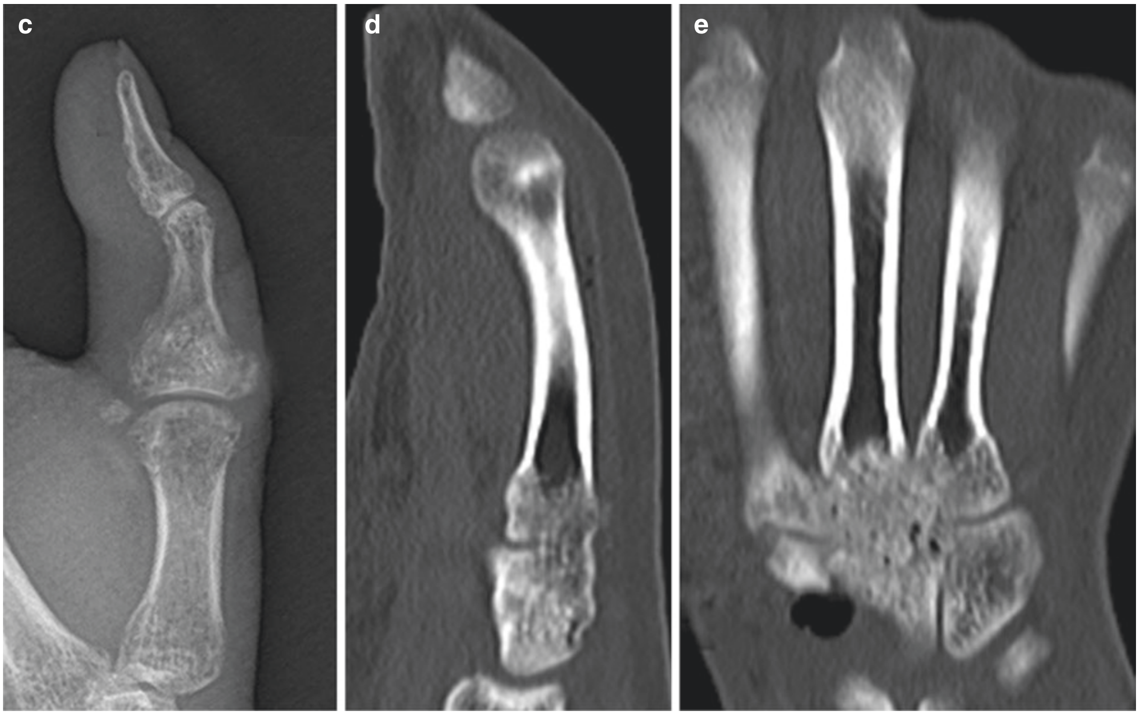


Fig. 15.5 (continued)

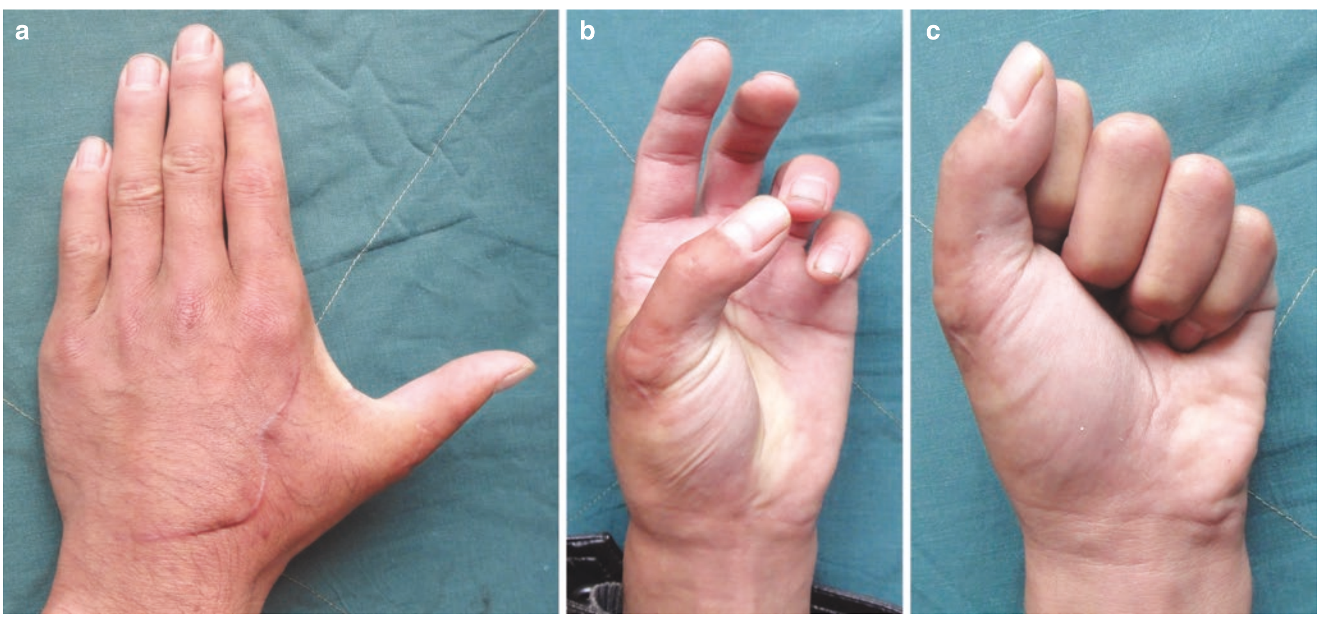


Fig. 15.6 (**a**) thumb extension. (**b**) thumb opposition. (**c**) thumb Flexion

15.5 Indication and Contraindication

Indication for the technique is existence of a new or old cartilage defect at either the proximal or the distal MCP joint surface. Contraindications include the existence of a small defect, an infectious condition, rheumatoid arthritis, or gout.

15.5.1 Case 2

A 22-year-old man had an old injury to the third MCP joint (Fig. 15.7–15.10).

Fig. 15.7 (**a**) Extension of the middle finger. (**b**) Flexion. (**c**) Radiograph shows a defect of the third metacarpal head. (**d**) Oblique view shows the defect associated with subluxation. (**e**) The third MCP joint on coronal CT image. (**f**) Sagittal image

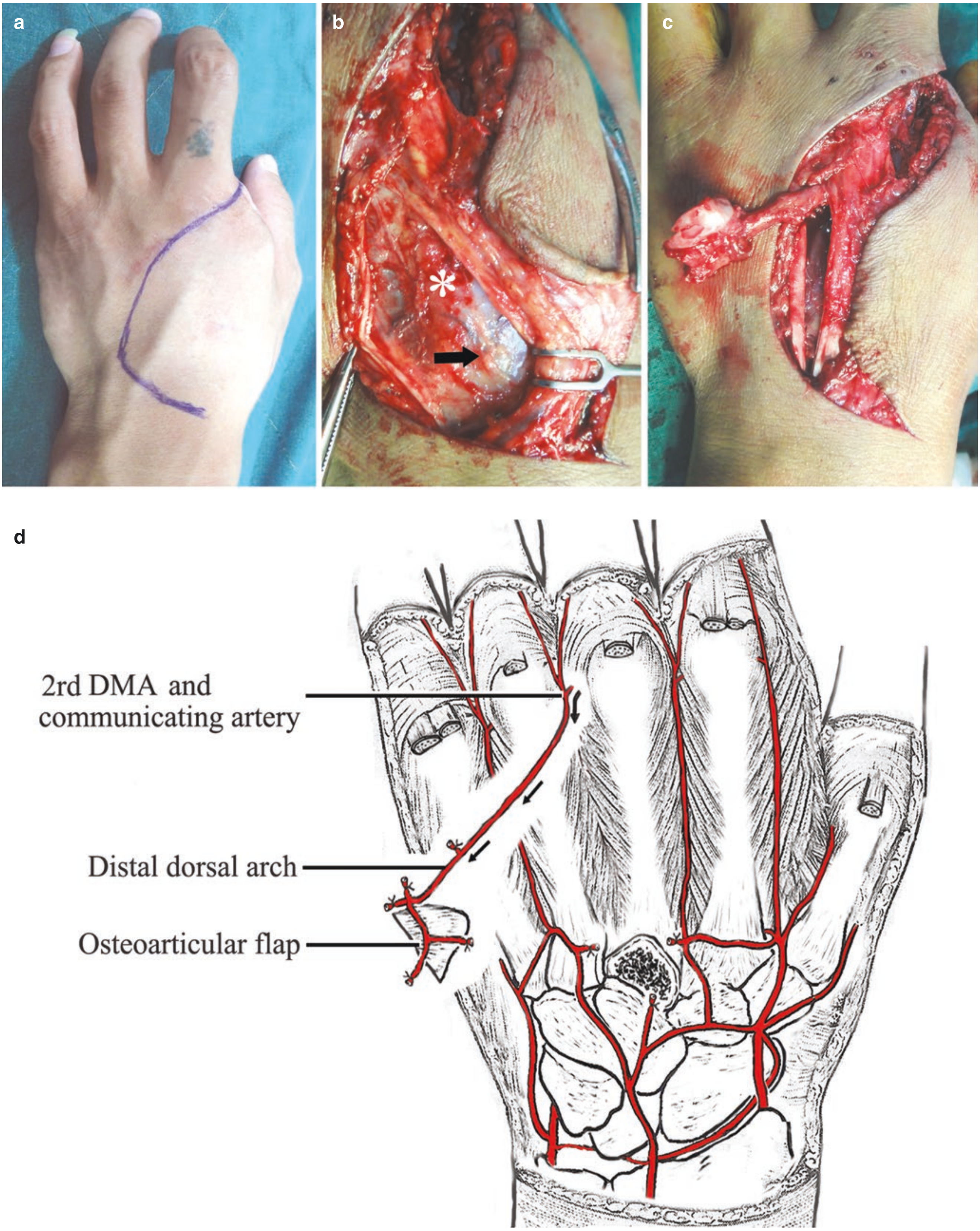


Fig. 15.8 (**a**) Incision design. (**b**) Exposure of the third DMA (asterik) and penetrating point of the nutrient arteries (arrow). (**c**) Osteoarticular flap is harvested. (**d**) Blood supply to the flap

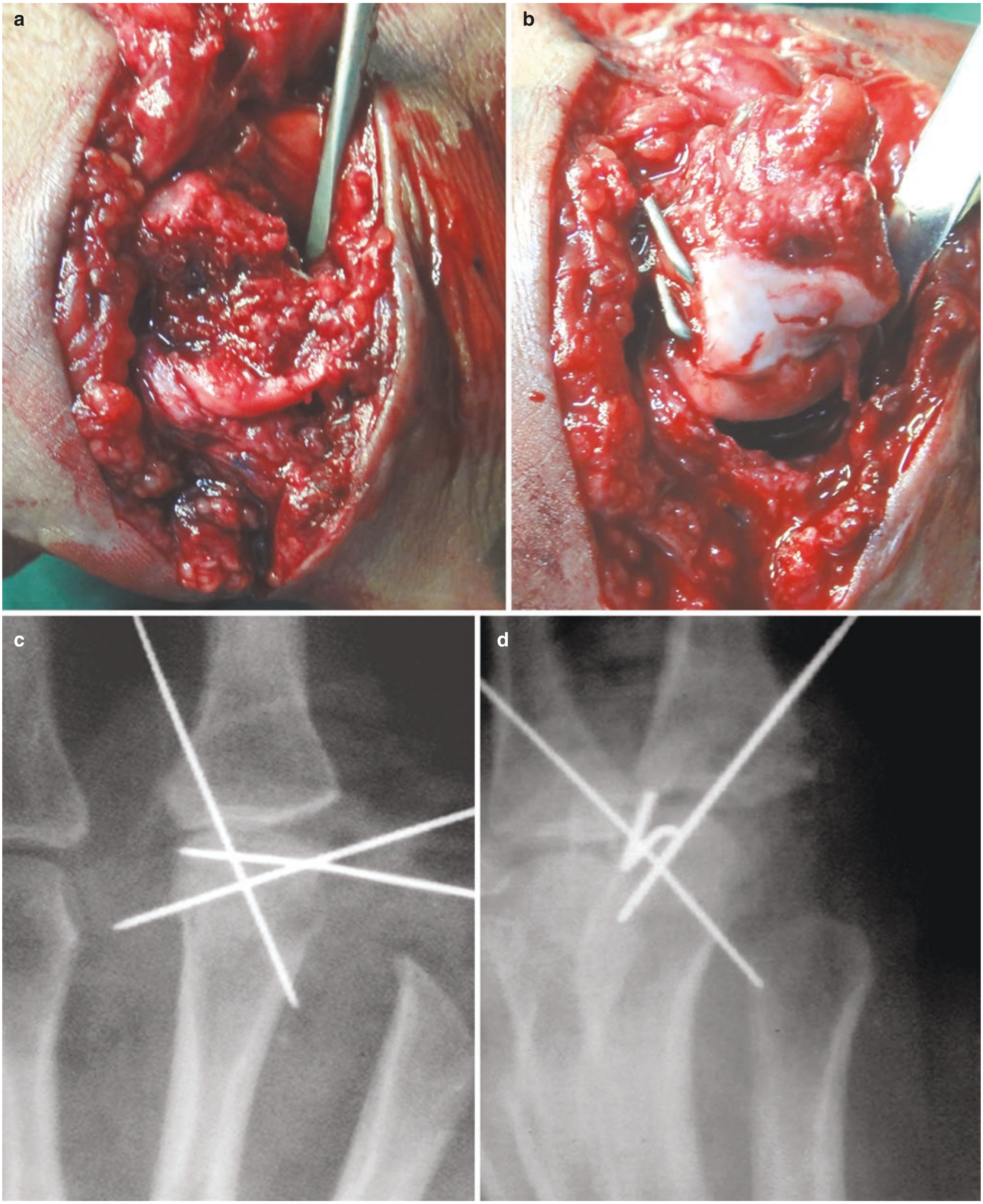


Fig. 15.9 (**a**) Osteoarticular defect of the third metacarpal head. (**b**) The flap is fixed using K-wires. (**c**) A radiograph shows flap fixation (antero-posterior view). (**d**) Oblique view

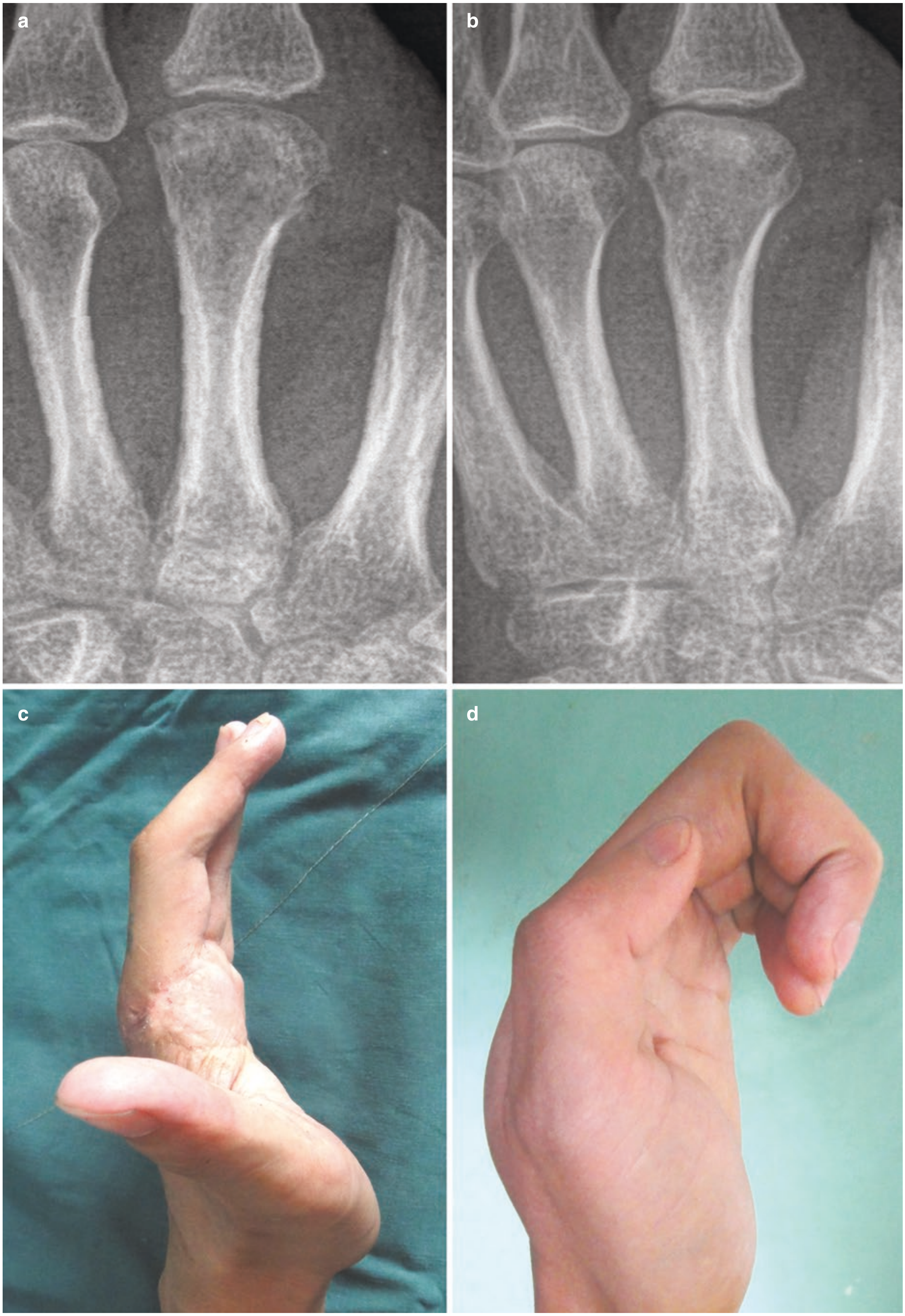


Fig. 15.10 (**a**) Anteroposterior view at 40 months. (**b**) Oblique view. (**c**) Extension. (**d**) Flexion

References

1. Abboud JA, Beredjiklian PK, Bozentka DJ. Metacarpophalangeal joint arthroplasty in rheumatoid arthritis. J Am Acad Orthop Surg. 2003;11:184–91.
2. Peterfy CG, van Dijke CF, Lu Y, Nguyen A, Connick TJ, Kneeland JB, et al. Quantification of the volume of articular cartilage in the metacarpophalangeal joints of the hand: accuracy and precision of three-dimensional MR imaging. AJR Am J Roentgenol. 1995;165:371–5.
3. Boulas HJ. Autograft replacement of small joint defects in the hand. Clin Orthop Relat Res. 1996;327:63–71.
4. Boulas HJ, Herren A, Büchler U. Osteochondral metatarsophalangeal autografts for traumatic articular metacarpophalangeal defects: a preliminary report. J Hand Surg. 1993;18A:1086–92.
5. Menon J. Reconstruction of the metacarpophalangeal joint with autogenous metatarsal. J Hand Surg. 1983;8A:443–6.
6. Malinin T, Ouellette EA. Articular cartilage nutrition is mediated by subchondral bone: a long-term autograft study in baboons. Osteoarthritis Cartilage. 2000;8:483–91.
7. Seradge H, Kutz JA, Kleinert HE, Lister GD, Wolff TW, Atasoy E. Perichondrial resurfacing arthroplasty in the hand. J Hand Surg. 1984;9A:880–6.
8. Engkvist O, Johansson SH. Perichondrial arthroplasty. A clinical study in twenty-six patients. Scand J Plast Reconstr Surg. 1980;14:71–87.
9. Zappaterra T, Obert L, Pauchot J, Lepage D, Rochet S, Gallinet D, et al. Post-traumatic reconstruction of digital joints by costal cartilage grafting: a preliminary prospective study. Chir Main. 2010;29:294–300.
10. Jung M, Daecke W, Bernd L, Martini AK, Schroeder K. Reconstruction of phalanx and metacarpal defects by autologous iliac crest transplants after tumour resection with joint involvement. Handchir Mikrochir Plast Chir. 2007;39:381–7.
11. Murray PM. Current status of metacarpophalangeal arthroplasty and basilar joint arthroplastry of the thumb. Clin Plast Surg. 1996;23:395–406.
12. Lourie GM. The role and implementation of metacarpophalangeal joint fusion and capsulodesis: indication and treatment alternatives. Hand Clin. 2001;17;255–60.
13. James RD, Michael JB. Skeleton anatomy in surgical anatomy of the hand and upper extremity. Lippincott Williams & Wilkins; 2003. p. 3–72.
14. Sebastin SJ, Mendoza RT, Chong AK, Peng YP, Ono S, Chung KC, et al. Application of the dorsal metacarpal artery perforator flap for resurfacing soft-tissue defects proximal to the fingertip. Plast Reconstr Surg. 2011;128:166–78.

16

Two-Staged Surgical Treatment of Composite Tissue Defects of the Dorsum of Hand and Finger Involving Fingerweb

Yu Jie Liu

16.1 Case Presentation

A 20-year-old female was admitted to our hospital for 4 h due to "dorsum of 2–5 fingers and hand wounded by machine which lead to pain, bleeding, and functional limitation." Physical examination: dorsum of 2–5 finger and hand skin defect involving finger web, company with 2–5 finger extensor tendon, and hood rupture or defect. The area of the extensor tendon defect is zone IV–VI. The palmar structure was intact (Fig. 16.1).

16.2 Choice of Treatment

The patient was a composite tissue defect of the tendon and skin of the hand. Common treatment strategies include: first, the skin flap was used to cover the wounds of fingers and dorsum of hand at one stage. At second stage, segmentation of the flap was used to complete finger-splitting and reconstruct the finger web, and at the third stage, free tendon transplantation was performed to reconstruct the function of the extensor tendon [1, 2]. Although the treatment is relatively safe, it requires multiple operations, long duration of treatment, and high cost. Joint stiffness often occurs [3]. Second, free dorsal foot flap with a vascularized extensor tendon was used to repair this type of wound in one stage [4]. This treatment has many advantages, such as short hospital stay, simultaneous reconstruction of defective tendons and skin, thin skin flaps, etc. However, the operation requires high microsurgical technology. The donor site of the skin flap could cause serious injury to the foot. Skin graft at donor dorsal foot is not easy to survive. Even survival of the dorsal skin graft area is often not wear-resistant, leading to form chronic ulcers. The sacrifice of 2–5 toe extensor tendon will lead to weakness of extensor digitorum and affecting bouncing.

Y. J. Liu (✉)
The Hand Surgery Center of CPLA, 971st Hospital of the CPLA Navy, Qingdao, China

Fig. 16.1 patient at admission:dorsal wound

In consideration of the number of operations, technical debond, donor site damage, and cost, we used the following methods: first-stage at emergency and free peroneal artery perforator flap to cover the wound. At the same time, free palmaris longus tendon transplantation to bridge the extensor tendon defect. Compared to the commonly used anterolateral thigh flaps or DIEP flaps, the thin skin of the lateral leg is a better choice for reconstruction of dorsal hand skin defect. Three weeks later, functional rehabilitation training of active and passive motion was started to avoid stiffness of joints. At the second stage, that is, 3 months later, the syndactylia was divided and to reconstruct the finger web, the flaps were thinned, and the extensor tendon was tenolysis at the same operation. Functional rehabilitation training will begin after 3 days. Six months later, the appearance and function of the injured hand were good.

16.3 Operative Technique

Brachial plexus block and epidural anesthesia were used at one-stage operation. After thorough debridement, according to the length of tendon defect, the extensor device and tendon cap were bridging repaired by free tendon transplantation of palmaris longus (Fig. 16.2). The free peroneal artery perfora-

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_16

Fig. 16.2 Tendon reconstruction:the extensor device and tendon cap were bridging repaired by free tendon transplantation of palmaris longus muscle at one stage

tor flap was designed on the lateral side of the contralateral leg [5, 6]. The design of the flap should be relaxed to provide with sufficient skin when performing finger-splitting and reconstruct the finger web later (Fig. 16.3). After the pedicle of flap was cut off, the perforator artery of the peroneal artery was anastomosed by side-by-end with the radial artery at snuff-box, and the vein of the flap was anastomosed with the accompanying vein and the cephalic vein. The flap survived well after the operation (Fig. 16.4). Plaster immobilized of the injured hand was at an extended position. After 3 weeks, plaster was removed and rehabilitation began. Three months later, finger-splitting and reconstruct finger web and tendon release were performed at the same operation. The functional exercise began on the third day after the operation. The follow-up at 1 year showed that the injured hand had good appearance and function (Fig. 16.5).

Fig. 16.3 The free peroneal artery perforator flap was designed and harvested at one stage

Fig. 16.4 Skin flaps survived

16.4 Clinical Implications

For the construction of composite tissue defect of dorsal hand, tendon reconstruction and cosmetic skin flap coverage and wide web reconstruction are the key points of treatment.

Because of extensor tendon defect, adjustment of appropriate tendon tension during tendon reconstruction will have a great impact on the outcome of function: over-load adjustment will lead to finger flexion disorder. If the tension is too small, it will lead to weakness of extensor fingers. If the tendon reconstruction is placed in the second stage, it is difficult to adjust the tendon tension and determine the length of the transplanted tendon accurately because of extensor muscle contracture. On the contrary, emergency tendon reconstruction is much more easier to

Fig. 16.5 One year after the second surgery, the patients achieved excellent cosmetic appearance and function

identify the length of tendon defect [7]. However, emergency tendon reconstruction needs admirable coverage of soft tissue in an emergency.

Full-thickness skin defect of the dorsum of hand and dorsum of a finger requires skin flap covering, which can lay a foundation for tendon sliding reconstruction simultaneously. Defect of the dorsum of the hand requires thinner skin for a young lady in those exposed areas. Finger web reconstruction requires broad and thin skin as related to finger abduction function. Therefore, in the first stage of skin flap coverage, the design of the finger web flap must be high quality and sufficient to meet the needs of the second stage reconstruction. Free peroneal artery perforator flap is a reliable and thin flap that can meet the above requirements [6].

Functional rehabilitation runs through the whole treatment process [8]. Early tendon reconstruction and wound coverage can achieve functional rehabilitation as early as possible and avoid stiffness of joints. At the second stage, initiative movement can be implemented early after the thinned of flap and tendon release. All of these factors ultimately enable patients to achieve good function.

Although the composite tissue defects of the skin and tendon on the dorsum of the hand are common, the final effects are compromised. Only by two-stage operations, our treatment strategy ultimately achieves excellent cosmetic appearance and function. At the same time, it has other advantages including less number of operations, shorter hospital stay, less cost, and moderate technique requirement.

References

1. Koch H, Kursumovic A, Hubmer M, et al. Defects on the dorsum of the hand—the posterior interosseous flap and its alternatives. Hand Surg. 2003;8(2):205–12.
2. Lin CH, Wei FC, Lin YT, et al. Composite palmaris longus-venous flap for simultaneous reconstruction of extensor tendon and dorsal surface defects of the hand—long-term functional result. J Trauma. 2004;56(5):1118–22.
3. Sundine M, Scheker LR. A comparison of immediate and staged reconstruction of the dorsum of the hand. J Hand Surg Br. 1996;21(2):216–21.
4. Stathas T, Tsinias G, Tsiliboti D, Tsiros A, Mastronikolis N, Goumas P. Dorsalis pedis free flap: the salvage option following failure of the radial forearm flap in total lower lip reconstruction. Case Rep Med. 2014;2014:458286.
5. Cheng L, Yang X, Chen T, Li Z. Peroneal artery perforator flap for the treatment of chronic lower extremity wounds. J Orthop Surg Res. 2017;12(1):170.
6. Ha Y, Yeo KK, Piao Y, et al. Peroneal flap: clinical application and cadaveric study. Arch Plast Surg. 2017;44(2):136–43.
7. Lukas B, Hartl P, Bäcker K. Soft-tissue reconstruction of the dorsum of the hand and finger to cover the extender tendons. Handchir Mikrochir Plast Chir. 2008;40(2):110–4.
8. Adani R, Marcoccio I, Tarallo L. Flap coverage of dorsum of hand associated with extensor tendons injuries: a completely vascularized single-stage reconstruction. Microsurgery. 2003;23(1):32–9.

17 Harvest and Separate the Second Toe for the Repair of Compound Tissue Defects for Multiple Fingers

Qiaohong Guo

It is very difficult to repair tissue defects of multiple fingers in the hand. In the present study, a toe was split into several different tissue blocks to repair tissue defects of multiple fingers. This is a method to achieve the ideal repair effect of multiple tissue defects with minimum trauma.

17.1 Case Presentation

A 19-year-old man was admitted to our hospital within 1 h due to a left hand injured by an electric shovel. Physical examination results: The general situations were good, defects occurred in the left index finger, nail body, nail arc shadow, and proximal nail wall; thrypsis occurred in phalange of the last section, and the distal interphalangeal joint was destroyed. In the middle finger, comminuted fracture occurred in the middle and distal phalanges, some skin and extensor and flexor tendon of the middle section presented with defects, the distal interphalangeal joint was destroyed. In the ring finger, the proximal ulnar skin, extensor tendon, and ulnar digital artery nerve of the middle section presented with defects. The diagnosis was as follows: multiple compound tissue defects of the left index, middle, and ring fingers. A second toe was chosen and split into three free tissue blocks to repair the tissue defects of left index, middle, and ring fingers, respectively, and the appearances and functions of the three fingers were restored (Fig. 17.1).

17.2 Treatment Selection

According to the condition analysis results, the patient had multiple isolated compound tissue defect areas of his fingers; for simplicity, finger shortening, joint fusion, and even finger amputation are required, which would result in poor prognosis, accumulation, and protrusion of skin and soft tissue on one side (complete side) of the finger and even disability. For preserving the appearance and function of the fingers as much as possible, the treatment is very difficult. In the present study, a second toe with the closest tissue structure was chosen, then the toe was divided into three free compound tissue blocks according to three specific tissue defects of three fingers, fine reconstruction and reconstruction of bones, tendons, blood vessels, nerves, and skin were carried out, and a relatively satisfactory curative effect was achieved.

17.3 Surgical Methods

17.3.1 Recipient Site Preparation

The patient was debrided thoroughly under brachial plexus anesthesia, all frustrated or inactivated tissues that were difficult to retain were not palliated but removed instead. The locations, scopes, and types of defect tissues were accurately determined. With the unaffected side as a benchmark, the scopes of defects of joints and the length of extensor tendon and flexor tendon defects and the areas of skin defects were measured with a ruler, and numerical values were recorded for splitting. The dorsal digital vein, innate nerve, and innate artery were dissected and separated for reserve.

17.3.2 Donor Site Preparation

According to the defects of the recipient sites, two interphalangeal joints and vascular nerve tendon skin compound tissues and one vascular nerve tendon compound tissue needed to be reconstructed. A second toe was chosen and removed from the space plane of the metatarsophalangeal joint. After removal, the toe body was divided into three compound tissue flaps according to the requirements, two of these blocks contained distal and proximal interphalangeal joints.

Q. Guo (✉)
Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_17

Fig. 17.1 Separation of the second toe to reconstruct multiple fingers. (**a**) Before operation. (**b**) Toe design. (**c**) Flap obtaining. (**d**) After operation. (**e**) Follow-up at half a year after the operation. (**f**) Follow-up at half a year after the operation

17.3.3 Transplant Repair

Three compound tissue flaps were used to repair the nail bed, distal interphalangeal joint, extensor tendon and insertion of the index finger, the distal interphalangeal joint, the surrounding digital artery, digital nerve, extensor tendon and skin of the middle finger, extensor tendon, ulnar vascular nerve, and skin of ring finger, respectively.

17.4 Application of Anatomy

The second toe interphalangeal joint is the trochlear joint, which consists of an adjacent phalangeal trochlea and toe base. Its joint flexion and extension movement is similar to the finger. So it is suitable for repairing the interphalangeal joint. The second toe veins are mainly superficial venous refluxes of the dorsal toe, the nerve and articular branches of the interphalangeal joint mainly originate from the dorsal digital nerve and the plantar digital nerve.

17.5 Precautions

1. The purpose of reconstructing multiple compound tissue defects of multiple fingers by splitting one toe is to achieve maximum repair with minimal surgical trauma and donor site cost by accurate anatomical dissociation. Therefore, before the operation, the anatomical characteristics of toes and the requirements of tissue repair in recipient sites should be fully understood for reasonable paired design, striving to achieve the purpose of what is missing then what is supplied.
2. The surgery requires careful design, careful and patient operation, and gentle action to protect the vessels and nerves of the joint sac branch from damage. Attention should be paid to the fixation position of the transplanted joint to prevent rotation and angular deformity.
3. The surgery has a certain risk, it requires the surgeon to have a rigid microvascular anastomosis technique and sufficient knowledge of anatomy before the surgery can be implemented. The separation of tissues is accurate to the millimeter. It belongs to the category of super microsurgery.
4. When splitting the toes, reasonable design and splitting should be carried out according to the structure of each part of the toe and the tissue defects of the recipient site, the broken ends of blood vessels, nerves, and tendons are retained as many as possible to reduce the difficulty and risk of anastomosis.

18 Combined Biological Reconstruction Can Be Used to Repair the Large Bone Defect after Resection of Malignant Bone Tumor

Jing Li and Chuanlei Ji

With the progress of diagnosis, chemotherapy, and imaging technology, most of the malignant tumors in the extremities can be cured by surgery, which is operable to save the limbs. The repair of the large bone defect after tumor resection includes biological reconstruction, prosthesis implantation, and rotational plastic surgery [1–4]. Each method has its advantages and disadvantages. The age, tumor property, prognosis, condition of soft tissue, complications, and social psychological factors should be taken into account in the selection of reconstruction methods. Combined biological reconstruction refers to the combination of two or more biological reconstruction methods, drawing on each other's strengths to achieve maximum functional recovery and minimizing the complications. Capanna [5] first reported combined biological reconstruction techniques in 1993, and he combined allograft bone with vascularized fibula to reconstruct the large bone defect of the lower extremity after resection of bone tumor. We extended the indications [6, 7] and methods [8, 9] of this technique and applied it to the reconstruction of the long bone defects of the limbs (such as femur, tibia, humerus, and calcaneus) after tumor resection.

18.1 Case Presentation

Case 1: Female patient, 21 years old, was hospitalized for right thigh mass for 3 months and could not walk because of pain for 1 month. Osteolytic bone destruction and pathological fracture in the middle and upper part of the right femur were observed on the radiograph. MRI examination revealed that the lesion ranged from 5 cm below the femoral trochanter to the middle and lower part of the femur. It was confirmed as femoral Ewing's sarcoma by puncture biopsy after admission. Preoperative diagnosis was right femoral Ewing's sarcoma combined with pathological fracture. The tumor was significantly reduced after preoperative chemotherapy and adjuvant radiotherapy, followed by the tumor resection and reconstruction of the femur.

A conventional lateral incision was selected to expose the lesion during operation and the whole tumor resection was performed after the osteotomy which was performed conducted 2 cm away from the tumor site margin. The length of bone defect caused by tumor resection was about 17 cm. The free fibula flap was dissected to about 21 cm in length through a conventional posterolateral incision. The lateral portion of the allogeneic bone was slotted about 17 cm in length. Afterward, the peroneal flap was inserted into the allogeneic bone marrow cavity and formed a composite, and the vascular pedicles were located in the grooves to avoid compression. The fibula at both ends of the composite was inserted into the proximal and distal part of the femur after tumor resection and then locked by the bone plate. The anterolateral femoral vessel was identified, ligated, freed, and severed its distal end and was anastomosed with the peroneal vessels end-to-end, reestablished the circulation of peroneal vessels.

Postoperative imaging showed that the reconstruction position was good in situ. Bone scan revealed peroneal graft survival, and the allogeneic bone and autologous bone healed successfully 1 year after the operation (Fig. 18.1a–e).

Case 2: Female patient, 9-year-old, was hospitalized for progressive deformity of the proximal upper arm for 2 years. It was confirmed as multiple endogenous chondromatosis with malignant lesions after admission. Proximal humerus irregular bone destruction and humerus deformity were observed through X-ray examination. We performed segmental resection of the proximal humerus and reconstructed the humerus with vascularized fibula combined with massive bone allograft. The metaphysis, epiphysis, and diaphysis of the humerus were resected about 10 cm in length with the conventional anterolateral approach. Allograft bone was selected in the same length, afterward, the ipsilateral fibula flap was harvested by 14 cm in length which was inserted into the allograft, and the stump composite was fixed after instal-

J. Li (✉) · C. Ji
Department of Orthopedic Surgery, Xi Jing Hospital, Air Force Medical University, Xi'an, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_18

Fig. 18.1 Combined biologic reconstruction was used to repair the large bone defect after femoral tumor resection. (**a**) Preoperative X-ray showed femoral fracture; (**b**) MRI scan showed the bone region of tumor; (**c**) The allogeneic bone and autologous vascularized fibula were combined; (**d**) Postoperative X-ray image after the reconstruction; (**e**) Postoperative SPECT showed peroneal survival; (**f**) The complex healed with the femur

lation resection of the complex and the tumor of humerus. The deep brachial vessels were freed, severed its distal end, and anastomosed with the peroneal vessels to reconstruct the peroneal circulation. Postoperative "anticoagulant, anti-spasm, and anti-inflammatory" treatment were used, and a bone scan was conducted to suggest the survival of fibula. Bone union was observed between the composite and the humerus 6 months after surgery. The shoulder joint function of the affected limb returned to normal (Fig. 18.2a–f).

Case 3: Male patient, 9 years old, was hospitalized for the proximal mass of right calf which the needle biopsy confirmed proximal osteosarcoma of the left tibia. Neoadjuvant chemotherapy was administered 3 times, and the tumor responded well to chemotherapy. Preoperative X-ray images showed mixed proximal tibia lesions, involving the epiphysis of the tibia. MRI showed partial response area involvement of the lateral tibial plateau. Before surgery, CT/MRI fusion images were input into Stryker navigation for intraoperative recognition of the tumor bone range for accurate resection. Sufficient dissociation of the surrounding tissue was first done, continued to use navigation devices to determine the extent of the tumor in the bone for accurate osteot-

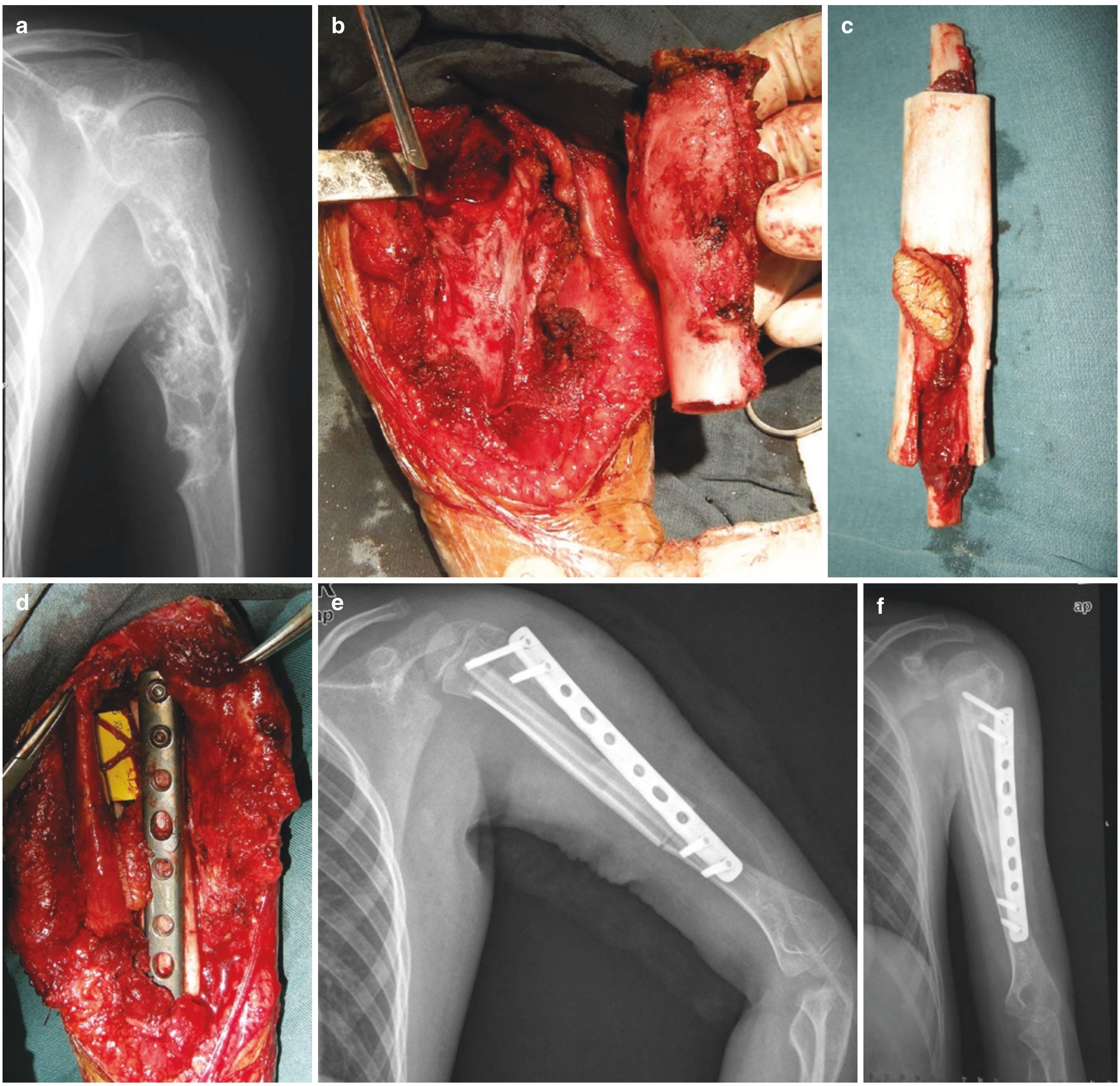


Fig. 18.2 Combined biological reconstruction was used to repair the large bone defect after resection of humeral bone tumor. (**a**) Preoperative X-ray image; (**b**) Resection of tumor segment; (**c**) Bone allograft combined with fibula flap; (**d**) The complex was fixed and anastomosed; (**e**) Postoperative X-ray image after reconstruction; (**f**) Bone healing occurred half a year after reconstruction

omy of tumor proximal, and distal segment under the guidance of navigation. The tumor was resected under the premise of a safe surgical margin so that the medial tibial plateau and the adjacent cruciate ligament were retained. Transferred ipsilateral pedicled fibula flap to tibia which was inserted into an allograft with part of the lateral plateau articular surface to form a composite for repairing the bone defects. The lateral collateral ligaments around the knee and the extensor apparatus were reconstructed by allograft bone after removal of the fibula. The wound healed well after the operation, the knee joint is straightened and immobilized fixed for 6 weeks, knee flexion and extension were allowed at 6 weeks after the operation, partial weight training was available at 3 months after the operation, and full weight training was available at 8 months after the operation. At 11 months after the operation, the allograft, fibula, and autologous bone were completely healed. The knee flexion and extension activity were consistent with the healthy side, the MSTS score was 100%, and no recurrence was found in 5 years after operation (Fig. 18.3a–g).

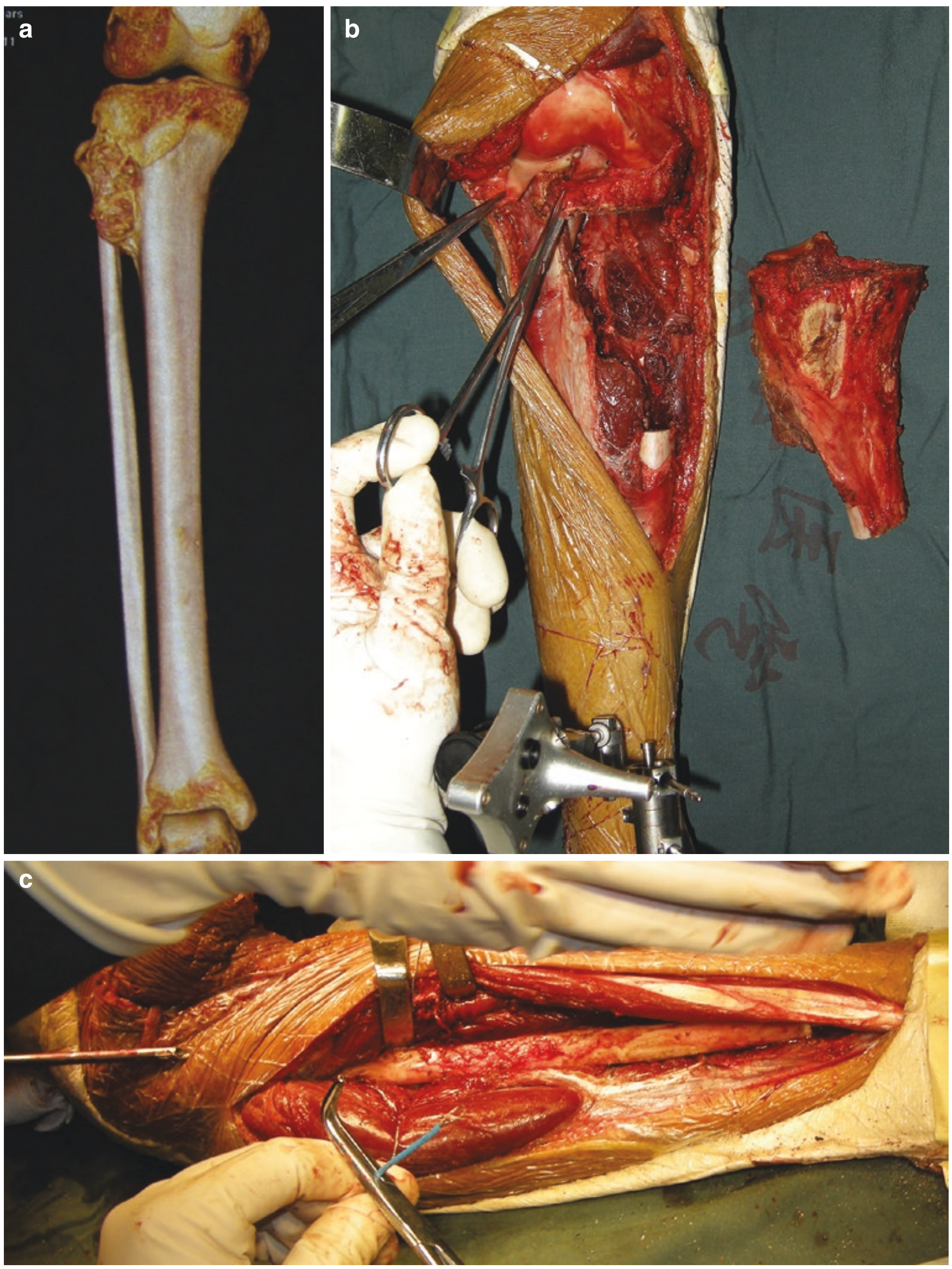


Fig. 18.3 Combined biologic reconstruction was used to repair the large bone defect after resection of the tibial bone tumor. (**a**) Preoperative three-dimensional CT image; (**b**) Intraoperative tumor excision; (**c**) The fibula flap was incised; (**d**) allograft; (**e**) Allograft bone implantation; (**f**) Postoperative follow-up X-ray image; (**g**) Postoperative follow-up

Fig. 18.3 (continued)

18.2 Choice of Treatment

Both cases 1 and 2 were tumors of long bones, the reconstruction methods of the large bone defect after resection of bone tumor usually include distraction osteogenesis retraction bone growth [10], tumor inactivation and replantation [11–13], allograft bone [14–16], and autologous vascularized fibular bone graft [17]. However, delayed healing or nonunion, fracture, and infection are common complications after biological reconstruction [18, 19]. It often requires multiple surgeries, and in some cases, it ends with amputations. In combination technique, allogeneic bone provides bone mass, early mechanical support and protection of fibula, the vascularized fibula promotes the healing of allograft and host bone, and the fibula can provide mid and late mechanical support after healing. For the long segment of the femur, tibia and other major weight-bearing bone defects, combined biologic reconstruction was used to obtain a reliable repair of the defect.

Case 3 is proximal osteosarcoma of the tibia with effective tumor reduction after chemotherapy. The tumor invaded the lateral plateau of the tibia. There are two general options for surgery, one is an intra-articular resection of the tumor of the proximal tibia followed by arthroplasty which the advantage is that the early movable joints can be obtained, but this method wastes the tumor joints and sacrifices the femoral side which is not affected by the tumor. Meanwhile, the current bone cement tumor prosthesis has a very high risk of long-term prosthesis loosening and fracture in the long term. Therefore, if the patient has a long-term survival, it will require multiple renovations during the survival period. The other is the proximal tibia tumor resection and artificial joint reconstruction which has the advantage of not sacrificing the femoral lateral bone, but allograft half joint transplantation needs to rebuild the stability of the structure joints such as the cruciate ligament; as a matter of fact, we found that joint function after surgery for reconstruction was poor, and this might not only lead to bone nonunion and other heterotopic bone complications but also long-term joint instability, degeneration, reduced range of motion, and even total loss of joint function. In this case, the accurate osteotomy was performed under computer navigation, the medial platform, and the continuous cruciate ligaments were retained so that the internal stability of the joint could be preserved to the greatest extent and accurate reconstruction of the articular surface was achieved by compositing an allograft with a portion of the lateral plateau articular surface. In order to promote the healing between allograft and autologous bone and enhance bone activation subchondral bone cartilage, we adopted ipsilateral fibula transplantation with vascularized pedicles. For the defect after the ipsilateral fibula resection, immediate and permanent stability of the lower limbs, we obtained through reconstruction with allograft bone. This patient obtained ideal function by the method of composite biological reconstruction, and there was no difference in motion between the knee and the opposite side. At the same time, due to the addition of vascularized fibula, both the plateau joint and the diaphysis joint were found to be well healed.

18.3 Operative Technique

The surgical method was introduced with case 3 as an example:

1. Two incisions were made on the inner and outer side of the lower leg, the medial incision was used for tumor resection, and the lateral incision was used for transposition of vascularized fibula flap and reconstruction of fibula defect.
2. The medial incision was located slightly anterior to the medial posterior margin of the tibia, protected the great saphenous vein, and pulled it behind the incision. The tracker of the computer navigation device was placed at the distal end of the tibia.
3. The patellar ligament was cutoff at the endpoint of the tibial tuberosity and transected laterally to expose the knee joint. The position of the planned osteotomy line was determined by navigation guidance and noted the position of the osteotomy line above the response band 5 mm shown on MRI to ensure a safe surgical margin.
4. Used an electric knife to mark the position of the osteotomy line.
5. The medial platform osteotomy was performed with a sharp bone knife.
6. After the osteotomy, the medial platform with the internal and external cruciate ligaments was turned up.
7. After osteotomy 2 cm away from the distal part of the tumor, the tumor segment was turned up, and the appendages of the anterior and posterior muscle groups were gradually cutoff on the tumor segment to protect the tibialis posterior vessels and peroneal vessels in the posterior group of muscles.
8. The resected tumor segment showed the reserved medial platform with its continuous anterior and posterior cruciate ligaments and medial–lateral meniscus.
9. The medial platform cartilage and part of cartilage were removed from the size-matched allogeneic bone, and then transformed into the allogeneic bone with partial articular surface exactly matched to the size of the resected tumor.
10. The vascularized fibula flap was dissociated from the posterolateral incision. Note that the fibula flap was remote-sided and the proximal line saw was surrounding the fibula to prepare the cut.

11. The allogeneic bone marrow cavity was slotted for admission of the vascularized fibula.
12. The vascularized fibula turned forward through the intermuscular septum, ready to be inserted into the allograft for recombination.
13. The fibula with blood vessels was inserted into the allograft and reassembled.
14. The reserved medial platform and the complex connected with the anterior and posterior cruciate ligaments were fixed.
15. The composite was fixed with the lateral bone plate at the distal tibia stump.
16. The defect of the fibula was reconstructed by an allograft fibula.
17. The iliac ligament stump was reconstructed on the tibial tuberosity of the allograft.

18.4 Matters Need Attention

The core theory of composite reconstruction is that the bone formation of the biologically active fibula promotes the healing of the bone junction and the allograft provides bone mass and early support. Therefore, the following points should be noted during the operation:

1. Note the quality of fibula excision and vascular anastomosis to ensure the survival of the transplanted fibula.
2. The length of the fibula should be 3–5 cm longer than that of the allograft. Both ends of the fibula can be inserted into the stump of the tumor segment after resection by about 2 cm, which is conducive to generate contact, and the healing probability between the non-living fibula and the autologous bone is greatly increased.
3. When insertion is difficult, a groove should be made on the surface of the allograft to prevent protect the vasculature from being compressed.
4. The allograft should be fixed with as few screws as possible to reduce the possibility of stress fractures at the screw hole.
5. The complex composite should be supported as much as possible with strong internal fixation to prevent failure of fixation before bone healing.
6. Good compact attachment is required between the contact end of allograft and autologous bone to increase the probability of healing between them.
7. The healing of the outer half between the allogeneic bone and the autologous bone is accomplished by the reptile filling of the outer periosteum of the autologous bone, therefore, the periosteum and soft tissue around the residual bone should be protected as much as possible during tumor resection.
8. The patients with vascular anastomosis need routine treatment of anticoagulation, anti-spasm, and anti-inflammation to ensure the survival of the transplanted fibula.

References

1. Ortiz-Cruz E, Gebhardt MC, Jennings LC, et al. The results of transplantation of intercalary allografts after resection of tumors. A long-term follow-up study. J Bone Joint Surg Am. 1997;79(1):97–106.
2. Hanna SA, Sewell MD, Aston WJ, et al. Femoral diaphyseal endoprosthetic reconstruction after segmental resection of primary bone tumours. J Bone Joint Surg Br. 2010;92(6):867–74.
3. Harris JD, Trinh TQ, Scharschmidt TJ, et al. Exceptional functional recovery and return to high-impact sports after Van Nes rotationplasty. Orthopedics. 2013;36(1):126–31.
4. Sewell MD, Hanna SA, McGrath A, et al. Intercalary diaphyseal endoprosthetic reconstruction for malignant tibial bone tumours. J Bone Joint Surg Br. 2011;93(8):1111–7.
5. Capanna R, Bufalini C, Campanacci C. A new technique for reconstruction of large metadiaphyseal bone defects: a combined graft(allograft shell plus vascularized fibula). Orthop Traumatol. 1993;2(5):159–61.
6. Li J, Wang Z, Guo Z, et al. The use of massive allograft with intramedullary fibular graft for intercalary reconstruction after resection of tibial malignancy. J Reconstr Microsurg. 2011;27(1):37–46.
7. Li J, Wang Z, Guo Z, et al. The use of allograft shell with intramedullary vascularised fibula graft for intercalary reconstruction after diaphyseal resection for lower extremity bony malignancy. J Surg Oncol. 2010;102(5):368–74.
8. Li J, Wang Z, Guo Z, et al. Precise resection and biological reconstruction for patients with bone sarcomas in proximal humerus. J Reconstr Microsurg. 2012;28(6):419–25.
9. Li J, Wang Z, Guo Z, et al. Composite biological reconstruction following total calcanectomy of primary calcaneal tumors. J Surg Oncol. 2012;105(7):673–8.
10. Tsuchiya H, Tomita K, Minematsu K, et al. Limb salvage using distraction osteogenesis: a classification of the technique. J Bone Joint Surg Br. 1997;79(3):403–11.
11. Krieg AH, Davidson AW, Stalley PD. Intercalary femoral reconstruction with extracorporeal irradiated autogenous bone graft in limb-salvage surgery. J Bone Joint Surg Br. 2007;89(3):366–71.
12. Manabe J, Ahmed AR, Kawaguchi N, et al. Pasteurized autologous bone graft in surgery for bone and soft tissue sarcoma. Clin Orthop Relat Res. 2004;419:258–66.
13. Khattak MJ, Umer M, Haroon-ur-Rasheed, et al. Autoclaved tumor bone for reconstruction: an alternative in developing countries. Clin Orthop Relat Res. 2006;447:138–44.
14. Ortiz-Cruz E, Gebhardt MC, Jennings LC, et al. The results of transplantation of intercalary allografts after resection of tumors. J Bone Joint Surg Am. 1997;79(1):97–106.
15. Hornicek FJ, Gebhardt MC, Tomford WW, et al. Factors affecting nonunion of the allograft-host junction. Clin Orthop Relat Res. 2001;382(1):87–98.
16. Muscolo DL, Ayerza MA, Aponte-Tinao L, et al. Intercalary femur and tibia segmental allografts provide an acceptable alternative in reconstructing tumor resections. Clin Orthop. 2004;426:97–102.
17. Zaretski A, Amir A, Meller I, et al. Free fibula long bone reconstruction in orthopedic oncology: a surgical algorithm for reconstructive options. Plast Reconstr Surg. 2004;113(7):1989–2000.
18. Aponte-Tinao LA, Ayerza MA, et al. Should fractures in massive intercalary bone allografts of the lower limb be treated with ORIF or with a new allograft? Clin Orthop Relat Res. 2015;473(3):805–11.
19. Thompson RC Jr, Garg A, Clohisy DR, et al. Fractures in large-segment allografts. Clin Orthop. 2000;370:227–35.

19 Anterolateral Thigh Flap for the Reconstruction of Forearm with Severe Injury

Guangyue Zhao, Zhao Yang, Yonggang Zhu, Jun Li, and Jiwei Zou

19.1 Case Presentation

An 18-year-old girl was referred to us with composite defects in the left forearm due to a crush injury 8 hours after the initial injury. Severe injury occurred including the fracture of left ulna, the rupture of palmaris longus tendon, flexor carpi radialis tendon, flexor pollicis longus tendon, and flexor digitorum profundus tendon, the defects of the radial artery and median nerve, and 17 × 10 cm soft tissue defect in the anterior forearm (Figs. 19.1 and 19.2).

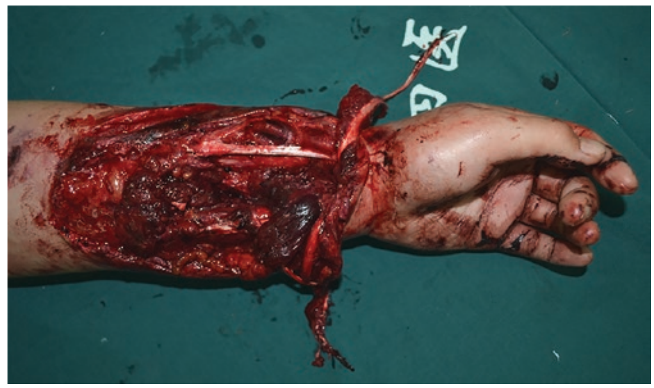


Fig. 19.1 Appearance of the left forearm due to a crush injury 8 h after initial injury

19.2 Choice of Treatment

This patient needs soft tissue coverage and ulna fixation and tendons, artery, nerve reduction to restore the hand's function.

The flap cover plays an important role in reconstruction when deep structures (tendons, nerve, and/or bone) are exposed.

In this case, the left forearm needs a well vascularized viable tissue for defects covering and vessel repairing, thus preventing infection. Flaps as anterolateral thigh (ALT) flap has been reported to successfully bridge vascular gaps of up to 20 cm and provide soft tissue coverage up to 30 cm in length and 15 cm in width.

We manage the patient in one stage—"Orthoplastic" solution. The "Orthoplastic" solution means to repair the soft tissue, bone fracture, and other defects(vessel/nerve) in the same stage.

Fig. 19.2 Radiographs of left forearm

G. Zhao (✉) · Z. Yang · Y. Zhu · J. Zou
Department of Orthopedic Surgery, Xijing Hospital, Air Force Military Medical University, Xi'an, Shaanxi Province, China

J. Li
Department of Oral and Maxillofacial-Head and Neck Oncology, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_19

19.3 Operative Technique

Under general anesthesia, the patient is placed in the supine position. After thorough debridement, the defect of soft-tissue coverage was measured at approximately 19 cm vertically ×11 cm transversely (Fig. 19.3). The posterior incision was made in the distal ulna to restore the fracture and insert the plate. After ulna reduction, the posterior incision was closed. Kessler anastomosis was performed to restore the palmaris longus tendon, flexor carpi radialis tendon, flexor pollicis longus tendon, and flexor digitorum profundus tendon using 3-0 nylon sutures (Fig. 19.4). A sural nerve of more than 20 cm was then obtained in the right leg and prepared for median nerve anastomosis in the left forearm (Fig. 19.5). After being divided into three parts, the sural nerve was anastomosed in parallel for repairing the left median nerve defect (Fig. 19.6). Then we designed and elevated the right anterolateral thigh flap (ALT flap, 20 × 12 cm) as the left forearm cover flap (Fig. 19.7). A microsurgical end-to-end anastomosis was performed between the pedicle of the ALT flap and proximal radial artery/proximal cephalic vein using a 10-0 nylon suture. The blood circulation of the flap was observed until the color, temperature, tension, and vascular filling response were all admirable (Fig. 19.8). Finally, an external fixator was used to make the stability of the left forearm and wrist (Fig. 19.9). The right donor areas are covered by vacuum sealing drainage (VSD).

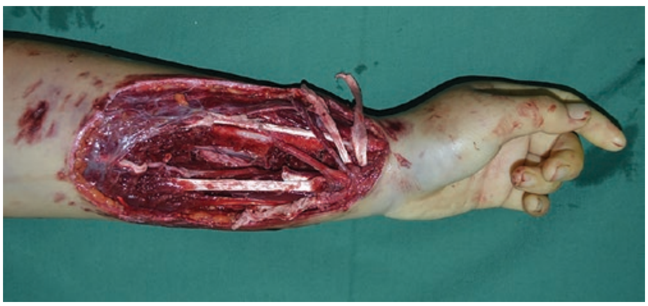


Fig. 19.3 After debridement

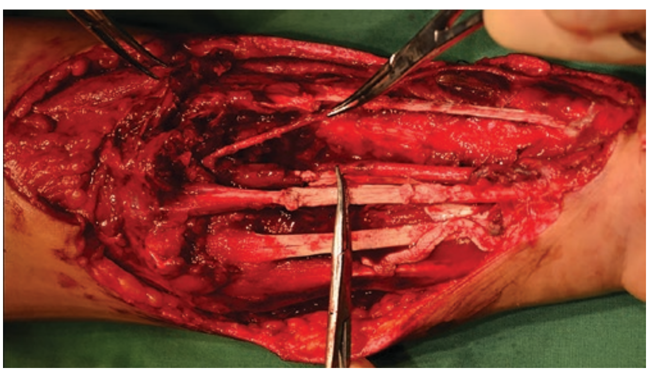


Fig. 19.4 After the tendons' restoration

One week later, a second operation is performed to cover the right donor areas with a skin graft. The flap survived uneventfully after the operation. Ten weeks after the operation, the patient was permitted partial weight-bearing. Functional recovery was achieved at the sixth-month' follow-up (Figs. 19.10 and 19.11). The length of follow-up was over 12 months.

19.4 Clinical Implications

Complex traumatic injury with soft tissue defects and vascular impairment is a challenging problem for reconstructive surgeons. Microsurgical techniques such as flap transfer provide patients with tissue loss in extremities a reliable option for accessing healthy free tissues and recipient vessels [1, 2]. Free anterolateral thigh flap provides a reliable solution for composite defects involving bone and soft tissue. It provides a well vascularized viable tissue cover for exposed deep structures (tendons, nerve, and/or bone). It avoids further infection after first debridement [3]. One stage management is the key point of the "Orthoplastic" conception [4–8]. It has been proved more effectively and safely in severe open fracture management [9–11].

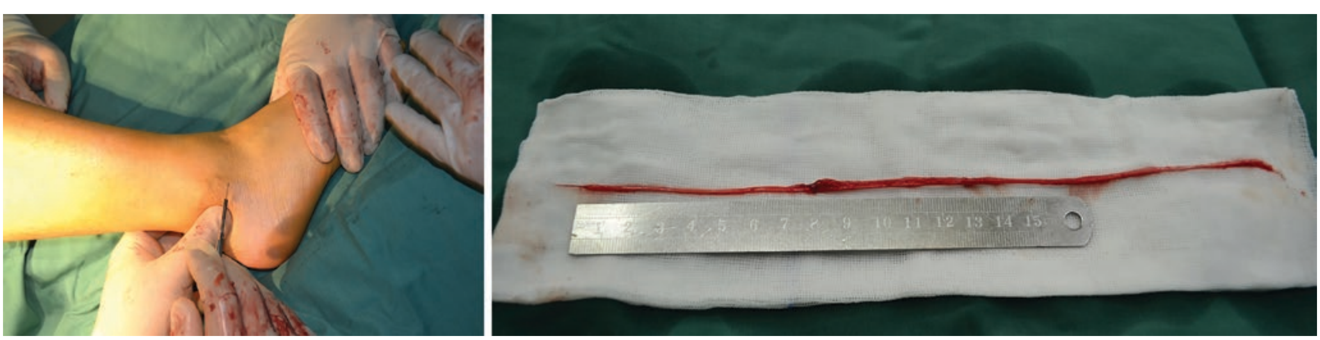


Fig. 19.5 A right sural nerve with more than 20 cm long was elevated

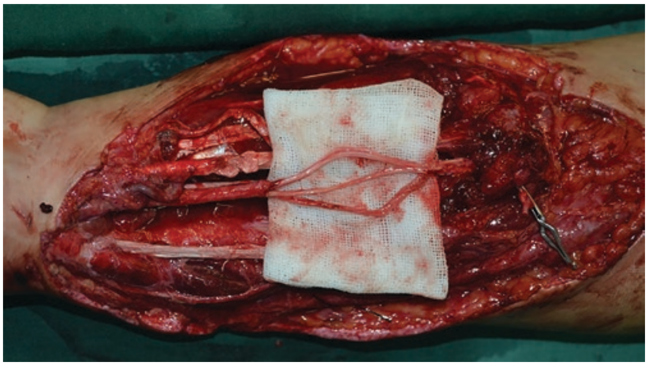


Fig. 19.6 The sural nerve was cut into three parts and anastomosed in parallel onto the median nerve

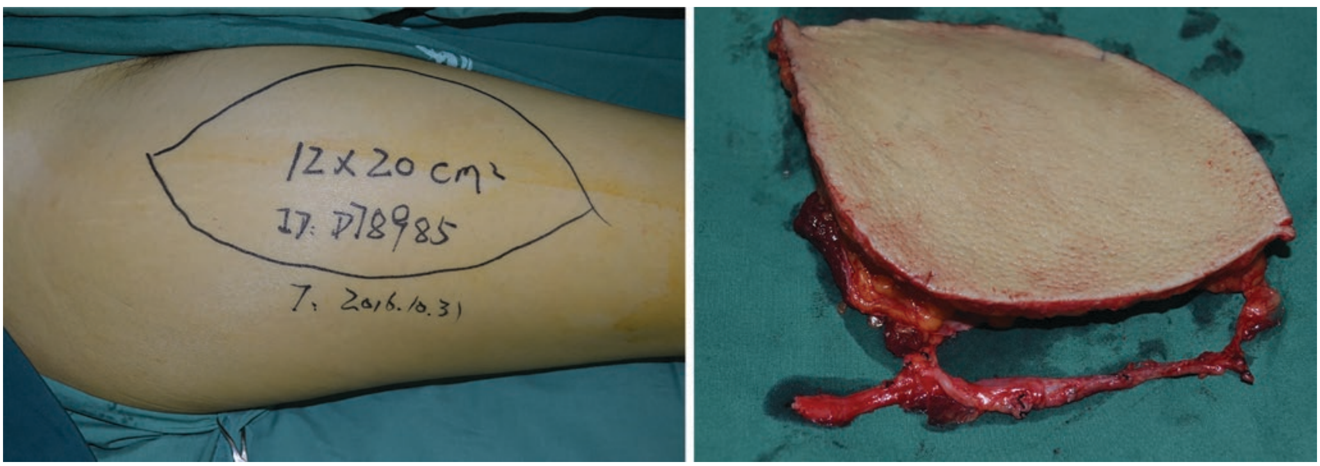


Fig. 19.7 Right anterolateral thigh flap (ALT flap, 20 × 12 cm) was obtained for the left forearm cover flap

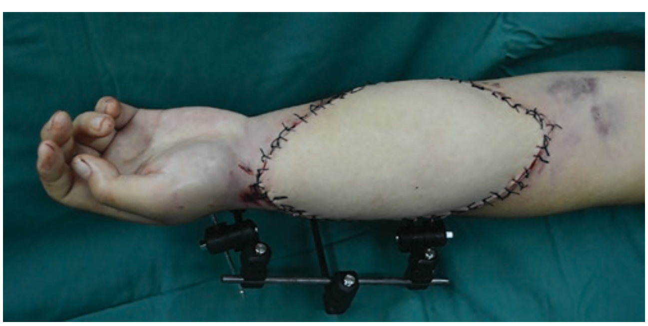


Fig. 19.8 Appearance of the external fixator and the survived flap after the operation

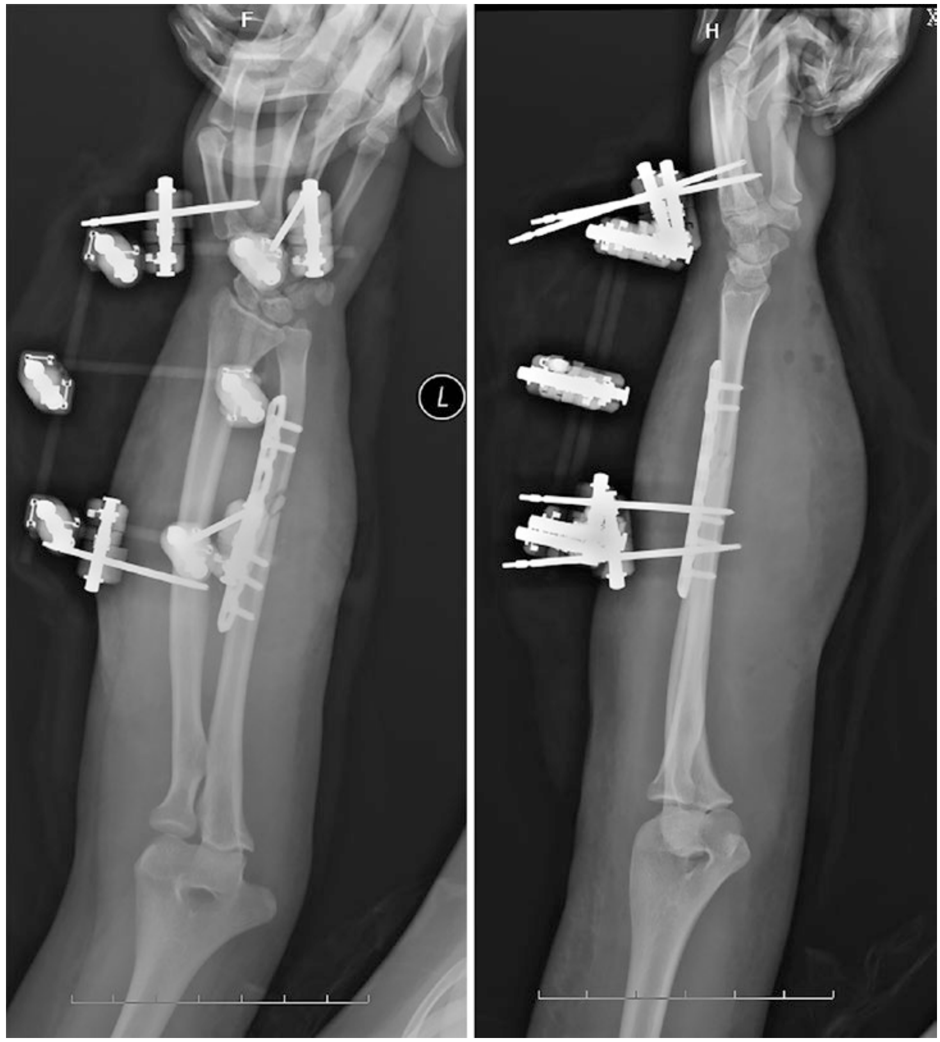


Fig. 19.9 X-ray examinations of the left forearm after the operation

Fig. 19.10 Six months later, the patient can move his left hand freely

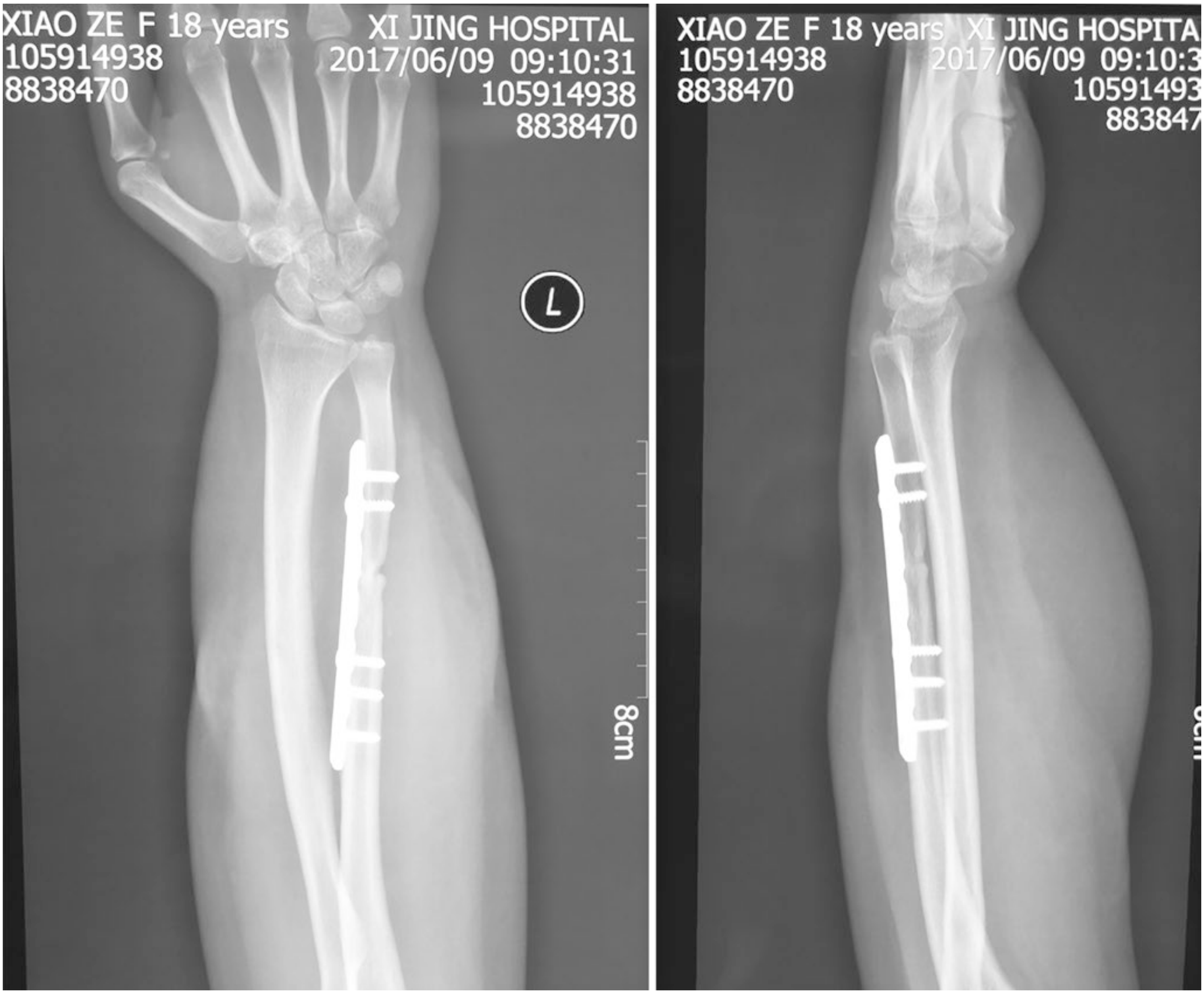


Fig. 19.11 X-ray examinations of the left forearm 6 months later

References

1. Ozkan O, Ozkan O, Bektas G, Cinpolat A. Experiences with the flow-through radial forearm flap as a bridge in lower extremity reconstruction. Microsurgery. 2015;254:433–45.
2. Ozalp T, Masquelet AC, Begue TC. Septocutaneous perforatorsof the peroneal artery relative to the fibula: anatomical basis of the use of pedicled fasciocutaneous flap. Surg Radiol Anat. 2006;28:54–8.
3. Bullocks J, Naik B, Lee E, Hollier LJ. Flow-through flaps: a review of current knowledge and a novel classification system. Microsurgery. 2006;26:439–49.
4. Lykoudis EG, Dimitrios P, Alexandros BE. One-stage reconstruction of the complex midfoot defect with a multiple osteotomized free fibular osteo-cutaneous flap: case report and literature review. Microsurgery. 2010;30:64–9.
5. Lerman OZ, Kovach SJ, Levin LS. The respective roles of plastic and orthopaedic surgery in limb salvage. Plast Reconstr Surg. 2011;127(1S):2156–275.
6. Scott Levin L. George Cierny: Orthoplastic Pioneer—"the soft tissue envelope". Tech Orthop. 2015;30(4):215–22.
7. Nanchahal J, Nayagam S, Khan U, Moran C, Barrett S, Sanderson F, et al. In: Laing H, editor. Standards for the management of open fractures of the lower limb. London: Royal Society of Medicine Press Ltd.; 2009.
8. The early management of severe tibial fractures: the need for combined plastic and orthopaedic management. BOA/BAPS, London, January 1993.
9. Boriani F, Ul Haq A, Baldini T, Urso R, Granchi D, Baldini N, Tigani D, Tarar M, Khan U. Orthoplastic surgical collaboration is required to optimise the treatment of severe limb injuries: a multi-Centre, prospective cohort study. J Plast Reconstr Aesthet Surg. 2017;70(6):715–22.
10. Germann G, Levin LS. Intrinsic flaps in the hand: new concepts in skin coverage. Tech Hand Upper Extrem Surg. 1997;1:48–61.
11. Heitmann C, Levin L. The orthoplastic approach for management of the severely traumatized foot and ankle. J Trauma. 2003;54(2):379–90.

Part II

Lower Limbs and Feet

20 Repair and Reconstruction of the Segmentally Destructed Lower Limb in a Child

Bingfang Zeng, Yunfeng Chen, Zhongren Zhang, and Shanhua Wang

20.1 Case Presentation

A 7-year-old girl had her right lower limb crushed by a trunk wheel on June 1, 1996, resulting in extensive soft-tissue destruction extending from the middle portion of the thigh to 3 cm proximal to the ankle joint (Fig. 20.1, left). The femoral condyle, the epiphysis of the tibial plateau, and the tibial shaft sustained comminuted fractures and were extensively exposed (Fig. 20.1, right). The wound was severely contaminated. The physical examination revealed that the affected foot presented with a low skin temperature but nearly normal capillary filling and sensation of the toes and that all the toes were capable of flexion and extension.

Fig. 20.1 A 7-year-old girl presented with an extensively destroyed soft tissue (left) and a severely comminuted fracture (right) in her right lower limb as a result of a road accident. (Adapted from ref. [5]; with permission)

B. Zeng (✉) · Y. Chen · Z. Zhang · S. Wang
Department of Orthopaedic Surgery, Shanghai Sixth People's Hospital, Shanghai Jiaotong University, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_20

20.2 Consideration and Decision-Making of the Treatment

In this case, all the bone and soft tissues in the lower third of the thigh and the upper two-thirds of the leg sustained a destructive injury. Because no repair and reconstruction to the destroyed portion of the limb could be done, amputation through the middle third of the thigh was indicated. However, the girl was only 7 years old; such an amputation would certainly have led to an extremely severe disability. As the distal third of the leg and the foot were relatively intact, if they were reattached to the proximal stump after the destructed middle portion of the limb was resected, it would be possible to cover the resultant wound thus to preserve the lower limb to some extent. Particularly, the remaining distal epiphysis of the tibia would play an important role in the growth of the affected limb. Therefore, replantation of the remaining part of the lower limb, although with significant shortening, was necessary.

The knee and the ankle are both ginglymoid joints and share a similar function. However, their ranges of motion in flexion and extension are just contrary to each other. In the knee, the flexion has a much wider range of motion than its extension; while in the ankle, the dorsal extension has a much wider range of motion than its plantar flexion. In the replantation of the distal part of the lower limb in this case, if the lower leg and foot were rotated 180 degrees to make the ankle function as a new knee, the dorsal extension of the ankle would be transformed into the flexion of the new "knee". This flexion is necessary for a functioning knee; its plantar flexion would be changed into the extension of the new knee, with an almost similar range of motion with the knee. These features will certainly benefit the function of the affected lower limb. It has been reported in the literature that, after the removal of malignant tumors around the knee, a rotationplasty with a well-fit prosthesis can improve postoperative function greatly [1, 2]. On the other hand, the fact that all the toes could move meant that the toes still had blood circulation, although reduced to some extent, and the intrinsic muscles in the foot were innervated. In other words, the posterior tibial neurovascular bundle might survive from the original injury. It would benefit the possible rotationplasy afterward.

When the above two points were combined together, it became clear that an emergency rotationplasty should be done to make the ankle function as a "knee".

20.3 Operative Technique

After the preoperative examination and preparation, a debridement was carried out under epidural anesthesia. All the destroyed structures between the proximal end of the femur and the distal end of the fractured tibia were resected; only the posterior tibial neurovascular bundle, which was revealed to present an anatomical continuation during the debridement, and the tendinous portion of the extrinsic muscles of the foot and ankle were preserved. The pneumatic tourniquet was deflated only to find an insufficient blood supply in the foot. A segmental hydraulic dilation with heparinized saline was performed on the posterior tibial artery. The middle portion of the tibial artery, 4 cm in length, was seen not to dilate well and was, therefore, resected. After the artery was reanastomosed, the blood circulation in the foot was much improved with good capillary filling in the pulps of the toes (Fig. 20.2).

The periosteum, approximately 4 cm in length, was stripped from the posterior aspects of both the femoral and the tibial stumps with the cortical surfaces trimmed flat. The distal leg and the foot were rotated 180 degrees and replanted onto the stump of the thigh. The tibia and the femur over-

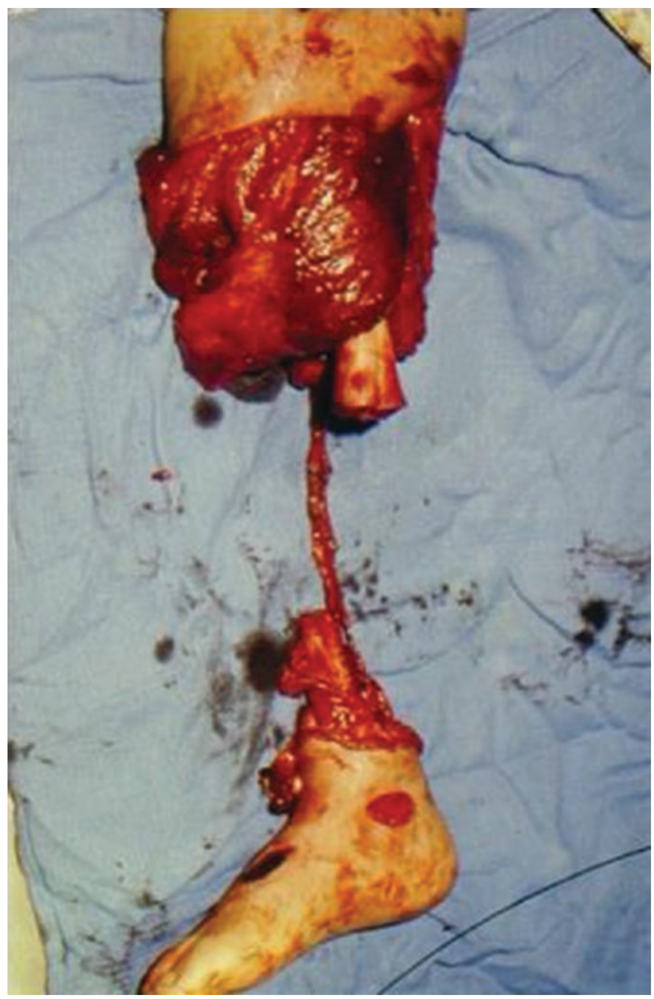


Fig. 20.2 After the resection of the destroyed portion of the limb, the remaining tibia, ankle and foot were connected to thigh by the posterior tibial neurovascular bundle after the posterior tibial artery had been managed. (Adapted from ref. [5]; with permission)

lapped, and their posterior aspects were brought in contact with each other (Fig. 20.3, right). The length of the limb was adjusted to make the new right knee aligned slightly distal to the normal left knee. The femur and the tibia were transfixed together with three screws. With the ankle joint kept in full plantar flexion, the Achilles tendon and the tendon of flexor posterior tibialis were sutured to the deep surface of the rectus femoris, the tendons of the extensor digitorum longus were sutured to the deep surfaces of the semitendinous muscle, and the tendons of the anterior tibialis were sutured to the deep surface of the biceps femoris. The posterior tibial neurovascular bundle wound gently and was covered with soft tissues nearby. The originally avulsed skin was thinned to become a full-thickness skin graft and was used to cover the remaining wound around the thigh and the leg (Fig. 20.3, left).

Fig. 20.3 The appearance (left) and X-ray film (right) of the lower limb right after the rotationplasty, showing the closure of the wound and the way of bony fixation. (Adapted from ref. [5]; with permission)

20.4 Postoperative Management and Result

The grafted skin was bandaged with even pressure. The new "knee" was fixed in extension with a plaster sprint. The postoperative treatment followed standard microsurgery protocol. The replanted leg and foot showed good blood circulation, although there was moderate swelling, which subsided 1 week later. Most of the grafted skin survived, whereas the remaining wound healed after dressing changes (Fig. 20.4, left). The X-ray films revealed callus formation at the connecting site between the femur and the tibia 2 months after the operation. The plaster splint was removed and active functional exercises begun. Solid bone union between the

Fig. 20.4 The appearance of the right lower limb (left) and the X-ray film when followed-up 5 months after operation, showing good healing of the wound and solid bone union between the tibia and the femur. (Adapted from ref. [5]; with permission)

femur and the tibia occurred 5 months postoperatively (Fig. 20.4, right). The "knee" has a motion range of 50 degrees with normal motion and sensation of the toes (Fig. 20.5). With a specially made and well-fit prosthesis, the girl could walk independently with an acceptable gait (Fig. 20.6).

20.5 Clinical Implication

The technique and concept of rotationplasy were first introduced by Borggreve in 1927 and were then explained in the surgical treatment of malignant tumors of lower extremities by many successors [3]. Exactly, the primary goal in the

Fig. 20.5 Range of motion of the new "knee" in flexion (left) and extension (right). (Adapted from ref. [5]; with permission)

Fig. 20.6 The repaired right lower limb can bear weight and control a specially made prosthesis in standing and walking. (Adapted from ref. [5]; with permission)

reconstruction of a lower limb is to achieve an optimal functional outcome for each patient and a good endurance in walking activities, by creating a stable weight-bearing lower extremity, is the other. Therefore, as it is said in the literature, a rotationplasty can be the best long-term functional option in patients with a postaxial deficiency with a functional ankle and foot and a femur that is too short for lengthening [4]. However, there have not been any reports on emergency rotationplasy yet. The girl in this case sustained irreparable destruction of her right lower limb but had preserved the relatively intact portion and some function following debridement and emergency rotationplasty. Then, she had undergone periods of rehabilitation and got a specially designed prosthesis that fits well; as a result, she was able to bear weight and walk with an acceptable gait. In this case, the posterior tibial nerve survived the severe injury, and the skin of the sole regained nearly normal sensation right after the operation. This sense of feeling played an important role in the proper fitting of the prosthesis and the recovery of the function. When walking and standing on the prosthesis, the body weight was transformed to the prosthesis through the rotated foot and ankle, with the sole being the dominant weight-bearing surface. Although the sensory nerve related to the dorsum of the foot was not repaired in the rotationplasty, to our surprise, the patient declared that she had had a somewhat crude sensation on the skin of the dorsum of the foot, when followed up 8 months after the operation. The girl got used to her new knee and enjoyed her daily life.

In a word, an emergency rotationplasty of an ankle to the knee can be an optional procedure to repair the segmentally destructed lower limb in a child as long as some certain technical know-how has been correctly carried out [5]. The repair and reconstruction should be expected to have a good result and benefit the patient for his/her daily life and labor.

References

1. Knahr K, Kristen H, Ritschl P, et al. Prosthetic management and functional evaluation of patients with resection of the distal femur and rotationplasty. Orthopedics. 1987;10:1241–8.
2. Gottsauner-Wolf F, Kotz R, Knahr K, et al. Rotationplasty for limb salvage in the treatment of malignant tumors at the knee: a follow-up of seventy patients. J Bone Joint Surg Am. 1991;73:1365–75.
3. Winkelmann WW. Rotationplasty. Orthop Clin North Am. 1996;27:503–23.
4. Sakkers R, van Wijk I. Amputation and rotationplasty in children with limb deficiencies: current concepts. J Child Orthop. 2016;10(6):619–26.
5. Zeng BF, Chen YF, Zhang ZR, Wang SH. Emergency rotationplasty of ankle to knee. Plast Reconstr Surg. 1998;101(6):1608–10. https://doi.org/10.1097/00006534-199805000-00027.

21 Exploration of the Superior Retinacular Arterial System of the Femoral Head after Femoral Neck Fractures in Young Adults

Dewei Zhao

21.1 Background

There are no well-accepted criteria for the treatment of femoral neck fractures in young adults. Currently, the main goal of the treatment is to preserve the native hip joint. Femoral neck fractures in young adults are often caused by severe injuries and manifested as displaced fractures (Garden stage III or IV fractures), in which certain injuries of the posterior–superior retinaculum in the femoral head and neck can easily cause distortion, traction, compression, and even rupture of the superior or/and inferior retinacular arteries (SRA and IRA), which are the main arteries that supply the femoral head. Consequently, secondary avascular necrosis of the femoral head may occur. Preoperative and intraoperative evaluation of the blood supply to the femoral head is of great significance for the treatment selection and prognosis. Preoperatively, super-selective digital subtraction angiography (DSA) can be used to objectively determine the blood supply of the retinacular arteries (SRA and IRA) to the femoral head. However, DSA cannot clearly distinguish the specific causes of blood supply interruption (such as distortion, traction, compression, and rupture). It is necessary to consider whether to explore the retinacular vessels during surgery according to the specific fracture type to monitor and restore the blood supply under direct vision.

In recent years, we have investigated the damage condition of the superior retinaculum during open reduction of displaced femoral neck fractures to determine the accuracy of the preoperative Garden classification. During surgery, the posterior/posterolateral approach was used, and osteotomy of the greater trochanter was performed to expose the posterior–superior region of the femoral head and neck and to explore the posterior–superior retinaculum and SRA. In the case of preoperative DSA showing disruption of the blood supply but intraoperative exploration confirming an intact superior retinaculum, the cause of the compromised retinacular artery is mainly the distortion, traction, or compression caused by fracture displacement. In rare cases, the SRA stump can be visualized at the side of the femoral head; thus, microsurgical techniques can be used to perform anastomosis of the SRA to restore the blood supply to the femoral head.

21.2 Anatomy and Blood Supply of the Femoral Head

Previous anatomical studies have suggested that the endogenous blood supply of the femoral head originates from different sources and that the medial femoral circumflex artery (MFCA) contributes the primary arterial supply to the femoral head [1]; the SRA and IRA branch off and enter the hip capsule to nourish the femoral head [2, 3] (Fig. 21.1). Compared to other nourishing blood vessels, both the SRA and the IRA have a larger caliber [4, 5] (on average, 0.84 mm and 0.41 mm, respectively, in adults [4]). Furthermore, many studies have reported that the vessels of the superior system, as the primary blood supply to the femoral head, are larger and more significant than those of the inferior retinacular system [4, 6, 7]. Therefore, the superior system has a stronger compensatory ability. Thus, reanastomosis of the disrupted SRA may contribute to a dependable blood supply for the femoral head, which is the theoretical basis of this surgery.

The SRA originates from the ascending branch of the MFCA and is located in the posterior–superior region of the femoral head and neck (Fig. 21.2), approximately underneath the piriformis tendon. The artery is covered with a tough superior retinaculum and the synovium (Fig. 21.3). Since this region overlaps with the greater trochanter and the external rotator tendon, it is often necessary to perform osteotomy of the greater trochanter and to cut the piriformis tendon during the surgery to adequately expose and explore the superior retinaculum.

D. Zhao (✉)
Department of Orthopedics, Affiliated Zhongshan Hospital of Dalian University, Dalian, Liaoning, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_21

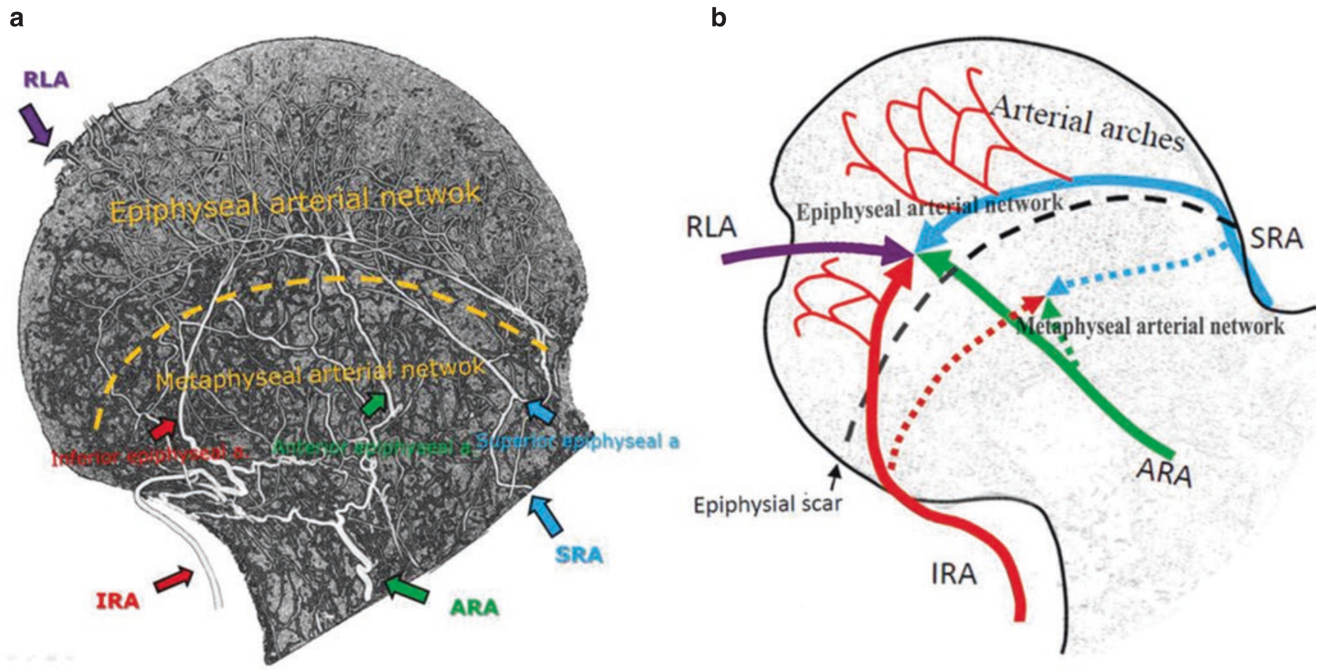


Fig. 21.1 The illustrations show the three groups of retinacular arterial systems (superior, inferior, and anterior) and the round ligament arterial systems that formed the epiphyseal and metaphyseal arterial network after entering the femoral head (reproduced with permission [8]). (**a**) A graphic micro-CT image of the femoral head after arteriographic injection and (**b**) a schematic diagram is shown. The superior retinacular arteries give off superior epiphyseal (small light blue arrow, **a**; solid light blue line, **b**) and superior metaphyseal (broken light blue line, **b**) arteries that begin at the epiphyseal scar level (broken yellow line, **a**; broken black line, **b**). The inferior retinacular arteries give off inferior epiphyseal (red arrow, **a**; solid red line, **b**) and inferior metaphyseal (broken red line, **b**) arteries that begin below the epiphyseal scar. The femoral epiphyseal arterial network is formed by epiphyseal branches of the superior and inferior retinacular arteries and anterior retinacular arteries (green arrow, **a**; solid green line, **b**) above the epiphyseal scar along with the branches of the round ligament arteries (purple arrow, **a**; solid purple line, **b**). The metaphyseal arterial network is formed by metaphyseal branches of the superior, inferior, and anterior arteries (broken light blue line, red and green lines, **b**) in the metaphysis (below the epiphyseal scar). *RLA* round ligament artery, *SRA* superior retinacular artery, *IRA* inferior retinacular artery, *ARA* anterior retinacular artery

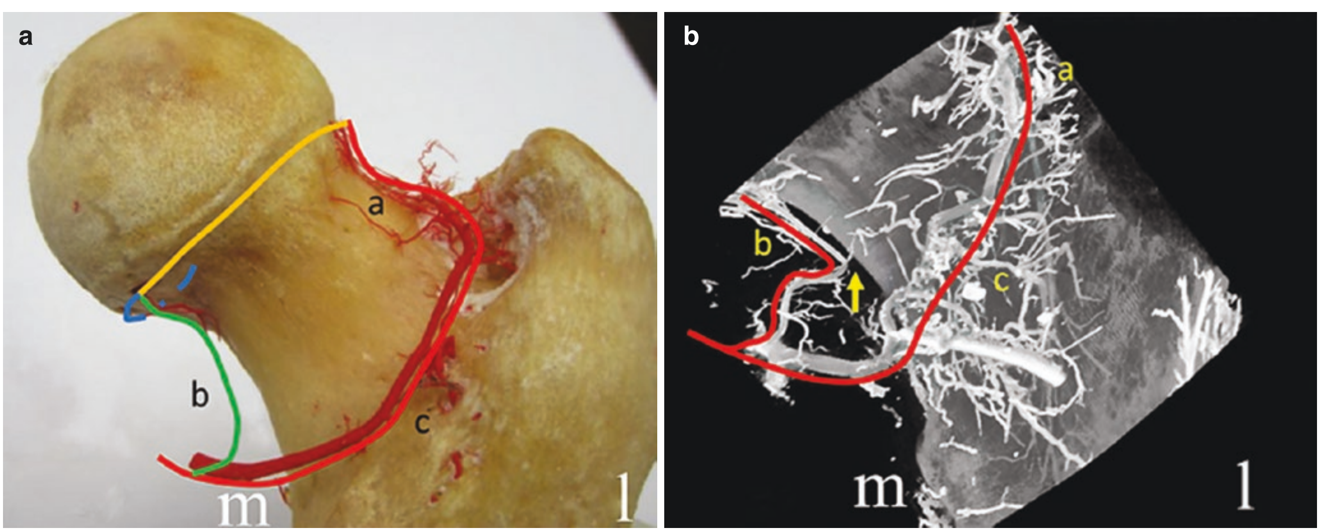


Fig. 21.2 The posterior–superior region of the femoral head and neck (**a**) and the “C-shaped ring” shown on the angiography (**b**) (reproduced with permission [8])

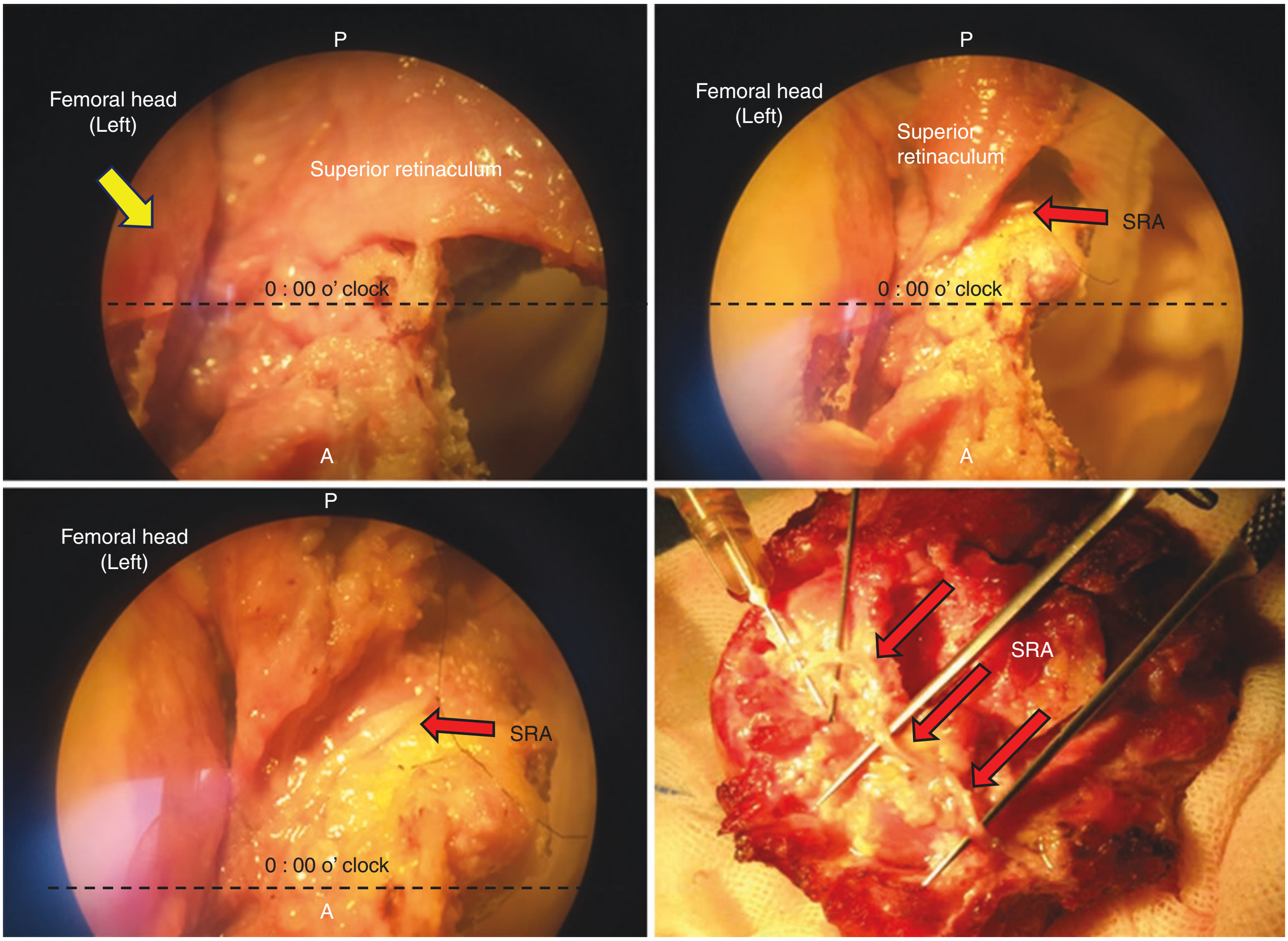


Fig. 21.3 The location and microanatomy of SRA under the microscope. The SRA is located in the posterior–superior region of the femoral head and neck and is covered with a tough superior retinaculum and the synovium

21.3 Surgical Procedure and Key Points

For young patients with displaced femoral neck fractures (Garden stage III or stage IV), in addition to preoperative X-ray radiographs, CT plain scans, and other examinations to determine the fracture displacement, we use super-selective DSA to observe the blood supply of the affected femoral head. DSA of the normal femoral head can clearly show the "C-shaped" structure containing the MFCA, SRA, and IRA (Fig. 21.2). Clinically, an incomplete "C-shaped" structure is very common due to a compromised SRA in patients with a displaced fracture. The absence of the SRA and IRA indicates a severely compromised blood supply to the femoral head. During an open reduction, the superior retinaculum and arteries should be exposed for further exploration.

We used a posterior or posterolateral approach. The 8-cm incision started from the posterior part of the greater trochanter along with the gluteus maximus. A posterolateral capsulotomy was performed from the gluteus maximus, deep fascia, and extensors to expose the hip capsule. The piriformis tendon can be used as a marker to determine the approximate position of the SRA. After the division of the piriformis tendon, a moderate osteotomy of the posterior greater trochanter was required to adequately expose the posterior–superior region of the femoral neck (Fig. 21.5c). The hip capsule was cut, and blood clots were removed to fully expose the synovial layer of the posterior–superior region of the femoral neck. At this point, the fractures and the intactness of the superior retinaculum could be examined. Attention should be paid to the location of the fracture line. Vascular exploration is not necessary for a fracture at the proximal end of the superior retinaculum.

After fracture reduction and internal fixation, the superior retinaculum and the synovial layer of the femoral neck were incised and dissected under a microscope. The superior retinacular vessels are located below the superior retinaculum and the femoral neck synovium, closer to the bone surface. Due to the toughness of the superior retinaculum, a surgical scalpel can be used to carefully incise the retinaculum, and then dissection can be performed with micro-scissors. After exposure of the superior retinacular vessel, a vascular patency test can be performed to determine the degree of vascular injury and the next step of treatment.

21.4 Case Presentation

Case 1: A 22-year-old man presented with a 2 h history of pain of the right hip and restricted activity after falling from a height. A femoral neck fracture (Garden type III) was shown in X-ray radiographs of the right hip. The fracture line was below the femoral head (subcapital fracture), and obvious displacement, adduction deformity, and femoral head rotation were observed. A coronal CT scan confirmed the right femoral neck fracture with angular deformity (Fig. 21.4a, b). The patient was treated with right lower extremity skin traction, resulting in the reduction of swelling and pain. Two days later, the patient underwent DSA investigation, which showed that the blood supply from the right MFCA to the SRA to the femoral head was interrupted (Fig. 21.4c). During the operation, the posterolateral approach to the hip joint was used to expose the posterior–superior region of the femoral neck and to fix the femoral neck with a cannulated screw and a Kirschner wire. Exploration confirmed the rupture of the superior retinaculum. After the retinaculum and synovium were incised, the two ends of the SRA were identified under the synovial layer located in the posterior upper part of the femoral neck. The pulsation of the proximal vessel was good. An artery thrombosis was removed, and the artery was sutured with a surgical suture needle (11/0) (Fig. 21.4g). The postoperative course was uneventful, and no complications occurred. The patient was discharged 2 weeks after the surgery. An X-ray displayed the precise anatomic alignment. Weight-bearing on the repaired limb was avoided for 6 weeks. Passive flexion-extension and weight-bearing exercises of the hip joint were initiated at 2 and 8 weeks after surgery, respectively, under the guidance of a rehabilitation physician. The patient was persuaded to undergo a desensitized-DSA investigation 3 months after surgery, and the images showed that the blood supply via the SRA to the femoral head was successfully reconstructed (Fig. 21.4h).

Case 2: A 15-year-old male was diagnosed with a right femoral neck fracture (Garden stage III). DSA showed that the femoral retinacular vessels were all involved, and the "C-shaped" structure was destroyed. After intraoperative reduction, exploration showed that the retinaculum of the femoral head was partially damaged but remained intact. After incising the retinaculum and synovium, the intact retinacular artery was visualized. A blood vessel patency test confirmed vascular patency, indicating that the compromised artery was caused by fracture displacement and hematoma (Fig. 21.5).

Case 3: A 32-year-old male was diagnosed with a left femoral neck compression fracture. DSA showed that the femoral retinacular vessels were all involved, and the "C-shaped" structure was destroyed. During the open reduction, the posterior–superior region of the femoral head and neck was exposed to visualize the fracture line, which was located at the proximal side of the insertion of the retinaculum (i.e., close to the femoral head). The SRA has lost its function of supplying blood to the femoral head and cannot be repaired in this type of fracture (Fig. 21.6). To improve the blood supply to the femoral head, a vascularized bone flap might be used to enhance the blood supply.

21.5 Precautions

1. The diameter of the superior retinacular vessel of the femoral head is similar to that of the middle and proximal segments of the finger vessel. The vessel wall is thick and tough. Microsurgical anastomosis is reliable [10]. The superior retinacular artery is located underneath the synovial membrane, obliquely travels along the posterior–superior femoral neck, and enters the nutrient foramen at approximately a 9- to 0-o'clock position in the sagittal plane of the femoral head.
2. The target vessel we explore is the superior retinacular vessel, which anatomically runs between the 11- and 0-o'clock position in the sagittal plane of the femoral head. Therefore, we employ a posterior approach to the hip joint and place the patient in a lateral position with an angle of 30–40°. This position provides a good operating angle to visualize the superior retinacular vessel under microscopic operation. Moreover, a short distance to the microscopic operation area can be obtained via the posterior approach, which is helpful to reduce the relative difficulty of the operation under a surgical microscope.

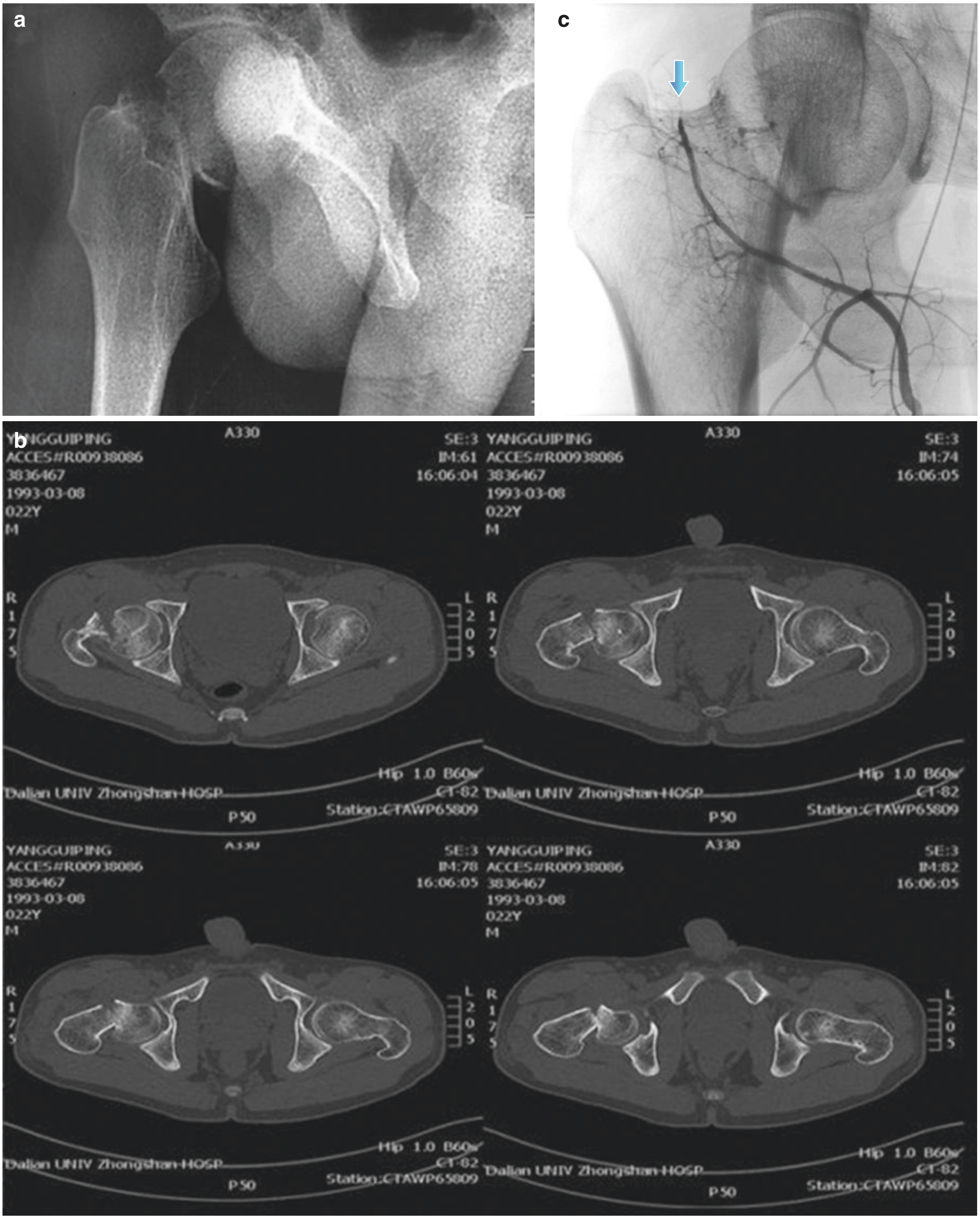


Fig. 21.4 Case 1: A 22-year-old man presented with a 2 h history of pain of the right hip and restricted activity after falling from a height (reproduce with permission [9]). (**a**) A femoral neck fracture (Garden type III) was shown in X-ray radiographs of the right hip. The fracture line was below the femoral head (subcapital fracture), and obvious displacement, adduction deformity, and femoral head rotation were observed. (**b**) A coronal CT scan confirmed the right femoral neck fracture with angular deformity. (**c**) The DSA imaging showed that the blood supply from the right MFCA to the SRA to the femoral head was interrupted. (**d**) The posterolateral approach to the hip joint was used to expose the posterior-superior region of the femoral neck. (**e**, **f**) During the exploration, the synovial layer on the femoral neck was dissected under the microscope. Fortunately, two ends of SRA were identified under the synovial layer which was located posterior upper part of the femoral neck. (**g**) Microscopic observation of the SRA during operation after vascular anastomosis. (**h**) Postoperative DSA showed that the blood supply via superior retinacular artery (SRA) to the femoral head was successfully reconstructed. (**i**) Postoperative X-ray displayed the precise anatomic alignment. (**j**) After 6 months, X-ray imaging showed that the fracture healed well

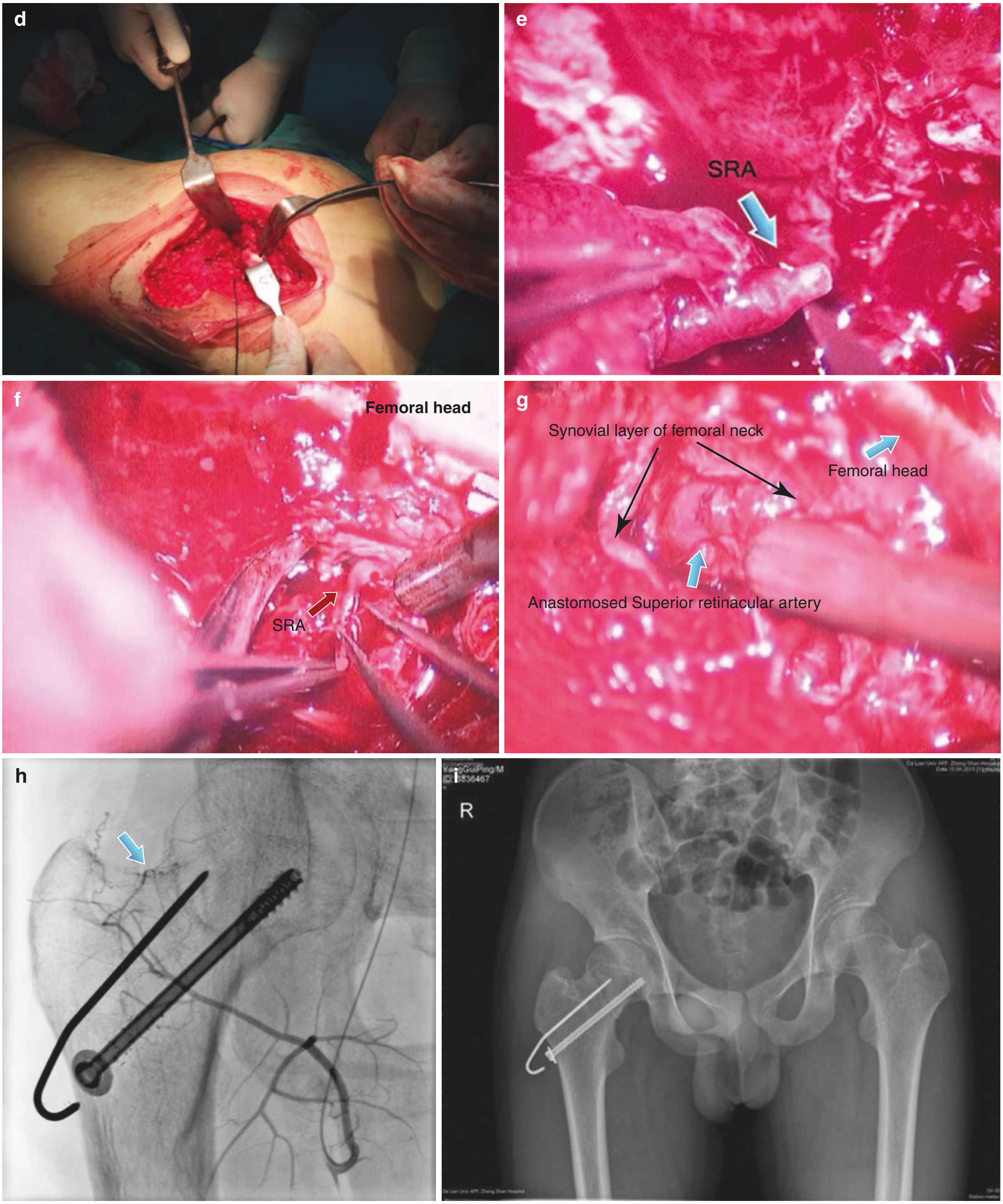


Fig. 21.4 (continued)

Fig. 21.4 (continued)

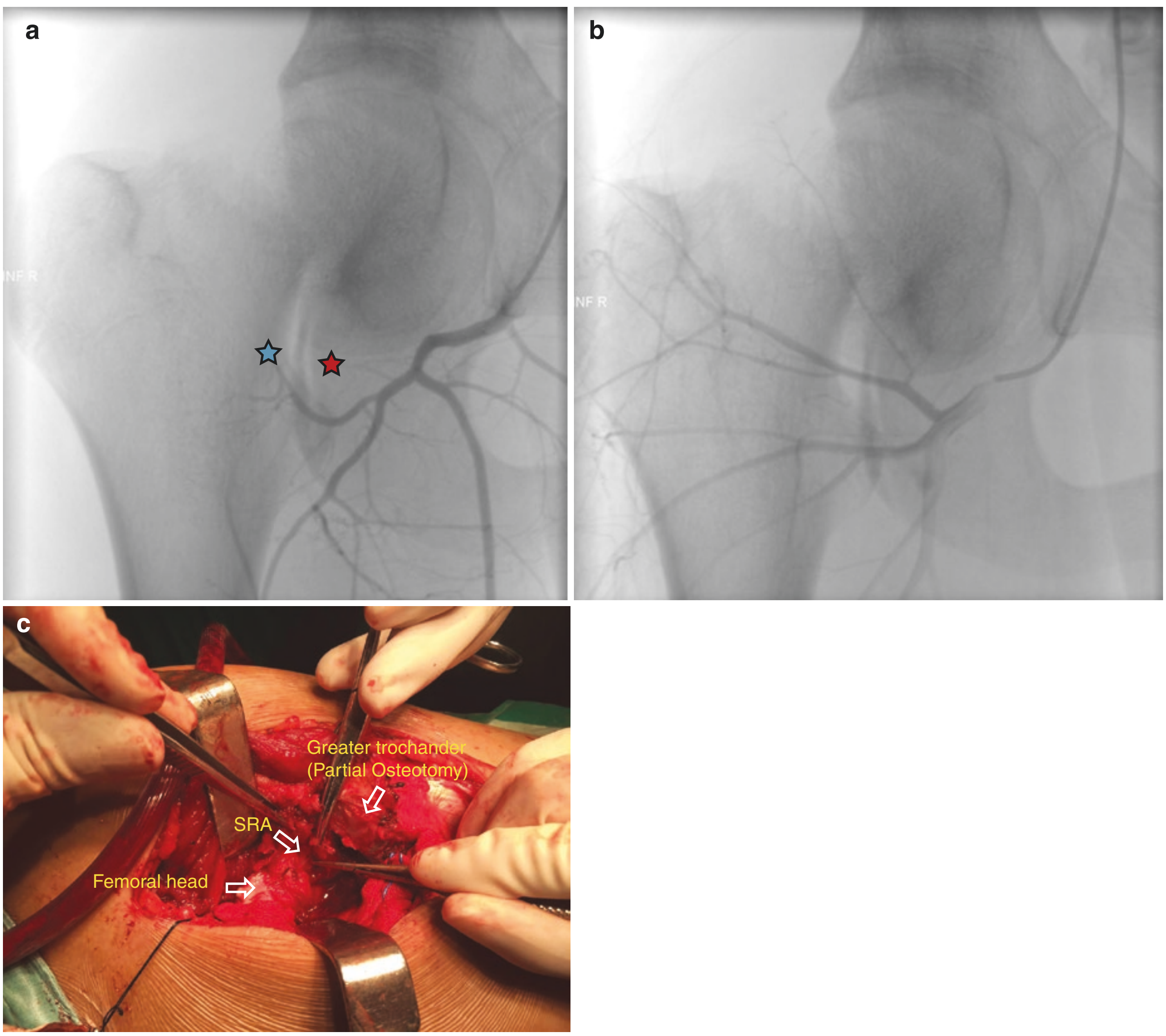


Fig. 21.5 Case 2: A 15-year-old male was diagnosed with a right femoral neck fracture (Garden stage III). (**a**, **b**) The preoperative DSA showed that the femoral retinacular vessels were all involved, and the "C-shaped" structure was destroyed. (**c**) The exploration showed that the retinaculum of the femoral head was partially damaged but remained intact. After incising the retinaculum and synovium, the intact retinacular artery was visualized. A blood vessel patency test confirmed vascular patency, indicating that the compromised artery was caused by fracture displacement and hematoma

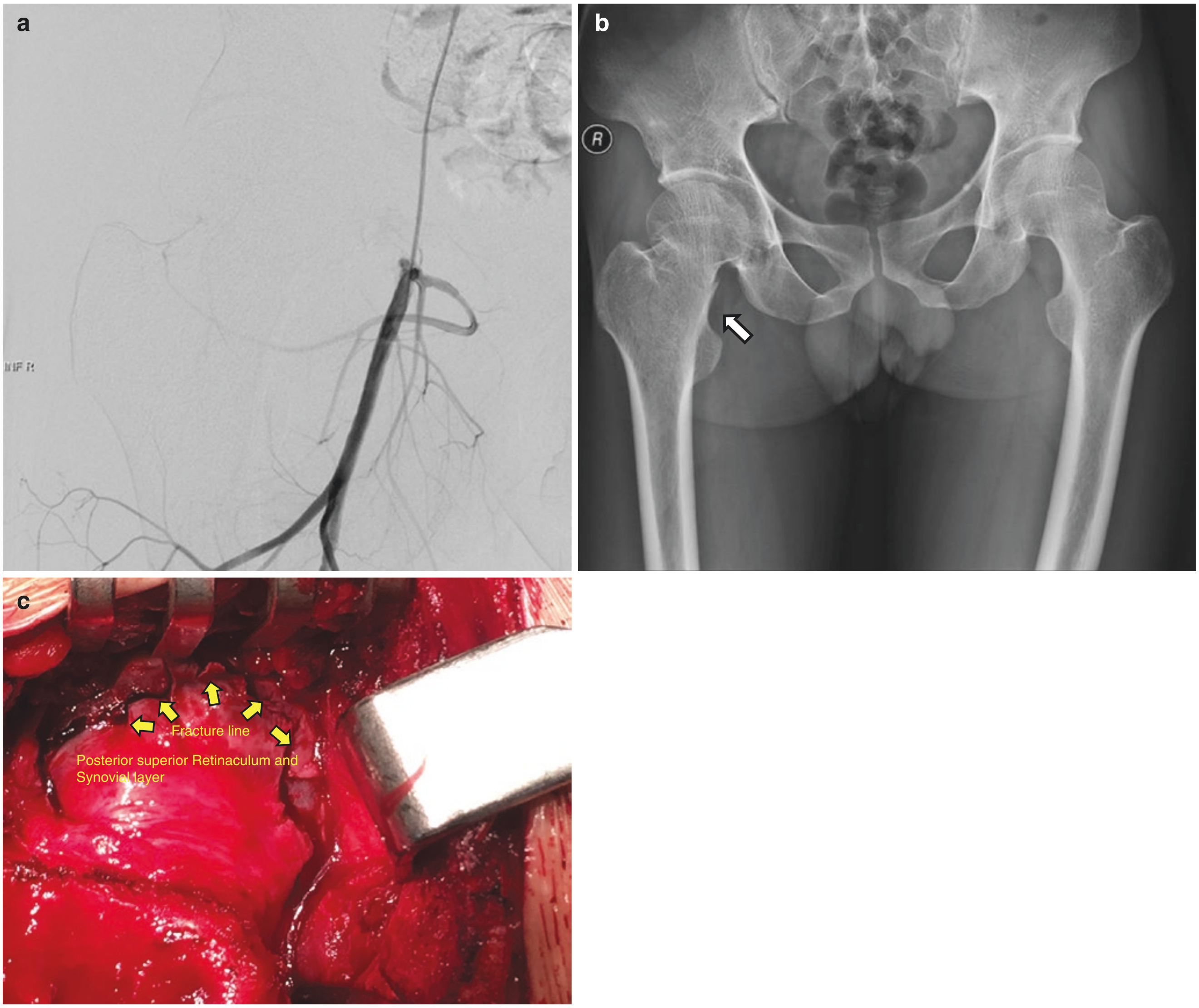


Fig. 21.6 Case 3: A 32-year-old male was diagnosed with a left femoral neck compression fracture. (**a**) Preoperative DSA showed that the femoral retinacular vessels were all involved, and the"C-shaped"structure was destroyed. (**b**) A subcapital compression femoral neck fracture was shown in X-ray radiographs of the right hip, and the degree of fracture displacement seems not very high. (**c**) During the open reduction, the posterior–superior region of the femoral head and neck was exposed to visualize the fracture line, which was located at the proximal side of the insertion of the retinaculum. It means that the SRA has lost its function of supplying blood to the femoral head

3. When using a posterior approach to the hip joint, the microscopic operation field appears deep. In an obese patient or a patient with a muscular hip, the operation could become more difficult, and greater surgical skills, an elongated microscopic instrument, and an extended incision are required. Because of the non-suitability for the use of tourniquet and the rich blood vessels in the hip, bleeding in the operative field could increase the difficulty of the operation.
4. A key point for repairing ruptured femoral vessels during surgery is whether an arterial stump is available on the side of the femoral head for anastomosis (In fact, this kind of case is extremely rare). The position of the retinaculum insertion and the fracture line on the side of the femoral head should be carefully examined at the beginning of surgery. In addition, preoperative DSA is very important in terms of assessing the blood supply of the affected femoral head, the degree of the blood vessel rupture, and the location of the ruptured artery.

References

1. Zlotorowicz M, Szczodry M, Czubak J, et al. Anatomy of the medial femoral circumflex artery with respect to the vascularity of the femoral head. J Bone Joint Surg Br. 2011;93(11):1471–4.
2. Gautier E, Ganz K, Krugel N, et al. Anatomy of the medial femoral circumflex artery and its surgical implications. J Bone Joint Surg Br. 2000;82(5):679–83.

3. Lazaro LE, Klinger CE, Sculco PK, Helfet DL, Lorich DG. The terminal branches of the medial femoral circumflex artery: the arterial supply of the femoral head. Bone Joint J. 2015;97-B(9):1204–13.
4. Tucker FR. Arterial supply to the femoral head and its clinical importance. J Bone Joint Surg (Br). 1949;31-B:82–93.
5. Ogden JA. Changing patterns of proximal femoral vascularity. J Bone Joint Surg[Am]. 1974;56-A:941–50.
6. Kalhor M, Beck M, Huff TW, Ganz R. Capsular and pericapsular contributions to acetabular and femoral head perfusion. J Bone Joint Surg Am. 2009;91-A:409–18.
7. Kalhor M, Horowitz K, Gharehdaghi J, Beck M, Ganz R. Anatomic variations in femoral head circulation. Hip Int. 2012;22:307–12.
8. Zhao D, Qiu X, Wang B, et al. Epiphyseal arterial network and inferior retinacular artery seem critical to femoral head perfusion in adults with femoral neck fractures. Clin Orthop Relat Res. 2017;475(8):2011–23.
9. Zhao D, Wang Z, Wang B, et al. Revascularization of the femoral head by anastomosis of superior retinacular vessels for the treatment of femoral neck fracture: a case report. Microsurgery. 2016;36:426–9.
10. Wang Z, Gu L, Cheng L. Open reduction and internal fixation and intraoperative exploration of the superior retinacular arterial system in young adults garden III femoral neck fracture: a 10 case report. Ann Plast Surg. 2020;84(5S Suppl 3):S222–4.

22 Replantation of Segmental Destructive Disconnect of the Child's Calf

Yonggen Zou, Xuchao Luo, and Changliang Ou

22.1 Case Presentation

A 7-year-old male child has been crushed by a train causing the disconnect of the right calf, hospitalized 4 h after the injury, and the child was comatose with severe hemorrhagic shock. The right calf was disconnected 6 cm below the tibial plateau, and the stump was severely crushed (Fig. 22.1). The distal end combined with the middle and upper segment of about 10 cm bone and skin muscle composite tissue defected. The area below the ankle joint was relatively intact, and there was no skin covering above the ankle joint.

22.2 Choice of Treatment

The child's right lower leg was broken, and a 10-cm composite was missing and accompanied by severe hemorrhagic shock. If replanting immediately to retain the original length, the surgical design would be more complicated. It was necessary to perform multiple operations in a short period, such as wound debridement, bone flap transplantation, internal fixation of the fracture, long-term vascular graft reconstruction, arteriovenous access, combined flap transplantation for repair of soft tissue defect of the lower leg, and skin graft closure of the donor site. And this will make the warm ischemia time of the limbs significantly exceed the replanting time limit, which will significantly increase the risk of failure in the first stage of replantation surgery. From the perspective of a child's life safety, replantation that preserved the length of the limb was far more harmful. Therefore, the surgeon intended to perform debridement and replantation first and then used the technique of Ilizarov to perform long-term limb extension to reconstruct the length, appearance, and function of the calf.

Y. Zou (✉) · X. Luo · C. Ou
Department of Orthpaedic Surgery, Traditional Chinese Medicine Hospital Affiliated to Southwest Medical University, Luzhou, Sichuan, China

Fig. 22.1 Patient at admission

Comprehensive consideration, we chose to manage patients in several phases.

First, emergency debridement and short replantation were performed. The skeletal bones were replanted by using a trans-knee external fixation bracket and Kirschner wires. At the same time, the injured vascular nerves were repaired, and the tendon was embedded in the residual muscle abdomen according to the anatomical landmark. Finally, the defective skin is covered with closed negative pressure drainage (VSD). After replanting 2 weeks after surgery, the skin graft of the healthy thigh was covered to cover the original wound.

Forty days after the emergency operation, the replanted limb wound was completely closed, and the patient assisted in functional exercise (Fig. 22.2). We used the Ilizarov external fixator to perform the tibia osteotomy and the limb extension (Fig. 22.3).

After half a year, the length of the limbs recovered to the same extent, the epiphysis grew continuously, but the epiphysis grew unbalanced, the tibia was angled to the posterior side, and the osteotomy line was corrected again.

In follow-up 1.5 years after the operation, the X-ray showed that the tibia gradually prolonged, the fracture

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_22

Fig. 22.2 After the first stage of short-thin replantation surgery, the replanted limbs of the child were completely closed, and the osteophytes of the fracture end were well-growed

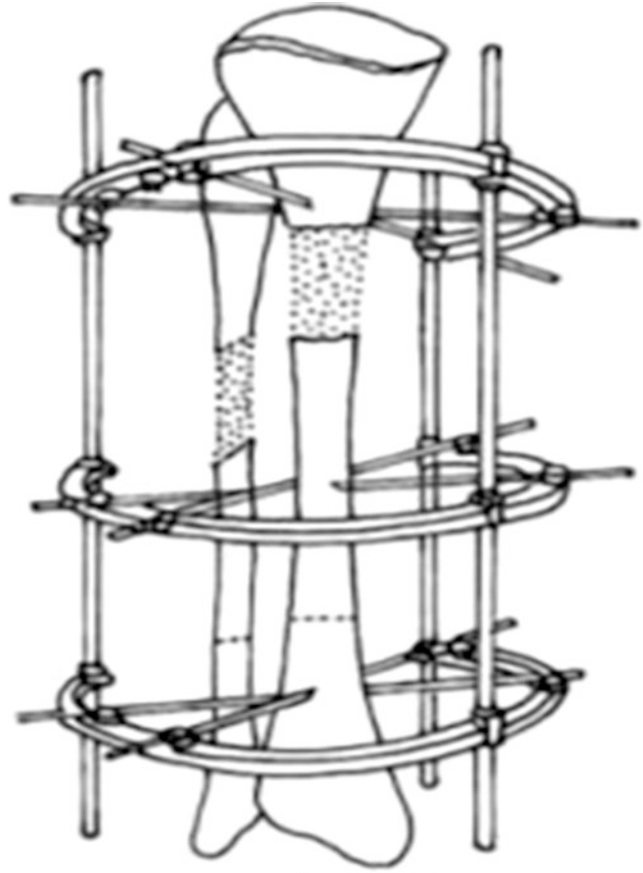


Fig. 22.3 Schematic diagram of tibia osteotomy with Ilizarov bone extension technique

healed, and the knee joint and ankle joint were in a good position (Fig. 22.4). The soles of the feet, the toes, and the back of the feet recovered, and two points of the resolution were 11 mm. The joint activities of the knee joint, the ankle joint, and the toes were basically normal (Fig. 22.5).

22.3 Operative Technique

First-stage surgery: After admission, debridement was performed under general anesthesia with tracheal intubation. We used heparin Ringer's solution to wash the anterior and posterior arteries and veins and completely removed the thrombus attached to the inner wall of the blood vessel by using a vascular thrombectomy device. All inactivated tissue is removed and replanted in a completely normal tissue plane. Intraoperative application of a simple and fast single-arm external fixation bracket and Kirschner wire combined fixation of the tibia. We anastomosed anterior tibial artery and posterior arteries and accompanying veins, saphenous veins, anastomosing all arteries and veins that can be anastomosed, repairing the common peroneal nerve and phrenic nerve. And the tendon was embedded in the residual muscle abdomen according to the anatomical landmark. Finally, the defective skin is covered with VSD. The entire surgical procedure needed to be quick and easy. After replantation, the blood supply to the affected limb was good, and there was no vasospasm or distal skin blisters from beginning to end. After the operation, we replaced the patient's VSD on time and applied the epidermal growth factor and conventional douche (papaverine + chymotrypsin + glucose + hyperbaric oxygen) to alternately wash the wound for 3 weeks, and the granulation grew well. At this point, we took the left thigh free skin graft to cover the wound. The external fixation bracket was removed from the knee, and the knee joint, ankle joint, and interphalangeal joint passive movement were started after skin grafting.

Second stage surgery: Forty days after an emergency operation, the epiphyseal growth of the tibial was good. Considering the growth and development factors of the child, the Ilizarov external fixator was used to perform the tibia osteotomy, and the limb extension was performed for 3 months. And double lower limb recovered equal length. After half a year, the child's osteophytes in the extended limbs grew well. His early application of increased shoes assisted walking because the growth of

Fig. 22.4 Radiographs of the 3 months after bone extension surgery using the Ilizarov bone extension technique

Fig. 22.5 One and a half years after surgery, the knee and ankle joint activities were basically normal

limbs increased and the shoes gradually abandoned, and finally walked in cotton shoes. The foot gradually recovered the feeling, and it produced sweat and pain. Due to traumatic stimulation, the growth of the humeral epiphysis is active and unbalanced, resulting in a change in the force line of the lower part of the tibia, bending deformity, and unsightly appearance. The tibia osteotomy was performed again after the operation for half a year.

22.4 Clinical Implications

1. Children's calf segmental destruction is often accompanied by severe hemorrhagic shock, and it is necessary to actively correct anemia in the early stage. In the case of relatively stable vital signs, the surgeon should try to replant the limbs as much as possible [1–3]. And for those who have serious damage to the broken end, they can be replanted in the first phase and extended in the long term to reconstruct the length, appearance, and function [4, 5].
2. It should be thorough in early debridement. The surgeon must thoroughly remove contaminated and degraded skin, subcutaneous tissue, muscles, and bones without periosteum to avoid infection, which delays wound healing and affects subsequent surgery [6–9].
3. Combined application of advanced medical technologies such as microsurgery, closed negative pressure drainage (VSD), single-arm external fixation, Ilizanov external fixation, recombinant epidermal growth factor, and experience irrigation fluids make patients the most reasonable and efficient treatment.
4. When the limb is replanted, the surgeon should try to repair and match all the nerves and blood vessels that can be found, and embed the tendon in the residual muscle abdomen according to the anatomical landmark to preserve the anatomical basis of the distal limb movement [3, 10]. All operations should be based on cosmetic surgery methods to achieve perfection. The surgeon tries his best to perfect the skin, reduce the scar formation, choose the hidden donor area, and pay attention to postoperative rehabilitation training and psychological counseling for children throughout the treatment cycle.

References

1. Tomlinson JE, Hassan MSU, Kay SP. Temporary ectopic implantation of digits prior to reconstruction of a hand without metacarpals. J Plast Reconstr Aesthet Surg. 2007;60(7):856–60.
2. Godina M, Bajec J, Baraga A. Salvage of the mutilated upper extremity with temporary ectopic implantation of the undamaged part[J]. Plast Reconstr Surg. 1986;78(3):295.
3. Graf P, Groner R, Horl W, et al. Temporary ectopic implantation for salvage of amputated digits. Br J Plast Surg. 1997;50(2):144.
4. Yousif JN, Dzwierzynski WW, Anderson RC, et al. Complications and salvage of an ectopically replanted thumb. Plast Reconstr Surg. 1996;97(3):637–40.
5. Wang JN, Tong ZH, Zhang TH, et al. Salvage of amputated upper extremities with temporary ectopic implantation followed by replantation at a second stage. J Reconstr Microsurg. 2006;22(01):015–20.
6. Matloub HS, Yousif NJ, Sanger JR. Temporary ectopic implantation of an amputated penis. Plast Reconstr Surg. 1994;93(2):408–12.
7. Ramdas S, Thomas A, Kumar SA. Temporary ectopic testicular replantation, refabrication and orthotopic transfer. J Plast Reconstr Aesthet Surg. 2007;60(7):700–3.
8. Wang JN, Wang SY, et al. Temporary ectopic implantation for salvage of amputated lower extremities: case reports. Microsurgery. 2010;25(5):385–9.
9. Kayikçioğlu A, Ağaoğlu G, Nasir S, et al. Crossover replantation and fillet flap coverage of the stump after ectopic implantation: a case of bilateral leg amputation. Plast Reconstr Surg. 2000;106(4):868–73.
10. Chernofsky MA, Sauer PF. Temporary ectopic implantation. J Hand Surg. 1991;15(6):910–4.

Extension of the Lower Limbs for Extreme Flexion of Knee Joint Induced by Dorsal Scar Adhesion After Burned for 13 Years in a Child

23

Jingliang Zhang and Mingfei He

23.1 Case Representation

The patient is a 17-year-old man. After burned by a roast basin at the age of 4 years, the patient's right lower limb developed flexion and limb-adhesion deformities due to the absence of medical intervention, and the patient could not stand upright legs and squatted for 13 years. Later, he was hospitalized in our hospital. Specific examination: The entire right thigh and the back of the leg adhered together by a webbed scar. The right knee joint was in flexion position and could not be straightened (Fig. 23.1), and the active and passive activities range was: 150° (flexion)–140° (extension)–0. The right lower limb muscle had atrophy, and the muscle strength was level IV. The right ankle joint had varus deformity, the blood supply at the terminals of the toes was good, sensation was normal, and toe muscle strength was level IV. The right thigh was approximately 37.5 cm long, the calf was approximately 36 cm long, the left thigh was approximately 40 cm long, and the left leg was approximately 38 cm long. The affected side was approximately 4.5 cm shorter than that of the unaffected side. X-ray of knee joint revealed that the right knee joint had flexion deformity, could not extend, the right knee joint was normal, the position relationship was basically normal, the bone structures of the knee joint were intact and continuous, and the diaphysis joints were small. No other abnormalities were found.

Fig. 23.1 Pre-op

23.2 Choice of Treatment

This patient was very special and complex. The patient healed spontaneously without medical intervention after burns as an infant, causing scar adhesion between posterior thigh and calf and the flexion deformity of the knee joint, and the patient squatted for 13 years in development without medical treatment, and limb development was affected causing tissue contracture. Preoperative analysis was carried out, then scar was incised, deep tissues were free and released, and thus the almost closed thigh and calf were separated. According to the intraoperative conditions, the patient might have contractures of articular capsules, ligaments, tendons, blood vessels, and nerves in the popliteal fossa, which needed to be relaxed and prolonged. If nerve contracture

J. Zhang (✉) · M. He
Department of Hand-Microsurgery, Shunde Heping Surgery Hospital, Shunde, Guangdong Province, China
e-mail: jingliang.zhang@hmmedicalgroup.com

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_23

affected knee extension, first intention extension could not be completed; therefore, second-stage nerve extension was needed after the operation to achieve the purpose of straightening the knee joint. A large area of skin defect at the posterior side and exposure of tissues in the popliteal fossa needed flap transplantation. The selected plan was that with the lateral descending branch of circumflex femur as pedicle, the pedicled ipsilateral retrograde anterolateral femoral vessel flap was reversely turned over and covered the wound.

23.3 Operative Technique

Surgical procedures: Under spinal-epidural anesthesia, connecting scar between the right thigh and leg was incised, flexion side of the right knee joint was relaxed, and then the posterior popliteal vessels, nerves, and tendons of the knee joint were exposed. Contracture of semiterninous muscle, semimembranous muscle, and biceps muscle of thigh was observed, and the range of passive motion of the knee joint was 150° (flexion)–100° (extension)–0. The tendons of semiterninous muscle, semimembranous muscle, and biceps muscle of the thigh were cut off in a "Z" shape and then prolonged for future use (Fig. 23.2) The sciatic nerve, the common peroneal nerve, the tibial nerve, the popliteal artery, and the accompanying vein continued to be explored, and the surrounding contracture tissues were released and separated, and then the range of passive motion of the knee joint was 150° (flexion)–70° (extension)–0; and then an 11 cm × 10 cm skin defect could be seen in the popliteal fossa. The posterior tibial and common peroneal nerves were still exposed in an arch-stringed shape. A 15 cm × 14 cm anterolateral femoral retrograde flap of the right thigh with the distal descending branch of anterolateral femoral artery as pedicle was designed [1] (Fig. 23.3) (considering the need for prolongation in late stage, it was designed that 4 cm was reserved for

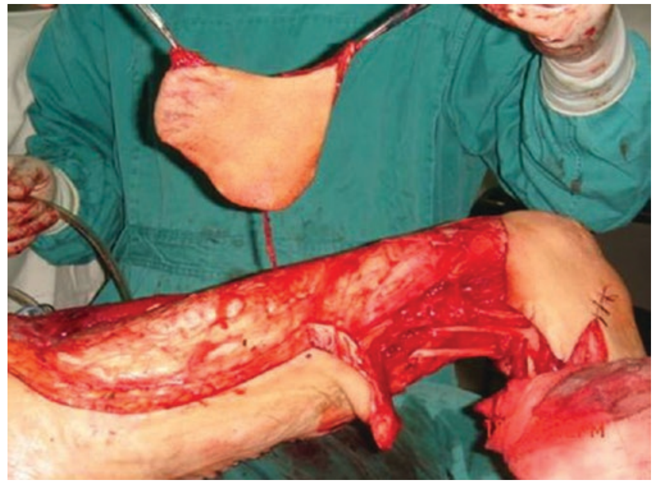


Fig. 23.3 A anterolateral femoral retrograde flap with the distal descending branch of anterolateral femoral artery as pedicle was designed

Fig. 23.4 The flap and free skin grafting were cover and repair skin and soft tissue defect in the right popliteal fossa and the donor area of the flap

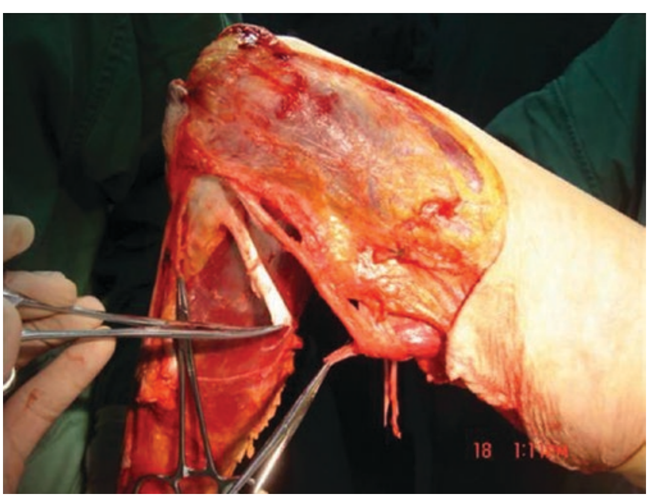


Fig. 23.2 Semimembranous and biceps tendons were cut off in a "z" shape

the length and width of the flap each), then the flap was reversely turned over to cover and repair skin and soft tissue defect in the right popliteal fossa. Free skin grafting was performed for the donor area of the right thigh and the posterior side of the calf, the skins needed were obtained from the left thigh (Fig. 23.4). After closing the wound, the single-arm external fixator was adjusted to the straight line and the shortest position, a screw for external fixator was inserted into the distal femur and proximal tibia each at suitable positions, the distal and proximal clamp blocks were placed on the screws to slightly fix the clamp blocks, but screws were not fixed (relative rotation was allowed between screws and clamp blocks). Under this condition, a triangle was formed between the elongation rod of the fixator fixed in the straight position with the thigh and calf, the bottom edge of the triangle was the extension rod. The bottom edge was slowly lengthened to straighten the knee joint (Fig. 23.5). After the

Fig. 23.5 A single-arm external fixator was installed to lengthen slowly to straighten the knee joint

Fig. 23.6 Six-year follow-up appearance of the leg

operation, the flaps and skin grafts survived smoothly; additionally, the external fixator was adjusted to continuously extend at the speed of 1 mm per day. After 60 days of extension traction, the range of the knee joint had been adjusted to 5° (flexion)–5° (extension)–0, and no abnormal sensation and movement of the distal limbs were found. Then, the external fixator was removed. First, the patient underwent stand-up walking training with double crutches. Next, a month of systematic rehabilitation and self-exercise was performed at home. To date, 6 years of follow-up showed that both limbs walked freely without limping, and the range of active and passive motion of the knee joint was 150° (flexion)–0–0° (extension). No atrophy in the appearance of the right lower limb was found, and no difference in circumference was found. Muscle strength reached level V. No varus deformity of the right ankle joint was found (Figs. 23.6 and 23.7).

23.4 Applied Anatomy

The posterior popliteal fossa of the knee has a complex structure and is an important channel for blood vessels and nerves of lower limbs to the distal end and an important hub for

Fig. 23.7 The 6-year follow-up function is excellent

muscles and tendons. The popliteal vessels, posterior tibial nerves, common peroneal nerves, and other important vessels and nerves are located in the deep layer, distributed close to the joint capsule, while the tendons of the semiterninous muscle, semimembranous muscle, and biceps muscle of the thighs are far from the posterior joint capsule.

23.5 Clinical Implications

The operation has relatively high difficulty, the workload is large. In addition to scar incision, posterior knee tissue release, tendon lengthening, and skin flap coverage in the first stage, nerve lengthening and knee extension were also performed in the second stage. Special attention needs to be paid to the following: (1) the condition should be assessed as full and accurate as possible before the operation, and a detailed operation plan and alternative plan should be formulated; (2) the surgeon should be familiar with detailed anatomy of the popliteal fossa to achieve the fullest and most possible relaxation and dissociation; (3) nerve prolongation is a difficulty, a slight inadvertence or carelessness can cause neuromuscular paralysis in the distal limbs; therefore, during the whole process of nerve lengthening the surgeon should be careful and focused, the sensory and motor changes of the limbs should be closely observed, to adjust the lengthening speed at any time, lengthening at a rate of 1 mm per day should be performed in at least four times, to ensure safety of the nerves. (4) Early engagement in life and work is very beneficial for rehabilitation.

Reference

1. Yu Y, Shao X, Bai Y. Microsurgery repairing for complex soft defect of leg[J]. Chin J Microsurg. 2009;32(06):498–9. https://doi.org/10.3760/cma.j.issn.1001-2036.2009.06.023.

24 Posterior Tibial Artery Flap in Series with Medial Plantar Artery Flap for Repair of Anterior Foot Degloving Injury

Xiang Wang, Wei Wang, and Zhenlin Wang

The anterior foot plays an important role in walking and loading, and the distribution of anterior foot force in walking is about 37%. When the heel is off the ground, almost all of the body's gravity falls on the anterior foot. The degloving injuries of the anterior foot are rare, often accompanied by tendon, bone exposure, and it is difficult to repair in clinically. In October 2010, the author used a free posterior tibial artery flap in series with the medial plantar flap over and out to repair the anterior foot degloving injury. Satisfactory shape and function have been obtained.

24.1 Case Introduction

The patient, male, 30 years old, was admitted to the emergency department on October 10, 2010, with a mechanical wound of the left foot. Physical examination: Left foot 2–5 toe, dorsal metatarsal and metatarsal base skin were degloved, the wound was irregular, skin soft tissue contusion was serious, and phalangeal tendon exposed with a defect. The blood circulation at the end of the 2–5 toe of the left foot disappeared and the sensation disappeared. The oil and sediment pollution of the wound was heavy, and iron scraps were attached to the wound. The X-ray film showed fracture of distal interphalangeal joint of left foot 2–5 toe. Considering the anterior foot injury, the area of skin defect was large, and, accompanied by tendon and bone exposure, necrosis boundary was not clear. Combine the patient's age with prognosis requirements, in order to effectively prevent infection, preserve the length of the anterior foot, reduce donor injury, and restore limb function to the maximum extent. Primary debridement and negative pressure sealing drainage were used to delay the over and out repair of posterior tibial artery flap in series with medial plantar flap. Postoperative follow-up for 21 months, the metatarsal base flap, and the dorsal foot flap reached S3-S3+ grade according to the British Medical Research Council sensory Assessment Standard; the flap texture was good, not bloated, and the appearance was beautiful. There were no ulcers and callosities in the metatarsal base, and the patient had no pain in walking. The donor site had no cicatricial contraction, and ankle joint movement was free (Fig. 24.1).

X. Wang (✉) · W. Wang · Z. Wang
Department of Hand Surgery, The People's Liberation Army No. 906 Hospital, Haidian, China

Fig. 24.1 Left foot dorsal skin defect

24.2 Choice of Treatment

The anterior foot degloving injury is a serious injury of the foot, which often forms a continuous skin defect from the back of the foot to the end of the foot and then to the base of the metatarsal. The defect area is large and located at the farthest end of the limb. At the same time, it is often accompanied by the exposure of the tendon and bone, so it is difficult to repair. At present, there are few clinical reports. The traditional treatment methods are mainly amputation or free skin grafting which seriously affect the appearance and function of the foot; so, it is often difficult for patients to accept. Qu Bingyi et al. reported that the length of the middle foot was preserved, and some function was restored by using the free thoraco-umbilical flap to repair the anterior foot deglov-

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_24

ing injury. But the appearance is bloated, and it needs to be reshaped again; in addition, the plantar was not wear-resistant and easily formed ulcers. Cai Jinfang et al. reported that the flap was repaired with a pedicle of posterior tibial artery flap. The flap has a good blood supply and can reconstruct the feeling, but major vessels in the calf need to be sacrificed, which has aggravated the trauma of the affected extremity. Using primary debridement and negative pressure sealing drainage to delay the posterior tibial artery flap in series with medial plantar flap for over and out repair of an anterior foot injury, it can effectively prevent tendon and bone exposed necrosis and reduce the risk of surgical failure caused by wound infection. The total area of the series flap is larger than that of the single large flap, the single limb feels better, the appearance of one pedicle series over and out repair is beautiful, and the risk is small. The two supplement each other, and the therapeutic effect is obviously improved.

24.3 Operative Technique

Debridement treatment Primary thorough debridement was performed in the emergency department, and VSD technique was used to deal with the wound. After 1 week, the dressing was removed; if the granulation of the wound is fresh, after bacterial culture isnegative, perform the flap repair; otherwise, replace the VSD dressing and continue to do negative pressure drainage until the wound granulation is fresh and bacterial culture is negative (Fig. 24.2).

Fig. 24.2 Debridement of VSD negative pressure drainage

Recipient site treatment After careful debridement, the middle and distal phalanx are liberated from the proximal interphalangeal joint, and the distal flexor digitorum longus tendon is sutured with the flexor tendon sheath of proximal phalanges. Separate the dorsal foot artery, great saphenous veins, and the first and fourth nervi digitales plantares communes for use (Fig. 24.3).

Resect the posterior tibial artery flap Take the line of the posterior edge of the medial tibial condyle and the posterior edge of the medial malleolus as the axis to design the posterior tibial artery flap, with the area of 11 cm × 8 cm ~ 14 cm × 10 cm. The great saphenous vein is separated to repair the posterior tibial artery. The distal end was ligated at the medial malleolus, and the branches that match the lateral plantar artery can be found in the proximal end of the popliteal fossa; the saphenous nerve is preserved in the flap.

Resect the medial plantar flap Take the line from the distal point of the foot arch to the medial malleolus as the axis to design the medial plantar flap; the width of the anterior metatarsal base of the uninjured side is taken as the length of the flap, with the area of 8 cm × 6 cm ~ 12 cm × 8 cm. Pay attention to preserve the medial saphenous nerve of the foot and the cutaneous nerve from the medial plantar nerve in the flap. Free from the medial plantar artery to the proximal end, ligate the rami profundus and lateral plantar artery (Fig. 24.4).

Open the ankle canal along the posterior tibial artery Pay attention to protect medial plantar nerve, lateral plantar nerve, and medial calcaneal nerve. Then, free thoroughly the posterior tibial artery, satellites from far and near, and resect the series posterior tibial artery flap and medial plantar flap. The separated great saphenous vein is transplanted to repair the proximal end of the posterior tibial artery and lateral plantar artery in the donor site (Fig. 24.5).

Skin flap transplantation After the pedicle is broken, the series skin is moved to the recipient site of the affected foot, the medial plantar flap is placed on the metatarsal base, and the distal end of the flap was placed on the lateral side. The vascular pedicle goes round from the toe web to the back of the foot, suture, and fix subcutaneously on both sides. Adjust the posterior tibial artery flap to cover the toe stump with its distal end and suture it with the medial plantar flap. Anastomose the posterior tibial artery and satellites with the dorsal foot artery and satellites or great saphenous veins in the proximal end.

Repair the nerve foot Medial plantar cutaneous nerve—the first common metatarsal base nerve; distal cutaneous branch of saphenous nerve—the fourth common metatarsal nerve; and saphenous nerve—intermedius or medial cutaneous nerve of dorsalis pedis (Fig. 24.6).

Fig. 24.3 (**a**) Left foot dorsal wound after 10 days. (**b**) Metatarsal base wound after 10 days

Fig. 24.4 Design of series flap

24.4 Clinical Implication

24.4.1 The Role of VSD in Open Fracture with Skin and Soft Tissue Defect Wound

In the early wound repair and treatment of open fracture combined with soft-tissue defect, for the soft-tissue defect wound that can not be closed immediately, the clinical application of the VSD technique first has the following advantages: (1) Sealing makes the power of negative pressure drainage sustainable, thoroughly removes the exudation of wound and lacunae, avoids the accumulation of local exudation, accelerates tissue apocatastasis, and it is beneficial to the control of wound infection [1–3]. (2) Prevent the formation of the residual abscess and dead space and make the wound in drainage area clean. (3) Improve the blood flow of wound, improve local microcirculation, and promote the growth of granulation tissue. (4) Avoid frequent dressing changes to reduce the pain of patients.

24.4.2 Advantages and Disadvantages of the Flap

Advantages: (1) The medial plantar flap has well-known sensory nerves at the distal and proximal end, which can guarantee good eneurosis in the anterior foot load area. (2) The thickness of the flap is moderate and the texture is similar to that of the original metatarsal base skin, the appearance is beautiful after repair. (3) The medial plantar flap is removed

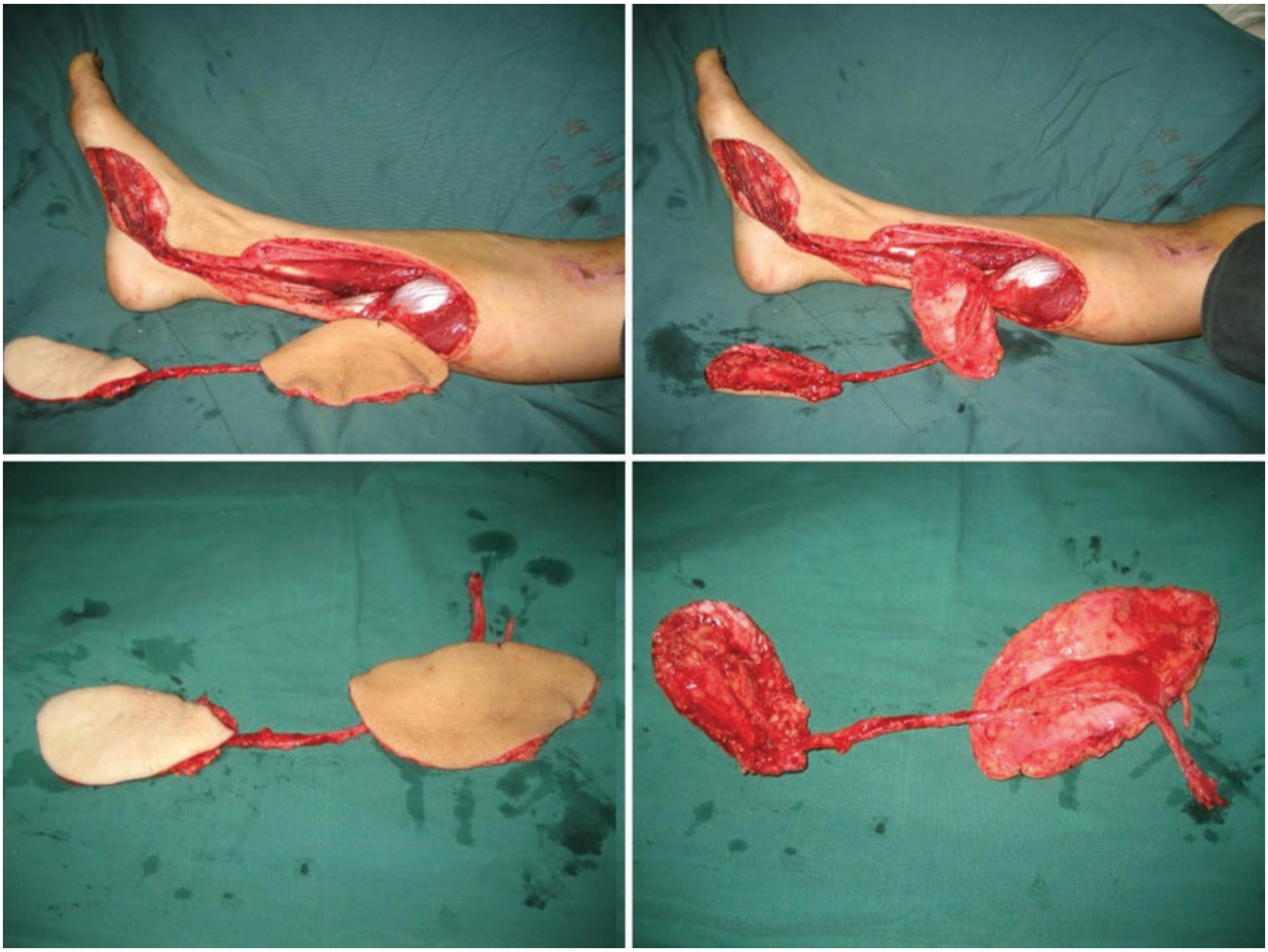


Fig. 24.5 Flap resection

Fig. 24.6 (**a**) Appearance of the metatarsal base after 3 months of operation. (**b**) Appearance of dorsal foot and donor site after 3 months of operation

from the deep plantar aponeurosis, carrying the cutaneous ligaments, friction-resistant, and sliding small, which is beneficial to the foot walk and load. The donor site is concealed, which is non-load position and has little damage to the foot. (4) After using the posterior tibial artery and medial plantar artery to connect the two flaps together, only one set of blood supply is needed to meet the needs of the two flaps. The risk was low, the survival rate is high, and the operation time is shortened. (5) The blood vessel is constant, the external diameter is thicker, and the success rate of anastomosis is high. (6) The flap of posterior tibial artery is thin, and the texture is the closest to the skin of the dorsum of the foot; after repairing the dorsal foot wounds, the appearance is beautiful, it does not need the later plastic surgery, and the sensory recovery is reliable. (7) Using great saphenous vein transplant to repair the posterior tibial artery and lateral plantar artery, it has no significant effect on the blood supply of the donor site [4, 5].

24.4.3 Disadvantages

The operation technique of this flap is complicated, it has high technical requirements for vascular anastomosis, and some microsurgical techniques are needed. The area of the flap donor is limited; what's more, it needs skin grafting, which affects the beauty.

24.4.4 Matters Need Attention

(1) Treat the wound with VSD, seal the wound, and keep the drain unobstructed. Wash the drain repeatedly with normal saline every day. Often observe the negative pressure sealing drainage system. If the PVA under the hyaline membranes is restored to fluffy from the concave shape, it indicates that there is the submembrane effusion and the negative pressure is invalid. We need to find out the cause in time, and replace it and restore the negative-pressure state. The possibility of wound infection should be taken into account when the local odor of the affected extremity was found, and the bacterial culture and drug sensitivity test should be done by sending drainage fluid in time. If the proximal skin of the affected extremity is red and swollen obviously, the VSD device should be removed as soon as possible, open the wound and drain.

(2) The design of medial plantar flap must be located in the instep area behind the first metatarsal bone weight-bearing area so as not to affect the weight-bearing function of the foot after removing the flap [6].

(3) The medial plantar nerve is the main branch of the tibial nerve and the main nerve of plantar sensation, the trunk should be left in place to protect the anterior foot sensation during the operation [7].

References

1. Jinfang C, Zihai D, Zhongwei C. Micropodal surgery. Jinan: Shandong Science and Technology Press; 2002. p. 275–81.
2. Bingcheng Q, Zhanming Y, Baozai D, et al. Free thoraco-umbilical flaps to repair the anterior foot degloving injury. Inn Mong Med J. 2009;41(2):151–2.
3. Jinfang C, Baoguo S, Pan J, et al. Repair and reconstruction of anterior foot injury defects. Chin J Microsurg. 1993/16;2:83–4.
4. Jinghui L, Xu Z, Haibin C, et al. Pedicled flap combined with negative pressure sealing drainage to repair soft tissue defects of extremities. Chin J Microsurg. 2011;34(4):418–9.
5. Fengbo WY, Zhi Z, et al. Negative pressure sealing drainage combined with free flaps to repair large-area soft tissue defects of extremities. Chin J Microsurg. 2011;34(4):496–8.
6. Witkowski W, Jawien A, Witkiewicz W, et al. Initial multi-Centre observations upon the effect of a new topical negative pressure device upon patient and clinician experience and the treatment of wounds. Int Wound J. 2009;62(6):167–74.
7. Thompson G. An overview of negative pressure wound therapy (NPWT). Br J Community Nurs. 2008;13:S23–30.

25 Adipofascial Turnover Flap for Dorsal Foot Coverage and Dead Space Filling

Shimin Chang

25.1 Case Presentation

A 28-year-old man suffered a crush injury of his left foot in a boat in the Pacific Ocean during his fishing work. The wound was bandaged, and the patient came back to China in 2 weeks. The dorsal skin of the foot was almost all necrotized. The dorsal wound was penetrated to the plantar, with a dead space through the crashed calcaneus (Fig. 25.1). There were multiple fractures of the foot and ankle, including medial and lateral malleolus, calcaneus, Lisfranc, and the fifth metatarsal neck (Fig. 25.2).

25.2 Choice of Treatment

The patient needs soft tissue coverage and skeletal reduction and fixation to restore walking ability.

In complicated open fractures with large integument defect, soft tissue coverage is more important than fracture fixation and should be performed prior to or concomitant to the deep bone reconstruction.

In this case, the dorsal foot needs a thin and pliable soft-tissue coverage, and the penetrating dead space needs a well-vascularized viable tissue to fill and eradicate its empty to prevent infection. There are several options in clinical practice, such as ALT free flap or a pedicled sural flap from the posterior lower leg region.

We chose to manage the patient in several stages.

In the first stage, complete debridement and temporary K wire fixation of the ankle, the calcaneos, and Lisfranc fractures were performed (Figs. 25.3 and 25.4). Vacuum sealing drainage (VSD) was applied over the wound.

One week later in the second stage, to eradicate the dead cavity and cover the dorsal exposed bones and joints, the wound was covered by a distally based sural adipofascial flap.

Still 1 week later in the third stage, as the adipofascial flap stabilized and survived, split-skin graft was performed.

In the fourth week as the flap and skin graft survived and stabilized, delayed fracture reduction and plated fixation were performed. After a total of 3 months, the patient could wear his shoes and walk freely.

25.3 Operative Technique

A longitudinal line roughly representing the course of the peroneal artery is drawn from the midpoint between Achilles tendon and lateral malleolus in the leg. This also represents the course of the superficial sural nerve and the lesser saphenous vein in the posterolateral aspect. Therefore, the perforator flap based on the posterior lateral sural region resembles the distally based sural artery neurofasciocutaneous flap. The flap is then outlined on the lower leg according to location and the size of the tissue defect. The flap was designed with pivot point 4-cm above the lateral malleolus, with 22 cm in length and 5 cm in width.

Under continuous epidural anesthesia, the patient is placed in a lateral position. A thigh pneumatic tourniquet is used, and the leg is exsanguinated by elevation and hand compression for 1 min. This allows emptying most of the blood from the leg but retains enough in the perforator vessels to allow for easier identification during exploration.

An S-shaped skin incision was made over the designed adipofascial flap. To fully expose the width of the adipofascial flap, a subdermal vascular plexus flap was elevated bilaterally. Then a sharp, long exploratory incision of 7 cm in length is first made straight down to the deep fascia from the wound to the distal half of the flap, along its posterior margin (Achilles side). Some stitches are put to hold the deep fascia layer with the overlying adipose tissue together. To search the septal perforator, then the incision is elevated forward from the subfascial plane to the septum. After a proper

S. Chang (✉)
Department of Orthopedic Surgery, Yangpu Hospital, Tongji University School of Medicine, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_25

Fig. 25.1 Patient at admission. (**a**) dorsal wound, (**b**) plantar wound

perforator is identified, the flap design is re-evaluated and tailored according to the exact location of the perforating vessels. Then, the dissection proceeds from the subfascial plane in the proximal-to-distal direction, until the distal perforating vessel is reached, forming a "perforator-plus-adipofascial pedicle". No attempts are made to preserve the superficial cutaneous nerves if they are located in the flap dimension (Fig. 25.5).

Then, the pneumatic tourniquet is released, and blood circulation of the flap is observed. Usually, the whole flap is arterially perfused in 2–3 min after tourniquet release. If the large subcutaneous vein in the flap becomes extremely engorged, it is ligated and dissected at the distal adipofascial base to interrupt venous ingress. The flap is turned over upside down to reach the dorsal foot and then introduced to the plantar foot to eliminate the calcaneus dead space (Fig. 25.6). No venous anastomosis for super drainage or neurorrhaphy is performed at the recipient site. The donor areas are closed directly. An adipofascial flap was covered with Vaseline gauze.

One week later, a second operation is performed to cover the fascial flap with split-skin graft. The skin graft healed completely (Fig. 25.7).

After the soft tissue coverage was successfully achieved, we performed open reduction and internal fixation of the lateral malleolar fracture and the fifth metatarsal fracture (Fig. 25.8). The patient was followed up in 1 year, he could wear normal shoes and restore foot and ankle function and worked as before (Fig. 25.9).

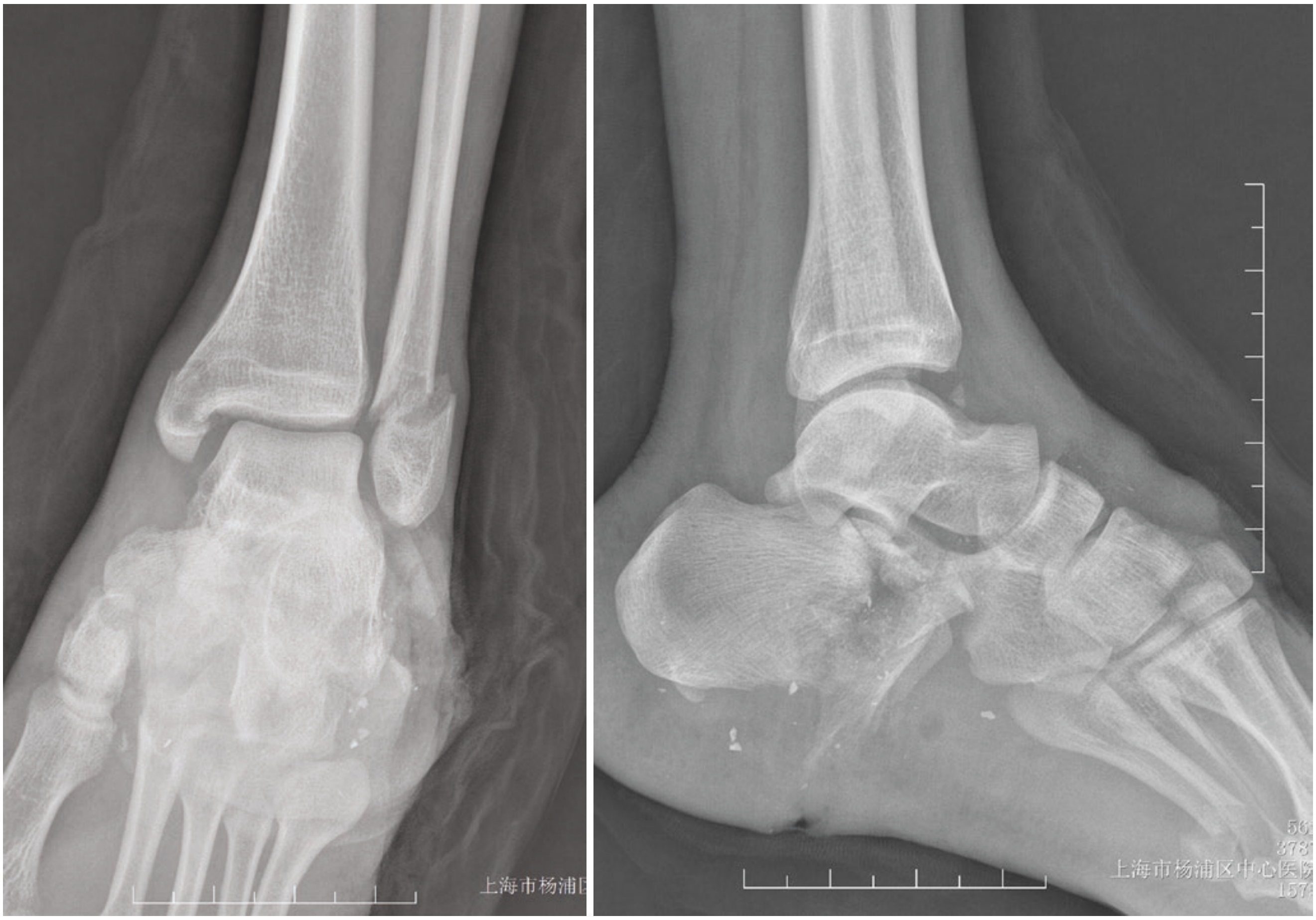


Fig. 25.2 Radiographs of foot and ankle fractures and dislocations

Fig. 25.3 After debridement and temporary K wire fixation

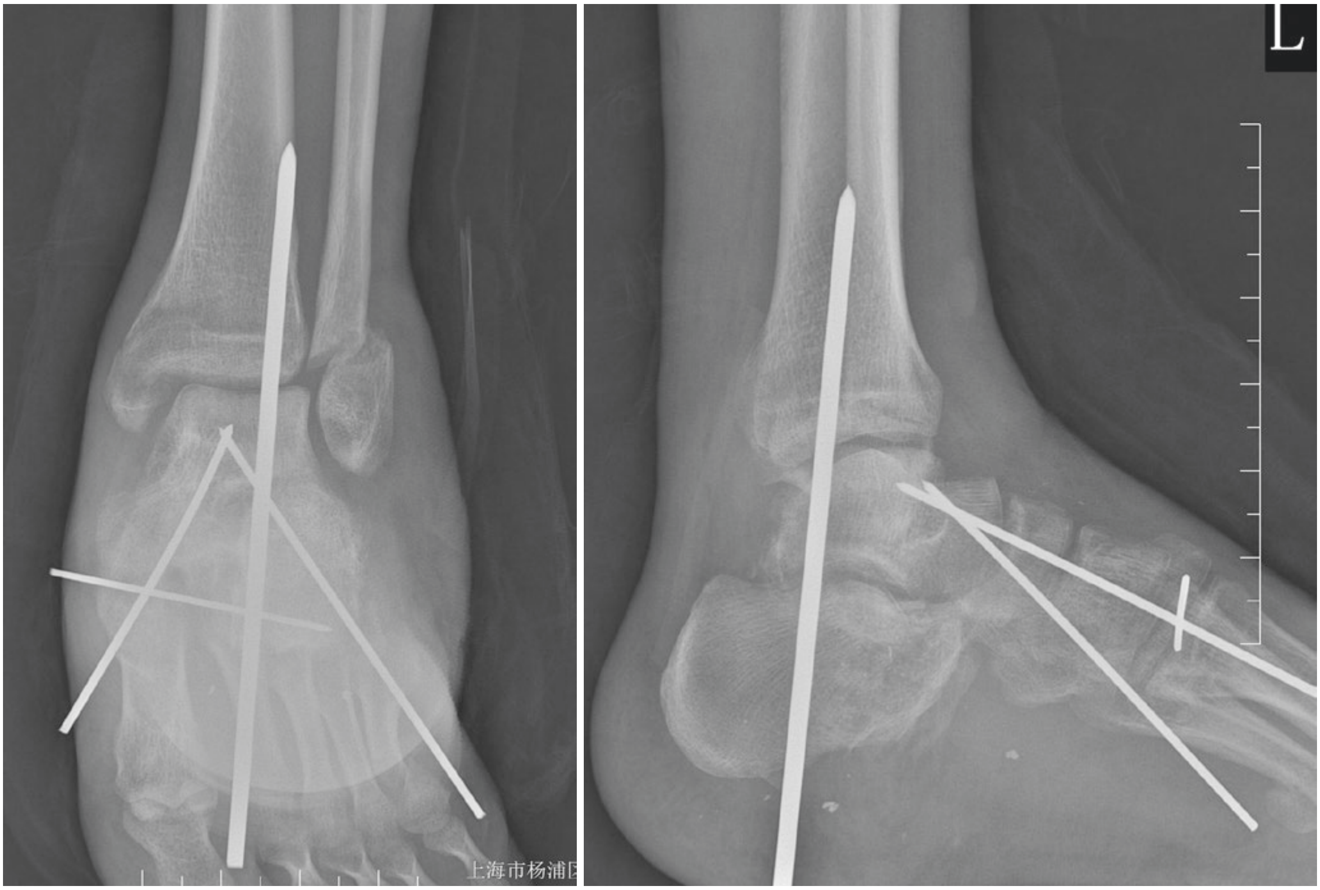


Fig. 25.4 Radiographs after K wire fixation

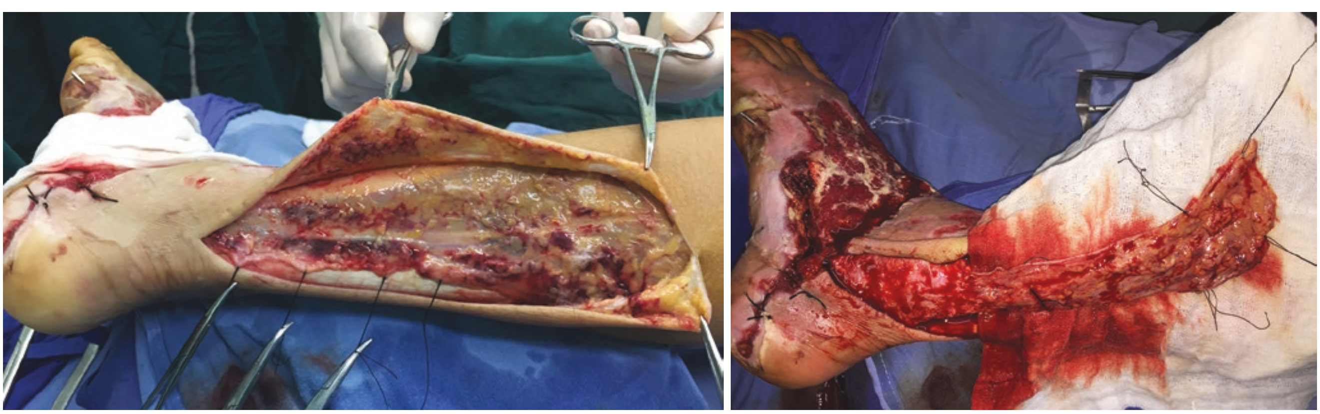


Fig. 25.5 A distally pedicled adipofascial flap, 20 cm long and 5 cm wide and nourished by the distal-most peroneal septal perforator located 4 cm above the lateral malleolus, was elevated. Note the good blood supply at the tip of the flap (adapted from [12] with permission)

Fig. 25.6 The adipofascial flap was turned over to cover the dorsal and passed through to reach the plantar wound to eliminate the dead space (adapted from [12] with permission)

Fig. 25.7 After split-skin graft, the wound was completely covered

25.4 Clinical Implications

Distally based sural neurofasciocutaneous flap is a reliable and versatile technique for foot and ankle coverage [1–5]. But venous drainage is an inherent problem in distally based flaps as all venous blood need primarily reverse flow to the distal base and then go to the normal circulation [6, 7]. Raising an adipofascial flap without the overlying skin permits venous blood oozing from the fascial flap surface and thus reduces the venous overload and improves flap circulation.

Distal-based adipofascial turnover flap is a simple and reliable wound coverage technique [8–10]. It avoids venous congestion as is usually seen in distally based fasciocutaneous flaps. It is suitable for the dorsal foot that needs a thin flap and tendon gliding. It is pliable and convenient to pass through deep dead space to fill the cavity and eliminate potential infections [11, 12]. Staged management is safe for complicated foot and ankle injuries, and good functional outcomes can be anticipated in these patients.

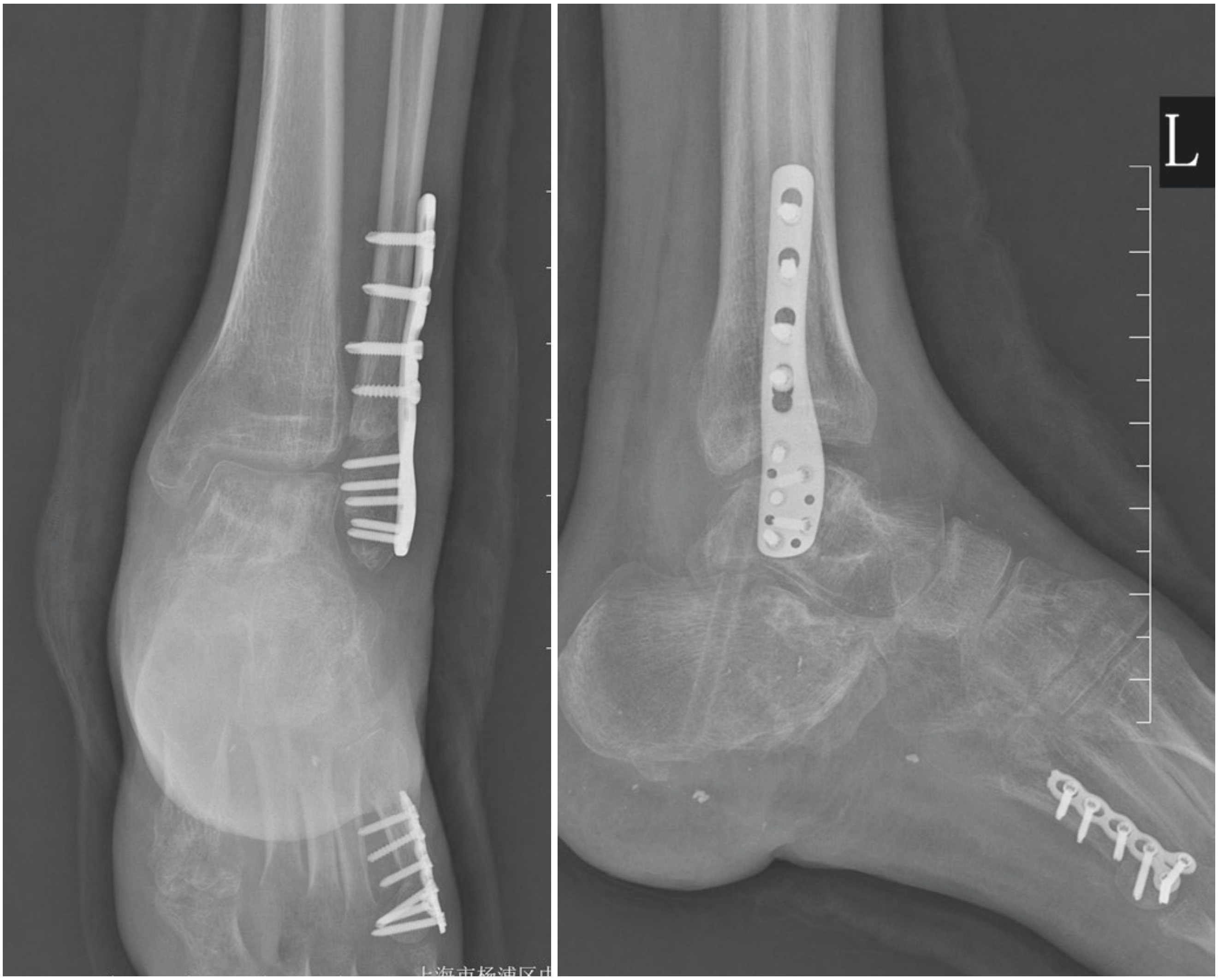


Fig. 25.8 Fracture reduction with plate fixation

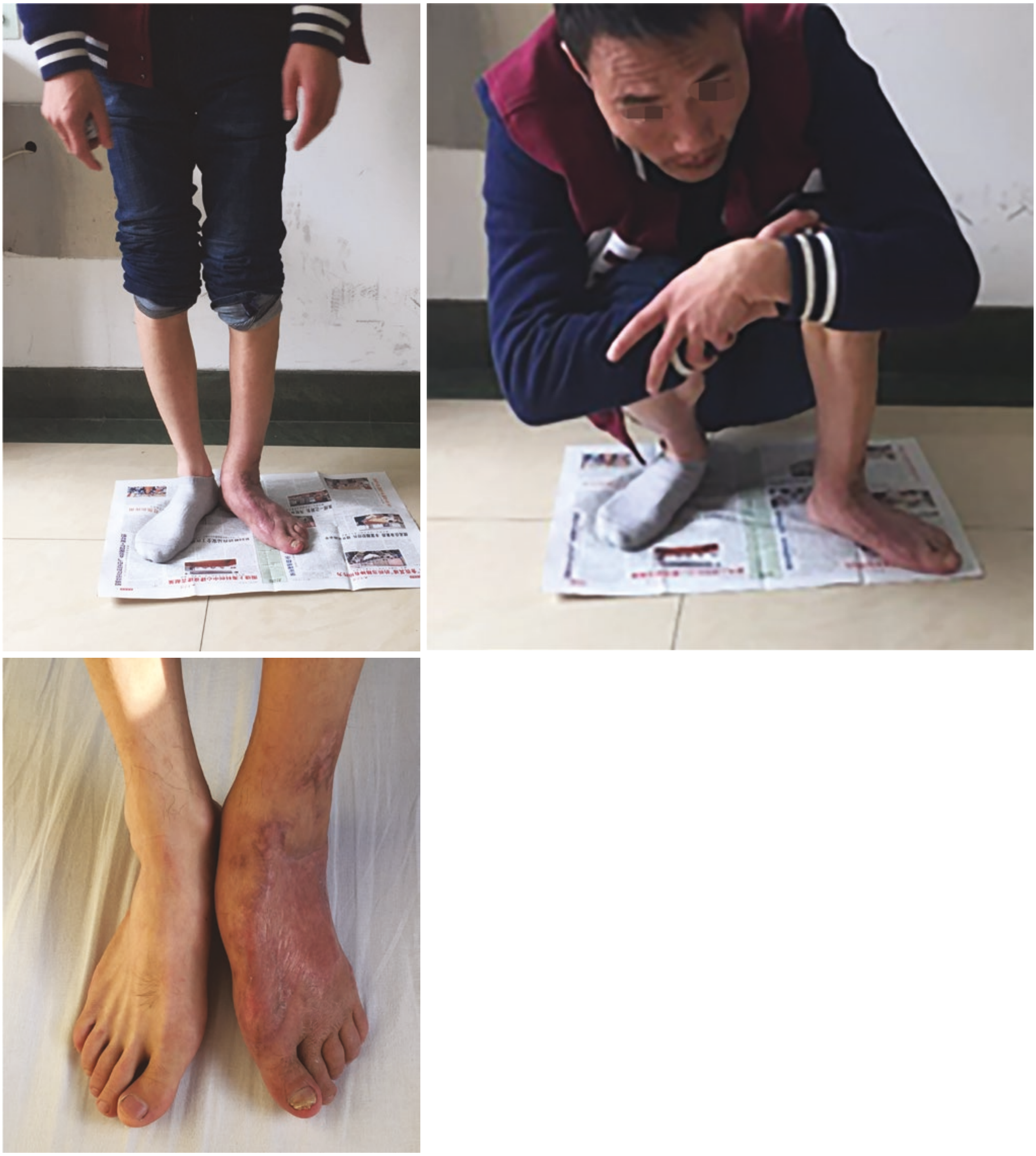


Fig. 25.9 1-year later, the patient can wear his shoes and walk freely

References

1. Chang SM, Li XH, Gu YD. Distally based perforator sural flaps for foot and ankle reconstruction. World J Orthop. 2015;6(3):322–30.
2. Chang SM, Tao YL, Zhang YQ. The distally perforator-pedicled propeller flap. Plast Reconstr Surg. 2011;128(5):575e–7e.
3. Chang SM, Zhang F, Xu DC, et al. Lateral retromalleolar perforator-based flap: anatomical study and preliminary clinical report for heel coverage. Plast Reconstr Surg. 2007;120(3):697–704.
4. Chang SM, Zhang F, Yu GR, Hou CL, Gu YD. Modified distally based peroneal artery perforator flap for reconstruction of foot and ankle. Microsurgery. 2004;24(6):430–6.
5. Chang SM, Zhang K, Li HF, et al. Distally based sural fasciomyocutaneous flap: anatomic study and modified technique for complicated wounds of the lower third leg and weight bearing heel. Microsurgery. 2009;29(3):205–13.
6. Chang SM, Gu YD, Li JF. The role of the large superficial vein in survival of proximally based versus distally based sural veno-neuro-fasciocutaneous flaps in a rabbit model. Plast Reconstr Surg. 2005;115(1):213–8.
7. Chang SM, Wang X, Huang YG, et al. Distally based perforator propeller sural flap for foot and ankle reconstruction: a modified flap dissection technique. Ann Plast Surg. 2014;72(3):340–5.
8. Lee KJ, Lee SH, Kim MB, Lee YH. Adipofascial fold-down flaps based on the posterior tibial artery perforator to cover the medial foot and ankle defects. J Plast Reconstr Aesthet Surg. 2016;69(12):e229–37.
9. Schmidt K, Jakubietz M, Djalek S, et al. The distally based adipofascial sural artery flap: faster, safer, and easier? A long-term comparison of the fasciocutaneous and adipofascial method in a multimorbid patient population. Plast Reconstr Surg. 2012;130(2):360–8.
10. Suliman MT. Distally based adipofascial flaps for dorsal foot and ankle soft tissue defects. J Foot Ankle Surg. 2007;46(6):464–9.
11. Zhou ZB, Pan D, Tang JY. Adipofascial extension of the propeller perforator flap: achieve two things at one stroke. J Plast Reconstr Aesthet Surg. 2017;70(4):542–3.
12. Li B, Chang SM, Du SC, Zhuang L, Hu SJ. Distally based sural Adipofascial turnover flap for coverage of complicated wound in the foot and ankle region. Ann Plast Surg. 2020;84(5):580–7.

26 The Free Peroneal Artery Perforator Flap for Combined Medial Ankle Injury

Xianyou Zheng

26.1 Case Presentation

A 51-year-old man had a 13 × 7 cm soft tissue defect and fracture at the right medial ankle because of traffic accident. The scratching wound of his right shank excluded the opportunity of applying saphenous neurocutaneous flap.

26.2 Choice of Treatment

For the patient with highly contaminated open fracture combined with enormous soft tissue loss, detailed treatment strategy should be made. Effective skin coverage is essential for the following treatment and rehabilitation. This patient was suffered from a medial ankle defect and medium-sized soft-tissue loss. Appropriate reconstruction of medial ankle and effective soft-tissue coverage are important for the following treatment and rehabilitation (Fig. 26.1).

After emergency evaluation and clinical examination, staging treatment strategy was determined. After complete surgical debridement, vacuum sealing drainage (VSD) technique was used for temporary coverage of wound. Due to the high risk of infection leading by severe containment of wound, hospitalized anti-inflammation therapy was decided to be carried out. And debridement was performed on day 4th.

On day seventh, after detailed evaluation of patient's general and wound situation, we decided to apply the free peroneal artery perforator flap to cover the wound. Free left iliac bone graft was performed to restore medial ankle defect following internal fixation.

On day ninth, an arterial thrombosis was found and successfully salvaged by vascular reexploring and anastomoses in emergency.

X. Zheng (✉)
Department of Orthopaedic Surgery, Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai, China

After 1-week hospitalized observation, the flap completely survived and was stable.

26.3 Operative Technique

Prior to the surgery, the perforator is located along the posterior border of the fibula with a handheld Doppler. The flap is designed according to size, shape, and the recipient vessel position of the defect with the louder and higher pitched signal perforator in its proper portion, then the portion of perforators was marked.

Under general anesthesia combined nerve block, patient was placed in supine position with tourniquet applied to left thigh. Left knee was fixed at 90° and foot was placed on the operating bed steadily. During the surgery, fibula head and top of lateral ankle was identified to localize the fibula. An ultra-long flap was then identified and outlined according to the defect localization and size, which were 14 cm in length and 9 cm in width (Fig. 26.2a).

First, the recipient vessel was dissected carefully till an artery with sufficient blood injection can be observed. Subsequently, the harvest procedure of flap was conducted under tourniquet control. An incision directly down to the fascia was made on the anterior border of the flap. The precise position and pattern of the perforator were confirmed by subfascial dissection. Then incision on the posterior border of the flap was made till a pure perforator connected to the donor site (Fig. 26.2b, c). After sufficient pedicle was harvested, the flap circulation was confirmed by observing bleeding from the flap edge without tourniquet control. It was 1 mm in perforator diameter and 4 cm in pedicle length. And before final ligation of the flap, reconstruction of the medial ankle was performed. Bone harvested from left iliac crest was modified to fit the medial ankle defect and grafted to the defect. Then screw and plate were used for fixing (Fig. 26.2d, e). Then the FPAP flap was transferred to the receiving area with microsurgical anastomoses (Fig. 26.2f). Due to the relatively large vascular diameter mismatch, an

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_26

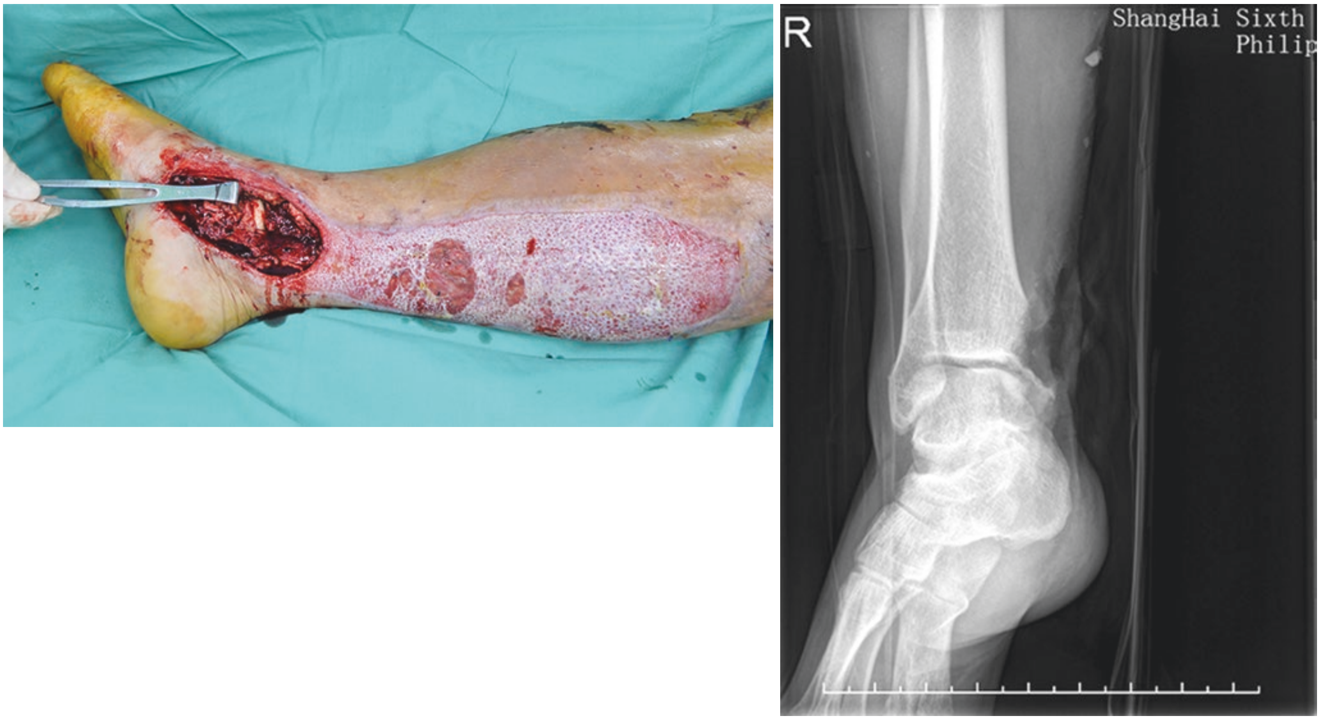


Fig. 26.1 Wound appearance after first debridement. Left: Medial view of wound; right: X-ray result indicating medial ankle loss

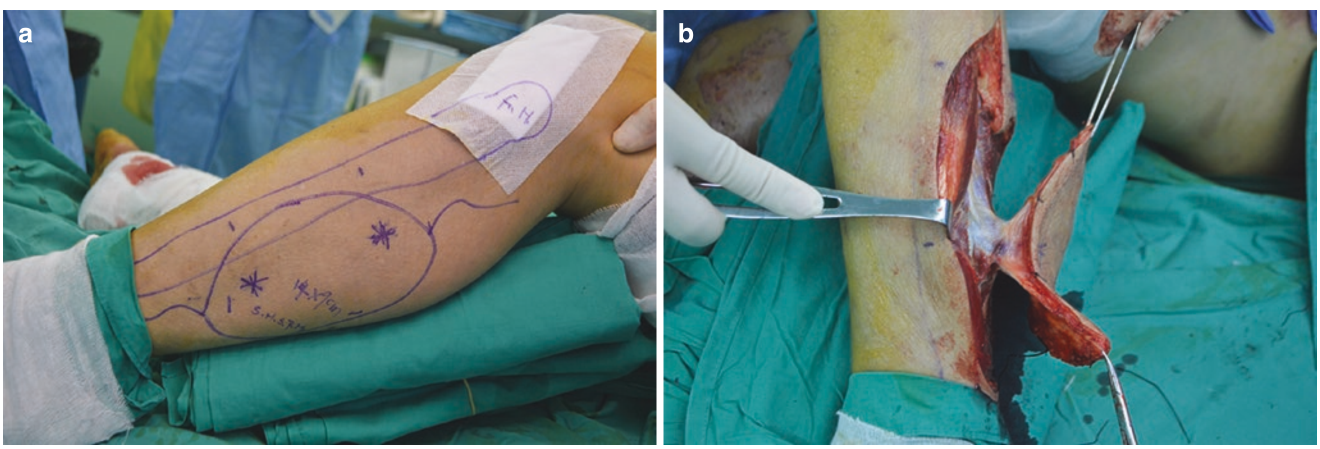


Fig. 26.2 Flap harvesting and coverage with medial ankle reconstruction. (**a**). Flap design; (**b**) Perforator pedicle identification; (**c**). Perforator pedicle exposure; (**d**) Medial ankle reconstruction by left iliac bone grafting with internal plate and K-wire fixation; (**e**) Inter-surgery X-ray result. (**f**) Defect covered by flap

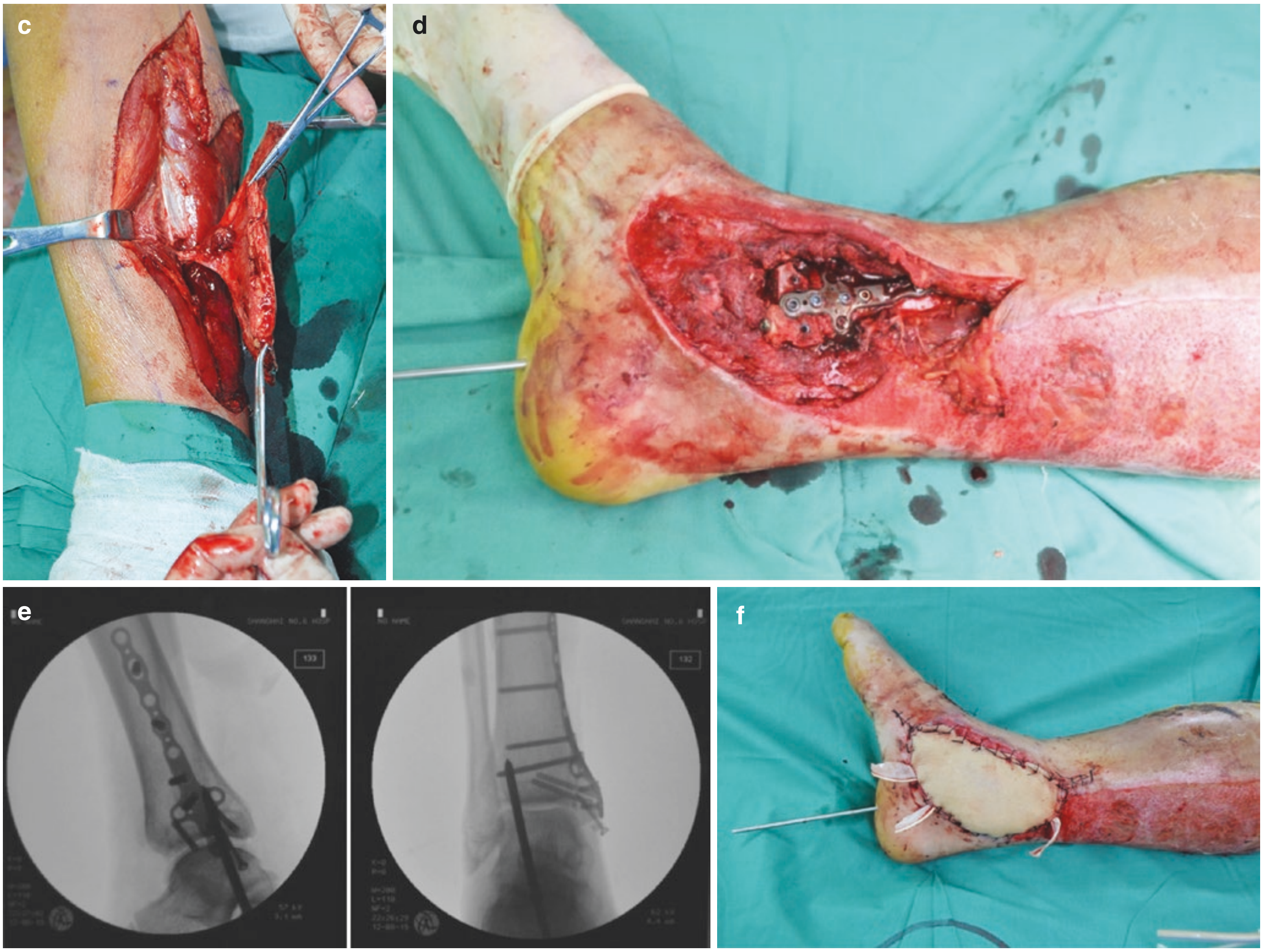


Fig. 26.2 (continued)

end-to-side anastomosis was performed on the dorsalis pedis artery. The "fish-mouth" suture and hydraulic expansion were performed to cross over the vascular mismatch. The vein of flap was anastomosed to the branch of the great saphenous vein. The donor site was closed through thigh skin grafting.

After 1-week hospitalized observation, the flap completely survived and was stable. Three-month and 6-month follow-up indicated satisfied wound coverage and function recovery (Figs. 26.3a, b and 26.4a–c).

26.4 Clinical Implications

The free peroneal artery perforator flap is a kind of flexible flap which can be used in coverage for small-to-medium sized soft tissue defect [1–4]. Some researchers indicated the average size of harvested ranging from 5 × 3 cm to 14 × 5.5 cm [3, 4], while the flap size in this case reached 14 × 9 cm and it finally survived. Its survival might extend the application area of FFAP on the maximum size of this flap can be applied.

Fig. 26.3 Three-month follow-up indicated satisfied coverage, appearance of wound, and X-ray result. (**a**) Defect covered by satisfied flap; (**b**) X-ray result of reconstructed medial ankle

This is a simple and reliable flap which can be performed in emergency and sub-emergency operation. The anatomical position of the peroneal artery perforator is relatively consistent which enable surgeons to harvest it easily. And some modified applications of this flap have also been used in reconstruction of complex defects [5]. Implication of this flap is not only limited to injury-caused defect but also extended to defects caused by other diseases including occlusive vascular diseases, diabetes mellitus, infections, and osteomyelitis [6, 7]. In general, this kind of flap is commonly used in coverage of distal limb defects, which may partially due to the relatively similarity between the vascular diameter between flap pedicle and recipient area [3]. And in this case, we applied the FFAP flap in the coverage of combined tissue defect in ankle which also extended the clinical implications of this flap due to our experience in dealing with vascular mismatch and close post-operation monitoring of flap circulation that enable us to observe the vascular crisis and fix it in time.

Fig. 26.4 Six-month follow-up. (**a**) appearance of wound; (**b**) satisfied function of reconstructed ankle; (**c**) X-ray result

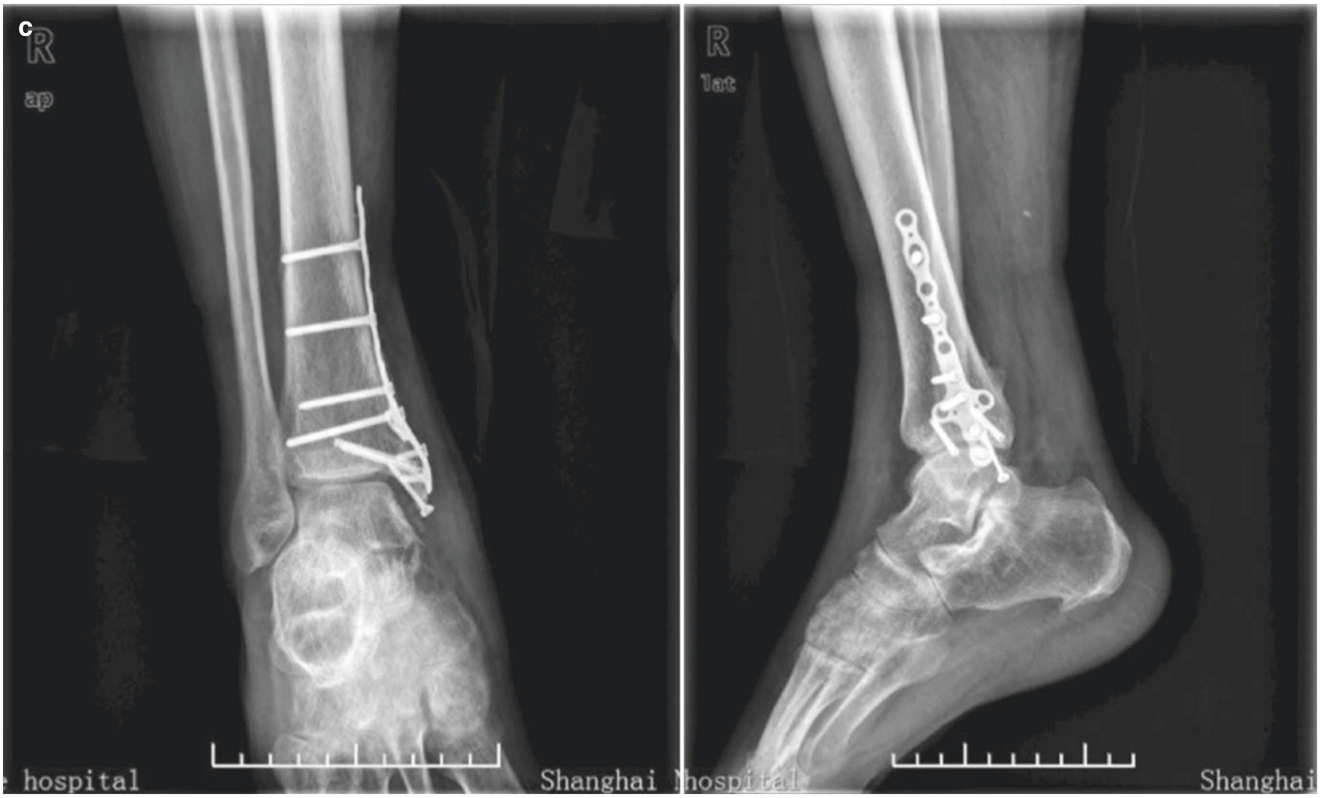


Fig. 26.4 (continued)

References

1. Kenji K, Hiroshi Y, Yasunori K, Koji S, Yoshinori T. Clinical applications of free soleus and peroneal perforator flaps. Plast Reconstr Surg. 2005;115(1):114–9.
2. Mario FS, Yur-Ren K, Yenhou C. Reconstruction of distal hand and foot defects with the free proximal peroneal artery perforator flap. Microsurgery. 2014;36(3):183–90.
3. Lee ZH, Alfonso AR, Stranix JT, et al. Vein size mismatch increases flap failure in lower extremity trauma free flap reconstruction. J Reconstr Microsurg. 2019;35(8):587–93.
4. Seo SW, Kim KN, Yoon CS. Extended scope of the use of the peroneal perforator flap in lower limb reconstruction. J Reconstr Microsurg. 2015;31(9):654–9.
5. Hayashida K, Saijo H, Fujioka M. Peroneal perforator-based peroneus longus tendon and sural neurofasciocutaneous composite flap transfer for a large soft-tissue defect of the forearm: a case report. Microsurgery. 2018;38(1):85–8.
6. Kim CY, Naidu S, Kim YH. Supermicrosurgery in peroneal and soleus perforator-based free flap coverage of foot defects caused by occlusive vascular diseases. Plast Reconstr Surg. 2010;126:499.
7. Cheng L, Yang X, Chen T, Li Z. Peroneal artery perforator flap for the treatment of chronic lower extremity wounds. J Orthop Surg Res. 2017;12(1):170.

Check for updates

27 The Ultra-Long Free Peroneal Artery Perforator Flap for Lateral Foot Defect Coverage

Jialin Song

27.1 Case Presentation

A 63-year-old man suffered from a right foot open fracture (bone loss from the middle of the fifth metatarsal bone) and ultra-long soft tissue loss due to a traffic accident. After emergent surgical debridement, a 15 × 7 cm soft-tissue defect involving two-third of the lateral border of the foot and the lateral half of the fourth toe.

27.2 Choice of Treatment

For a patient with a highly contaminated open fracture combined with enormous soft tissue loss, a detailed treatment strategy should be made. Effective skin coverage is essential for following treatment and rehabilitation.

In general, there are multiple choices for soft-tissue defect coverage including skin grafting, pedicled flap, free flap, etc. Considering the exposed bone tissue, skin grafting is not suitable for this patient. And pedicled flap was also not preferred due to the overlength from the common pedicle to the distal foot which forming a long invalid area easily fail. Multiple types of free flaps were considered to cover this defect. Considering the defect's large length to width ratio and its location at the lateral foot which requires relatively thin flap coverage, we decided to apply free peroneal artery perforator flap (FFAP) to cover this defect due to its advantages that it is a kind of thin flap and its donor region is relatively slim which enables surgeons to harvest suitable-sized flap easily.

After emergency evaluation and clinical examination, staging treatment strategy was determined to be divided into primary debridement, infection control, and final flap coverage.

J. Song (✉)
Department of Orthopaedic Surgery, Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai, China

Primarily, the fracture border was modified following the complete surgical debridement (Fig. 27.1a, b). The vacuum sealing drainage (VSD) technique was used for temporary coverage of the wound. Due to the high risk of infection leading by severe containment of wound, hospitalized anti-inflammation therapy was decided to be carried out, and the second debridement was performed on day 4th.

On day 7, after a detailed evaluation of the patient's general and wound situation, we decided to apply the free peroneal artery perforator flap to cover the wound. And donating region was closed by skin grafting from the contralateral thigh.

After 1 week of hospitalized observation, the flap completely survived and was stable.

27.3 Operative Technique

Prior to the surgery, the perforator is located along the posterior border of the fibula with a hand-held Doppler. The flap is designed according to size, shape, and the recipient vessel position of the defect with the louder and higher pitched signal perforator in its proper portion, and then the portion of perforators was marked.

Under general anesthesia combined nerve block, the patient was placed in supine position with tourniquet applied to the left thigh. The left knee was fixed at 90 degrees and the foot was placed on the operating bed steadily. During the surgery, the fibula head and top of the lateral ankle were identified to localize the fibula. An ultra-long flap was then identified and outlined according to the defect localization and size, which was 16 cm in length and 9 cm in width (Fig. 27.2a).

First, the recipient vessel was dissected carefully till an artery with sufficient blood injection and proper venous vessels were observed (Fig. 27.2b). Subsequently, the harvest process began with an incision directly down to the deep fascia made on the anterior border of the flap. Then, we

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_27

Fig. 27.1 Wound appearance after the first debridement. (**a**) Lateral view; (**b**) Plantar view

Fig. 27.2 Flap harvesting process. (**a**) Flap design (16*8 cm); (**b**) Perforator pedicle marked; (**c**) Perforator pedicle exposure; (**d**) Harvested flap

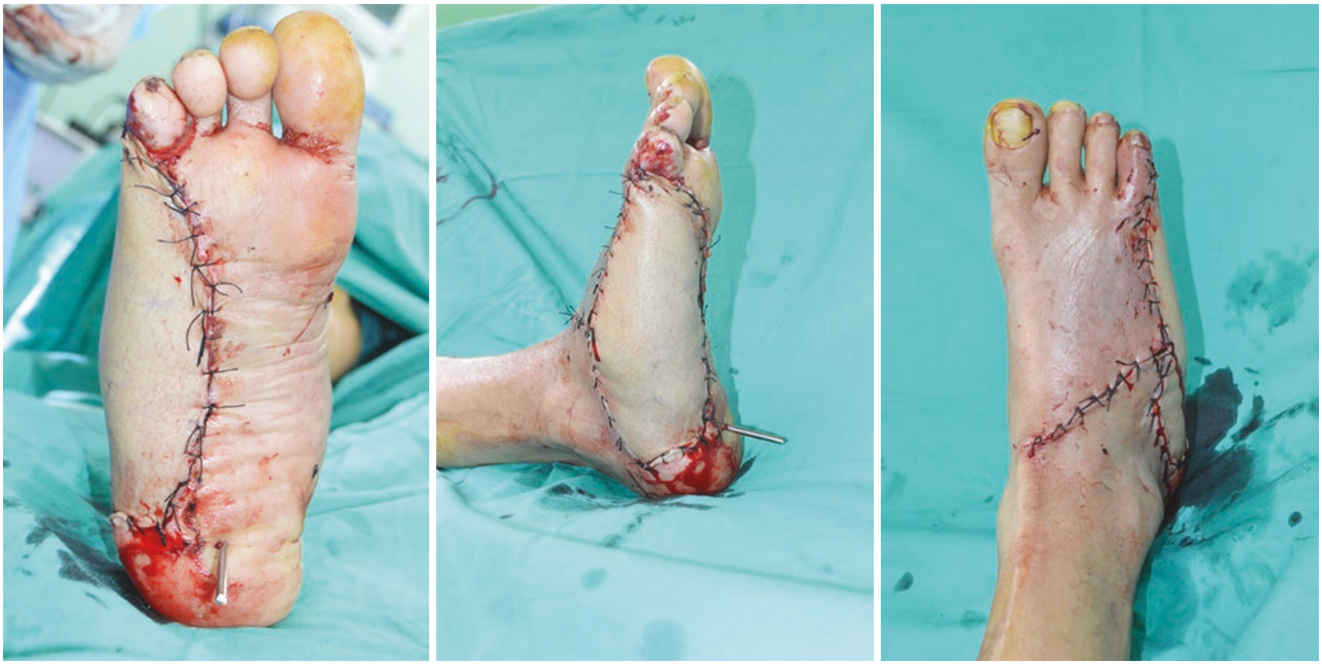


Fig. 27.3 Defect covered by the flap

applied some sutures to bring the deep fascia and skins altogether to prevent the separation influencing the blood supply of the flap. The precise position and pattern (musculocutaneous or septocutaneous) of the perforator were confirmed by subfascial dissection of deep fascia, peroneus longus, and peroneus brevis and marked subsequently.

Then, an incision on the posterior border of the flap is made till a pure perforator connected to the donor site. After exposing the perforator, a second evaluation of flap design was made according to the recipient area (defect shape, size, and vascular location). After sufficient pedicle is dissected (Fig. 27.2c, d), we released the thing tourniquet and observe the flap circulation. After satisfied circulation of the flap was confirmed, the flap was transferred to the recipient area with microsurgical anastomoses (one artery and two veins) (Fig. 27.3). The donor site was closed through thigh skin grafting.

And 2-month and 6-month follow-up indicated a satisfied recovery of the covered defect (Figs. 27.4 and 27.5).

27.4 Clinical Implications

The free peroneal artery perforator flap is a kind of flexible flap that can be used in coverage for small-to-medium-sized soft-tissue defect [1–4]. Some researchers indicated the average size of harvested ranging from 5 × 3 cm to 14 × 5.5 cm [3, 4], while the flap size, in this case, reached 16 * 8 cm and it finally survived. Its survival might extend the application area of FFAP to the maximum size of this flap can be applied.

This is a simple and reliable flap that can be performed in emergency and sub-emergency operation. The anatomical position of the peroneal artery perforator is relatively consistent which enables the surgeons to harvest it easily. And some modified application of this flap has also been used in the reconstruction of complex defects [5]. The implication of this flap is not only limited to injury-caused defect but also extended to defects caused by other diseases including occlusive vascular diseases, diabetes mellitus, infections, and osteomyelitis [6, 7]. In general, this kind of flap can be used for coverage of distal limb defects.

Fig. 27.4 2-month follow-up indicated satisfied coverage and appearance of the wound

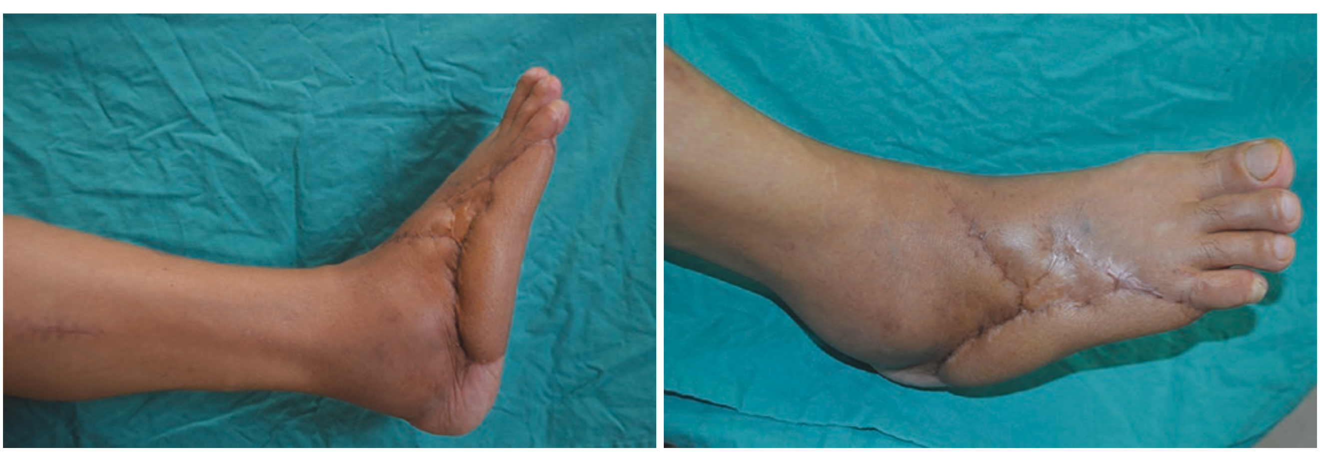


Fig. 27.5 6-month follow-up of the covered wound

References

1. Kenji K, Hiroshi Y, Yasunori K, Koji S, Yoshinori T. Clinical applications of free soleus and peroneal perforator flaps. Plast Reconstr Surg. 2005;115(1):114–9.
2. Mario FS, Yur Ren K, Yenhou C. Reconstruction of distal hand and foot defects with the free proximal peroneal artery perforator flap. Microsurgery. 2014;36(3):183–90.
3. Lee ZH, Alfonso AR, Stranix JT, et al. Vein size mismatch increases flap failure in lower extremity trauma free flap reconstruction. J Reconstr Microsurg. 2019;35(8):587–93.
4. Seo SW, Kim KN, Yoon CS. Extended scope of the use of the peroneal perforator flap in lower limb reconstruction. J Reconstr Microsurg. 2015;31(9):654–9.
5. Hayashida K, Saijo H, Fujioka M. Peroneal perforator-based peroneus longus tendon and sural neurofasciocutaneous composite flap transfer for a large soft-tissue defect of the forearm: a case report. Microsurgery. 2018;38(1):85–8.
6. Kim CY, Naidu S, Kim YH. Supermicrosurgery in peroneal and soleus perforator-based free flap coverage of foot defects caused by occlusive vascular diseases. Plast Reconstr Surg. 2010;126:499.
7. Cheng L, Yang X, Chen T, Li Z. Peroneal artery perforator flap for the treatment of chronic lower extremity wounds. J Orthop Surg Res. 2017;12(1):170.

Sural Nerve Nutritional Vessel Axial Flap for the Heel Skin Defect Coverage and Calcaneal Reconstruction

28

Xianyou Zheng

28.1 Case Presentation

A male, Asia patient, 66-year-old, had a history of calcaneal fixation surgery for about 28 years ago because of the calcaneal fracture during a severe traffic accident. The patient reports a long-term skin defect before the right ankle with calcaneal exposure as a result of not standard treatment after surgery. Half-year ago, the patient said that the calcaneal was injured again and then with the body fluid leaked. Upon physical examination, the patient presented a 5 × 3 cm heel soft-tissue defect with a scar and calcaneal exposure (Fig. 28.1). X-ray shows calcaneus bone fracture (Fig. 28.2). The patient had neither other medical history nor drunk any immunosuppressive drugs or exposed to any other immunosuppressive factor.

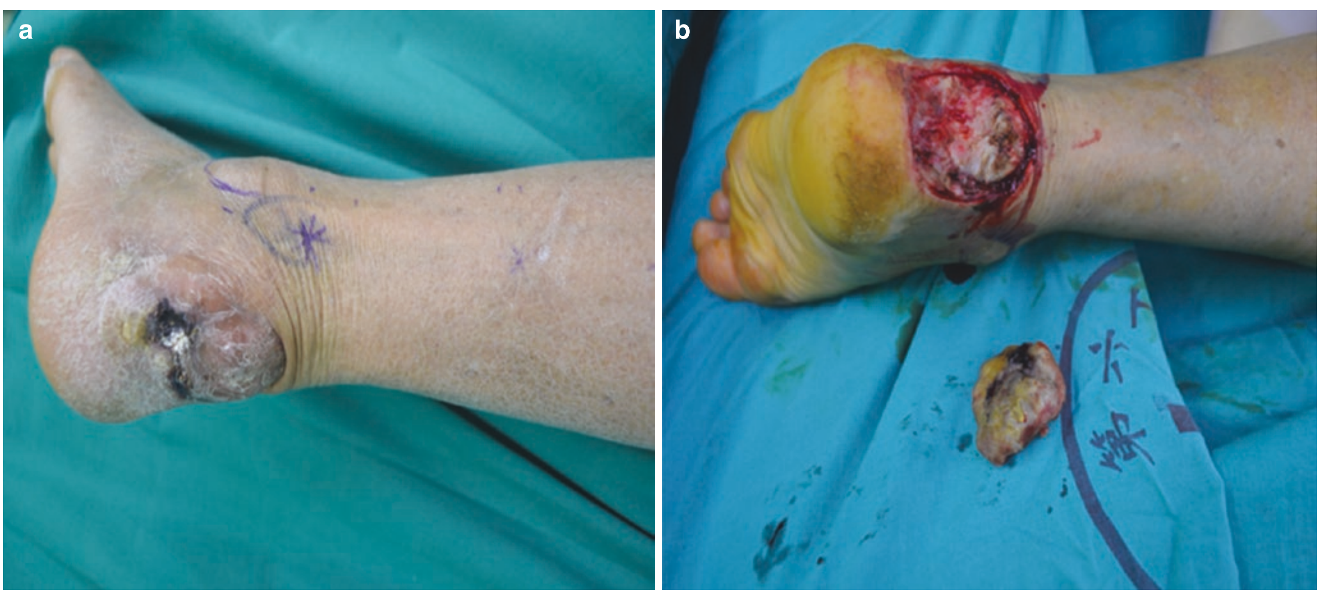


Fig. 28.1 Patient at admission. (**a**) wound behind the ankle, (**b**) 5 × 3 soft tissue defect after removing scar

X. Zheng (✉)
Department of Orthopaedic Surgery, Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_28

Fig. 28.2 Radiographs of calcaneus bone

28.2 Choice of Treatment

Skin defect and bone exposure are high-risk factors for many diseases like osteomyelitis and bone necrosis, which will cause more severe complications after surgery. Skin coverage and bone reconstruction are essential processes to repair skin defects and restore the walkability.

In this case, with the long-term bone exposure, the heterotopic ossification was formed at the ending site of Achilles tendon. Before the skin coverage, the calcaneal needed to be osteotomy and the lesion of heterotopic calcification required to be resected first.

There are many treatment methods in fixation of the calcaneal fracture including no surgical treatment (conservative treatment, plaster fixation treatment), open reduction and internal fixation (plate fixation system, hollow compression screw, and Kirschner wire fixation), and repair and reconstruction operation (arthrodesis and calcaneal osteotomy). For this patient, to incise the heterotopic ossification lesion and repair the insertion of Achilles tendon, calcaneal osteotomy and insertion of Achilles tendon reconstruction surgery were performed first.

According to the patient's skin defect, the heel skin wound needs thin and pliable tissue coverage. There are many options like the peroneal perforator flaps in clinical practice in selecting the suitable flap in skin coverage. According to the site and size of the skin defect, a sural neuro-lesser saphenous venous flap was used in repairing the patient's skin damage.

28.3 Operation Technique

Masquelet et al. first described the distally based flap based on the vascular axis around the sural nerve (also called distally based superficial sural artery flap). These flaps had been popularly used in reconstructing the medium or extensive soft tissue damage of the foot and ankle. This flap was nutri-

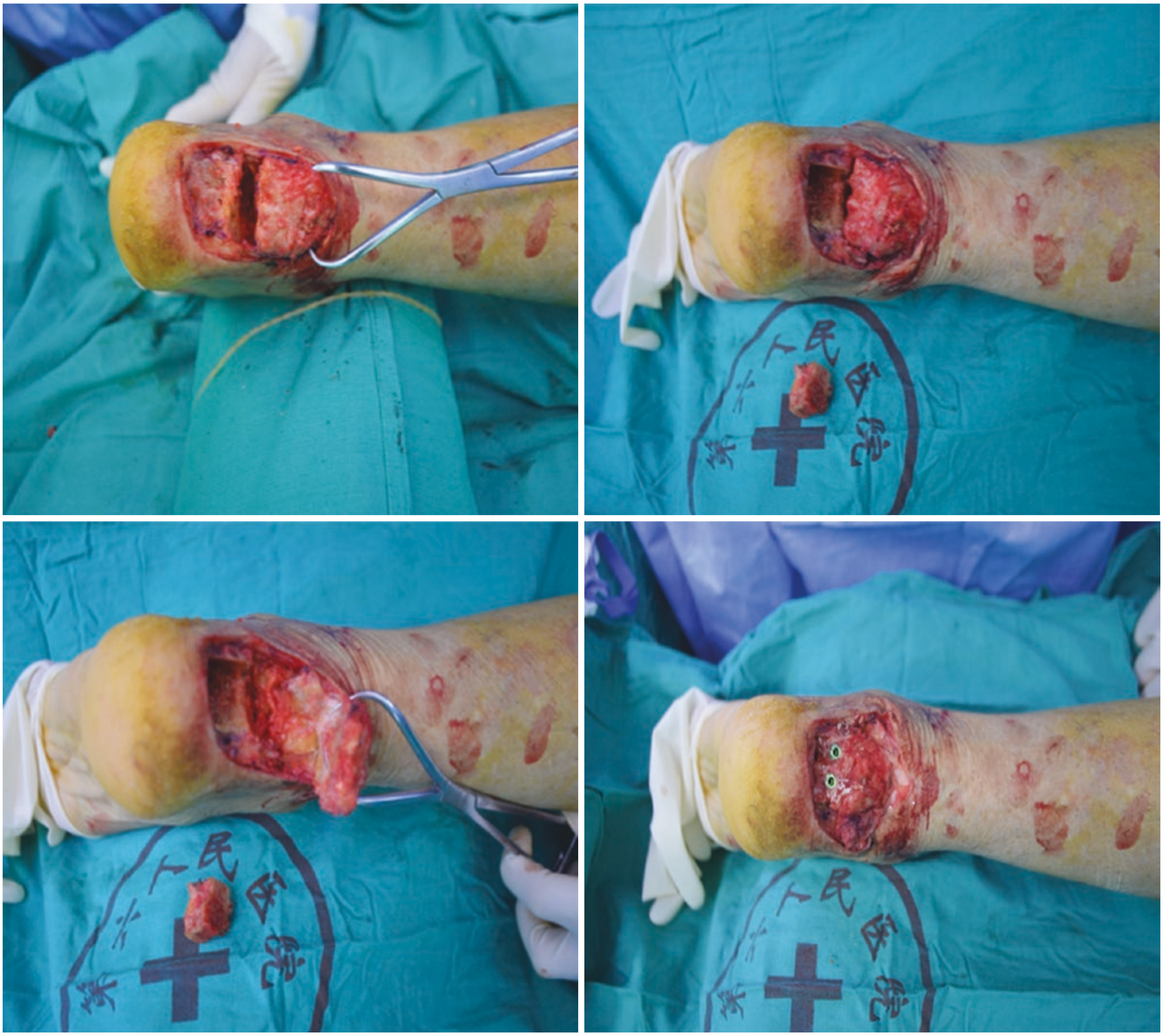


Fig. 28.3 Calcaneus osteotomy and fixation

ent by a median superficial sural artery, which takes septocutaneous perforators from the distal part of the peroneal and tibial arteries of the leg. According to the heel skin defect, the flap was designed with pivot point 3 cm above the lateral malleolus, with 14 cm in length and 7 cm in width.

The patients were placed in a prone position with general anesthesia. Before the surgery, the perforators were detected by using the handheld Doppler and marked with purple crosses and circles. Then we use the thigh pneumatic tourniquet to empty most of the blood on the surgery side thigh temporarily by elevating and compressing the leg for 1 min. The remaining blood was the identification sign for exploring the perforator vessels.

Complete debridement of the heel skin defect was performed before the flap dissertation. After the scar dissertation and wound debridement, the skin defect was expanded to 5 cm in length and 6 cm in width. To incise the lesion of heterotopic ossification and to reconstruct the Achilles tendon, calcaneal were performed with wedge-shape osteotomy near and behind the tendon of the peroneus longus (Fig. 28.3). After a wedge-shaped osteotomy of the heel, the osteotomy surface is fixed with hollow compression screws (Fig. 28.4).

The point of emanation of the cutaneous perforating artery nearest to the trauma was used as the point of rotation. According to the shape and size of the skin defect, the flap was designed along the axis of the peroneal nerve (the line from the midpoint of the popliteal fossa to the posterior border of the lateral ankle). The skin of the anterolateral edge of the lower calf is incised according to the preoperative marks, and the perforator artery is located and separated along with the intermuscular plane of the peroneus longus and brevis muscles (Figs. 28.5 and 28.6). The perforating artery is isolated up to the peroneal artery, the main trunk of the peroneal vein, as needed for trauma. Then the flap is incised along with flap design marks. The peroneal nerve is cut off at the upper end of the flap, and its nutrient vessels are ligated, while the small veins are ligated at the lower end. The flap was lifted under the deep fascia. Then, the tourniquet was released, and the blood supply was observed before rotation of the flap. After confirming the blood supply, the flap was rotated 90° ~ 180° to repair the wound, and the donor area was covered with skin grafts.

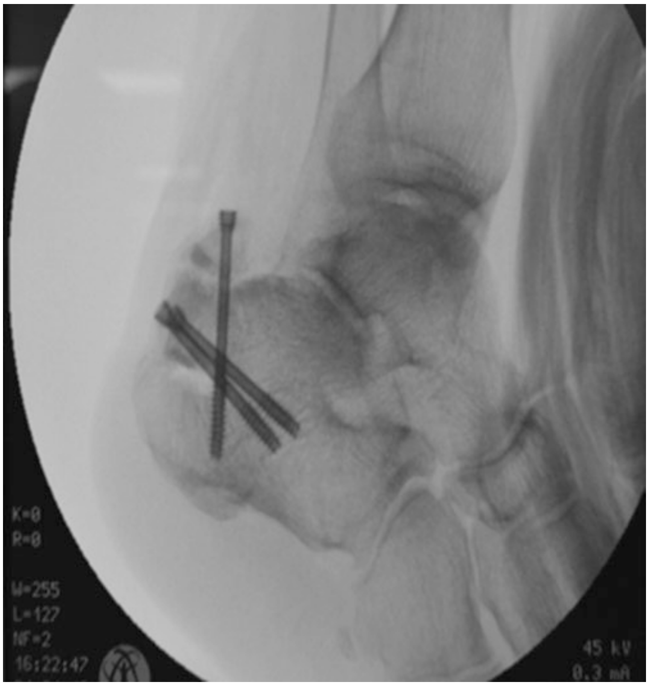


Fig. 28.4 Radiograph after osteotomy and fixation

After 15 months, the patient was followed up. The flap survived and the fracture healed well (Figs. 28.7 and 28.8).

28.4 Clinical Implications

The flap plays an essential role in repairing soft tissue defects [1–4]. First, the flap has a moderate thickness and soft texture, which can be used to repair many traumatic injuries [5–6]. Second, the flap's blood supply does not require sacrificing the trunk vessels, and the flap has a long perforating branch artery pedicel, which provides an abundant supply of blood for the flap to repair the significant skin defects [7, 8]. Third, this flap has a simple surgical process, with more flexibility in design and incision, which can undergo the operation in multiple regions. Finally, the flap can be designed as a sensory flap with a cutaneous nerve [9, 10]. Therefore, it is suitable for the wound repair of large soft tissue defects of the lower leg and ankle.

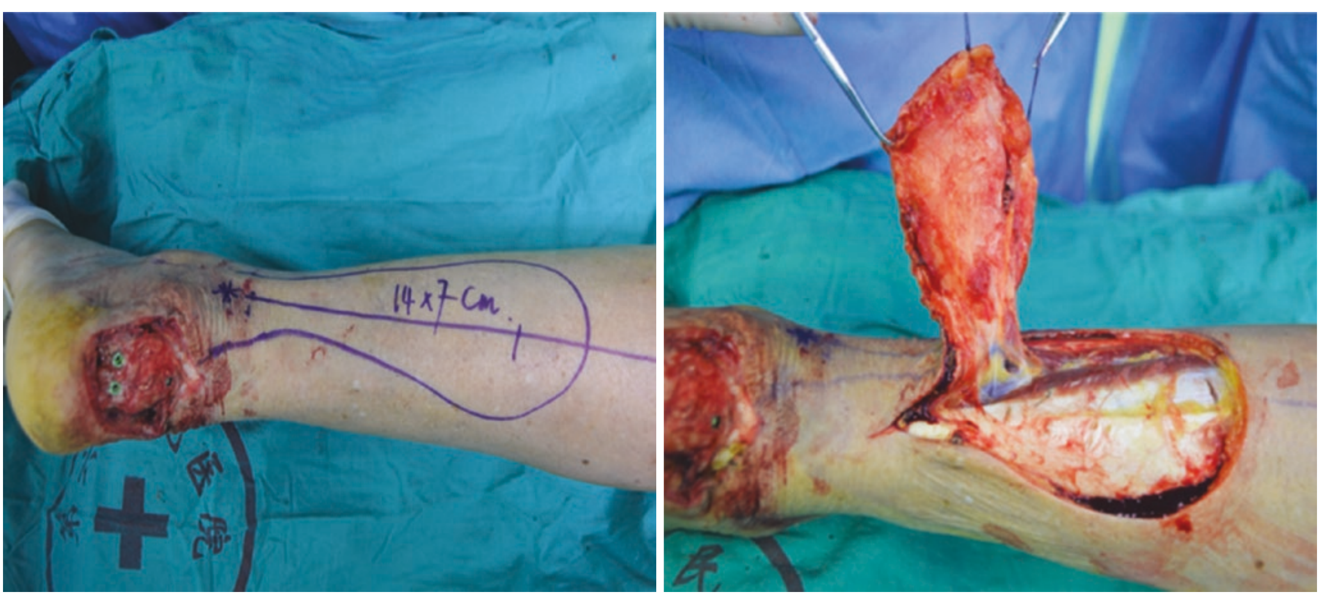


Fig. 28.5 A distally pedicled adipofascial flap with 14 cm long and 7 cm wide, nourished by the sural nerve nutritional vessel, was elevated. Note the good blood supply at the tip of the flap

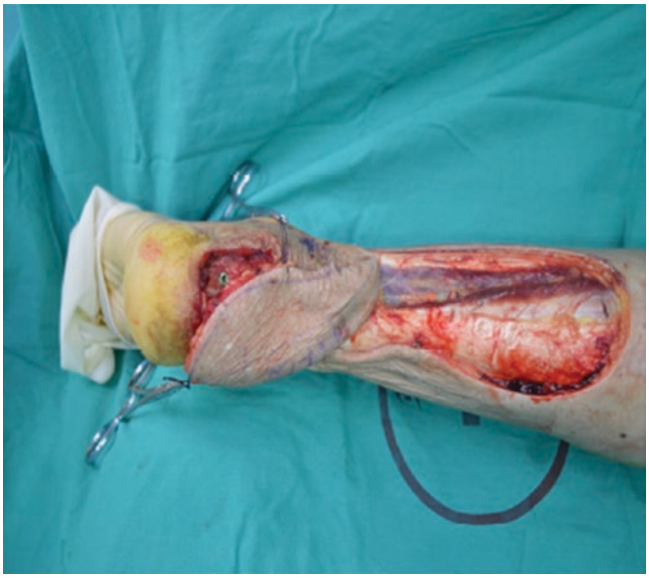


Fig. 28.6 The sural nerve nutritional vessel axial flap was turned over to cover the wound behind the left heel to eliminate the dead space

Fig. 28.8 Fifteen months after surgery

Fig. 28.7 Fracture relocation with plate fixation

References

1. Masquelet AC, Romanan MC, Wolf G. Skin island flap supplied by the vascular axis of the sensitive superficial nerves: anatomic study and clinical experience in the leg. Plast Reconstr Surg. 1992;89:1115–21.
2. Oberlin C, Azoulay B, Bhatia A. The posterolateral malleolar flap of the ankle: a distally based sural neurocutaneous flap—report of 14 cases. Plast Reconstr Surg. 1995;96:400–5. discussion 406-7
3. Byeon JY, Choi HJ. Survival of neuro-venous flap without perforator due to accidental division of perforator. Arch Hand Microsurg. 2018;23(4):290–5.
4. Wu J, Peng H, Yang G, et al. Repair of ankle and foot soft tissue defect in elder with sural nerve nutritional vessel axial flap pedicle with perforating branch of peroneal artery. J Clin Orthopaed. 2010;6:49.
5. Zhang Q, Qiao Q, Gould LJ, et al. Study of the neural and vascular anatomy of the anterolateral thigh flap. J Plast Reconstr Aesthet Surg. 2010;63(2):365–71.
6. Song Q, Guorong Y, Zhenguang C. Applied anatomy of island flap pedicled with nutrient vessels of sural nerve. Chin J Clin Anat. 2000;2:18.
7. Hui L, Jinpin W, Hongbing X. Anatomy of sural nerve nutritional flap and its clinical application. Anat Clin. 2003;4
8. Hasegawa T, Nakamura S, Manabe T, et al. Vascularized nerve grafts for the treatment of large nerve gap after severe trauma to an upper extremity. Arch Orthop Trauma Surg. 2004;124(3):209–13.
9. Yang H, Li X, Ning J. Clinical application of distally based neurovascular island flap pedicled with the sural superficial nerve. J Plast Reconstr Surg. 2004;3:6.
10. Lin Y, Liao J, Wei J. Applied anatomy of the fasciocutaneous flap pedicled the sural nerve and its nutrient vessels. Chin J Microsurg. 1999;S1

29 Repair Hot-Pressed Wound of the Hand with Lobulated Chimeric Flaps of Perforator Branch of Lateral Circumflex Femoral Artery

Xiu Jun Tang

29.1 Case Presentation

A 32-year-old man suffered a crush injury of his left hand during work. The wound was bandaged, and the patient was sent to our hospital. The dorsum and palm skin of the left hand were almost all necrotized. All extensor tendons and part of the aponeurosis of the dorsum of the left hand were destroyed. The thenar muscle of the hand was serious squeezed, accompanying partial muscle necrosis (Figs. 29.1 and 29.2).

29.2 Choice of Treatment

The patient needs soft-tissue coverage and reconstruction of the extensor tendon to restore hand function. Because it is a hot compression injury, the necrotic tissue must be debrided

Fig. 29.1 Skin defect and muscle necrosis of the right palmar after hot-pressing injury

Fig. 29.2 Skin and tendon defect of the dorsum of hand, partial bone degeneration with joint capsule damage

in order to create conditions for later repair. Vacuum sealing drainage (VSD) was applied over the wound after debridement had been implemented.

In this case, the dorsal and palm of the hand need a thin and pliable soft-tissue coverage. The extensor tendon needs simultaneous reconstruction to ensure the finger extension function. So we chose free lobulated engomphosis perforator flaps of lateral circumflex femoral artery to reconstruct the tendon and cover the skin defect of the hand simultaneously while carrying part of the lateral thigh muscle to reconstruct the thenar muscle to improve the appearance and function of the palm.

This case requires a large area of skin. In order to reduce donor site damage, the length of thigh skin should be fully utilized and donor site can be sutured directly due to the application of lobulation technique.

After 3 years of follow-up, the patient was able to devote to his normal daily work.

X. J. Tang (✉)
Department of Burn and Plastic Surgery, Guizhou Provincial People's Hospital, Guiyang, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_29

Fig. 29.3 Design of chimeric lobulated skin flaps

Fig. 29.4 Palmar appearance after skin flap transplantation

29.3 Operative Technique

In the first step, we used Doppler to detect the perforators of the lateral circumflex femoral artery and mark them. We designed a lobulated skin flap according to the perforators. The width of the flap was controlled within 8 cm (Fig. 29.3).

In the second step, we completely debrided again and found the radial artery and the accompanying vein of the hand as the supplying vessels of the anterolateral femoral skin flap. Meanwhile, another group of surgeons incised the skin along the flap design line to find out the cutaneous perforating branch of the lateral circumflex femoral artery. We carefully dissected the perforator vessels and traced the main trunk. At the same time, a small amount of muscle was carried at the distal end of the main artery to reconstruct the thenar muscle. The nerves innervating the lateral femoral muscle should be protected while dissecting the perforator vessels. When the chimeric skin flap was successfully cut off, it was moved to the recipient area and the lobulation was adjusted again according to the shape of the wound (Figs. 29.4 and 29.5). The proximal and distal extensor tendons were anastomosed after fascia lata was harvested and sliced. After simple fixing and suturing the skin, the arteries and accompanying veins of the flap were anastomosed with the radial artery and accompanying veins of the recipient area under the microscope. The anastomosis portion of arteries and veins was 1:2. The hand should be fixed in a straight position with plaster after ascertaining the good blood supply of the flaps. At the same time, another group of surgeons repaired the muscles of the donor site (Fig. 29.6) and closed and sutured skin after subcutaneous separation. The patient was followed up for 3 years. There was no depression in the thenar region, and the appearance and function of the wrist recovered well (Figs. 29.7, 29.8, and 29.9). There was linear scarring in the donor site (Fig. 29.10).

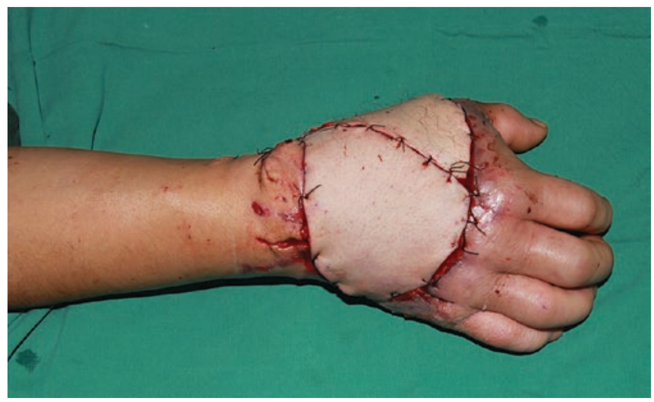


Fig. 29.5 The appearance of the dorsum of hand after skin flap transplantation

Fig. 29.6 Direct suture of donor site after the operation

29.4 Clinical Implications

The high-energy injury of the upper limb usually causes local skin irregular defect and tendon tissue necrosis. The lobulated skin flap was a reliable method to reduce donor

Fig. 29.7 The appearance of skin flap after 3 years

Fig. 29.8 The appearance of skin flap after 3 years

Fig. 29.9 There is no depression in the thenar region after 3 years

damage and avoid skin graft [1]. At the same time, it conforms to the economic principle of skin flaps. The lateral circumflex femoral artery has multiple perforating branches in the anterolateral femoral region, including descending to the trunk, horizontal branches, and ascending branches [2, 3]. The lobulated skin flap of the lateral circumflex femoral artery perforator can convert the "length" and "width" of the flap into each other through different types of perforators so

Fig. 29.10 Linear scar in donor site after 3 years

as to repair the irregular receiving area and minimize the damage to the donor area and obtain the maximum functional recovery and the best shape [4, 5]. The flap can carry a variety of complex tissues such as muscle and fascia, and the fascia lata can be carried in the first stage to repair the tendon defect so as to avoid reoperation and reduce the patient's injury [6, 7]. The patients were allowed to exercise in the early stages to reduce the likelihood of joint stiffness and disability. Therefore, it is suitable for patients with multi-site skin defects and tendon injuries caused by thermal compression injury and is a perfect way to repair large area irregular wounds at present.

References

1. Zhang W, Xie WG, Yang F, et al. Clinical application of lobulated transplantation of free anterolateral thigh perforator flap in the treatment of electric burns of limbs[J]. Chin J Burns. 2019;35(11):790–7.
2. Marsh DJ, Chana JS. Reconstruction of very large defects: a novel application of the double skin paddle anterolateral thigh flap design provides for primary donor-site closure[J]. J Plast Reconstr Aesthet Surg. 2010;63(1):120–5.
3. Yu P, Selber J. Perforator patterns of the anteromedial thigh flap.[J]. Plast Reconstr Surg. 2011;128(3):151e–7e.
4. Tayfur V, Magden O, Edizer M, Yonguc GN, Aksu F, Gocmen MN. Anatomy of the anteromedial thigh flap based on the oblique branch of the descending branch of the lateral circumflex femoral artery. Folia Morphol (Warsz). 2016;75(1):101–6.
5. Erh-Kang C. Betul, Ulusal, Ali, & Fu-Chanet al. Using the descending branch of the lateral femoral circumflex vessel as a source of two independent flaps. Plastic and reconstructive surgery. Plast Reconstr Surg. 2006;117(6):2059–63.
6. Vuksanovic-Bozaric A, Radojevic N, Muhovic D, Abramovic M, Radunovic M. Significance of anatomical variations of the lateral circumflex femoral artery for the tensor fasciae latae flapping. Folia Morphol (Warsz). 2015;74(3):389–95.
7. Kuo YR, Jeng SF, Kuo MH, Huang MN, Liu YT, Chiang YC, Yeh MC, Wei FC. Free anterolateral thigh flap for extremity reconstruction: clinical experience and functional assessment of donor site. Plast Reconstr Surg. 2001;107:1766–71.

30

The Waveform Design of Descending Branch of Lateral Circumflex Femoral Artery Perforator Flap for the Heel Defect Reconstruction

Juyu Tang and Ding Pan

30.1 Case Presentation

A 51-year-old man suffered from skin and soft-tissue defect at the right heel in a crush injury. In a local hospital, a skin grafting surgery was conducted but left a scar contracture, shortening of the Achilles tendon, and poor mobility of the ankle joint. The patient had pain in his heels and soles with limited walking (Figs. 30.1, 30.2, 30.3, and 30.4).

30.2 Choice of Treatment

Skin and soft tissue reconstruction on the heel is a challenge. Traditional techniques provide both local and free tissue transplantation options, such as medial plantar artery perforator (MPAP) flap transfer [1]. However, the MPAP flap is only suitable for small and medium wounds because the donor site is limited. In addition, when the medial plantar nerve is separated from the cutaneous nerve bundle of the flap, it is easy to damage the nerve bundle and cause sensory disturbance in the forefoot area and toe [2, 3].

Fig. 30.1 The patient had a skeletal scar at the heel and sole, with ankle flexion contracture (anteromedial view)

Fig. 30.2 The patient had a skeletal scar at the heel and sole, with ankle flexion contracture (posterolateral view)

Fig. 30.3 Wound surface after skeletal scar excision, ankle joint release, and Achilles tendon lengthening (anteromedial view)

J. Tang (✉) · D. Pan
Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China
e-mail: panding@csu.edu.cn

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_30

Fig. 30.4 Wound surface after skeletal scar excision, ankle joint release, and Achilles tendon lengthening (posterolateral view)

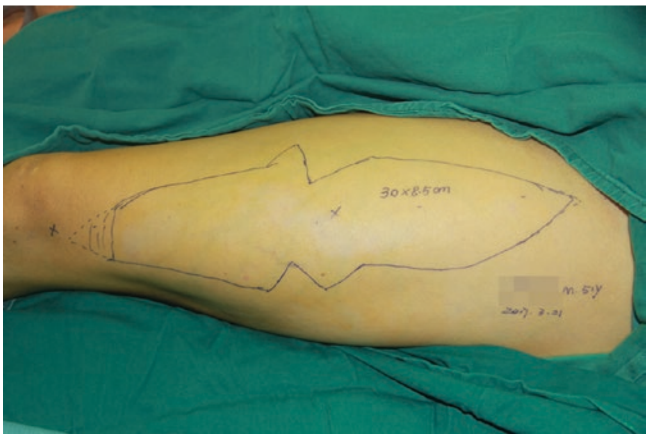


Fig. 30.5 Flap design

For a large area of heel defects and irregular wounds, our experience is using a waveform-free perforator flap. The most characteristic design of the flap is the flap waveform, which can perfectly reconstruct the shape of the heel and directly approach the donor site. The lateral femoral cutaneous nerve flap was taken. Then, the defect was covered with a skin flap, and the donor site was closed initially. For the wide wound, the donor site cannot be directly closed (Figs. 30.5, 30.6, 30.7, 30.8, 30.9, 30.10, and 30.11).

We use the waveform design of the descending branch of the lateral femoral circumflex artery perforator flap (db-LFCAP) to achieve the coverage of heel defect with primary closure of donor site. It provides a reconstruction with good contour and sensation for the heel. The patients were followed up for 18 months, with less complications and more satisfactory results. The most important thing is that the shape of the heel has been reconstructed close to normal (Figs. 30.12, 30.13, 30.14, 30.15, and 30.16).

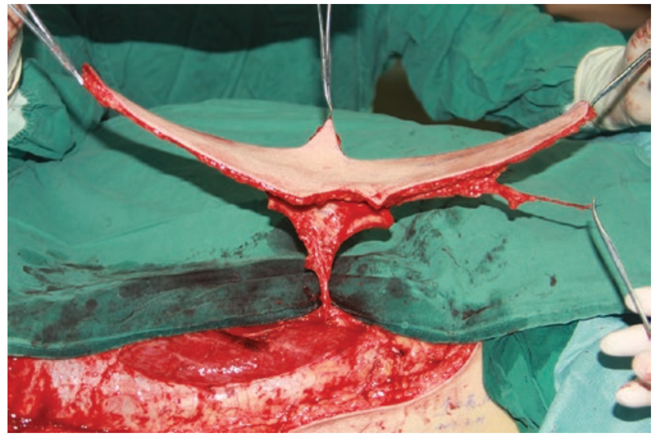


Fig. 30.6 Flap harvest

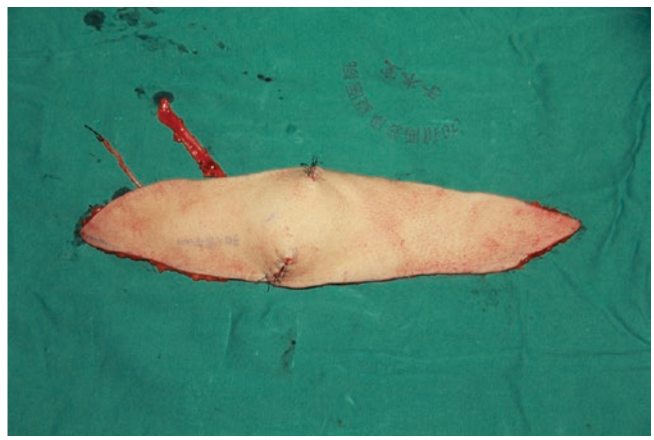


Fig. 30.7 The flap was formed into near heel appearance

Fig. 30.8 The appearance of the heel after transplantation (anteromedial view)

Fig. 30.9 The appearance of the heel after transplantation (posterolateral view)

Fig. 30.10 The appearance of the heel after transplantation (plantar view)

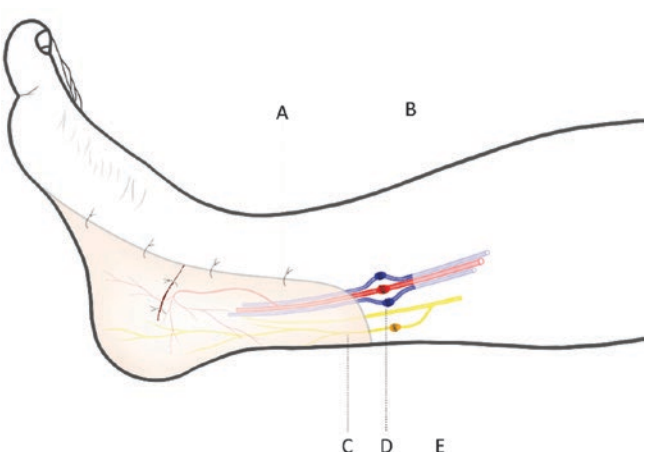


Fig. 30.11 The blood flow reconstruction. (**a**) Descending branch of lateral circumflex femoral artery and veins; (**b**) Posterior tibial artery and veins; (**c**) Lateral femoral cutaneous nerve; (**d**) Vascular anastomosis; (**e**) Tibial nerve

Fig. 30.12 The donor site was closed directly

Fig. 30.13 This patient was followed up 18 months (anteromedial view)

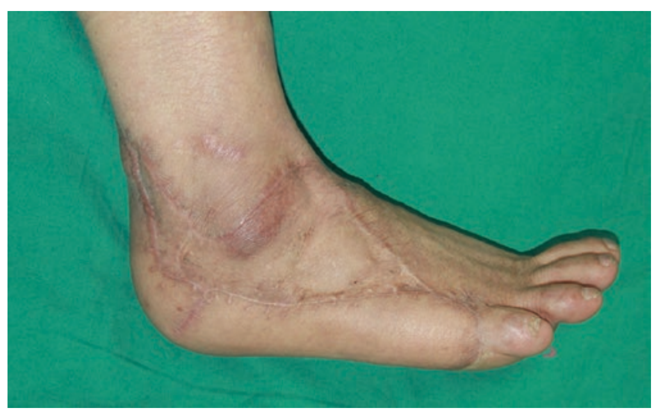


Fig. 30.14 This patient was followed up 18 months (posterolateral view)

Fig. 30.15 This patient was followed up 18 months (plantar view)

Fig. 30.16 The liner scar was left at the donor site at postoperative 18-month follow-up

30.3 Operative Technique

The imaging navigation of perforator flaps includes simple ultrasound Doppler, color Doppler ultrasound (whether using contrast agents), CTA (venography, arteriography), MRA, fluorescein angiography, DSA, and so on.

Harvesting the Perforator flaps is the key process of the operation. The anterograde and retrograde methods of skin flaps are used. The anterograde method refers to the initial exposure of the source vessels and then dissection of the perforators, which is totally a blind design. To our experience, we create and are accustomed to a retrograde four-side dissecting method, which we believe is simple, fast, and reliable. Following is an example of retrograde quadrilateral excision of the db-LFCAP.

First, dissect the first lateral in front of the surgeon, that is, the first side of the perforator, the surface of which is clearly exposed on the fascia lata, and then separate part of the lateral femoral muscle until the descending branch of the LFCA, and then dissect the second side. The section of the perforator vessels on the left side of the surgeon retains about 3 mm of the membrane tissue and was dissected in the same way on the third side, that is, the section of perforator vessels on the right side of the surgeon. At last, the medial edge of the flap was cut open, and the perforator was met from inside to outside on the fascia lata surface. Then, the fourth side of the perforator was dissected (facing the section of the first aid). The muscle sleeve was retained about 3 mm.

After complete hemostasis, a negative pressure drainage tube was placed deep into the donor site and below the layer of incised muscle tissue. The fascia lata, subcutaneous tissue, and skin were sutured in separated layers.

The flaps were transplanted to the recipient area. The descending branch of the lateral circumflex femoral artery was anastomosed with the recipient artery and vein, and the lateral femoral cutaneous nerve was anastomosed with the recipient sensory nerve. The changes in blood supply of the flaps were observed after the operation. The drugs such as spasmolysis, anticoagulation, dilatation, and antibiotics were used with supplement albumin and blood transfusion.

30.4 Clinical Implications

The db-LFCAP has many advantages, including: (1) relatively concealed donor site; (2) reliable blood supply and large cutting area of the flaps; (3) relatively constant perforators; (4) long pedicle and thick caliber of the vessels; and (5) a lateral femoral cutaneous nerve could be coaptated to reconstruct the sensation of the flaps and can also be used for bridging and repairing motor nerve defects, which is the most widely used skin flaps for micro-reconstruction of extremities and maxillofacial regions.

In addition, the use of this design can be made into a chimeric flap, especially for the patients with deep tissue defect or dead cavity in the heel [4]. If the patient is more obese, a micro-dissected thinning technique can be applied in the transplantation [5]. The flow-through technique can be used to bridge the vessel defect on the recipient area if necessary [6]. If we evaluate the maximum gain and loss ratio from the perspective of patients, the choice would be more individualized and precise [7].

References

1. Scaglioni MF, Rittirsch D, Giovanoli P. Reconstruction of the heel, middle foot sole, and plantar forefoot with the medial plantar artery perforator flap: clinical experience with 28 cases. Plast Reconstr Surg. 2018;141(1):200–8.
2. Mahmoud WH. Foot and ankle reconstruction using the distally based sural artery flap versus the medial plantar flap: a comparative study. J Foot Ankle Surg. 2017;56(3):514–8.
3. Macedo JLS, Rosa SC, Neto A, Silva AAD, Amorim ACS. Reconstruction of soft-tissue lesions of the foot with the use of the medial plantar flap. Rev Bras Ortop. 2017;52(6):699–704.

4. Song B, Chen J, Han Y, Hu Y, Su Y, Li Y, et al. The use of fabricated chimeric flap for reconstruction of extensive foot defects. Microsurgery. 2016;36(4):303–9.
5. Ince B, Yarar S, Dadaci M. Simultaneous flap thinning with ultrasound-assisted liposuction during free flap surgery: preliminary results. Microsurgery. 2019;39(2):144–9.
6. Qing L, Wu P, Yu F, Zhou Z, Tang J. Sequential chimeric deep circumflex iliac artery perforator flap and flow-through anterolateral thigh perforator flap for one-stage reconstruction of complex tissue defects. J Plast Reconstr Aesthet Surg. 2019;72:1091–9.
7. Zhang YX, Hayakawa TJ, Levin LS, Hallock GG, Lazzeri D. The economy in autologous tissue transfer: part 1. The kiss flap technique. Plast Reconstr Surg. 2016;137(3):1018–30.

31 Chimeric Peroneal Artery Perforator Flap for Reconstruction Post-traumatic Osteomyelitis of the Tibia

Juyu Tang and Panfeng Wu

31.1 Case Presentation

A 24-year-old man was injured in a car accident, suffering from an open fracture of the right tibia and fibula. Fracture reduction and plate internal fixation were performed in a local hospital. The wound remained non-union after the operation with plate exposed and repeated purulence lasting for 3 years. After removing the steel plate, there was a soft-tissue defect on the medial of the right leg. On the tibial, there was evident osteonecrosis without a blood supply and absence of callus growth at the fracture end.

31.2 Choice of Treatment

To our experience, the patients need thorough debridement, infection control, effective soft tissue coverage, bone defect reconstruction, and systemic support treatment. For composite tissue defects with bone involved, antibiotic treatment is fundamental. At the same time, it is necessary to reconstruct the bone defect. In this case, a thin skin flap is needed to cover the wound on the leg, and a large bone flap transplantation is needed to reconstruct the osseous mechanical support and control the deep infection. There are several options in clinical practice, such as chimeric peroneal artery perforator flaps [1].

31.2.1 A Phased Operation Was Performed

In the first stage, thorough debridement of soft tissues and bone around the fracture end was operated until fresh bleeding appeared on the bone surface, followed by an external fixator, and coverage with Vacuum sealing drainage (VSD) on the wound.

J. Tang (✉) · P. Wu
Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

One week later (the second stage), a contralateral chimeric peroneal artery perforator flap was transplanted to repair the wounded leg. The fracture site was fixed with an external fixator, and the transplanted vascularized fibula was stuck in and filled bone defect.

After 9 months (the third stage), with the healing of the fibula, the external fixator was removed and fixed with braces, and weight-bearing training was gradually carried out.

Twelve months later (the fourth stage), the fracture site was completely healed, the flap obtained stable survival, and the patient walked freely without the brace.

31.3 Operative Technique

The chimeric peroneal artery perforator flap was designed in the middle and upper leg [2]. The fibula was used as the longitudinal axis of the incision, and the skin flaps were designed according to the area of skin defect in the recipient area plus about 0.5 cm. The proximal tip of the flap is marked in the neck of the fibula. The area of skin flaps was 23 cm × 10 cm, and the length of the fibular flap was 15 cm.

31.3.1 Posterior Incision

Draw the size of the skin flaps on the skin with gentian violet. First, the posterior edge of the flap was cut on the skin and then directly to the deep fascia. The separation moves from the deep side of the deep fascia to the gastrocnemius and soleus muscles and then forward, during which attention should be paid that not entering the subcutaneous tissue, but only in the deep fascia layer, so as not to damage the blood supply. When separating to the posterior edge of the fibula, special attention should be paid to the branches perforating to the skin (several circular arteries slightly distal to the bottom of the soleus muscle attached to the fibula), which penetrate deep fascia from the posterior edge of the fibula into

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_31

the subcutaneous tissue. Otherwise, the injury will cause necrosis of the skin flap. About 0.5 cm from the posterior side of the cutaneous perforator, the soleus muscle was longitudinally cut and pulled back to expose the fibular artery and vein. The vascular bundle was separated upward to the posterior tibial artery and vein and downward to the arch of the flexor longus tendon. According to the length of transplanted fibula needed in the recipient area, the fibula was cut by a wire saw and then rotated forward. The flexor longus muscle was cut along the peroneal artery and vein until the distal end of the fibula graft was cut off. The peroneal artery and vein were ligated and cut off at this level.

The incision of the front edge of the flap is deep to the deep fascia. From the deep side of the deep fascia to the extensors of the lower leg and between the long and short fibula, the flap is separated backward to the posterior edge of the long fibula. After protecting the common peroneal nerve, the anterior fibular muscles were cut in turn, and 3–4 mm thick muscle fibers were reserved on the fibula. The fibula was rotated backward and the interosseous membrane was cut longitudinally. The transplanted fibula segment was pulled outward to achieve clear exposure of the tibial nerve. The posterior tibial muscle was cut outward, and the thickness of the fibula muscle fibers attached to the fibula was retained about 5 mm to protect the fibula nutrient vessels, periosteal branches, and annular arteries from the fibula artery and vein. When the posterior tibial muscle is cut, the direction of the fibular artery and vein should be recognized frequently so as not to be injured by mistake. After the posterior tibial muscle was divided, the fibular skin flap was completely free except that it was connected with the peroneal artery and vein.

After suturing and loosening the pneumatic tourniquet, the flaps turned from pale to ruddy gradually, with active hemorrhage at the skin margin, good capillary filling, and continuous exudation of blood from muscles and marrow cavity, suggesting a good blood supply of the bone and skin flaps. The proximal peroneal artery and vein can be cut off, ligated, and transferred to the recipient area after the operation on recipient area is completed. After complete hemostasis, fascia, subcutaneous tissue, and skin were sutured. Due to the removal of the fibula and some muscles, incisions can usually be sutured directly. If the suture is difficult, medium-thickness skin graft can be used to cover the wound.

31.4 Clinical Implications

The fibula is long enough to provide 20–26 cm bone length. The free fibula flap pedicled with the peroneal artery and vein has the advantages of sufficient blood supply, strong anti-infection ability, easy to shape, simultaneous implantation, constant anatomy, good matching with the recipient area blood vessel caliber, easy to anastomose successfully, long vascular pedicle, and so on [3]. It can be used as the main donor site for the long bone defect. The peroneal artery chimeric perforator flaps are suitable for the primary reconstruction of large bone defects with skin and soft tissue defects (Figs. 31.1, 31.2, 31.3, 31.4, 31.5, 31.6, 31.7, 31.8, and 31.9).

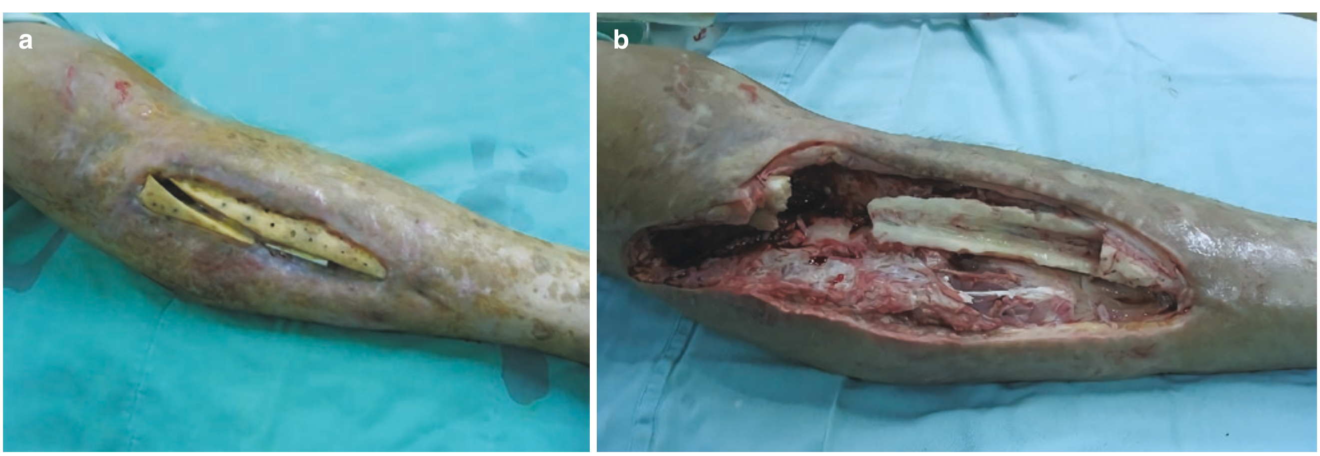


Fig. 31.1 Patient at admission. (**a**) Before debridement (bone necrosis with bone and plate exposure); (**b**) After debridement (large tibial defect with large area of skin and soft tissue defect)

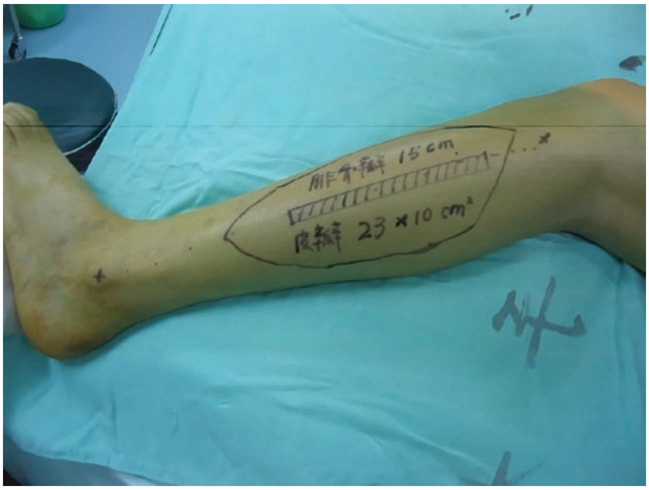


Fig. 31.2 Flap design

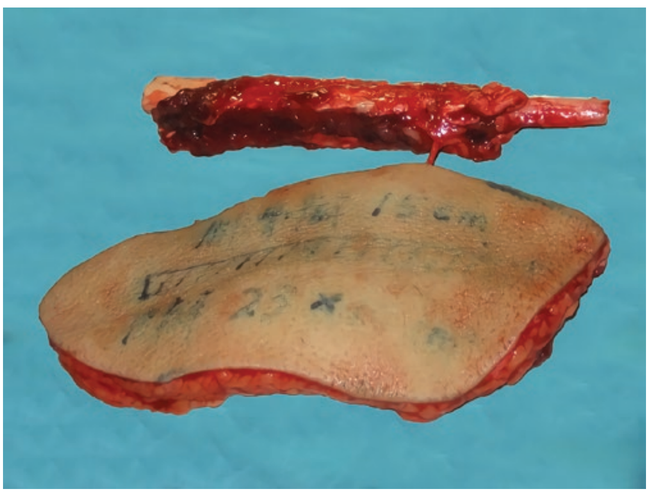


Fig. 31.3 Flap harvest (the arrow shows the perforating branch of the peroneal artery)

Fig. 31.5 Radiographs of the fracture (2 months postoperatively)

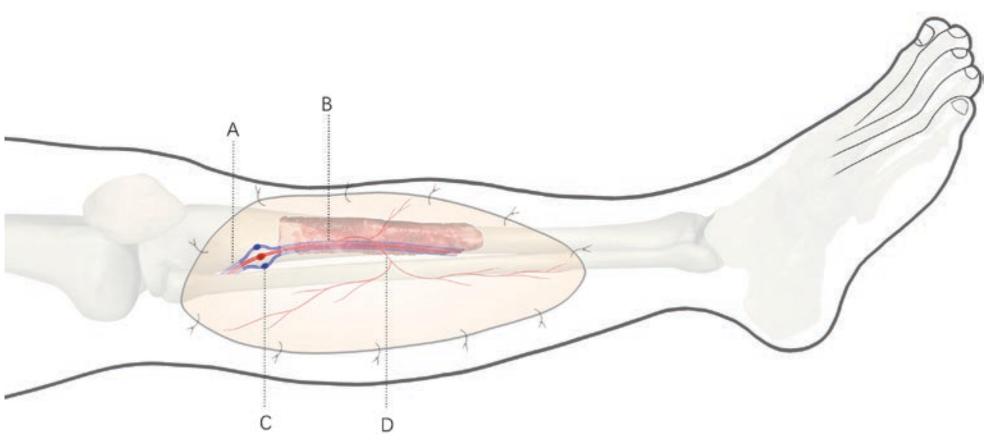


Fig. 31.4 Diagrammatic sketch of blood flow reconstruction. (**a**) Anterior tibial artery and veins; (**b**) Peroneal artery and veins; (**c**) Vascular anastomosis; (**d**) Musculocutaneous perforator of peroneal artery

Fig. 31.6 Radiographs of the fracture (9 months postoperatively). After fracture healing, the fixator was removed, and no displacement occurred again

Fig. 31.7 The wound healed well (9 months postoperatively)

Fig. 31.8 3 years after the operation, the X-ray films showed that the fibula and tibia were fused together

Fig. 31.9 Three years after operation, the shape of the lower leg was well

References

1. Awad ME, Altman A, Elrefai R, Shipman P, Looney S, Elsalanty M. The use of vascularized fibula flap in mandibular reconstruction; a comprehensive systematic review and meta-analysis of the observational studies. J Craniomaxillofac Surg. 2019;34(6):165–72.
2. Abou-Foul AK, Fasanmade A, Prabhu S, Borumandi F. Anatomy of the vasculature of the lower leg and harvest of a fibular flap: a systematic review. Br J Oral Maxillofac Surg. 2017;55(9):904–10.
3. Abou-Foul AK, Borumandi F. Anatomical variants of lower limb vasculature and implications for free fibula flap: systematic review and critical analysis. Microsurgery. 2016;36(2):165–72.

Dual Skin Paddles Descending Branch of the Lateral Circumflex Femoral Artery Perforator Flap for One-Staged Reconstruction of Two Adjacent Wounds

32

Juyu Tang and Liming Qing

32.1 Case Presentation

A 53-year-old male presented with a traffic accident that caused two separated skin and soft-tissue defects at the right foot. A dorsal wound and a medial foot wound were left after radical debridement. There are exposure of deep important structure, such as extensor tendon and bone. Moreover, there were multiple fractures of the foot, including Lisfranc, the fourth metatarsal neck, and fifth metatarsal neck.

32.2 Choice of Treatment

The patient needs enough soft tissue for coverage of the two separated defects in a single procedure and simultaneously achieve skeletal fixation to repair walking capacity. In this context, harvesting of multiple flaps for reconstruction of multiple soft-tissue defects in one operation is frequently adopted [1, 2]. However, for a multiple flap transfer, additional requirements for another group of recipient vessels or a flow-through flap to revascularize the second free flap is needed. In addition, it is extremely time-consuming for added microsurgical anastomosis. Furthermore, harvesting multiple flaps is associated with higher donor site morbidities [3–5].

In this case, we preferred to choose the dual skin paddles perforator flap. The dual skin paddles perforator flap refers to a kind of flap design in which each skin paddle is supplied by its separate perforator, and both perforators share the same source vessel [6]. The use of this flap just needs to sacrifice one donor site to obtain two skin paddles for the defect reconstruction; moreover, only one pair of vessels was required for microsurgical anastomosis. This approach can not only shorten the operation time but also reduce the donor site morbidities.

J. Tang (✉) · L. Qing
Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China
e-mail: qingliming@csu.edu.cn

32.3 Operative Technique

32.3.1 Flap Design

In the first stage, thorough debridement was conducted. Vacuum sealing drainage (VSD) was applied to cover the wound. The second stage procedure was performed a week later, and the dual skin paddles descending branch of the lateral circumflex femoral artery perforator flap (db-LCFAP) was designed and harvested to recover the soft-tissue defects. The feasibility of the dual skin paddles db-LCFAP hinges on the occurrence of at least two proper perforators, the suitable vascular pedicle length between the paddles and each perforator drains into the same source vessel [7, 8]. With regards to this concern, a preoperative thigh computed tomography-assisted angiography (CTA) scan is of great benefit.

After complete debridement, two paper templates of the same size as the defect were created. Two paddles were designed based on the separate perforators of the descending branch of the lateral circumflex femoral vessel (LCFV). The dual skin paddles db-LCFAP is designed to have two independent skin islands supplied by different perforators that share the same original vessel, usually the descending branch of LCFV. Notably, the pedicle length between the paddles and the trunk pedicle length should be fully assessed to minimize the pedicle tension and twisting.

32.3.2 Flap Harvesting

Patients were placed in the supine position with the leg straight in a neutral position. The flap was outlined on the anterolateral thigh according to the templates above.

To avoid a failed elevation, the flap incision is focused on one edge of a paddle since the perforator location may errors. In this way, the location of the skin paddle could be altered according to the position of the selected perforator. The flap was harvest at the superficial plane. Encountered

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_32

perforators should be reserved in the flap before the main perforator of each skin paddle been recognized. Additionally, the pedicle length between the main perforators should also be considered to minimize the restriction for the free rotation of the skin paddle. Afterward, the deep fasica was incised to trace the perforator origin. In this step, the incision of the deep fasica should be wide enough to gain full exposure and avoid unexpected damage to the perforator vessels [8, 9]. Subsequently, dissection of the intramuscular course of the perforator vessel comes to be the hardest task. The surgeon wears a loupe magnification to carefully dissect the perforator vessels in this step. To avoid injury to the perforator, a 3-mm wide facia around the perforator should be reserved. After that, the medial incision of the flap was made, and the flap was raised at the superficial layer in a medial to the lateral direction. The dissection was temporarily ceased when reached the perforator vessel. It is noteworthy that the dissection should be performed at least 1–2 mm away from the perforator to avoid accidental injury to the perforator and provide an operational space for the hemostasis of oozing or persistent bleeding. The perforator pedicle was patiently dissected retrograde toward the main trunk of the descending branch of the lateral circumflex femoral artery (LCFA) until proper pedicle length was available. Afterward, confirm the blood supply of each perforator in each paddle by clamping other perforators. Do not split two paddles between the perforators before suitable perforators are recognized.

After flap was transferred, the donor site was closed primarily after complete hemostasis and reliable wound drainage.

32.4 Clinical Implication

For reconstruction of nonadjacent defects, the split paddles can be three-dimensional inset with more degrees of freedom. However, the vascular pedicle length between the paddles and the trunk pedicle length should be fully assessed and considered to reduce the pedicle tension and twisting. The dual skin paddles db-LCFAP is a reliable choice for the reconstruction of multiple adjacent defects at one stage. It provides two independent skin paddles to reconstruct the defects and minimize the donor site morbidities to the greatest extent possible. This approach has the advantages of flexible, numerous skin paddles available, maximal freedom, and a large cutaneous area (Figs. 32.1, 32.2, 32.3, and 32.4).

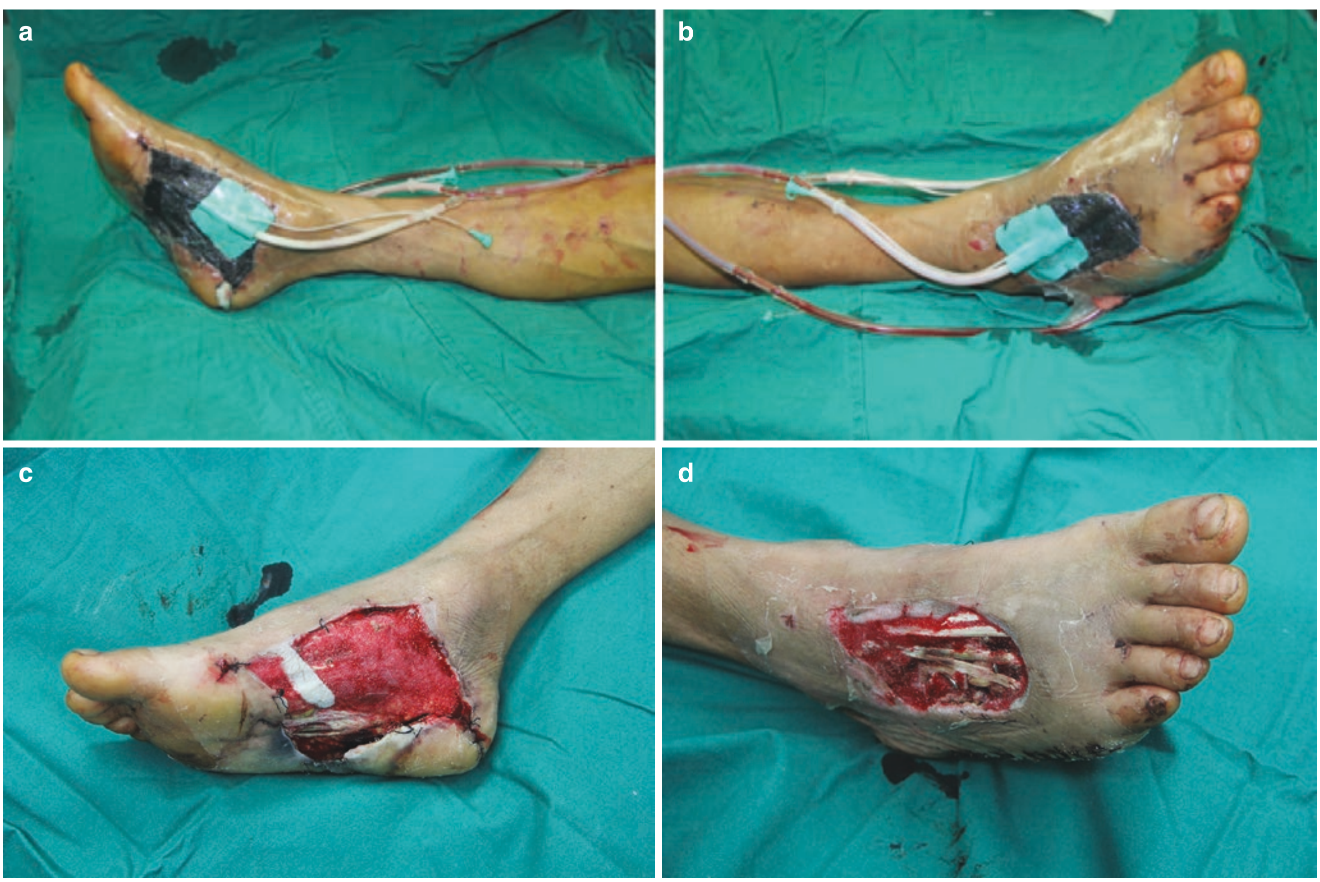


Fig. 32.1 (**a**, **b**) A 53-year-old male who suffered a traffic accident and presented with two separate soft-tissue defects in the right foot. Vacuum sealing drainage (VSD) was performed over the wound for 1 week. (**c**, **d**) Complete debridement was conducted and left the exposure of tendons and bones

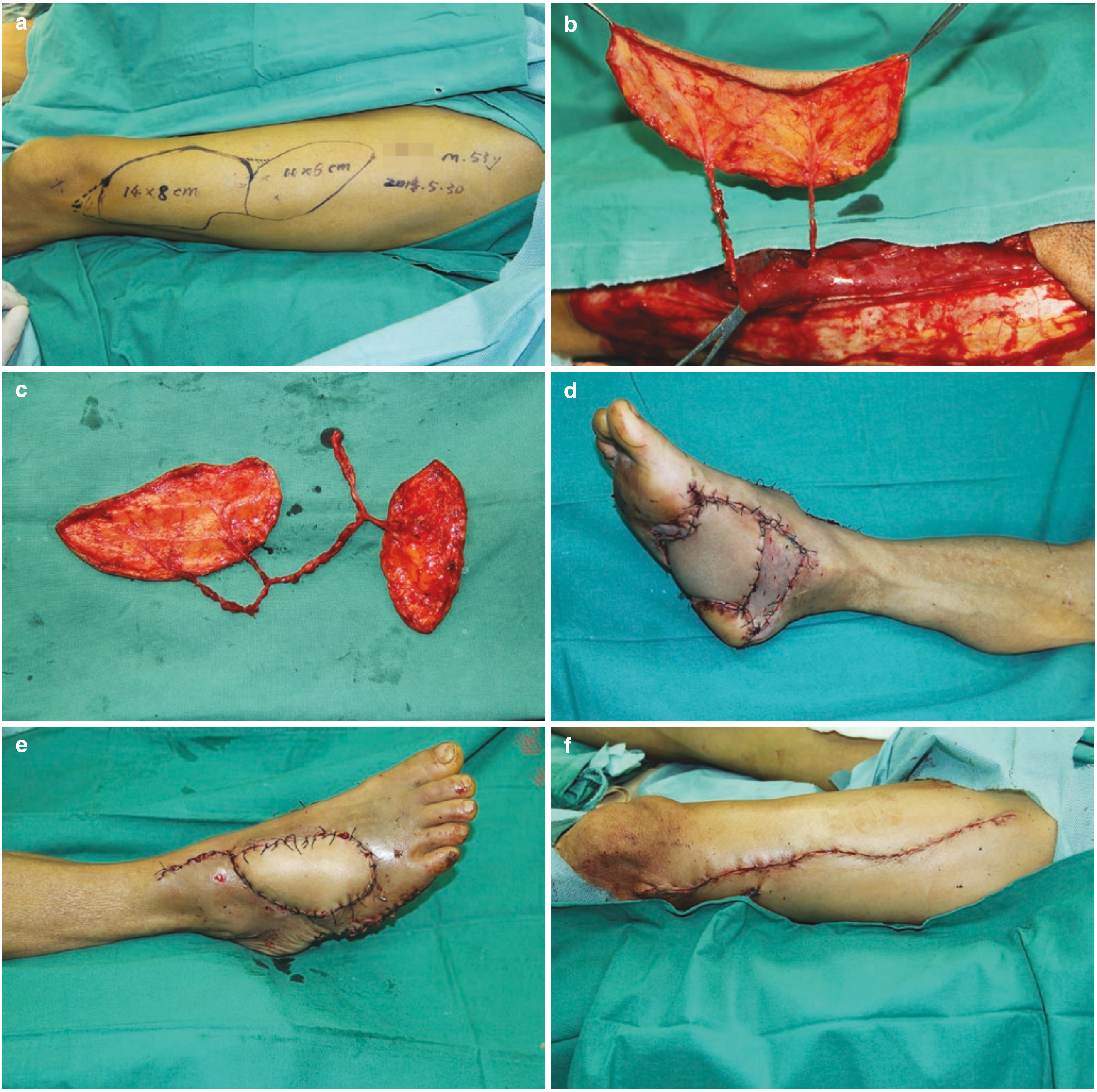
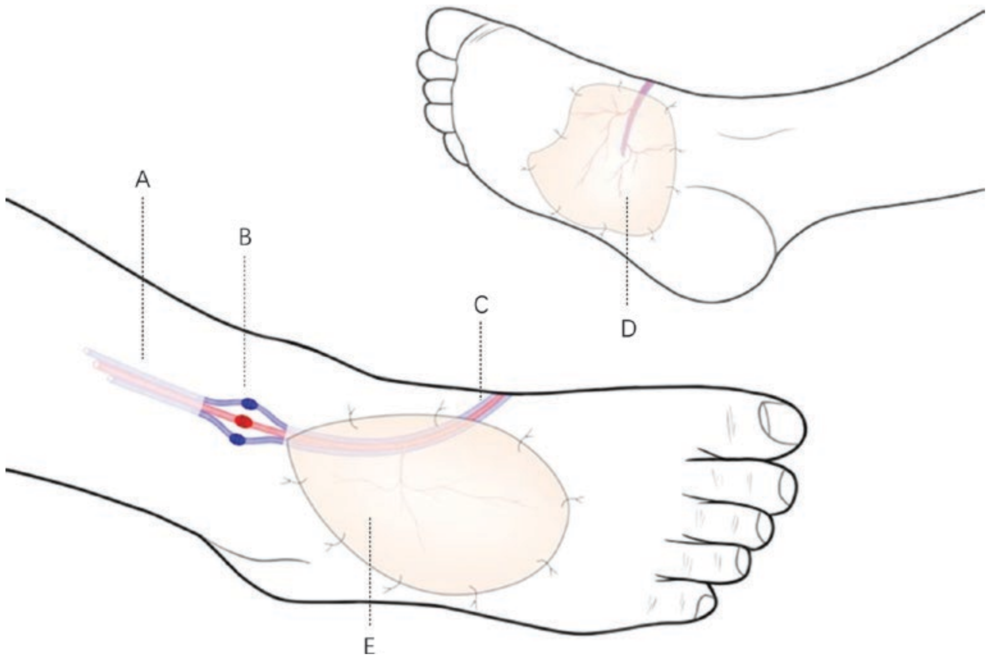


Fig. 32.2 (**a**) A dual skin paddles db-LCFAP was designed to cover the soft-tissue defect at one stage. The size of the skin paddle was 14 cm × 8 cm and 11 cm × 6 cm, respectively. (**b**, **c**) Intraoperative view after the elevation of a dual skin paddle db-LCFAP. The effective vascular pedicle length between the paddles and the trunk pedicle length has been dissected. (**d**, **e**) Postoperative view of the recipient site; (**f**) The donor site was closed directly

Fig. 32.3 Diagrammatic sketch of the operation. (**a**) Anterior tibial artery and veins; (**b**) Vascular anastomosis; (**c**) Descending branch of the lateral circumflex femoral artery and veins; (**d**) Flap 1; (**e**) Flap 2



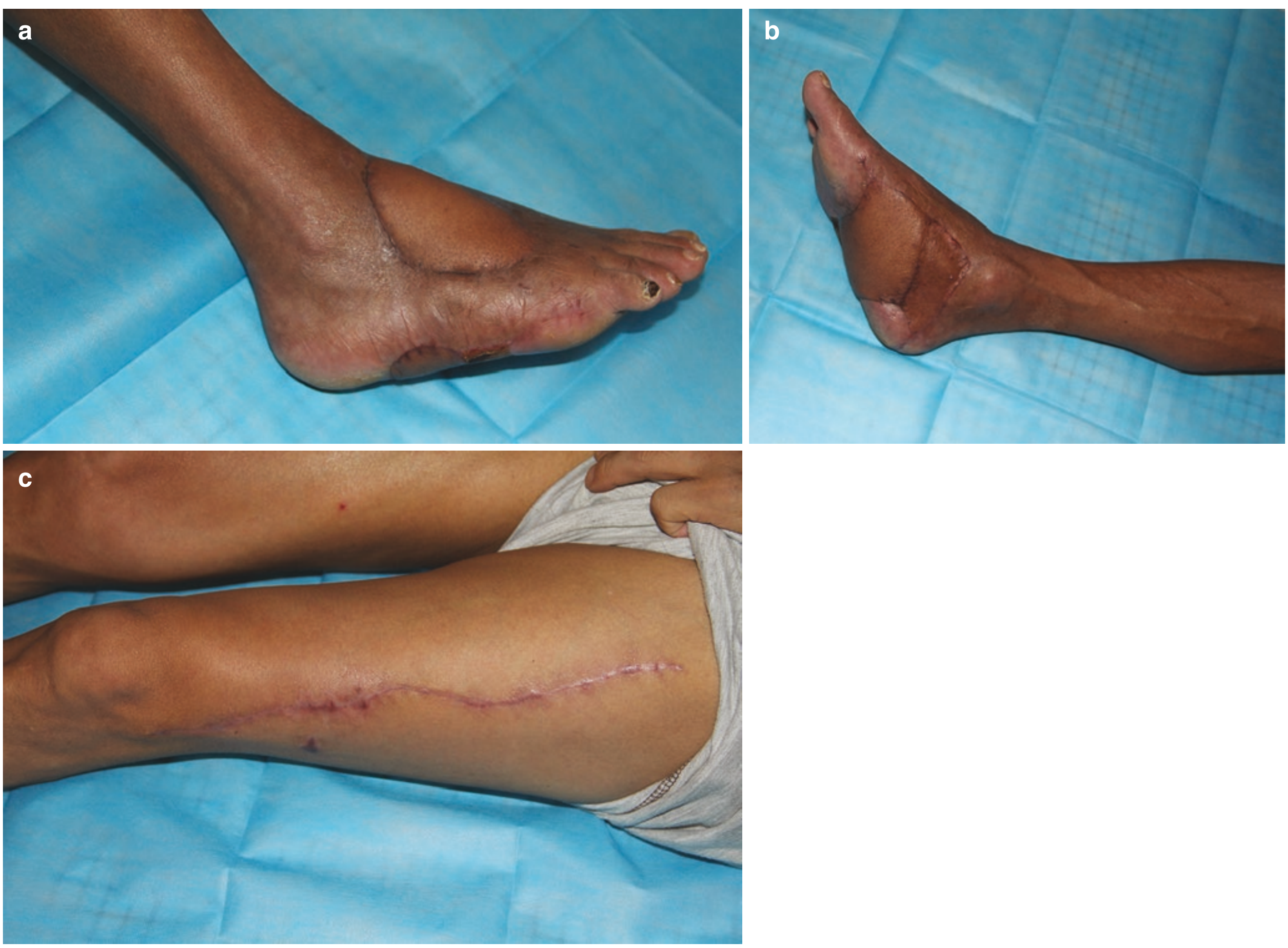


Fig. 32.4 (**a**–**c**) Postoperative view of the recipient site and donor site at 14-month follow-up. The recipient site showed satisfactory contour, and there was no excessive bulk; only a scar line was left at the donor site

References

1. Zelken JA, Chang NJ, Wei FC, Lin CH. The combined ALT-groin flap for the mutilated and degloved hand. Injury. 2015;46:1591–6.
2. Xu Z, Zhao XP, Yan TL, et al. A 10-year retrospective study of free anterolateral thigh flap application in 872 head and neck tumour cases. Int J Oral Maxillofac Surg. 2015;44:1088–94.
3. Qing L, Wu P, Liang J, et al. Use of flow-through anterolateral thigh perforator flaps in reconstruction of complex extremity defects. J Reconstr Microsurg. 2015;31:571–8.
4. Olivan MV, Busnardo FF, Faria JC, et al. Chimerical anterolateral thigh flap for plantar reconstruction. Microsurgery. 2015;35:546–52.
5. Miyamoto S, Fujiki M, Nakatani F, Sakisaka M, Sakuraba M. Free flow-through anterolateral thigh flap for complex knee defect including the popliteal artery. Microsurgery. 2015;35:485–8.
6. Qing L, Wu P, Yu F, Zhou Z, Tang J. Use of dual-skin paddle anterolateral thigh perforator flaps in the reconstruction of complex defect of the foot and ankle. J Plast Reconstr Aesthet Surg. 2018;35:546–52.
7. Loeffelbein DJ, Holzle F, Wolff KD. Double-skin paddle perforator flap from the lateral lower leg for reconstruction of through-and-through cheek defect - a report of two cases. Int J Oral Maxillofac Surg. 2006;35:1016–20.
8. Tsai FC, Yang JY, Mardini S, Chuang SS, Wei FC. Free split-cutaneous perforator flaps procured using a three-dimensional harvest technique for the reconstruction of postburn contracture defects. Plast Reconstr Surg. 2004;113:185–93. discussion 94-5
9. Marsh DJ, Chana JS. Reconstruction of very large defects: a novel application of the double skin paddle anterolateral thigh flap design provides for primary donor-site closure. J Plast Reconstr Aesthet Surg. 2010;63:120–5.

33 Dual Skin Paddles Descending Branch of the Lateral Circumflex Femoral Artery Perforator Flap for Reconstruction of Extensive Foot Defects

Juyu Tang and Liming Qing

33.1 Case Presentation

A 16-year-old male suffered a traffic injury and led to extensive soft-tissue defects at the left foot. About 227 cm^2 skin defects and exposure of Achilles tendon and calcaneal bone need to be repaired at the heel after radical debridement.

33.2 Choice of Treatment

Reconstruction of extensive soft-tissue defects in the foot has always been a challenging issue for reconstructive surgeons, especially those involving exposure of tendon, bone, or joint [1, 2]. A variety of repair strategies have been reported in the reconstruction of complex defects of the foot, including local cutaneous flaps, pedicled fasciocutaneous flaps, pedicled muscle flaps, and microsurgical free flaps [1–5]. However, limited dimensions of soft tissue and less versatile design restrict the application of regional and pedicled flaps to recover the large defects at the foot [6]. To overcome the drawbacks of the conventional flap, multiple flaps transfer to reconstruct complex defects in a single operation are frequently applied [7, 8]. However, multiple flaps transfer meaning that additional recipient vessels or a flow-through flap to revascularize the second free flap is required. Moreover, it is time-consuming to perform added microsurgical anastomosis. Besides, harvesting additional flap is related to higher donor site morbidities [9–11].

Dual skin paddles perforator flap was defined as an alternative method for extensive defects reconstruction, and outcomes are usually satisfied [12–15]. The dual skin paddles perforator flap is designed such that each skin paddle is supplied by a separate perforator and both perforators come from the same source vessel. When this technique is used to repair a wider defect, the main principle of the dual skin paddles perforator flap is converting the wound width into the flap length. The separated skin paddles can be placed side by side and thus result in a single wider and unified flap. Therefore, in the present case, we performed a dual skin paddles perforator flap to repair the extensive foot defects.

33.3 Operative Technique

33.3.1 Flap Design

In the first stage, radical debridement was conducted. Vacuum sealing drainage (VSD) was applied over the wound. The second stage procedure was performed a week later, and the dual skin paddles descending branch of the lateral circumflex femoral artery perforator flap (db-LCFAP) was raised to reconstruct the soft-tissue defect. The feasibility of the dual skin paddles db-LCFAP relies on the presence of at least two proper perforators, the suitable vascular pedicle length between the paddles, and each perforator drains into the same source vessel [16, 17]. Considering this, a preoperative thigh computed tomography-assisted angiography (CTA) scan can be beneficial.

After thorough debridement, a paper template with the same dimension as the defect was made. A pinch test was adopted to assess the available skin dimension at donor sites. Then, dual paddles were designed and depicted based on the various perforators of the descending branch of the lateral circumflex femoral vessel (LCFV), considering the wound shape and size and the skin laxity of the anterolateral thigh as well. Notably, the dual skin paddles db-LCFAP have two independent skin islands supplied by different perforators, and the perforators derive from the same source vessel, most generally being the descending branch of LCFV.

J. Tang (✉) · L. Qing
Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_33

33.3.2 Flap Harvesting

Patients were placed in the supine position with the leg straight in a neutral position. The flap was outlined on the anterolateral thigh based on the perforators mapped and three-dimensional features of the wound.

To avoid failure, the flap incision is focused on one edge of a paddle because the perforator location may error. In this way, the location of the skin paddle could be adjusted according to the position of the selected perforator. The flap was raised at the superficial layer. Encountered perforators should be reserved in the flap before the main perforator of each skin paddle been recognized. Additionally, the pedicle length between the main perforators should also be considered to minimize the restriction for the free rotation of the skin paddle. Afterward, the deep fascia was incised to trace the perforator origin. In this step, the incision of the deep fascia should be wide enough to gain full exposure and avoid unexpected damage to the perforator vessels [17, 18]. Subsequently, dissection of the intramuscular course of the perforator vessel comes to be the hardest task. The surgeon wears a loupe magnification to carefully dissect the perforator vessels in this step. To avoid injury to the perforator, a 3-mm wide facia around the perforator should be reserved. After that, the medial incision of the flap was made, and the flap was raised at the superficial layer in a medial to lateral direction. The dissection was temporarily ceased when reached the perforator vessel. It is noteworthy that the dissection should be performed at least 1–2 mm away from the perforator to avoid accidental injury to the perforator and provide an operational space for the hemostasis of oozing or persistent bleeding. Besides, a sensory nerve anastomosis should be made to reconstruct the protectable sensory in the soft-tissue defect of the weight-bearing regions. The lateral femoral cutaneous nerve (LFCN) should be carried in the flap in order to repair the sensory in the weight-bearing regions. The perforator pedicle was patiently dissected retrograde toward the main trunk of the descending branch of the lateral circumflex femoral artery (LCFA) until proper pedicle length was available. Afterward, confirm the blood supply of each perforator in each paddle by clamping other perforators. Do not split two paddles between the perforators before suitable perforators are recognized.

After flap was transferred, the donor site was closed primarily after complete hemostasis and reliable wound drainage.

To recover the extensive soft-tissue defects, the two skin paddles are placed side by side to extend the width of the flap. This approach allows the db-LCFAP to be adopted for the reconstruction of large defects while ensuring direct closure of the donor site. We have also performed the sensory nerve coaptation in those flaps when the reconstruction of the soft-tissue defect was performed in the weight-bearing regions.

33.4 Clinical Implication

The approach of dual skin paddles db-LCFAP has several advantages. First, the flap can be designed to fit the defect well without the limitation of having a traditional flap fashion. Second, the separate skin paddles can be inserted more freely with various degrees and thus improve the aesthetics of the recipient site. For extensive or irregular soft-tissue defects, separating the defects into several skin paddles takes advantage of geometrical shapes to fill the defect more accurately without excess tissue wasted. Furthermore, it allows the primary closure of the donor site to achieve fewer morbidities.

The dual skin paddles db-LCFAP is a reliable choice for the reconstruction of extensive soft-tissue defects at the foot. It provides two independent skin paddles for the reconstruction of large soft-tissue defects while minimizing donor site morbidities (Figs. 33.1, 33.2, 33.3, 33.4, and 33.5).

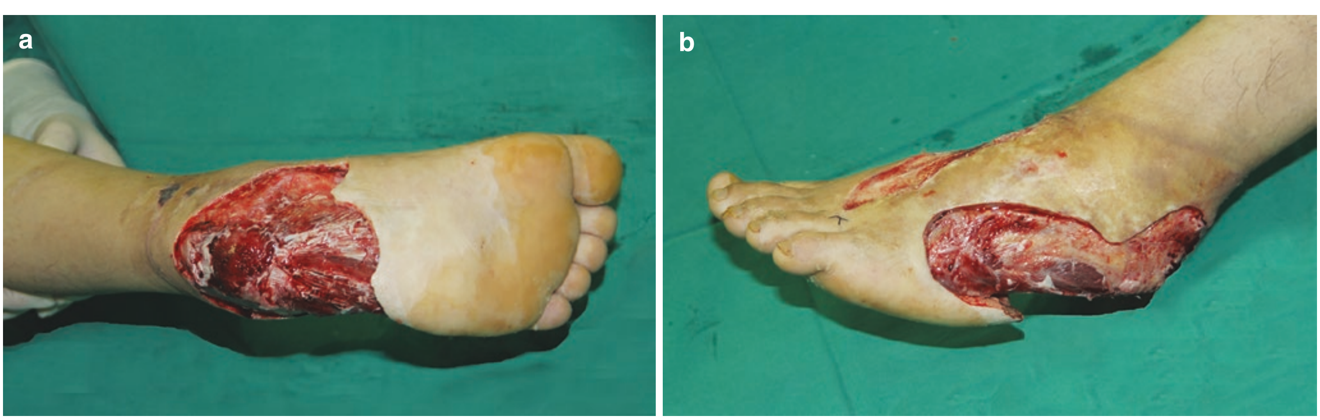


Fig. 33.1 (**a**, **b**) A 16-year-old male suffered a traffic injury that resulted in extensive soft-tissue defects at the left foot; (**c**) Dissection the medial calcaneal branches nerve for the reinnervation of flap; (**d**) Dissection the posterior tibial vessel for the recipient vessel

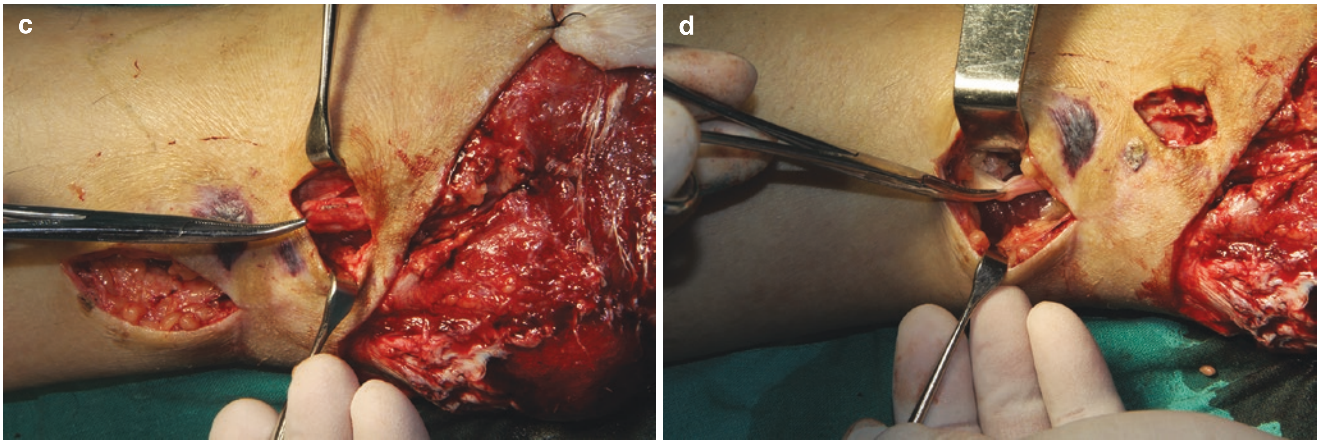


Fig. 33.1 (continued)

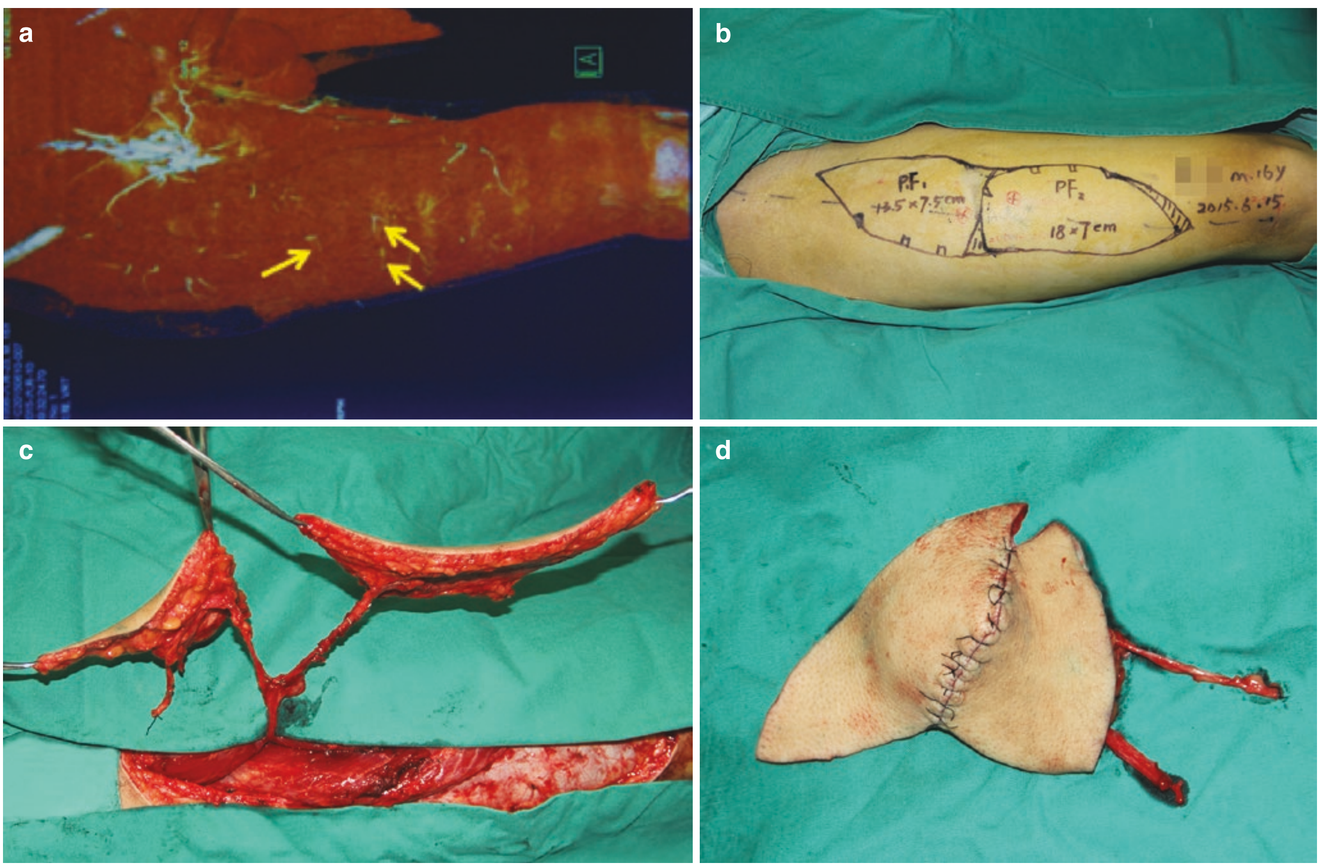


Fig. 33.2 (**a**, **b**) A catheter-based computed tomography-assisted angiography (CTA) scan has been performed preoperatively to map the location of the perforator. Three reliable perforator vessels were found in the donor site (as it was showed with yellow arrows). (**c**, **d**) Intraoperative view after the harvest of a dual skin paddles db-LCFAP. Two skin paddles were placed side by side to cover the defects. The two paddles were inset more freely improving the aesthetics of the recipient site. The LFCN was kept in the skin paddle which has been designed to cover the weight-bearing regions (shown by red arrows)

Fig. 33.3 (**a**, **b**) Postoperative view of the recipient site after the flap transfer; (**c**) The donor site was closed directly

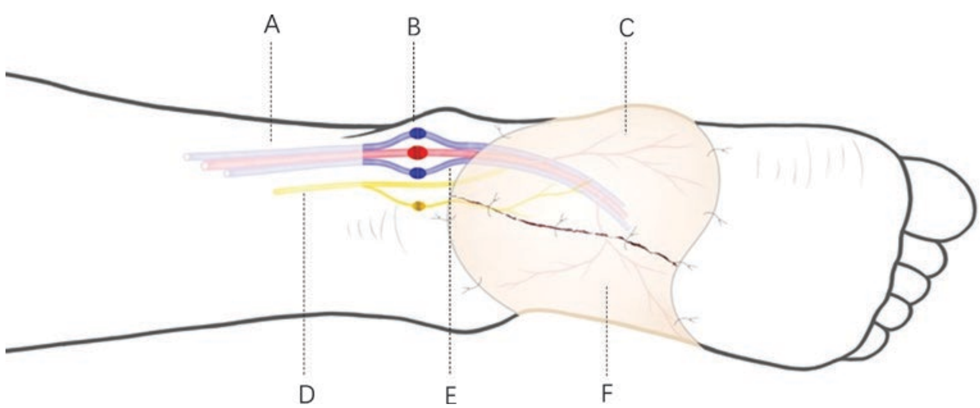


Fig. 33.4 Diagrammatic sketch of the operation. (**a**) Posterior tibial artery and veins; (**b**) Vascular anastomosis; (**c**) Flap 1; (**d**) Tibial nerve; (**e**) Descending branch of the lateral circumflex femoral artery and veins; (**f**) Flap 2

Fig. 33.5 Postoperative view of the recipient site and donor site at 12-month follow-up

References

1. Zhu YL, He XQ, Wang Y, et al. Traumatic forefoot reconstructions with free perforator flaps. J Foot Ankle Surg. 2015;54:1025–30.
2. Lee JH, Kang HW, Kim SM, Jun YJ, Kim YJ. Simultaneous reconstruction of forefoot and Hindfoot defects with a thoracodorsal-Axis chimeric flap. Arch Plast Surg. 2015;42:810–3.
3. Wang CY, Chai YM, Wen G, Han P, Cheng L. Superficial peroneal neurocutaneous flap based on an anterior tibial artery perforator for forefoot reconstruction. Ann Plast Surg. 2015;74:703–7.
4. Gunnarsson GL, Jackson IT, Westvik TS, Thomsen JB. The freestyle pedicle perforator flap: a new favorite for the reconstruction of moderate-sized defects of the torso and extremities. Eur J Plast Surg. 2015;38:31–6.
5. Tajsic N, Winkel R, Husum H. Distally based perforator flaps for reconstruction of post-traumatic defects of the lower leg and foot. A review of the anatomy and clinical outcomes. Injury. 2014;45:469–77.
6. Brunetti B, Tenna S, Aveta A, Segreto F, Persichetti P. Free-style local perforator flaps: versatility of the v-y design to reconstruct soft-tissue defects in the skin cancer population. Plast Reconstr Surg. 2013;132:451–60.
7. Zelken JA, Chang NJ, Wei FC, Lin CH. The combined ALT-groin flap for the mutilated and degloved hand. Injury. 2015;46:1591–6.
8. Xu Z, Zhao XP, Yan TL, et al. A 10-year retrospective study of free anterolateral thigh flap application in 872 head and neck tumour cases. Int J Oral Maxillofac Surg. 2015;44:1088–94.
9. Qing L, Wu P, Liang J, et al. Use of flow-through anterolateral thigh perforator flaps in reconstruction of complex extremity defects. J Reconstr Microsurg. 2015;31:571–8.
10. Olivan MV, Busnardo FF, Faria JC, et al. Chimerical anterolateral thigh flap for plantar reconstruction. Microsurgery. 2015;35:546–52.
11. Miyamoto S, Fujiki M, Nakatani F, Sakisaka M, Sakuraba M. Free flow-through anterolateral thigh flap for complex knee defect including the popliteal artery. Microsurgery. 2015;35:485–8.
12. Zhang YX, Xi W, Lazzeri D, et al. Bipaddle radial forearm flap for head and neck reconstruction. J Craniofac Surg. 2015;26:350–3.
13. Busnardo FF, Coltro PS, Olivan MV, et al. Anatomical comparison among the anterolateral thigh, the parascapular, and the lateral arm flaps. Microsurgery. 2015;35:387–92.
14. Wang X, Mei J, Pan J, et al. Reconstruction of distal limb defects with the free medial sural artery perforator flap. Plast Reconstr Surg. 2013;131:95–105.
15. Zhang YX, Messmer C, Pang FK, et al. A novel design of the multilobed latissimus dorsi myocutaneous flap to achieve primary donor-site closure in the reconstruction of large defects. Plast Reconstr Surg. 2013;131:752e–8e.
16. Loeffelbein DJ, Holzle F, Wolff KD. Double-skin paddle perforator flap from the lateral lower leg for reconstruction of through-and-through cheek defect - a report of two cases. Int J Oral Maxillofac Surg. 2006;35:1016–20.
17. Tsai FC, Yang JY, Mardini S, Chuang SS, Wei FC. Free split-cutaneous perforator flaps procured using a three-dimensional harvest technique for the reconstruction of postburn contracture defects. Plast Reconstr Surg. 2004;113:185–93. discussion 94-5
18. Marsh DJ, Chana JS. Reconstruction of very large defects: a novel application of the double skin paddle anterolateral thigh flap design provides for primary donor-site closure. J Plast Reconstr Aesthet Surg. 2010;63:120–5.

34 Treatment of Tibia GUSTILO IIIC Fractures by Bone Transfer Combined with the Flap Technique

Yabin Zhang, Lifeng Xia, and Shaokun Pei

With the rapid development of industry, the cases of high-energy injury are gradually increasing. Especially, the severe open comminuted fracture of the humerus is very common. Due to the anatomical characteristics of the calf, there is little soft tissue covering under the skin. After injury, it is often accompanied by large-area tissue damage and bone. Exposed, in the first stage, it is difficult to solve the problems of both soft tissue and bone defect at the same time, which are often needed to be treated by stages [1], and to deal with various tissue damages, respectively, to reach the best surgical results. The author had encountered a case of open fracture of the left tibia (GUSTILO IIIC type), in which solving all the problems simultaneously in the emergency treatment is very difficult due to the soft-tissue defect of the skin and vascular nerve injury. Meanwhile, due to skin soft-tissue defect, fracture with large segmental bone defect, and vascular nerve injury, the vascular nerve repair and external fixation of the fracture were adopted in the first stage, and when the patient's condition turned stable, the flap repair and the Ilizarov external fixator bone transfer were adopted next. As a result, the function of the patient's lower limb has achieved a satisfactory recovery.

34.1 Case Presentation

The patient was a 22-year-old male. On September 25, 2011, he was sent to our hospital with a "5-h restriction on pain and bleeding in the left lower limb caused by a car accident." The patient accidentally collided with an opposite truck when riding a motorcycle 5 h before admission. Suffering from pain in the left lower limb, with limited activity, he was sent to our hospital. Admission examination: A 15 cm × 40 cm skin soft-tissue defect was seen in the middle of the anterior side of the left calf. The wound tissue was contused obviously, the fracture end was exposed with bone mass, the left calf was deformed, the patient could not perform any active movement, and the left foot was pale, with low skin temperature, poor tension, and numb feeling (Fig. 34.1).

Given the severe injury on the left lower limb, skin defects of the soft tissue, comminuted fracture with a bone block with vascular nerve injury, and serious tissue contusion, it was difficult to solve all problems at the same time in the first stage; therefore, vascular nerve anastomosis and external fixation of fracture were adopted in the first stage, and after the patient's condition became stable, the free thoracic-umbilical flap was used to repair the exposed bone in the second stage. After the flap was repaired, the Ilizarov external fixation was performed in 1 month. After 18 months, the fracture healed well, and the external fixation was removed. The sensory movement of the patient's left lower limb recovered to the normal condition, and the calf muscle strength recovered to the fifth level. The patient and his family were satisfied with the recovery of the left lower limb function (Figs. 34.2, 34.3, 34.4, 34.5, 34.6, and 34.7).

34.2 Choice of Treatment

In this case, the left tibia fracture of the patient is GUSTILO IIIC type, with anterior tibial tissue defect. In the first stage, it was with high surgical trauma and risk to repair vascular nerve injury, skin defect and bone defect, complicated design, difficult operation, local soft-tissue injury window in acute injury. Unclear boundaries resulted in difficult vascular anastomosis of the flap, the risk is high, it is easy to aggravate the burden of vital organs in the body, and easy to cause skin flap necrosis, resulting in irreparable damage [2]. Staging treatment can refine the operation, is safe, and can achieve the best post-effects. In this patient, the left lower limb was completely debrided in one stage, the external fixation of the fracture was fixed, and the vascular nerve was repaired. After blood supply of the left lower limb was stable, the window of the local tissue damage was defined, the inactivated tissue and fracture block were debrided, and the

Y. Zhang (✉) · L. Xia · S. Pei
Department of Orthopaedic Surgery, The 4th People's Hospital of Shaan'xi, Xi'an, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_34

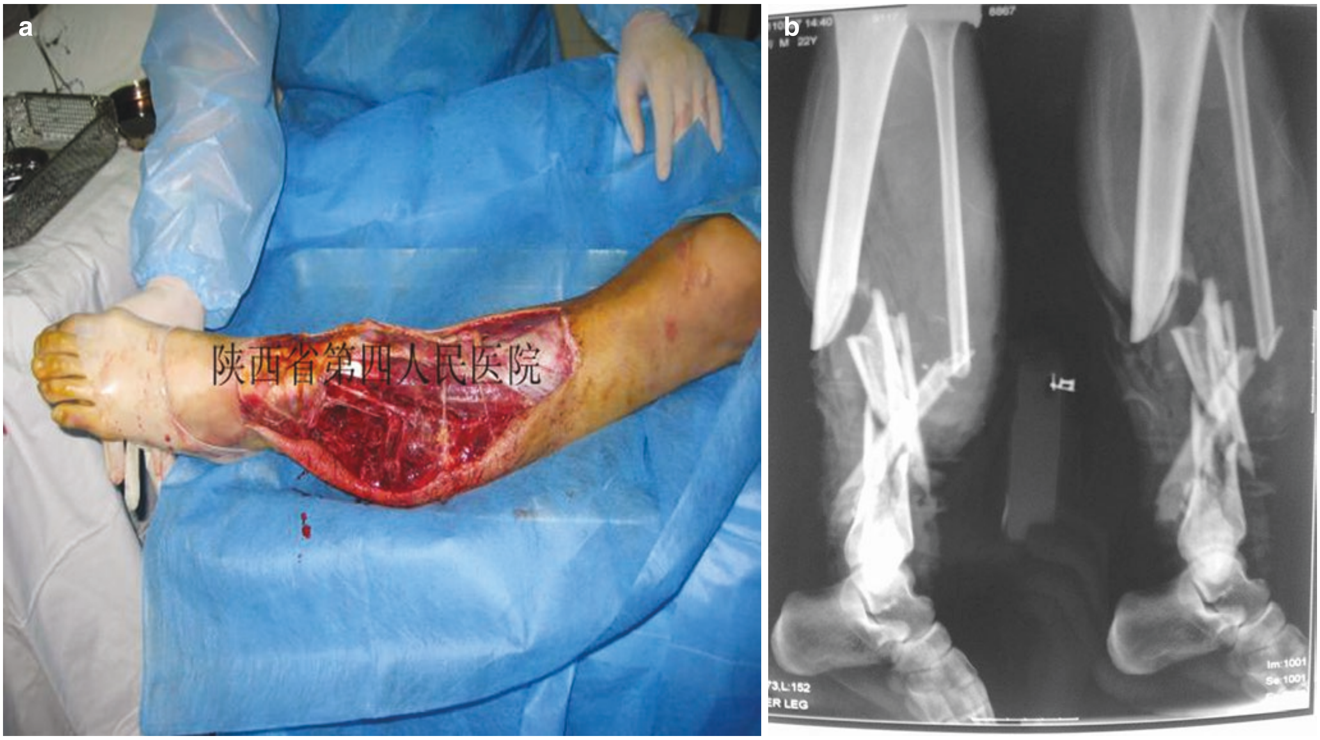


Fig. 34.1 X-rays of wounds and fractures in the lower leg

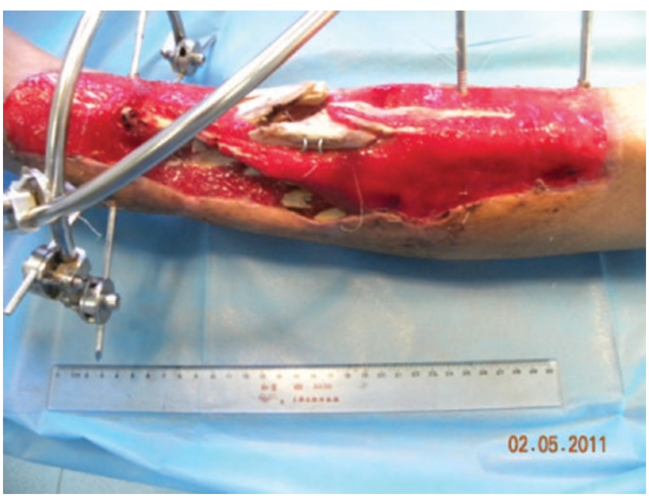


Fig. 34.2 Skin defect after primary repair

Fig. 34.3 Design of secondary thoracic-umbilical flap

thoraco-umbilical flap repaired of the wound in the second stage. The Ilizarov bone transfer was adopted to restore the lower limb line and bone continuity in the third stage.

34.3 Operative Technique

One-stage operation The operation was performed under the combination of hard lumbar anesthesia. After extensive debridement, a large area of skin defect in the left anterior iliac crest, left anterior tibiofibular artery and deep sacral nerve stenosis, sacral anterior tibial fracture external fixation, anterior tibial artery and radial nerve anastomosis, surgery, recovery stability, and lower limb continuity.

Two-stage operation After the wound was stabilized, there was no sign of infection. With the general anesthesia, the broken fragments of the inactivated tissue were completely removed, and the external fixator of the left lower limb was adjusted. The left thoraco-umbilical flap was used to repair the left lower limb wound.

Fig. 34.4 Postoperative repair of secondary flaps

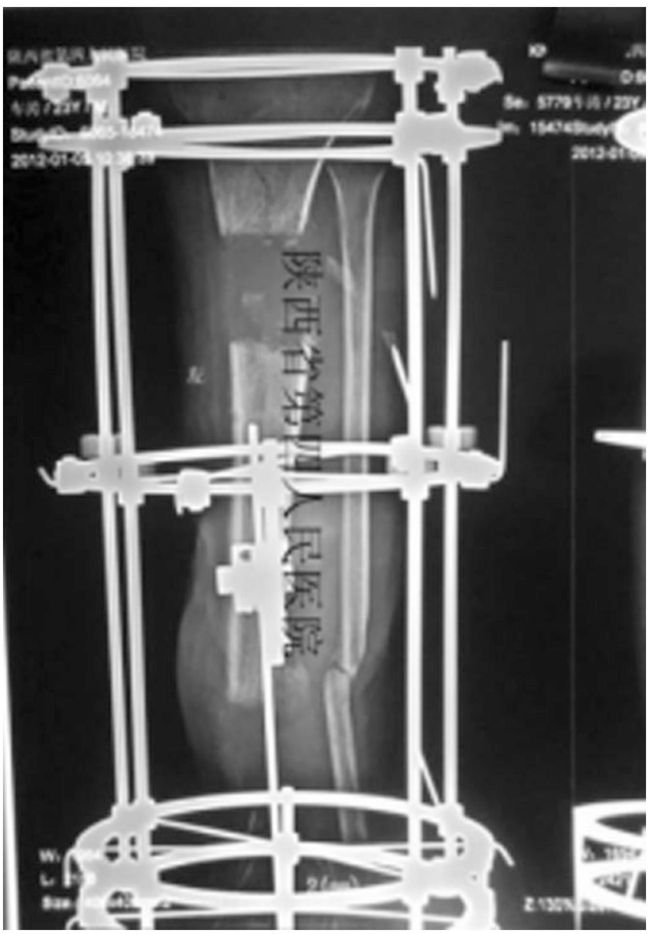


Fig. 34.5 Third-stage bone transport

Three-stage operation 1 month after the flap operation, Ilizarov bone transfer was performed in lumbar anesthesia. The minimally invasive osteoporosis method was used for

Fig. 34.6 Bones heal after bone transport

osteotomy at the metaphysis. The Achilles tendon stretching device was added to prevent the foot from dropping; 10 months after the operation, the fracture ends met with each other, and the fracture was well healed in 18 months. The bone was well mineralized, and the external fixation was removed.

34.4 Clinical Implications

1. Vascular anastomosis and skin flap repair require a physician with rich experience in microsurgery because of the large difference in vascular caliber, poor posture, and block from the external fixation stents after the occurrence of vascular crisis. Once the operation fails, the later remedy would be more difficult.
2. The timing of osteotomy extension is about 1 month after flap repair to avoid the interference of early stretch on flap survival.

Fig. 34.7 Postoperative follow-up

3. When the osteotomy was closer to the epiphysis, the time for the initiation of stretch was 1 week after the operation. Patients are encouraged to exercise 24 h after surgery to reduce complications.
4. After bone regeneration, complete mineralization will take 1–3 years, during which an external fixator should be retained to prevent fracture.

References

1. Tian R, Zheng F, Zhao W, Zhang Y, Yuan J, Zhang B, Li L. Prevalence and influencing factors of nonunion in patients with tibial fracture: systematic review and meta-analysis. J Orthop Surg Res. 2020;15(1):377.
2. Kang Y, Wu Y, Ma Y, Liu J, Gu J, Zhou M, Wang Y, Lin F, Rui Y. “Primary free-flap tibial open fracture reconstruction with the Masquelet technique” and internal fixation. Injury. 2020;51(12):2970–4.

35 Large Segmental Free Ectopic Revascularized and Prefabricated Bone Flap for Second Stage Repair of Bone and Soft-Tissue Defects

Mingwu Zhou, Kai Zhang, and Xun Zhang

In 1966, Diller et al. [1] demonstrated that the vascular ileal fragments of dogs can maintain the survival of prefabricated subcutaneous tissue for the first time and put forward the concept of "pre-fabrication." He believed that flap or composite tissue flap could be formed by pre-fabrication. With the deepening of relevant research, the concept of "pre-fabrication" had gradually improved. According to the needs of defect reconstruction, bone and other tissues such as skin, blood vessels, fascia, etc., were pre-transferred to specific sites to prepare appropriate compound tissue flap. After the blood circulation was established, the tissue flap was transferred to the defect area for reconstruction by pedicle transfer or free transplantation [2]. At present, the omental vascular pedicle, simple vascular bundle, muscle vascular pedicle, and allogeneic vascular bundle can provide the blood supply for the prefabricated flap. The skin, fascia, bones, muscles, and even tissue engineering of various parts of the body can be prefabricated as shaft flap or compound tissue flap. This article described a case using a large segmental free infected tibia to ectopic prefabricate bone flap which was used to repair the defect of the tibia in the second stage. The lateral calf medial flap combined with free latissimus dorsi flap were bridge transferred to repair the wound. In another case, a large segmental free-contaminated tibia was used to ectopic prefabricate heterotopic vascularized bone flap for repair bone and skin soft-tissue defect in the second stage.

35.1 Case Presentation

A 45-year-old man suffered an open comminuted fracture of the right tibia due to a car accident. He was first treated in the local emergency department with debridement of the right tibia fracture, external fixation, and flap transplantation to repair wounds. After the first surgery, postoperative wound infection and skin flap necrosis occurred. Then, he was transferred to the 153rd Hospital of the People's Liberation Army 4 weeks after the first surgery. Admission examination: the right lower leg was covered with a 16 cm × 28 cm free flap. The flap was black purple which had many purulent secretions. X-ray result showed a comminuted fracture of the right tibia with a 17.2 cm of free and relatively intact bone segment and fracture of the tibia. After admission, anti-infection and nutritional support treatment was given for 10 days. Then, the free tibia bone was removed and implanted inside the rectus femoris and lateral femoral muscle to revascularize the bone. At the same time, the wound was debrided and suctioned with VSD. After the wound condition was improved, the posterior tibial artery with blood supply bridge transfer with the latissimus dorsi flap was prepared to repair the right calf wound. The patient was discharged after the wound healed. Eleven months later, the ectopic prefabricated vascularized tibia bone flap was freely implanted to repair the right tibia and skin soft-tissue defects. After 3 months, the SPECT examination showed that the bone metabolism was active in the replanted bone segment. DSA examination showed that there were more neovascularizations around the bone segment. The patient began to exercise lower limbs with weight-bearing.

35.2 Choice of Treatment

Large segmental open comminuted fractures of the tibia caused by high-energy trauma such as traffic injuries, mechanical injuries, and war traumas are often accompanied by large areas of soft-tissue defects. There are often large segmental free bone fragments and broken bones in the wound that are seriously polluted [3–7]. How to deal with these large segmental free bones and broken bones is still a tough situation for orthopedic surgeons. Early thorough removal of contaminated bone segments can effectively prevent infection [8, 9], but it will cause large bone defects of

M. Zhou (✉) · K. Zhang · X. Zhang
Department of Microsurgery and Orthopedic Trauma, No. 988 Hospital of Joint Logistic Support Force, Zhengzhou, Henan Province, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_35

the tibia which is difficult to repair in the second stage. If the free bone segments are sterilized in vitro, and directly implanted in situ to restore bone continuity [10–13], the postoperative infection rate is very high [14, 15]. In this case, the autologous free large bone segment was restored and fixed with the external fixator at first. However, the infection occurred after the first operation. The free flap was used to repair the wound which failed due to infection. For those who have had a bone infection with a large area of soft-tissue infection or even a chronic infection, there are multiple intact bone segments or multiple large fracture segments. If they are not removed, the infection is difficult to control. Only when the entire infected bone segment and surrounding inflammatory tissue are completely removed, the infected lesion may be completely cured. Nevertheless, the treatment of a wide range of infected wounds is very difficult after taking out a large portion of the free infected bone. There is still a risk of failure if the musculocutaneous flap is used for repair. Even if the musculocutaneous flap survives and the wound is closed, the bone infection is hard to control, which still has the possibility of evolving into a chronic bone infection and bone non-healing. Removal of the infected bone results in a large segmental defect that limits the bone supply at the second stage of repair. In this case, we took out the large segmental free tibia segment and sterilized it in vitro. Afterward, the segmental free tibia segment was revascularized by a well-known blood vessel with muscles to prefabricate the bone flap. The infected wound was treated with anti-infection medicine and repaired with flap implantation at the same time. After the wound infection was completely cured, the prefabricated vascularized pedicle bone flap was implanted in situ to repair the bone and skin soft-tissue defects at the second stage.

Advantages: Completion of the revascularized and prefabricated bone flap of a large segmental infected bone with infection control and wound treatment at the same time. The purpose of reusing the infected bone segment is achieved, which can prevent or avoid the recurrence of bone infection and shorten the course of treatment.

35.3 Operative Technique

35.3.1 Right Leg Debridement and Extraction of the Infected Tibia Segment for In Vitro Sterilization

Remove the necrotic flap of the right calf. A 17.2-cm free segmental right tibia was exposed and removed. The upper free fracture piece about 3.5 × 3 cm was taken out, and the surrounding inflammatory granulation tissue was removed. The free bone was washed three times with hydrogen peroxide (hydrogen peroxide) and physiological saline and immersed in iodophor for 30 min. The soft-tissue defect of the right calf skin wound was about 28 × 13 cm. The infected bone fragment and fracture piece were rinsed three times with hydrogen peroxide and physiological saline before drilling with a 1.5-mm drill with an interval of 1.0–1.5 cm on the bone segment. Then, the infected bone fragment and fracture piece were boiled in 100 °C sterile saline for 30 min. Soak in the iodophor for 30 min and rinse with normal saline for 10 min (Fig. 35.1). The bone specimen was prepared for a bacterial culture test. The free fracture piece and the large segmental tibia were bundled and fixed together for future use.

35.3.2 Large Segmental Free Tibia Ectopic Revascularization

A straight line was drawn connecting the anterior superior iliac spine and the superior upper edge of the patella in the anterior lateral part of the right thigh and the midpoint of the line was marked. The line was used as the upper skin incision limit. At the lateral side of the upper skin incision limit, the arc incision was designed according to the length of the segmental tibia and the skin size needed for the second stage. When designing the incision, care should be taken to avoid the area of descending branch of the lateral circumflex femoral artery and the musculocutaneous perforator so as not to

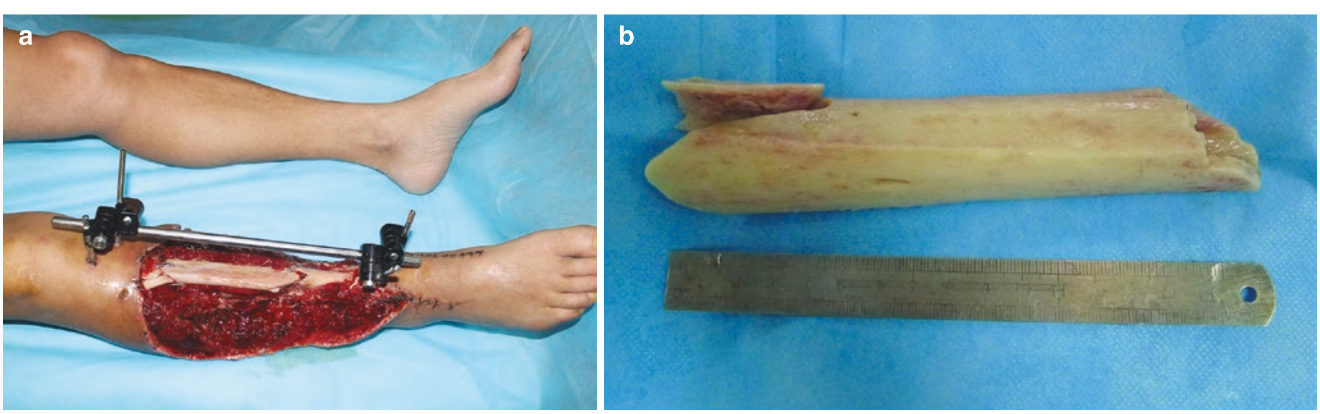


Fig. 35.1 Images before surgery. (**a**) The infected wound and bone before surgery. (**b**) The free tibia bone after sterilization

damage the blood vessels when cutting the skin and subcutaneous tissue. The skin and subcutaneous tissue along the curved design line were cut, and the rectus femoris and lateral femoral muscle were exposed. Then, the anterior lateral femoral myolemma was cut and the descending branch of the lateral femoral artery was found in the space between the rectus femoris and the lateral femoral muscle. The sterilized segmental tibia was implanted in the space of the lateral rectus muscle and the lateral femoral muscle, below the anterior lateral femoral myolemma of the lateral femoral artery descending branch. The sterilized segmental tibia was fixed on the femur with two 2.0 K-wire. Then, the anterior lateral femoral myolemma was sutured, and the skin incision was closed with a drainage strip placed (Fig. 35.2).

35.3.3 Right Calf Wound Repair

After in vitro sterilization of the right infected tibia bone, the residual calf wound was treated with multiple debridements and VSD negative pressure treatment. After the wound condition improved, a 25 cm × 14 cm right latissimus dorsi musculocutaneous free flap was prepared for wound repair. Due to the poor vascular condition in the recipient area, a 15 cm × 7 cm medial flap of the lower leg with the pedicle of the left posterior tibial artery was sutured as a tubule. The posterior tibial artery vein in the medial flap of the left calf is used as the vascular donor area. The vasotrophic thoracodorsal artery and vein of latissimus dorsi flap were anastomosed to the left posterior tibial artery and vein in the medial flap of the left calf by cross-bridge vascular anastomosis. Then, the medial flap of the lower leg formed a cross-bridge blood vessel, and the lower limbs were fixed in parallel by external fixation. Left calf wound skin graft survival. Two months after the operation, the cross-bridge flap's pedicle was cut, and the contralateral tibial vein was anastomosed to the tibial artery by arteriovenous anastomosis (Fig. 35.3). The pedicle flap was preserved which provided the backup blood supply system for the second-stage vascular bone replantation.

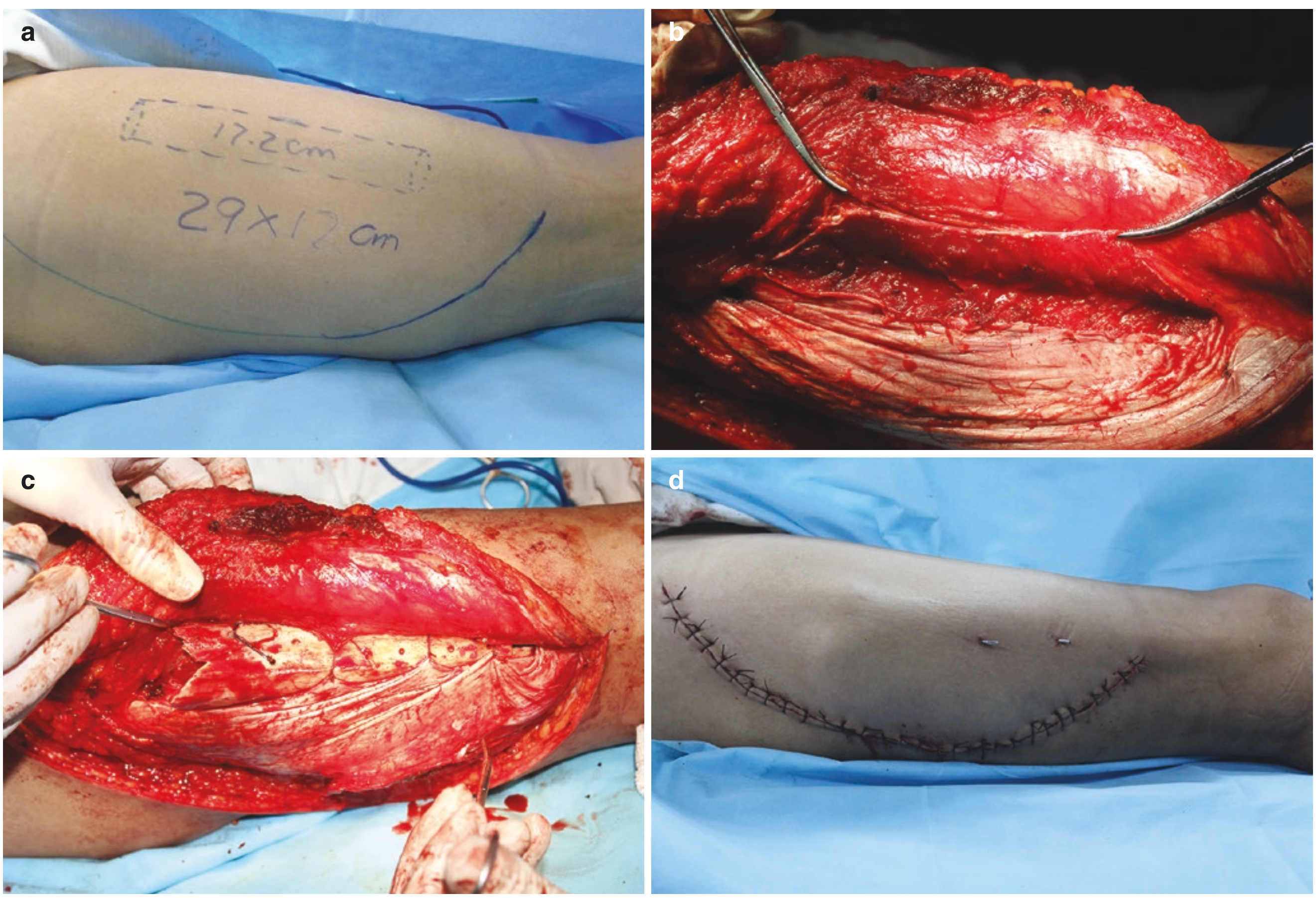


Fig. 35.2 The procedures of ectopic prefabricated vascularized tibia bone surgery. (**a**) The design of free infected tibia vascularization incision. (**b**) Exposure of the interparenchy between rectus femoris muscle and lateral femoral muscle. (**c**) Place the free infected bone at the interparenchy between rectus femoris muscle and lateral femoral muscle near the descending branch of the lateral femoral artery. (**d**) Close the incision after surgery

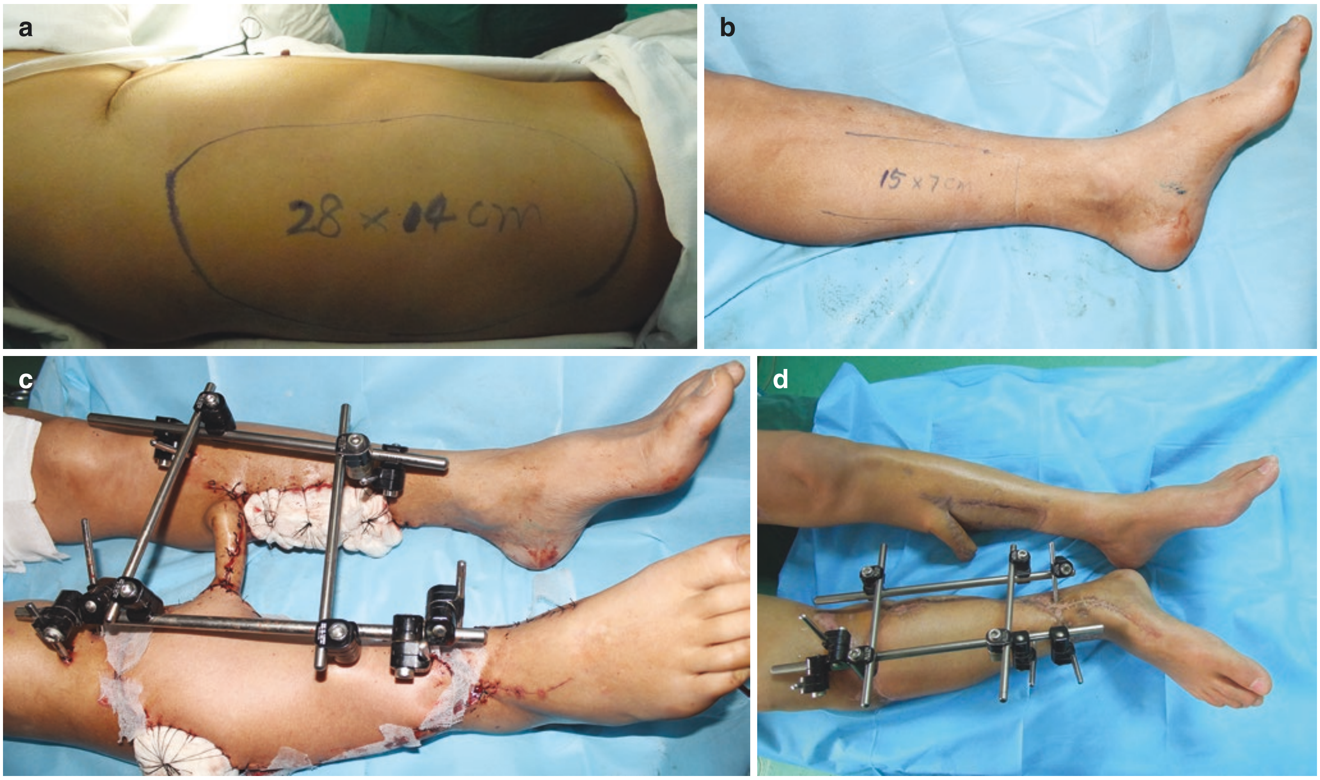


Fig. 35.3 The contralateral posterior iliac artery flap graft transfer with latissimus dorsi flap for repairing the infected wound. (**a**) The design of latissimus dorsi flap. (**b**) Design of the posterior tibial artery flap. (**c**) Left posterior tibial artery flap graft transfer with latissimus dorsi flap for repairing. (**d**) Cut the bridge flap pedicle

35.3.4 Ectopic Prefabricated Revascularized Bone Replantation

After 6 months of right calf wound healing, the patient was admitted for prefabricated revascularized bone flap replantation. DSA examination performed before operation showed vascularization was achieved in the bone flap which was suitable for replantation (Fig. 35.4). The skin was cut at the medial edge of the right calf flap and separated layer by layer. The hypertrophic scar tissue, the sclerotic bone end, and the granulation tissue in the medullary cavity were removed after exposing the distal and proximal fractures of the tibia. The patency of the contralateral reserved posterior tibial artery cross-bridge vascular pedicle was examined. The midpoint of the line connecting the anterior superior iliac spine and the superior upper edge of the patella in the anterior lateral part of the right thigh which was the perforating branches of the lateral femoral circumflex artery was used as the center for designing the composite tissue flap. The design area of the flap was 19 × 8 cm. The left calf skin and subcutaneous tissue along the lateral edge of the design line were cut and separated layer by layer to the space between the lateral femoral muscle and the rectus femoris muscle. Then anatomized the surface of the lateral femoral muscle where the ectopic vascularized bone segment and the surrounding tissue were exposed. The anterior lateral femoral flap was gradually dissected, and a small amount of vastus lateralis muscle sleeve was taken. Then, the lateral circumflex femoral vessel connected with vascularized bone segment was exposed, and a large number of tiny blood vessels were observed growing from the lateral circumflex femoral vessel to the membranous structure of the vascularized tibial

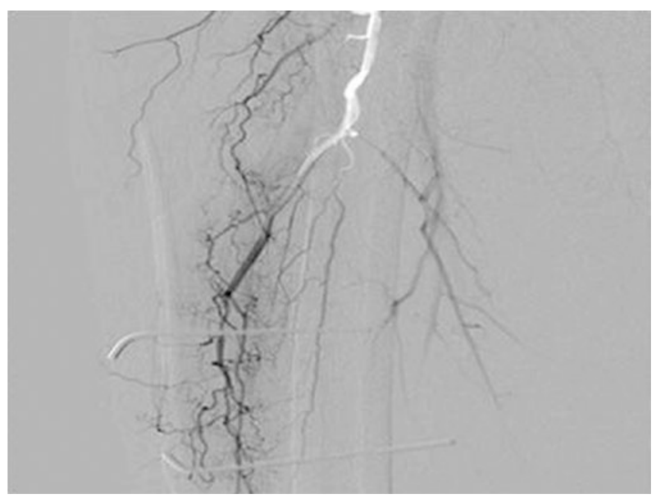


Fig. 35.4 DSA after 1 year of ectopic revascularizations shows a large number of blood vessels grow around the ectopic vascularized tibia

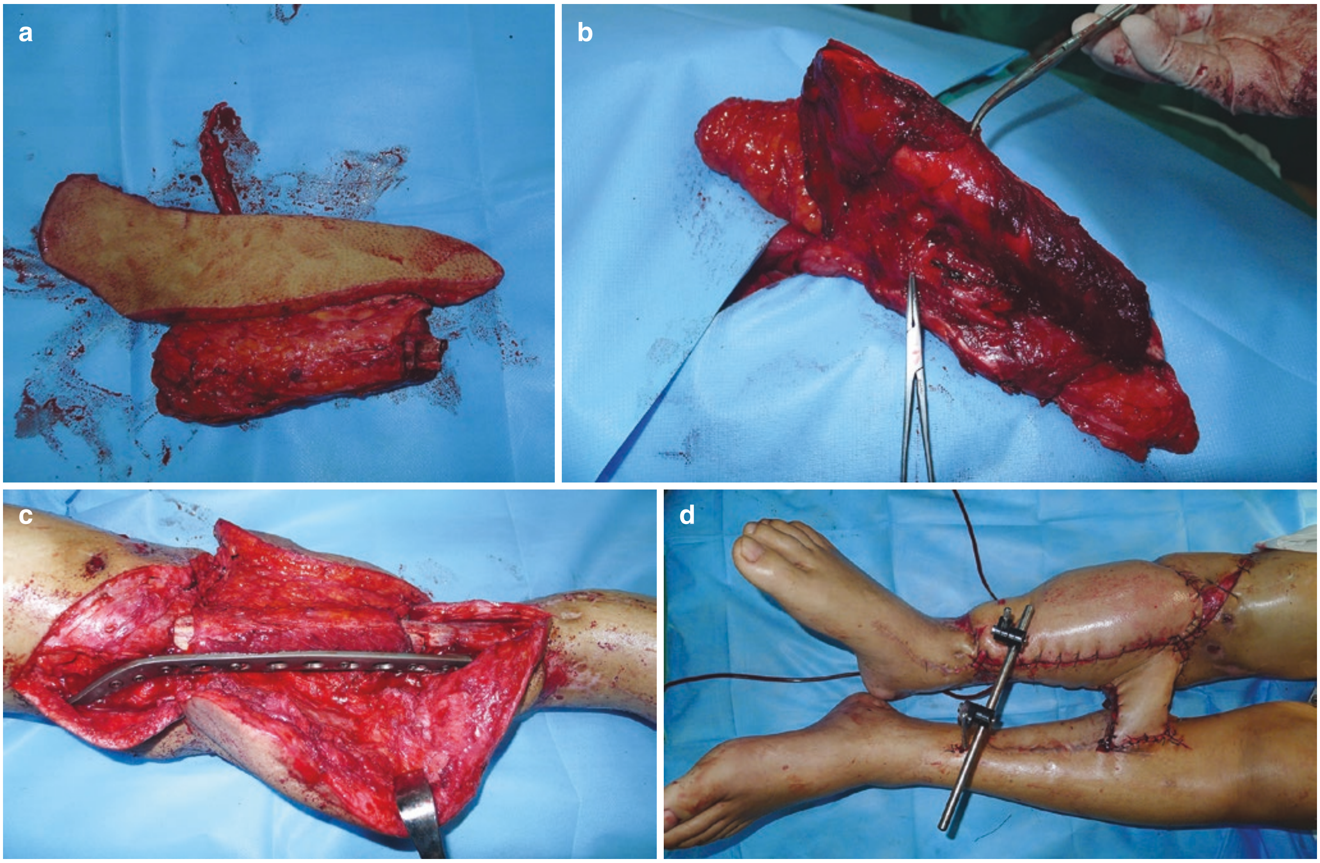


Fig. 35.5 Cut and replant the revascularized bone flap pedicled with the descending branch of the lateral femoral artery. (**a**, **b**) Harvest of revascularized bone flap. (**c**) In situ replantation of the revascularized bone flap. (**d**) The left posterior tibial artery flap bridged with ectopic vascularized tibia flap, and the posterior tibial arteriovenous anastomosed with the lateral femoral arteriovenous descending branch

bone segment surface. This membranous structure resembled periosteal tissue and was tightly bound in the cortical bone. Active hemorrhage was seen when the membranous structure was incised. The cortical bone at one end of the vascularized tibial bone segment was intercepted by an electric pendulum saw for 2 mm with active bleeding. A small amount of periosteal tissue and bone cortex of the proximal, middle, and distal vascularized bone were taken for pathological examination. A large number of microvascular growth and the indentation of new blood vessels on the surface of vascularized tibial bone were observed under a high-power microscope which fully demonstrated the success of revascularization of the ectopic tibia. The vascularized tibial bone segment and the flap together with the lateral circumflex femoral artery and its branches was dissociated. After separating of the vascularized tibial bone segment, the flap was observed to have a good blood supply, and the bone had nourishing blood vessels which oozed under microscopic observation. The start of the anterior lateral circumflex artery was cut and ligated. The flap and vascularized bone segment were placed at the right lower leg defect area and fixed with the residual tibia using a 11-hole plate. 8–0 non-invasive suture was used to anastomose the lateral circumflex femoral vessel and the contralateral reserved posterior tibial artery and its accompanying veins under the microscope. Successful blood flow at the first time. The right anterior superior iliac spine was incised obliquely, and a part of the iliac bone was taken out to construct a bone strip which was implanted at the fractured end of the tibia. Two external fixation screws were inserted paralleled into the lower part of the tibia and the lower part of the femur, and the lower limbs were fixed paralleled with a unilateral external fixator (Figs. 35.5, 35.6, and 35.7).

35.4 Clinical Implication

When the free ectopic prefabricated bone flap is used, the tension of the skin in the second stage of replantation should be taken into consideration when designing the surgical incision. Therefore, when designing the lateral flap of the circumflex femoral artery, a straight line connecting the anterior superior iliac spine and the superior upper edge of the patella in the anterior lateral part of the right thigh should be used as the

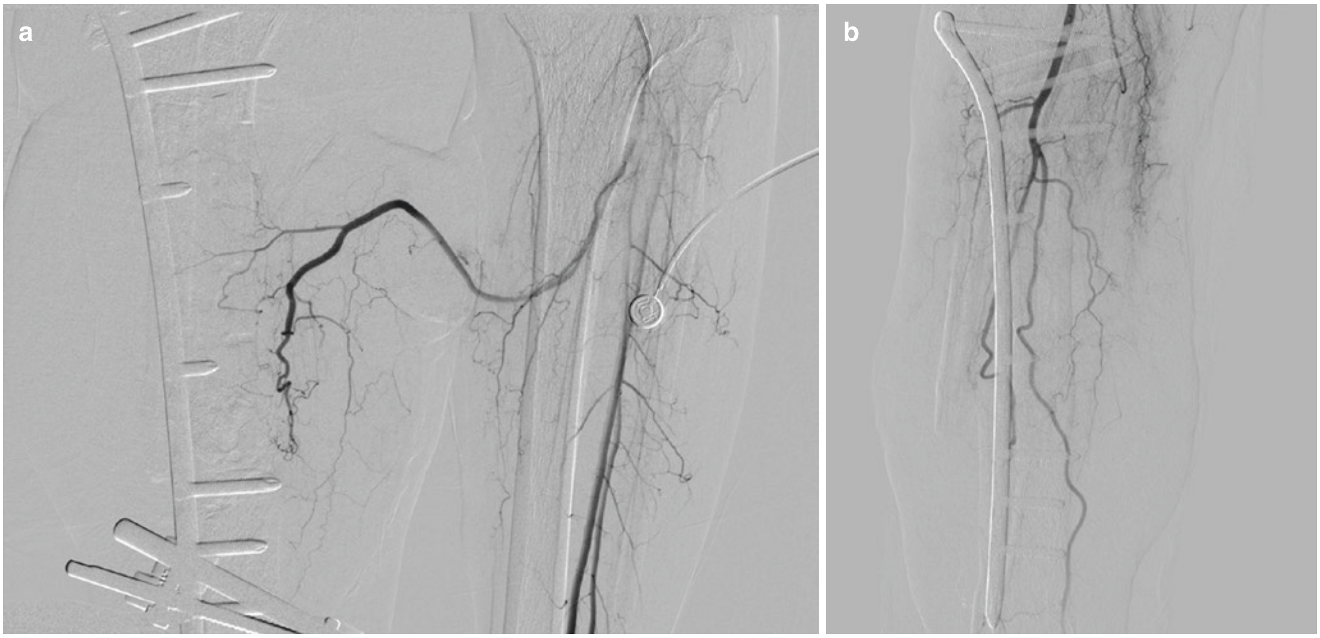


Fig. 35.6 (**a**) DSA showed that the blood vessels around the bone graft were well fluent and had new blood vessels 1 month after surgery. (**b**) DSA showed 3 months after replantation: more neovascularization appeared around the bone graft

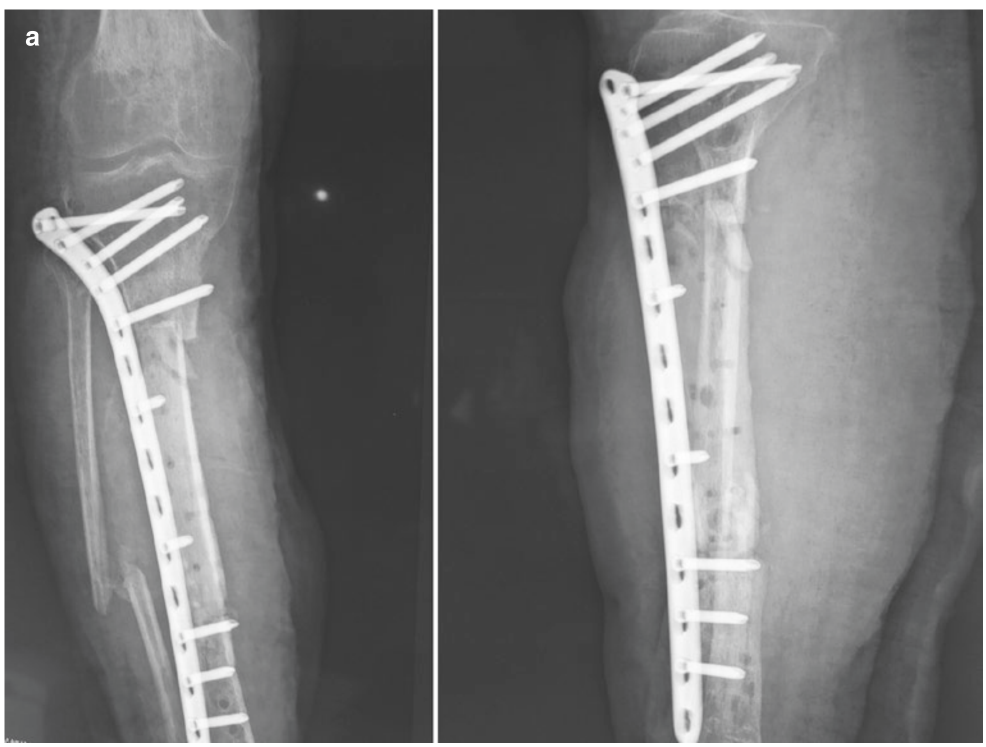


Fig. 35.7 (**a**) X-ray showed 6 months after the replantation: the fracture line was blurred, and a large number of callus were formed at the fracture end. (**b**) The affected limb began to carry weight-bearing walking function exercise 8 months after surgery

Fig. 35.7 (continued)

upper limit line of the flap. The lower limit line should be outside the width of the flap in the second stage of replanting, and the length should be 4–6 cm larger than the bone section.

The free bone segment is located near the descending branch of the lateral femoral circumflex artery. In order to avoid the affection of the prefabricated vascularized bone flap process, the muscle branch and the perforating branch vessel from the descending branch of the lateral femoral circumflex artery should be protected when exposing the incision. It can ensure good blood supply for the anterolateral thigh flap at the second stage of replanting at the same time.

When the vascular pedicle flap is implanted in situ, the position of the plate should be fully considered to make sure it will not be squeezed into the descending branch of the lateral femoral circumflex artery. Meanwhile, the flap should not be excessively separated from the bone segment which affects the blood supply. The position of the plate should facilitate the fixation and removal in the future.

The infectious free bone segment has pathological changes in hardening and necrosis which is difficult for neovascularization. The process of ectopic revascularization prefabricated bone flap is slower than that of the freely contaminated bone segment. Therefore, for infected segments with pathological changes, the time for prefabricating the bone flap should be relatively extended to ensure that enough blood vessels grow into the bone segments.

For infectious comminuted fractures, soft-tissue scars are formed due to local inflammatory stimuli. The blood supply is poor which is difficult for antibiotics to reach the lesion through blood circulation. The deep bacteria are in a stationary phase. Although there are no symptoms of infection, the deep bacteria in the stationary phase are prone to multiply and cause recurrence of infection when the body's immunity declines. Therefore, the anti-infective treatment time of infected wounds should be relatively extended to reduce the risk of recurrence of infection after replantation. It is generally recommended that the timing of revascularized and prefabricated bone replant surgery should be performed 4–6 months after wound infection control.

Due to the injury of the main blood vessels, long segmental defect or pathological change, the serious infection, and the vascular inflammatory reaction, there is no blood vessel for anastomosis in the affected limb. Therefore, the contralateral posterior tibial vascular could be cross-bridge transfer and anastomosis to lateral femoral circumflex blood vessels which provide blood supply when the bone flap is implanted in situ.

References

1. Diller JG, Hartwell SW, Anderson R, et al. The mesenteric vascular pedicle: review of its clinical uses and report of experiments in dogs. Cleve Clin Q. 1966;37:163.
2. Safak T, Akyürek M, Ozcan G, Keçik A, Aydin M. Osteocutaneous flap prefabrication based on the principle of vascular induction: an experimental and clinical study. Plast Reconstr Surg. 2000;105(4):1304–13.
3. Iheozor-Ejiofor Z, Newton K, Dumville JC, et al. Negative pressure wound therapy for open traumatic wounds. Cochrane Database Syst Rev. 2018;7:CD012522.
4. McQuillan TJ, Cai LZ, Corcoran-Schwartz I, et al. Surgical site infections after open reduction internal fixation for trauma in low and middle human development index countries: a systematic review. Surg Infect. 2018;19(3):254–63.
5. Zalavras CG. Prevention of infection in open fractures. Infect Dis Clin N Am. 2017;31(2):339–52.
6. Halawi MJ, Morwood MP. Acute Management of Open Fractures: an evidence-based review. Orthopedics. 2015;38(11):e1025–33.
7. Cherubino M, Valdatta L, Tos P, et al. Role of negative pressure therapy as damage control in soft tissue reconstruction for open Tibial fractures. J Reconstr Microsurg. 2017;33(S 01):S08–13.

8. Jorge-Mora A, Rodriguez-Martin J, Pretell-Mazzini J. Timing issue in open fractures debridement: a review article. Eur J Orthop Surg Traumatol. 2013;23(2):125–9.
9. Schenker ML, Yannascoli S, Baldwin KD, et al. Does timing to operative debridement affect infectious complications in open long-bone fractures? A systematic review. J Bone Joint Surg Am. 2012;94(12):1057–64.
10. Farrelly E, Ferrari L, Roland D, et al. Reimplantation of an extruded Osteoarticular segment of the distal tibia in a 14-year-old girl. Case report and review of the literature. J Orthop Trauma. 2012;26:e24–8.
11. Mazurek MT, Pennington SE, Mills WJ. Successful reimplantation of a large segment of femoral shaft in a type IIIA open femur fracture: a case report. J Orthop Trauma. 2003;17:295–9.
12. Kumar P, Shrestha D, Bajracharya S. Replacement of an extruded segment of radius after autoclaving and sterilizing with gentamicin. J Hand Surg. 2006;31:616–8.
13. Afshar A. Reimplantation of a large extruded segment of bone in an open fracture. J Hand Surg Am. 2017;42(2):128–34.
14. Edwards CC, Simmons SC, Browner BD, et al. Severe open tibial fractures. Results treating 202 injuries with external fixation. Clin Orthop Relat Res. 1988;230:98–115.
15. Ahmed AR, Manabe J, Kawaguchi N, et al. Radiographic analysis of pasteurized autologous bone graft. Skelet Radiol. 2003;32(8):454–61.

36 Repair of a Lateral Malleolus Defect with a Composite Pedicled Second Metatarsal Flap

Huihao Chen and Chunlin Hou

36.1 Case Presentation

The 26-year-old male patient fell while riding a motorcycle. There is friction between the lateral malleolus and the pavement resulting in defects in the lateral malleolus and soft tissue of the ankle. Wound debridement and dressing changes were performed at another hospital. The wound surface healed with scarring and skin grafting. Due to the complete absence of the lateral malleolus, the patient had symptoms of ankle joint instability 4 months after the injury (Figs. 36.1 and 36.2).

36.2 Choice of Treatment

What this patient needed was the reconstruction of the lateral malleolus which can restore the stability of the ankle and avoid long-term ankle osteoarthritis, the defects of the lateral malleolus, and the defect of soft tissue should be repaired in one stage. The current methods used to repair a lateral malleolus defect include a pedicled vascularized fibular head graft [1], iliac crest graft [2], bone flap from the lateral eminence of the scapula [3], and allograft bone transplantation [4], and these methods cannot repair the soft-tissue defect of lateral malleolus at the same time.

Fig. 36.1 Photograph of the patient with an external malleolus defect before the operation

Fig. 36.2 Preoperative X-ray shows a lateral malleolus defect

H. Chen · C. Hou (✉)
Department of Orthopedic Surgery, Changzheng Hospital, Second Military Medical University, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_36

Easily cut and removed, the metatarsus has been widely used for the reconstruction of the finger bones and metacarpal, ulna, and temporomandibular joints [5–8], and the removal of the second metatarsal does not lead to the dysfunction of the forefoot. There are two arterial sources of the metatarsus, one is the dorsal metatarsal artery from the dorsalis pedis artery, and the other is the plantar metatarsal artery from the posterior tibial artery [9]. Forming a wide arterial network in the head of the metatarsal bone, these two vessels provide the main blood supply to the metatarsal base, the dorsal end of the dorsalis pedis artery, and the first and second metatarsal arteries can be retained when the second metatarsal flap is cut [9, 10]. In the procedure of repairing the lateral malleolus with the second metatarsus, retention of these metatarsal arteries is conducive to fracture healing. The second metatarsal bone and spindle flap with dorsal foot artery as the axis can be cut at the same time to repair the defect of the lateral malleolus and soft-tissue defect while we take the dorsalis pedis artery as the vascularpedicle.

36.2.1 Operative Technique

To simultaneously repair the defects of the lateral malleolus and the soft tissue, the dorsalis pedis artery was taken as the vascular pedicle, and the second metatarsal bone and skin flap were used. We used the head of the metatarsal bone to reconstruct the lateral malleolus and the flap to cover the wound surface. We created a fusiform flap along the vertical axis of the dorsalis pedis artery, identified the dorsalis pedis artery between the extensor hallucis longus and the extensor digitorum longus, and retained the deep peroneal nerve. Including the extensor pollicis brevis and the dorsal skin of the foot, the dorsalis pedis artery from proximally to distally was dissociated to form a second metatarsal composite tissue flap with a dorsalis pedis artery pedicle. The flap was then transferred through a subcutaneous tunnel toward the proximal end to the recipient site. The fibular articular surface of the second metatarsus was made to fit the talus, and the fibula and metatarsus with steel plates were fixed to reconstruct the lateral malleolus. We used the extensor pollicis brevis to repair the lower tibiofibular ligament and the flap to cover the wound surface of the lateral malleolus (Figs. 36.3, 36.4, 36.5, and 36.6). At the donor site, the transverse metatarsal ligament was sutured in the dorsum of the foot, and the wound was directly sutured.

Fig. 36.3 The second metatarsal bone and skin flap were designed

Fig. 36.4 A second metatarsal composite tissue flap with a dorsalis pedis artery pedicle was formed

Fig. 36.5 The flap was transferred to the recipient site through a subcutaneous tunnel toward the proximal end

Fig. 36.6 Postoperative X-ray shows the ankle joint

When using a composite pedicled second metatarsal flap to repair a lateral malleolus defect, the main points for success are summarized as follows: (1), the designed flap must enable tension-free wound repair after flap transfer according to the degree of soft-tissue defect of the lateral malleolus. (2) Care must be taken to avoid damaging the first and second dorsal metatarsal arteries when dissociating the dorsal vessels that enter the second metatarsus from the dorsalis pedis artery. The soft tissue connection between the head and the flap must be protected when the head and flap of the metatarsal bone are cut. They cannot be separated because microvascular branches of the dorsalis pedis artery enter the flap. (3) To ensure that the vascular pedicle of the flap has sufficient length, the dorsalis pedis artery and vein must be dissociated as far as possible toward their proximal ends, which is performed to avoid tension on the vessels after the tissue flap is rotated. (4) The lower tibiofibular ligament must be inspected, repaired, and reconstructed as much as possible. (5) The wound at the donor site can be sutured directly. A rotational flap can be used to repair the wound at the donor site if the defect area is large and cannot be sutured directly.

36.3 Clinical Implications

For reconstructing the distal fibula, the second metatarsal composite tissue flap with a dorsalis pedis artery pedicle is a useful option. There are advantages and disadvantages to use a composite pedicled second metatarsal flap to repair a lateral malleolus defect. The advantages of this method are summarized as follows: (1) The anatomical positions of the vessels and bone tissues of the donor site are constant and are close to the recipient site. (2) Local transfer of the vascular system can be used to simultaneously repair defects of the lateral malleolus and the soft tissue. The occurrence of complications, such as an anastomotic stoma, can be minimized by the technically easy method, abundant blood supply, and good healing properties. (3) Feeling is retained on the skin over the area of the repaired lateral malleolus, and the shape is close to normal, which is conducive to wearing shoes and has good abrasion resistance. The disadvantages of using a composite pedicled second metatarsal flap to repair a lateral malleolus defect are as follows: (1) one main vessel of the ankle is damaged, and (2) the integrity of the transverse arch is damaged to varying degrees. To reduce morphological changes in the arch, the plantar fascia should be tightened and sutured (Figs. 36.7).

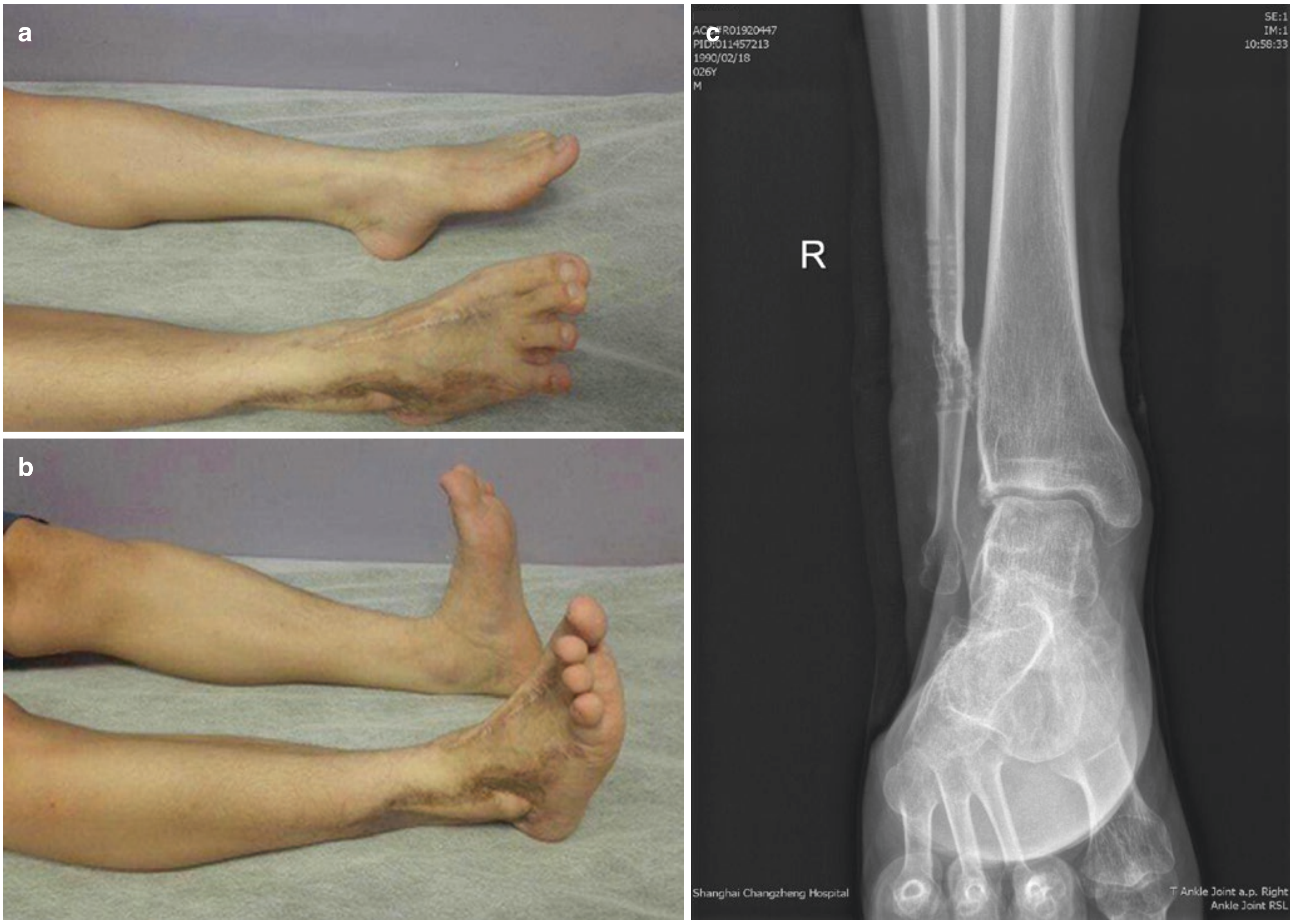


Fig. 36.7 Recovery of the patient. (a) Plantar flexion of the ankle joint. (**b**) Dorsal flexion in the ankle joint. (**c**) At 12 months postoperatively, radiography shows that the distal fibula and metatarsus are completely healed

References

1. Cavadas PC, Thione A. Ulnar head reconstruction with microvascular second metatarsal. Plast Reconstr Surg Glob Open. 2017;5(4):e2184.
2. Dieckmann R, Ahrens H, Streitbürger A, et al. Reconstruction after wide resection of the entire distal fibula in malignant bone tumours. Int Orthop. 2011;35(1):87–92.
3. Eger W, Schörle C, Zeiler G. Giant cell tumor of the distal fibula: fifteen-year result after en bloc resection and fibula reconstruction. Arch Orthop Trauma Surg. 2004;124(1):56–9.
4. Faure P, Canovas F, Bonnel F, et al. Free osteocutaneous scapular apophysis flap for reconstruction of the lateral malleolus. Ann Plast Surg. 2001;47(3):328–31.
5. Hu W, Trimaille A, De VP, et al. Paediatric distal fibula reconstruction using a pedicled composite second metatarsal flap: a technical note. Injury. 2015;46(10):2055–8.
6. Jamshidi K, Mazhar FN, Masdari Z. Reconstruction of distal fibula with osteoarticular allograft after tumor resection. J Foot Ankle Surg. 2013;19(1):31–5.
7. Herring CL Jr, Hall RL, Goldner JL. Replacement of the lateral malleolus of the ankle joint with a reversed proximal fibular bone graft. Foot Ankle Int. 1997;18(6):317–23.
8. Kitaoka HB, Alexander IJ, Adelaar RS, et al. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994;15(7):349–53.
9. Petersen WJ, Lankes JM, Paulsen F, et al. The arterial supply of the lesser metatarsal heads: a vascular injection study in human cadavers. Foot Ankle Int. 2002;23(6):491–5.
10. Rath B, Notermans HJ, Knifka J, et al. The microvascular anatomy of the metatarsal bones: a plastination study. Surg Radiol Anat. 2009;31(4):271–7.

Part III

Head, Neck and Trunk

37 Replantation Repair of Total Scalp Avulsion

Jian Lin and Li Zhi Wu

37.1 Case Presentation

A 42-year-old woman suffered a total scalp avulsion caused by the braid involved in the rotating machine. Physical examination: The wound and alvused scalp were seriously polluted. The laceration extended from the nose root in the anterior to the occipital hair in the posterior, and it extended across the back of two ears including part of the left ear with area about 18 cm × 14 cm bone exposed. The avulsed scalp was without blood supply, and we could see a 6.5 cm × 10.5 cm contusion of the occipital region and multiple lacerations. The patient was brought to the operating room when the vital signs were stable after hemostasis by compression bandage, antishock treatment, and completing essential examinations. The avulsed scalp was replanted in situ after complete debridement by anastomosing both superficial temporal arteries and veins, both posterior auricular arteries and veins, and two occipital nerves. After the replantation, the scalp had a good blood supply, and then we sutured the wound with 3–0 silk sutures, installed the Halo-vest head ring (Fig. 37.1), placed half tube drainage, and wrapped it with sterile gauze in order. The scalp was completely alive after 72 months of follow-up, and the patient was satisfied with the hair growth and the appearance (Fig. 37.2).

37.2 Choice of Treatment

By now, the common treatments for total scalp avulsion that is a serious trauma and hard to be cured are in situ repair, transplantation of free skin graft, thinned scalp in situ repair, free flap transplantation, and so on what is usually single used and the result is hard to be satisfied [1–4]. The combination of the Halo-vest ring which is usually used in the injury of cervical spinal cord and microsurgery technique could improve the survival rate and the recovery of appearance significantly. The main advantages of the new try are: (1) Cotton washer is instead of the Halo-vest ring that is installed on the skull with four points what could avoid necrosis caused by compression; (2) The Halo-vest ring could fix the replanted scalp and induce the cavity under the scalp which is helpful in reducing the occurrence of vascular crisis, hemorrhage, and infection, and the microcirculation would be rebuilt earlier; (3) It would reduce the workload of nursing staff to turn the head regularly; (4) Patients could rest in the supine position but not the half-lying position which could get better comfort and be helpful to coordinate to treatment; (5) It could alleviate the psychological burden of injury, pain, and so on. Otherwise, "purse string suture" (Fig. 37.3) would be convenient for taking off the hair and reduce the difficulty for debridement which would save operation time, reduce the infection rate and improve the survival rate.

Fig. 37.1 Halo-vest head ring

J. Lin (✉) · L. Z. Wu
Chongming Research Center for Wound Prevention and Treatment of Shanghai, Chongming Branch of Xinhua Hospital (Chongming) Affiliated to Medical College, Shanghai Jiaotong University, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_37

Fig. 37.2 (**a**) The avulsed scalp. (**b**) The prepared scalp. (**c**) The wound of the head. (**d**) The replanted scalp. (**e**) The installment of Halo-vest head ring. (**f**) 1 week after operation. (**g**, **h**) 4 months after operation

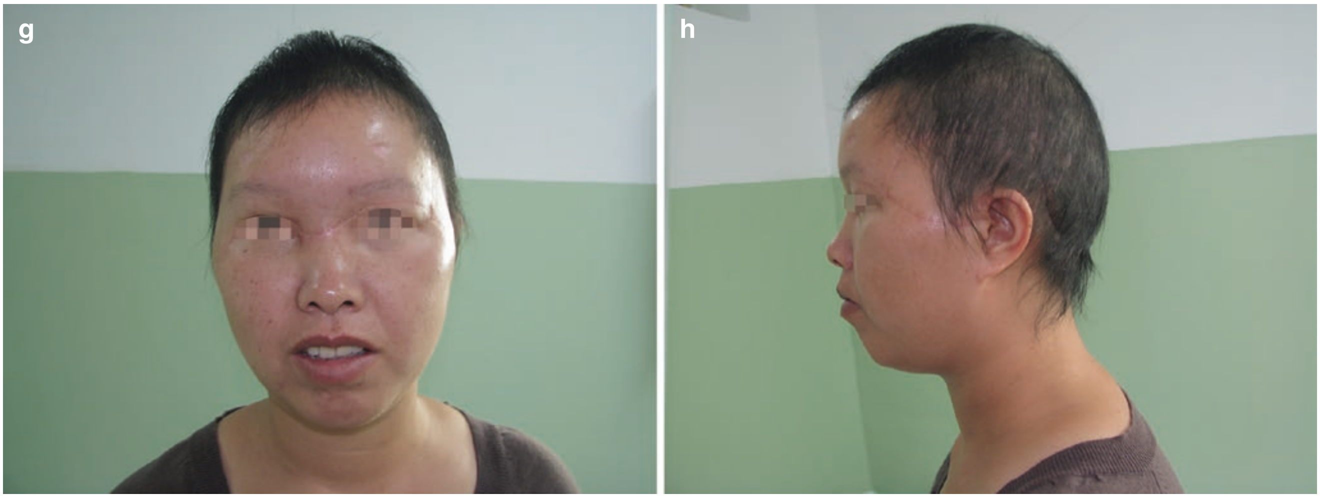


Fig. 37.2 (continued)

Fig. 37.3 Purse string suture

37.3 Operative Technique

Anti-shock therapy should be first performed and the operation could be carried out until the general condition is stable. The operation is divided into two groups: (1) One group is to take off the hair of the avulsed scalp using "purse string suture". Remove the suture after taking off the hair and complete debridement and mark the vessels and nerves on both sides under the eightfold microscope for in situ replantation. (2) The other group is to perform complete debridement for the wound of the head. The key point is to pay attention to the vessels and nerves of temporal, superior orbital, posterior auricular, and posterior occipital and mark them. The bilateral superior temporal arteries and vein should be anastomosed for 6–12 needles by 10–0 or 9–0 under the eightfold microscope, and the vessels of other parts should be anastomosed as far as possible. The scalp could be reserved to perform strict hemostasis on bleeding points after anastomosis for one side. The Halo-vest head ring should be installed at the point 2 cm above the eyebrow arch and back pillow with four screws after the scalp obtains good blood supply and the wound is closed with 3–0 silk and pay attention to balance the distance between the scalp and the head ring. Half tube drainage should be placed around the wound which should be wrapped with sterile gauze. After the operation, the change in vital signs and blood supply of the scalp should be strictly observed. Routine treatment including anemia correction, anticoagulation, anti-spasm, anti-infection, and fluid infusion should be performed. Avoid pressure on the scalp and reinforce dressing change. In the absence of infection, the dressing and suture could be removed 7 days after the operation and observe the scalp survival, and the Halo-vest head ring could be removed 10–14 days later.

37.4 Clinical Implications

(1) Due to abundant blood circulation of the scalp, patients would be accompanied by shock caused by much more bleeding, pain, and other reasons. Therefore, observation about general conditions and the changes to promote treatment of shock in time. (2) "Purse string suture" is convenient to take off the hair which helps shorten operation time and prevent short hair from entering the tendinous cap that would result in infection. (3) The scalp could be trimmed reasonably, but the wound should be closed without tension. We can make a patch for fixation with thick needle internal distance so as not to leave cav-

ity under the scalp [5]. (4) Place drainage tube as much as possible to prevent hemorrhage infection. (5) Pay attention to prevent postoperative complications such as vascular crisis, subcutaneous hematoma, infection, necrosis, and so on [6, 7].

References

1. Abdu WA, Bohlman HH. Techniques of subaxial posterior cervical spine fusion and overview. Orthopedics. 1992;15(3):287–95.
2. Heidecke V, Rainov N, Burkert W. Anterion cervical fusion with the Orion lock and plate system. Spine. 1998;23(16):1796–802.
3. Topalan M, Ermis I. Replantation and triple expansion of a three-piece total scalp avulsion: six-year follow-up. Ann Plast Surg. 2001;46(2):167–72.
4. Hallock GG. Scondary expansion of a replanted scalp sal vaged by an intrinsic art eriovenous shunt. Plast Reconstr Surg. 1999;103(7):1959–60.
5. Lin J, Wu LZ, Guo YH, et al. Application of Halo-vest head ring in replantation of total scalp avulsion. Chin J Plast Surg. 2015;31(6):334–447.
6. Zhao XJ, Liao XQ, Guan HY, et al. Surgical treatment of severe fracture and dislocation of cervical spinal. China J Orthop Traumatol. 2006;19(2):115.
7. Liu C, Liao N. Treatment of overtime avulsion of scalp with split thickness scalp skin grafting: 7 cases of reports. Chin J Reparative Reconstr Surg. 2003;17(5):338–40.

38 Replantation of Facial Tissue Mass

Jian Lin and Li Zhi Wu

38.1 Case Presentation

38.1.1 Case 1

A 56-year-old man suffered amputated tissue mass caused by a nose hurt and was admitted to the hospital in 2 h. Physical Examination (PE): The general situation was good; the vital signs were stable. There was a 3.5 cm × 2.0 cm irregular wound on the nose, including the tip and the left side of the nose. The amputated tissue mass was also irregular and seriously polluted. Successful debridement and replantation were performed under anesthesia under emergency conditions. First, the nasal vestibular skin was sutured from inside to outside; then sutured the subcutaneous layer of the amputated nasal tip back without dead space; and finally, intermittently sutured the dermis and skin of the tip and alar with needle distance 5 mm and margin distance 2 mm. Both sides of the nasal cavity were Filled with iodoform gauze plug, not too tight, and the replanted site shined with 60 W lamp for 24 h after the operation. Conventional treatments such as antibiotics, hormones, and antispasmodics should be carried out for 7 days, and the suture was removed. The replanted tissue mass successfully survived, and the appearance and function were good after 4-year follow-up (Fig. 38.1).

38.1.2 Case 2

A 29-year-old man suffered amputated right auricle mass because of right-side face hurt caused by iron material and was admitted to the hospital in 1.5 h. PE: The general situation was good, and the vital signs were stable. About a 2.0 cm × 2.0 cm wound could be seen in front of the right ear, deep to the subcutaneous tissue. In the middle part of the right auricle, there was an irregular defect about 3.5 cm × 2.5 cm with exposure of bone and bleeding. The amputated mass was also irregular and seriously polluted, and the size was about 3.0 cm × 2.0 cm. Successful debridement and replantation were performed under anesthesia under emergency conditions. The replanted site shined with 60-W lamp for 24 h after the operation. Conventional treatments such as antibiotics, hormones, and antispasmodics should be carried out for 7 days, and the suture was removed. The replanted tissue mass successfully survived, and the appearance and function were good after 2-year follow-up (Fig. 38.2).

38.1.3 Case 3

A 21-year-old man suffered an amputated tissue mass of submandibular hurt by wood and was admitted to the hospital in 3 h. PE: The general situation was good, and the vital signs were stable. About a 5.5 cm × 3.5 cm wound could be seen in the submandibular reached to the superficial layer of the mandible. The amputated mass was also irregular and seriously polluted, and the size was about 5.0 cm × 3.0 cm. Successful debridement and replantation were performed under anesthesia under emergency conditions. The replanted site shined with 60-W lamp for 24 h after the operation. Conventional treatments such as antibiotics, hormones, and antispasmodics should be carried out for 7 days, and the suture was removed. The replanted tissue mass successfully survived, and the appearance and function were good after a regular follow-up (Fig. 38.3).

38.2 Choice of Treatment

As we all know, the face is an important beauty part of the human body. Since the cause of the trauma is complex, and most of the wounds are irregular in shape, also accompanied by tissue defects of different levels, therefore, plastic surgical

J. Lin (✉) · L. Z. Wu
Chongming Research Center for Wound Prevention and Treatment of Shanghai, Chongming Branch of Xinhua Hospital (Chongming) Affiliated to Medical College, Shanghai Jiaotong University, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_38

Fig. 38.1 (1) The situation of amputation. (2) 5 weeks after operation. (3) 3 years after operation

Fig. 38.2 (1) The situation of amputation. (2) The situation after operation. (3) 2 years after operation

technique is usually used in clinical to meet the needs of reconstruction of soft-tissue defect and function but also meet the needs of aesthetic appearance. For now, in situ replantation cannot be replaced by any other method of reconstruction, so it is our first choice [1–3].

38.3 Operative Technique

(1) Complete debridement should be performed under general anesthesia with a ten-fold microscope to remove polluted and necrotic tissue, especially the hair in the wound. (2) Bone and muscle tissue should be repaired and fixed as need. (3) According to the local anatomy of the defected tissue mass, the arteries, veins, and nerves that could be anastomosed should be searched and marked with 9–0 noninvasive suture for use. (4) The arteries, veins, and nerves should be anastomosed with 11–0 or 12–0 noninvasive suture, small blood vessels could be anastomosed with 3–5 needles, and the nerves with 2–3 needles. End-to-end anastomosis should be considered first, and the proportion of anastomosed arteries and veins should be 1:1–1:2. If we cannot find enough veins, an arteriovenous short circuit could be adopted. The strict non-invasive technique should be used to master the space and edge distance of anastomosed vessels and nerves to prevent distortion and compression. (5) After successful replantation, the skin should be sutured with proper tightness to avoid compression, and the wound drain should be placed. Finally, the wound should be wrapped with sterile gauze.

Fig. 38.3 (1) The situation of amputation. (2) The situation after operation

38.4 Clinical Implications

(1) The success of the replantation of facial tissue mass requires not only excellent microsurgery techniques but also a dedicated, united, refined, and hard-working team. (2) The general condition of the patient, mechanism of injury, and the situation of the wound should be assessed by an experienced doctor and decided whether to perform the replantation or not. (3) Complete debridement should be performed to remove polluted and necrotic tissue, and the wound should be shaped to reduce scars and pigmentation formation. (4) Do not add adrenaline which would cause vasoconstriction that will affect tissue viability in local anesthesia. (5) We should master not only the non-invasive technique but also good microsurgery technique. (6) The patients with facial nerve rupture should be anastomosed as soon as possible. (7) We should observe the wound from any angle to restore it. For those patients with severe and deep injury, the dead cavity should be closed and layered suture. And the suture of expression muscles is particularly important. (8) Intraoperative hemostasis should be strict. (9) Sufficient psychological and physical preparation is essential, and the patients should be strictly observed and nursed during and after operation. (10) The patients should be placed in a quiet, comfortable, and ventilated ward that is forbidden to smoke after the operation. Maintain indoor temperature at 22–25 °C, and relative humidity should be 50–60%. The replanted site could be shined with a 60 W lamp with a distance of about 45 cm away which should not be closed to avoid skin burns.

References

1. Morming A, Meng WH, Kezi B. Reconstruction of the oral and maxillofacial soft tissue defect by microsurgical technique. Chin J Med Aesthet Cosmetol. 2005;11(4):203–5.
2. Zhou SX, Gu XM. The contemproary basic principle in treatment of maxillofacial trauma. Chin J Stomatol. 2001;36(2):85–6.
3. Lin J, Wu LZ, Zhang TH, et al. In situ suturing technique for severe amputation of facial composite tissues in 14 cases. Chin J Plast Surg. 2018;34(7):526–8.

A Case for Replantation of Amputated Ear

39

Yabin Zhang, Shaokun Pei, and Lifeng Xia

39.1 Background

It is not uncommon for the traumatic auricle to be completely dissected in clinical practice. Because of the special anatomic structure of the auricle after complete ear amputation, it is difficult to distinguish, find, and anastomose the small wall of arteriovenous vessels, so it is often difficult to replant the auricle [1]. Successful microvascular anastomosis can provide a normal or near-normal appearance, rather than the lack of aesthetic characteristics caused by multi-step treatment. If the severed auricle is intact without obvious contusion, it can be replanted with vascular anastomosis. The key to a successful operation is high-quality microvascular anastomosis and timely treatment of venous congestion.

39.2 Case Presentation

In a 19-year-old male student on May 14, 2014, the right external ear was severed due to trauma and admitted to hospital for 4 h. Four hours before admission, the patient was stabbed to the right external ear and right cheek with a knife. Immediately after the injury, he felt pain in the right external ear and was bleeding actively. The broken auricle was wrapped in a plastic sheet and placed in a warm cup, around which ice bars were placed in cold storage and sent to our hospital. Physical examination: the vital signs were stable; the heart, lung, and abdomen were normal; the good ear wound was bleeding; the skin laceration of 4.0 cm was found on the right cheek; and the middle and lower parts of the external auricle were dissected. The tissue was about the size of 3.0 cm × 1.0 cm in the middle and lower part of the external auricle. The ear wound is simply bandaged and pressed to stop bleeding. The auricle is pale and free of capillary reaction (Figs. 39.1, 39.2, and 39.3).

Fig. 39.1 The severed ear

39.3 Choice of Treatment

After admission, the related examination should be perfected, and the right amputated ear should be replanted in the emergency department under local anesthesia or general anesthesia. After the operation, infection prevention, fluid infusion, volume expansion, anticoagulation, spasmolysis, and so on should be treated.

In this case, the right external ear of the patient was severed, and the desire for replantation was strong, the wound

Y. Zhang (✉) · S. Pei · L. Xia
Department of Orthopaedic Surgery, The 4th People's Hospital of Shaan'xi, Xi'an, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_39

Fig. 39.2 The recipient site

Fig. 39.3 Preparing for replantation

was cut by a knife, the wound was neat, and the microvascular anastomosis technique was feasible for the replantation of the severed ear.

1. In the early days (1950s–1970s), many scholars advocated that the cartilage skin of the auricle should be removed completely and buried in the abdomen or under the skin behind the ear to protect the auricle. The skin was removed only by rubbing, and the ear was covered with skin grafts from the bag after 3 weeks. Although it initially had a better appearance, it gradually lost some of its silhouette and boundaries [2].
2. Replantation of the severed ear with microvascular anastomosis from 1980s to 1990s, some scholars began to implement partial ear replantation without vein repair (only anastomosis artery), small incision bloodletting after heparinization, or application of water frog bloodsucker to solve venous reflux problem, causing continued blood loss, leading to long hospital stays, and massive blood transfusion [2]. Complete amputation of the auricle anastomosing arteries and veins began at the beginning of the twentieth century with successful replantation of the auricle. It is considered that the volume of auricle tissue is small even if there is a thin vein with high-quality anastomosis, the speed of return flow will also be significantly higher than the bloodletting outflow route, and generally can meet the need for reflux. But it requires skilled microsurgical techniques to anastomose the diameter of the 0.15–0.2 mm vessels. The advantages of 1-year follow-up are as follows: back to the ear shape as usual, without pigmentation, slightly thinner than the healthy ear, pain, touch and almost no difference between the healthy ear, and the winter ear slightly cool but no frostbite.

39.4 Operative Technique

1. The patient took the left-side lying position, applied local invasion anesthesia, shaved the hair around the ear for 15 cm, and scrubbed and disinfected the napkin. At the same time, the ears were washed with an aseptic soap solution three times, dipped in chlorhexidine solution for 5 min, and then disinfected with 0.5: 10 iodophor.
2. The distal and proximal wounds were carefully debrided under the operation microscope, and the skin margin of 1–2 mm and the contaminated subcutaneous tissue were excised. The exploration showed that a pulsatile posterior auricular artery was found subcutaneously at the middle side of the wound at the back of the ear wheel. A subcutaneous vein of 0.3 mm in diameter was found in the upper position of 0.2 mm in diameter. The distal end of the vessel was found in the corresponding position of the section of the auricle, but no corresponding artery for anastomosis was found. The veins were marked one by one. After auricle reduction, cartilage and preauricular skin were sutured with 5–0 cosmetic suture; arteries and veins were anastomosed with 11–0 microsuture; and four stitches were anastomosed. After anastomosis, the broken ear was

ruddy, plump, tensional, and the capillaries filling test was good. One cutaneous nerve was sutured with 11–0 microsuture and anastomosed with four stitches.

3. After the operation, antibiotics were given to prevent infection local baking lamp to keep warm papaverine to prevent vasospasm urokinase thrombolytic heparin sodium and low-molecular dextran anticoagulant. After the operation, the complexion of the broken ear was dark red, the tension was increased, the capillary reaction was sensitive, and two sutures were removed 8 h after the operation. The swelling began to subside 3 days after the operation, and the use of urokinase and heparin sodium was discontinued. On the fifth day after operation, the use of papaverine and low-molecular dextran was discontinued (Fig. 39.4).
4. On the tenth day after the operation, the crud was removed, the wound II/A healed, and the auricle tissue mass survived completely. The patients were followed up 30 days postoperatively. The appearance of the affected ear was good, and there was no pigmentation. More than 3 months after the follow-up, the shape of the replanted ear was normal, and there was no significant difference between the left ear and the left ear (Figs. 39.5 and 39.6).

Fig. 39.5 Postoperative 2 weeks

Fig. 39.4 Intraoperative view after replantation

Fig. 39.6 Postoperative 3 months

39.5 Clinical Implication

1. The blood supply of the auricle is special: artery: the superficial temporal artery and the posterior auricular artery send out 3–4 branches in the craniofacial region of the auricle, which sends out the thin branches through the fissure of the cartilage or the rim of the ear wheel to the lateral side of the ear. Vein: Corresponding to the arteries of the auricle, there are many arteriovenous anastomoses in the skin of the auricle. More anastomoses can make the free tissue return fully, but sometimes because of the limitation of the condition, we can only anastomose one small artery and one small vein. It is found that if the free tissue quantity is small, the tension will be higher after the operation. There was no obstruction of venous reflux, and the free tissue survived smoothly.
2. The volume of auricle tissue is small; even if there is a thin vein after high-quality anastomosis, its return speed will be significantly higher than the bloodletting outflow way, generally can meet the need for reflux, and should strive for high-quality anastomosis. Because of the abundant circulation of the lateral branches of the head and face, especially the confluence of the peripheral arteries and veins, the arteries and the arteries interweave into a ball, and the small veins lack valves, no matter what kind of blood vessels are infused inward, can achieve this kind of globular structure, but realizes the circulation, therefore the vein arterialization auricle tissue block cuts off replantation to be able to survive.
3. The difficulty of replantation is that the small wall of the auricular artery and vein is very thin and difficult to find and distinguish. The wall of the vein is thin and soft, and the pulsation is weak. Find one side of the vessel and then find the other end in the corresponding position on the opposite side, marking all the blood vessels and nerves found [3].
4. Postoperative bloodletting treatment: if a vascular crisis occurs, it should actively explore the establishment of blood circulation; even if the vein cannot be repaired, the only way is to rely on small incision bloodletting or water frog bloodsucker treatment of venous congestion [3].

References

1. Shuqiang X, Jianxi H, Hongxin W, et al. Microsurgical replantation of completely severed ear with partial preauricular skin: two cases report. Chin J Clinicians. 2013;16:7667.
2. Zilong Y, Demin H, Haijiang D. Advances in replantation of severed ears with microvascular anastomosis. Foreign Med Otorhinolaryngol. 2003;27:130–1.
3. Wenhai S, Zengtao W, Xiaolei Z, et al. Replantation of severed ear with microvascular anastomosis. Chin J Otolaryngol Head Neck Surg. 2006;10:740–2.

40 Salvage of Large Scalp Defect with Exposed Skull Necrosis by a Free Vascularized Greater Omentum Graft in a 3-Year-Old Child: A Case Report and 10-Year Follow-Up

Juyu Tang and Panfeng Wu

40.1 Case Presentation

A 3-year-old boy was transferred to our hospital 2 weeks after sustaining severe burns to his head, face, and hands by a fire. Physical examination revealed a total burn surface area of approximately 15%, an exposed calvarium area of 26 cm × 22 cm, necrosis of the outer table calvarial bone, and granulation wounds (Fig. 40.1).

40.2 Choice of Treatment

Pediatric scalp reconstruction is a challenging problem that requires attention to the cause, size, and condition of the defect to formulate an optimal reconstructive plan 1, 2. Particularly in those cases accompanied by calvarial exposure, various options may not be suitable [1, 3]. Local flaps, free muscle flaps with skin graft, and free musculocutaneous

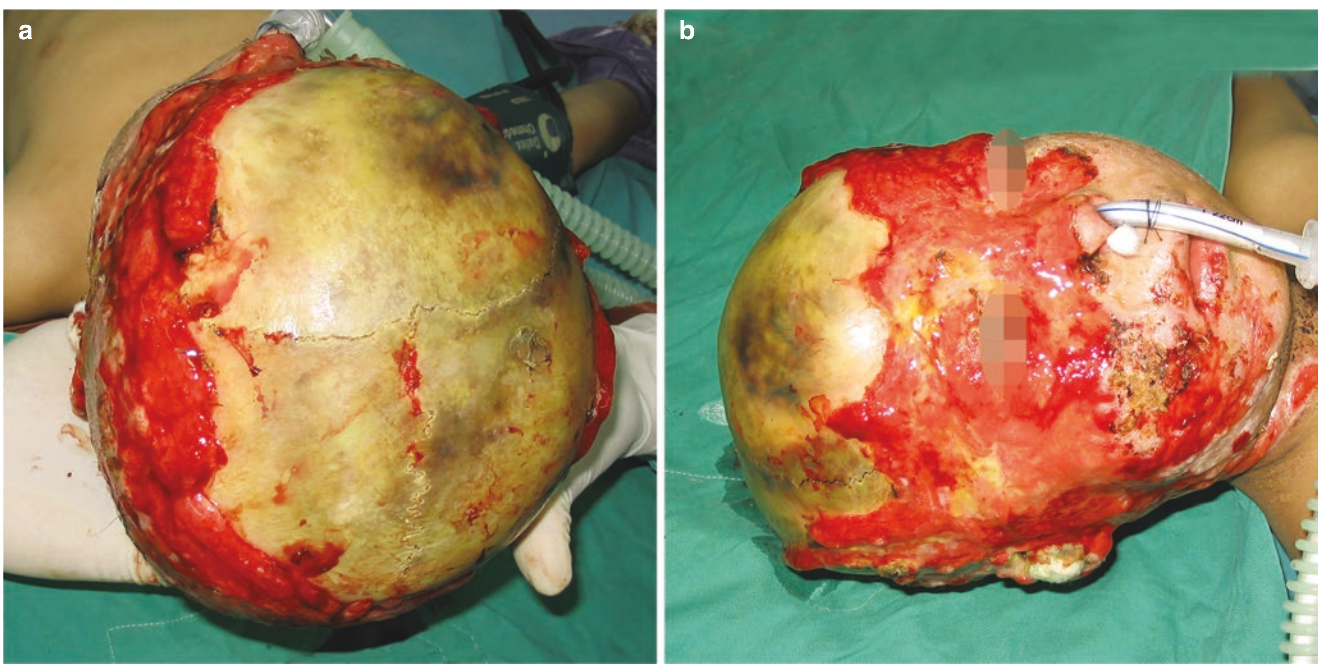


Fig. 40.1 (**a**) Preoperative view of scalp defects and skull necrosis (**b**) Preoperative view of facial defects

J. Tang (✉) · P. Wu
Department of Hand and Microsurgery, Xiangya Hospital, Central South University, Changsha, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_40

flaps were often considered to be the optimal option for covering the scalp defect [4–7]. However, those approaches would have the following disadvantages: insufficient area, bulky contour, and function loss (especially for muscle flaps).

The greater omentum can be molded to conform to almost any shape to adapt various wounds, provided sufficient area and limitation of morbidity of the donor site.

40.3 Operative Technique

With sufficient preoperative preparation, two surgical teams performed scalp debridement and obtained a greater omentum graft. After the scalp lesions and skull necrosis had been radically debrided, 1.5-cm-diameter holes were created in the external tabula of the calvarium until the spongious bone was reached, which was verified by blood leakage (Fig. 40.2a). A

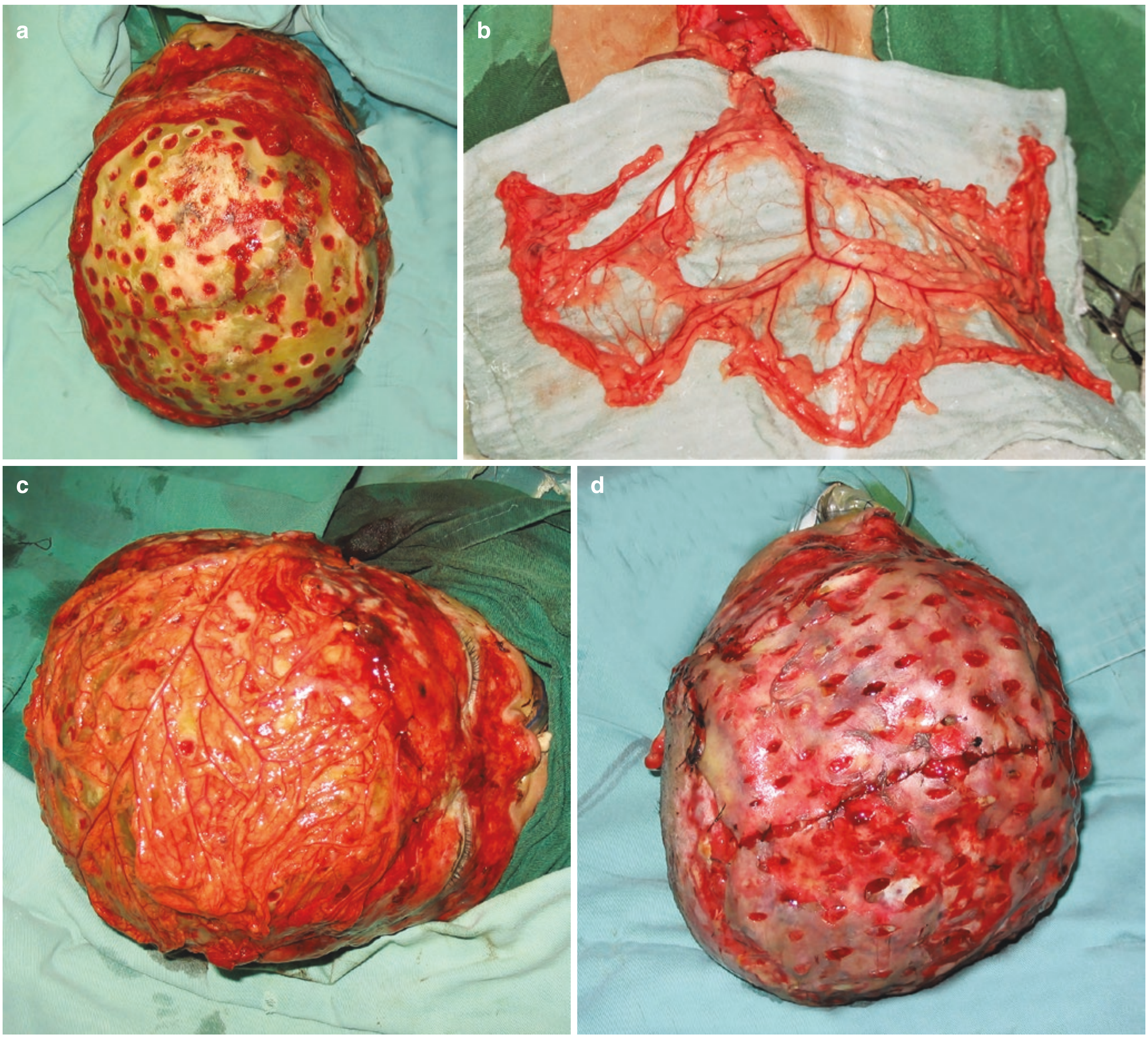


Fig. 40.2 (**a**) The edges of the scalp wounds were radically debrided, sequestrectomy was performed, the necrosis of surface skull defects was removed, and 1.5-cm-diameter holes were created in the external tabula of the calvarium until the spongious bone was reached, which was verified by blood leakage. (**b**) The abdomen was opened to free and harvest the greater omentum. The greater omentum was approximately 23 cm × 22 cm. (**c**) The omentum was used to cover the holes that had been created in the skull. (**d**) A meshed split-thickness skin graft was then sewn into place over the omentum

section of greater omentum, approximately 23 cm × 22 cm, was draped down from the stomach through a midline upper abdominal incision (Fig. 40.2b).

The omental branches of the right gastroepiploic were chosen as vessel pedicles (artery diameter, approximately 1.0 mm; vein diameter, approximately 1.5 mm), which were anastomosed end to end with the left superficial temporal vessels under microscopy. The greater omentum covered the defects and was discontinuously sutured with the edge of the scalp (Fig. 40.2c). The abdomen was closed by the conventional method. A split-thickness skin graft was then sewn over the omentum (Fig. 40.2d). The face and hand defects were covered with a large split-thickness skin graft. Occlusive dressings were used and changed daily. The patient received antibiotic, anticoagulative, and antispasmodic medications and appropriate postoperative nutritional support after the operation. The greater omentum graft and most of the skin graft survived (Fig. 40.3a, b). A very satisfactory treatment

Fig. 40.3 (**a**) The omental graft, with the meshed split-thickness skin graft healed over it, is shown 2 weeks postoperatively. (**b**) A view of the patient's face with the split-thickness skin graft is shown 2 weeks postoperatively. (**c**) The patient 10 years postoperatively. (**d**) The donor site of the greater omentum graft and split-thickness skin graft 10 years postoperatively

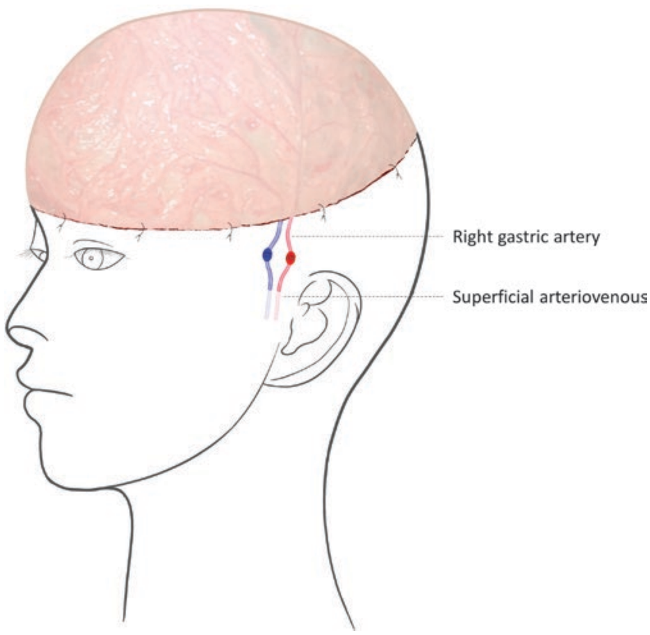


Fig. 40.4 Schematic drawing

effect was obtained during the 10-year follow-up; no infection, osteomyelitis, ulceration, fistula formation, abdominal adhesions, ventral hernias, or appreciable donor defects other than an upper abdominal scar occurred (Figs. 40.3c, d and 40.4).

40.4 Clinical Implication

Reconstruction of scalp defects with skull necrosis is a reconstructive challenge. The options for reconstruction depend on the size of the defect, structures exposed, quality of the surrounding tissues, and operative technique. Skin grafts can be used when the defects leave a viable base for grafting and vital structures are not exposed. Many centers [1] have successfully used tissue expansion in some cases of scalp scarring, but the proximity of foreign bodies to a contaminated wound makes this a less desirable option. In general, small and peripherally located scalp defects can be repaired by local rotation flaps. However, these flaps are associated with more extensive scalp loss and cannot provide enough tissue for coverage. Pedicled pectoralis, latissimus, or trapezius muscle flaps can be raised with a great deal of reliability and reach central or vertex defects of the skull [1]. However, these techniques are also limited with respect to the size of the defect and have not been extensively used for large scalp reconstruction. Free flap transfer provides a viable alternative for the reconstruction of extensive cranial defects. Many studies have reported the use of free tissue reconstruction of scalp defects. Free greater omentum transplantation, a type of free tissue flap, has been widely reported for the repair of scalp defects.

The greater omentum is rich in blood vessels and lymphatic vessels, giving it great ability to absorb exudate and fight infections. It exhibits rapid wound repair through cell proliferation, fibrous tissue formation, and adherence to peripheral tissue to form collateral circulation. The greater omentum also exhibits remarkable plasticity and can be placed into an irregular defect for coverage. Since the first reports of reconstruction using the greater omentum [2–4], greater omentum transfer has been used in many clinical conditions [5–8]. The use of omentum for myocardial revascularization was described by O'Shaughnessy et al. [9] in 1936. The omentum has also been successfully used for facial atrophy treatment and breast reconstruction [6]. The use of a free omental flap for scalp replacement was reported in 1972 by McLean and Buncke [3] and later by Harii et al. [10]. In 1983, Irons et al. [4] used a free omental flap to cover a scalp defect in a 65-year-old man who underwent resection of a recurrent angiosarcoma of the scalp, but the flap failed. The greater omentum was also successfully used to repair scalp defects by Lee et al. [11] in 1999. From 1975 to 2000, Hultman et al. [12] successfully harvested 16 omental flaps for the reconstruction of scalp defects. Omental flaps might serve as a good bed for split-thickness skin grafts in difficult areas, such as in periosteal defects of the skull, where skull necrosis, fibrosis, and poor vascularity are great problems. It is therefore ideal to know the size of the omentum to be expected in a given patient and whether it will reach the target area. Das [13] reported that the length of the omentum in adults is 25 ± 14 to 36 cm, and the width is 35 ± 23 to 46 cm. Measurements were statistically similar between living individuals and cadavers. However, no such information in children could be found in the literature.

In a review of the literature, we found that Gorgu et al. [14] repaired scalp defects in a 9-year-old girl by the traditional, simple conservative technique of opening holes in the skull and using a split-thickness skin graft to cover the granulation tissue 3 weeks later. The treatment required several operations and multiple stages at intervals sometimes lasting more than 3 weeks. Staged procedures are tedious and time-consuming; the outer table often dies, requiring its removal and the formation of granulation tissue before a split-thickness skin graft can be applied. With the development of microsurgical techniques, greater omentum transplantation to repair large scalp defects and exposed skull bone has obtained relatively satisfactory curative effects [15–18]. The operation can be completed in one stage, which greatly shortens the treatment course, reduces pain, and improves the quality of the repair. McLean and Buncke [3] used the greater omentum to cover a 6 × 8-inch scalp defect in a 29-year-old patient. Additionally, a large vertex defect (175 cm^2) was rebuilt with a greater omental free flap [19]. However, no reports have described free omental transplantation to repair large scalp defects with cranium exposure in very young children.

The present report provides information that can be used in future cases of greater omentum transplantation in children. Physiologically, children are characterized by a large head relative to a small torso. In this case, the total burn surface area was approximately 15%, the area of the exposed skull was about 13% (up to 26 cm × 22 cm, the same area as the side of the trunk), and the unhealthy area surrounding the defect and the donor tissue limited the application of a local rotation or pedicle flap. Other free flaps to repair such defects might include the bilateral latissimus dorsi musculocutaneous flap or bilateral trapezius dorsi flap. However, the use of these flaps in children has the following disadvantages: insufficient area, high donor area morbidity, unaesthetic flap contour, excessive flap mass, longer operation time, and possible function loss that may affect future jobs and abilities. Greater omentum transfer has many advantages over muscle flaps. It provides well-vascularized tissue to a potentially infected site. The vessels form a major arcade and numerous branches in turn form increasingly smaller arches that anastomose with one another to create a rich vascular bed that provides support similar to that of a skin graft [3]. Greater omental flaps can also be obtained without a significant sacrifice, thereby minimizing donor site morbidity. These flaps have a great ability to fight infections, and wound repair can be completed in a single stage. During a 10-year follow-up, our patient obtained a very satisfactory treatment effect without infection, osteomyelitis, ulceration, fistula formation, abdominal adhesions, ventral hernias, or any appreciable donor defects other than an upper abdominal scar. Drilling holes in the calvarium could lay a foundation for the healing and adhesion of the greater omentum to the skull. Disadvantages of this procedure are that the patient must wear a wig and that the preoperative area of greater omentum cannot be precisely determined (the area not covered by the greater omentum in the present case was approximately 5 cm × 2 cm). Additionally, this procedure requires close cooperation of multiple departments such as microsurgery, burn surgery, general surgery, pediatrics, and the intensive care unit. Finally, the vessel diameter is smaller in children than in adults; in particular, the wall of the right gastroepiploic vein is very thin, and anastomosis of this vessel is difficult. Therefore, this procedure requires a surgeon who is competent at anastomosing small vessels.

References

1. Hierner R, van Loon J, Goffin J, van Calenbergh F. Free latissimus dorsi flap transfer for subtotal scalp and cranium defect reconstruction: report of 7 cases. Microsurgery. 2007;27:425–8.
2. Dupont C, Menard Y. Transposition of the greater omentum for reconstruction of the chest wall. Plast Reconstr Surg. 1972;49:263–7.
3. McLean DH, Buncke HJ Jr. Autotransplant of omentum to a large scalp defect, with microsurgical revascularization. Plast Reconstr Surg. 1972;49:268–74.
4. Irons GB, Witzke DJ, Arnold PG, Wood MB. Use of the omental free flap for soft-tissue reconstruction. Ann Plast Surg. 1983;11:501–7.
5. Shilov BL, Milanov NO. Free transfer of the greater omentum. Ann Plast Surg. 1993;31:546–9.
6. Weinzweig N, Yetman R. Transposition of the greater omentum for recalcitrant median sternotomy wound infections. Ann Plast Surg. 1995;34:471–7.
7. Arnold PG, Irons GB. The greater omentum: extensions in transposition and free transfer. Plast Reconstr Surg. 1981;67:169–76.
8. Ghazi BH, Carlson GW, Losken A. Use of the greater omentum for reconstruction of infected sternotomy wounds: a prognostic indicator. Ann Plast Surg. 2008;60:169–73.
9. O'Shaughnessy BA, Dumanian GA, Liu JC, Ganju A, Ondra SL. Pedicled omental flaps as an adjunct in the closure of complex spinal wounds. Spine. 2007;32:3074–80.
10. Harii K, Omori K, Omori S. Hair transplantation with free scalp flaps. Plast Reconstr Surg. 1974;53:410–3.
11. Lee B, Bickel K, Levin S. Microsurgical reconstruction of extensive scalp defects. J Reconstr Microsurg. 1999;15:255–62. discussion 63-4
12. Hultman CS, Carlson GW, Losken A, Jones G, Culbertson J, Mackay G, et al. Utility of the omentum in the reconstruction of complex extraperitoneal wounds and defects: donor-site complications in 135 patients from 1975 to 2000. Ann Surg. 2002;235:782–95.
13. Das SK. The size of the human omentum and methods of lengthening it for transplantation. Br J Plast Surg. 1976;29:170–44.
14. Gorgu M, Erdogan B, Akoz T, Aslan G, Ayhan M. Review of a classic method for repair of total scalp defects in childhood. Ann Plast Surg. 1998;40:105–6.
15. Gurtner GC, Evans GR. Advances in head and neck reconstruction. Plast Reconstr Surg. 2000;106:672–82.
16. Perlyn CA, Schmelzer R, Govier D, Marsh JL. Congenital scalp and calvarial deficiencies: principles for classification and surgical management. Plast Reconstr Surg. 2005;115:1129–41.
17. Wang HT, Erdmann D, Olbrich KC, Friedman AH, Levin LS, Zenn MR. Free flap reconstruction of the scalp and calvaria of major neurosurgical resections in cancer patients: lessons learned closing large, difficult wounds of the dura and skull. Plast Reconstr Surg. 2007;119:865–72.
18. McCombe D, Donato R, Hofer SO, Morrison W. Free flaps in the treatment of locally advanced malignancy of the scalp and forehead. Ann Plast Surg. 2002;48:600–6.
19. Sury F, Orry D, Parmentier J, Goga D, Laure B. Microdialysis monitoring of a free omentum flap. Rev Stomatol Chir Maxillofac. 2010;111:84–7.

41 Maxillary and Orbital Floor Reconstruction with Anterolateral Thigh Flap and Individual Pre-bended Titanium Mesh

Zhigang Cai, Xiaofeng Shan, Yifan Kang, and Ying Liu

41.1 Case Presentation

An 11-year-old male was referred for a left maxillary defect with a recurrence of left maxillary osteofibroma. The boy complained about facial asymmetry and oral–nasal fistula which had a severe impact on the quality of life. It also had negative impact on the patient's, as a child, psychological development (Figs. 41.1 and 41.2).

41.2 Choice of Treatment

Peng et al. [1] suggested that maxillary reconstruction should achieve the following aims: obliteration of the defect; restoration of function, particularly speech and mastication; and structural support for the reconstruction of facial features. Maxillary defect combined with orbital floor defect is known as Brown class III defect. Brown and colleges suggested using fibular flap or iliac flap might be the best choice to reconstruct this type of defect because the bone tissue flap could provide enough bony support for eye globe and midface contour [2].

In this case, the patient was an 11-year-old child. The complication after harvesting fibular or iliac flap might bigger than in adults. Besides, whether flap harvesting might influence the growth of children or not was still uncertain. The anterolateral thigh flap was the best choice for this situation. ALT flap could provide enough soft tissue to obliterate the defect and support facial features. When the patient becomes an adult, the bony reconstruction and dental implantation will be considerate.

Preoperative digital design was performed. The mirror technique was used for orbital floor reconstruction (Fig. 41.3). A 3D model was printed for pre-bending titanium mesh which was used for orbital floor reconstruction (Fig. 41.4).

Z. Cai (✉) · X. Shan · Y. Kang · Y. Liu
Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

Fig. 41.1 Preoperative facial profile

41.3 Operative Technique

During the operation, two-team surgery was performed. The Weber-Fergusson's incision was used to expose the tumor. After tumor ablation, the pre-bended titanium mesh was placed precisely under the guidance of computer-assisted navigation system (Fig. 41.5). The depth of titanium mesh

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_41

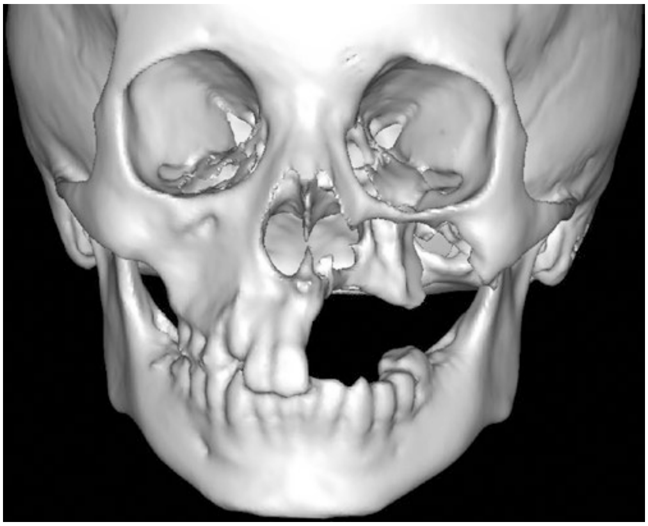


Fig. 41.2 Preoperative CT scan showed left maxillary defect

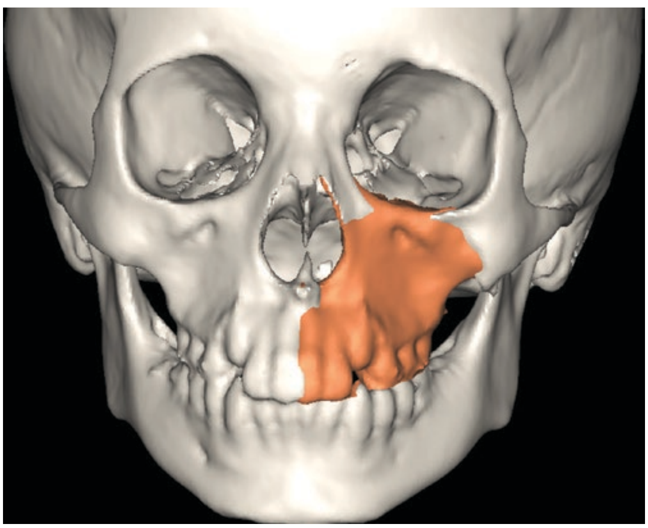


Fig. 41.3 Preoperative digital design using mirror technique to reconstruct orbital floor defect

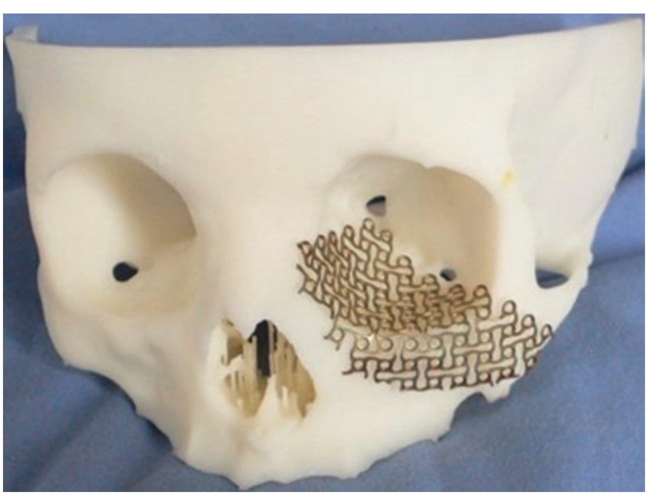


Fig. 41.4 3D-printed model for pre-bending titanium mesh

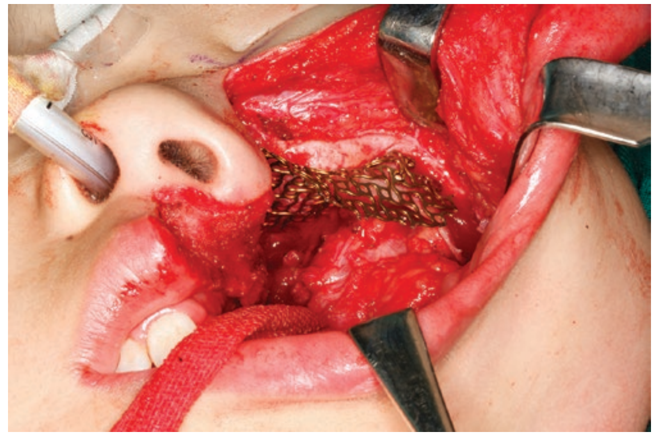


Fig. 41.5 Placed pre-bended individual titanium mesh precisely under the guidance of computer-assisted navigation system

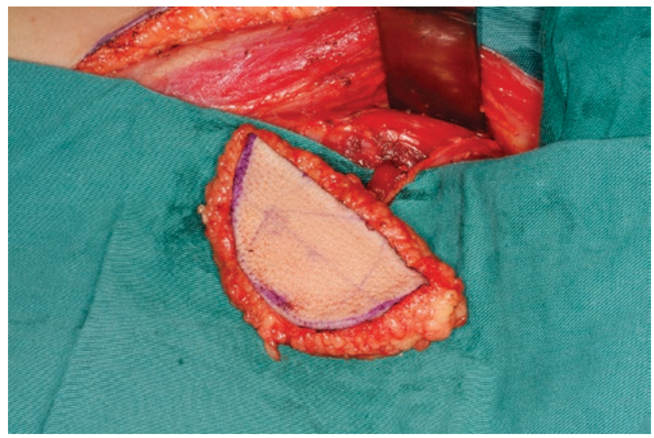


Fig. 41.6 Harvesting of anterolateral thigh flap with long pedicle

was about 1–2 cm. If the titanium mesh was placed too deep it might cause eye globe dysfunction.

The recipient vessels had two choice for maxillary reconstruction, one was temporal vessels and the other was submandibular vessels. Because the patient was a child, the temporal vessels were too thin to perform anastomosis. So, the submandibular vessels were chosen as recipient. The ALT flap needed to be harvested with as long as enough pedicle (Fig. 41.6). The pedicle passed through the pharyngeal wall and interior of the mandibular ramus to arrive at the submandibular recipient. They finished anastomosis in an end-to-end way (Fig. 41.7).

The ALT flap was used to separate the oral cavity and nasal cavity and padded on the exterior surface of titanium mesh to avoid the exposure of titanium mesh (Fig. 41.8). The facial feature was well reconstructed and the flap survived (Figs. 41.9 and 41.10). In a 3-year follow-up, the patient's midface was symmetrical, and no complication occurred (Figs. 41.11, 41.12, 41.13, and 41.14).

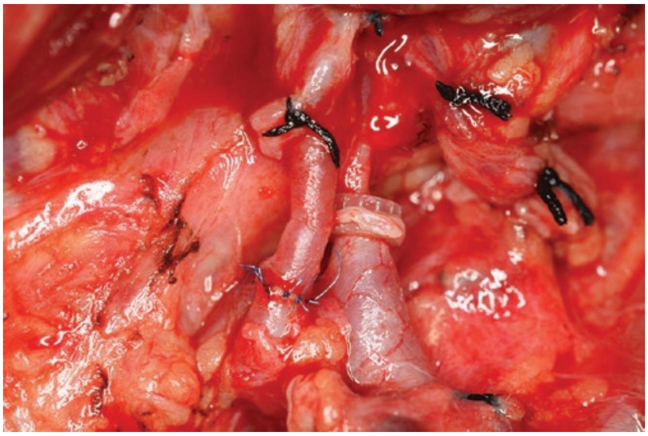


Fig. 41.7 Vessels anastomosis

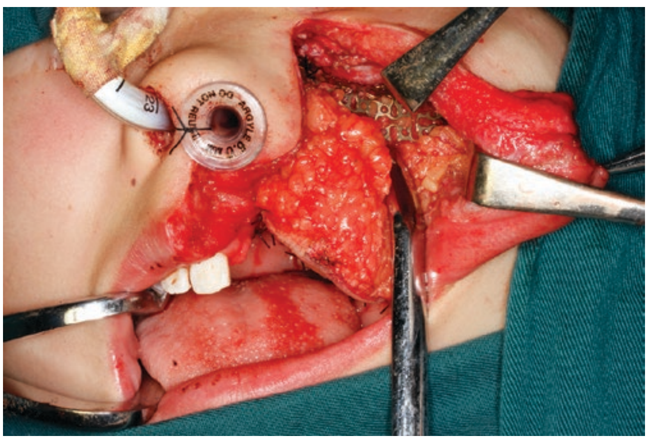


Fig. 41.8 The ALT flap was used to separate the oral cavity and nasal cavity and padded on the exterior surface of titanium mesh to avoid the exposure of titanium mesh

Fig. 41.9 Immediate postoperative facial profile

Fig. 41.10 Postoperative intraoral profile showed flap survived

Fig. 41.11 Facial profile at 3-month postoperatively

Fig. 41.12 Facial profile at 1-year postoperatively

Fig. 41.13 Facial profile at 3-year postoperatively

41.4 Clinical Implication

Maxillary reconstruction with anterolateral thigh flap in children is a safe method that will not affect children's growth.

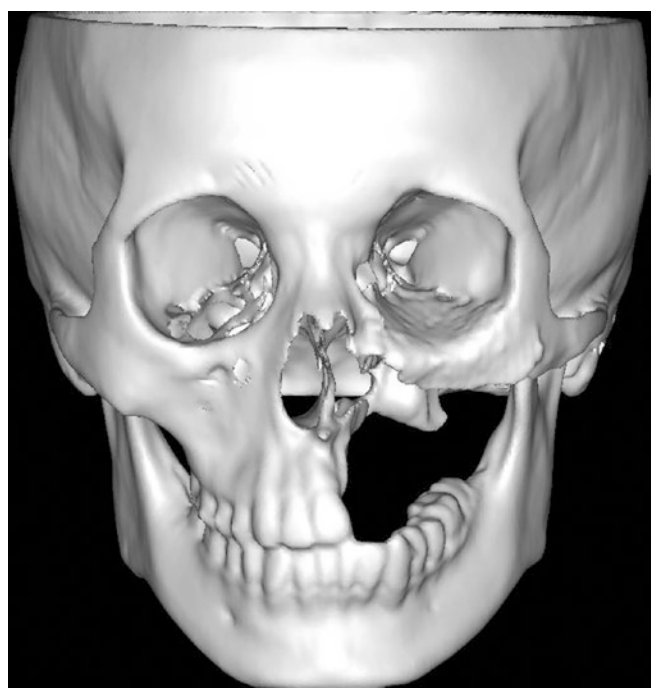


Fig. 41.14 CT scan at 3-year postoperatively

References

1. Peng X, Mao C, Yu GY, Guo CB, Huang MX, Zhang Y. Maxillary reconstruction with the free fibula flap. Plast Reconstr Surg. 2005;115:1562–9.
2. Brown JS, Shaw RJ. Reconstruction of the maxilla and midface: introducing a new classification. Lancet Oncol. 2010;11:1001–8.

42 Deep Circumflex Iliac Artery (DCIA) Flap for One-Staged Reconstruction of Left Mandible Defects

Xiaofeng Shan, Yifan Kang, and Zhigang Cai

42.1 Case Presentation

A 55-year-old female was referred for left mandibular ameloblastoma. The patient had a symptom of left mandibular swollen and loosen of left lower molars (Fig. 42.1). In the panoramic tomography, the tumor occupied the entire left mandibular body, from mentum to angle, and causing the absorption of roots (Fig. 42.2).

Fig. 42.1 Preoperative facial profile

42.2 Choice of Treatment

Mandibular reconstruction after tumor resection is challenging for functional and esthetic reasons [1]. Several techniques are available. The most popular approach is the use of vascularized bone flap, including fibular flap [2], iliac flap [3], etc. Because of the long vascular pedicle, wide diameter of peroneal vessels, and types and volumes of tissues, the fibular flap was the first choice in the last decades.

With the development of implant technique, the disadvantage of fibular flap appeared, which is the lack of bone height resulting in inconvenience for dental implant [4]. Compared to fibular flap, the iliac flap has enough height and volume for the implant. The patient needed a dental implant. Thus, our team chose iliac flap for mandible reconstruction.

In order to reduce surgery times, one-stage mandible reconstruction and implant surgery are the most suitable way for this patient. For the purpose of precise surgical result, the preoperative digital design was made to simulate the surgical procedure (Fig. 42.3). The 3D-printed mandibular model was used for pre-bending the titanium plate before surgery (Fig. 42.4). In order to transfer the information of digital design into the surgery precisely, the titanium plate was scanned by the 3Shape scanner. Combined with the information of osteotomy and titanium plate, the surgical guide was designed and printed (Figs. 42.5 and 42.6).

X. Shan · Y. Kang · Z. Cai (✉)
Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_42

42.3 Operative Technique

During the operation, two-team surgery was performed. Team A performed tumor ablation and team B harvested the deep circumflex iliac artery iliac crest flap at the same time. The submandibular incision was used for exposing the tumor. Because of the benign tumor the patient had, the gingiva was saved carefully in order to make a better soft tissue condition for implantation. Then, the surgical guide was fixed to the mandible margin, and the retention hole for surgical guide was also used to fixed titanium plate. The mandibular osteotomy was under the guidance of the surgical guide (Fig. 42.7). The pre-bended titanium plate was implanted (Fig. 42.8). Before vessel preparation, the submandibular gland was removed. The facial artery and superior thyroid artery were suitable choices for recipient artery. The facial vein and external jugular vein were suitable choices for the recipient vein.

The iliac bone flap was harvested under the guidance of the guide plate (Fig. 42.9). The DCIA flap contained a fascial paddle that was centered on the perforator. After the vascular anastomosis in an end-to-end way (Fig. 42.10), the iliac bone flap was fixed in place (Fig. 42.11), and four implants were inserted in the iliac crest at the same time (Figs. 42.12 and 42.13). The postoperative face contour was symmetrical, and the occlusal relationship was good with the implant denture (Figs. 42.14, 42.15, and 42.16).

Fig. 42.2 Preoperative OPG showed the tumor occupied the entire left mandibular body, from mentum to angle, and causing the absorption of roots

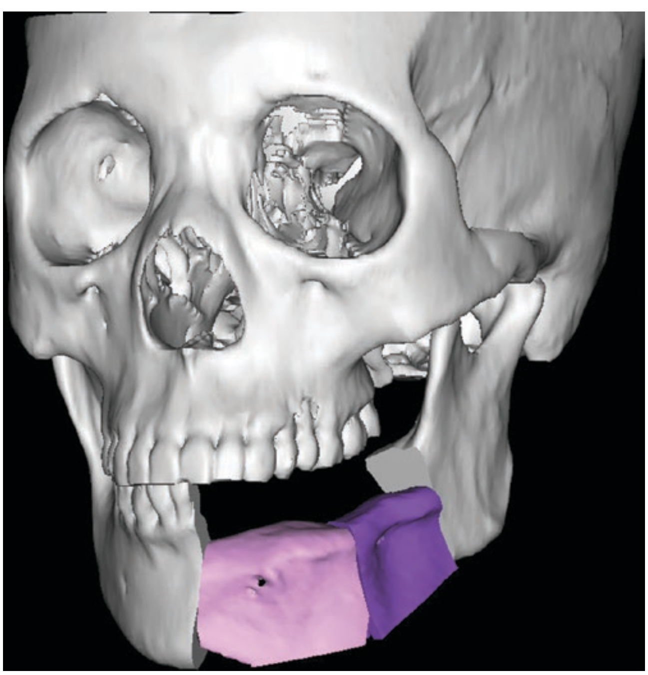


Fig. 42.3 Preoperative digital design. Two pieces of the iliac crest were used for mandibular reconstruction

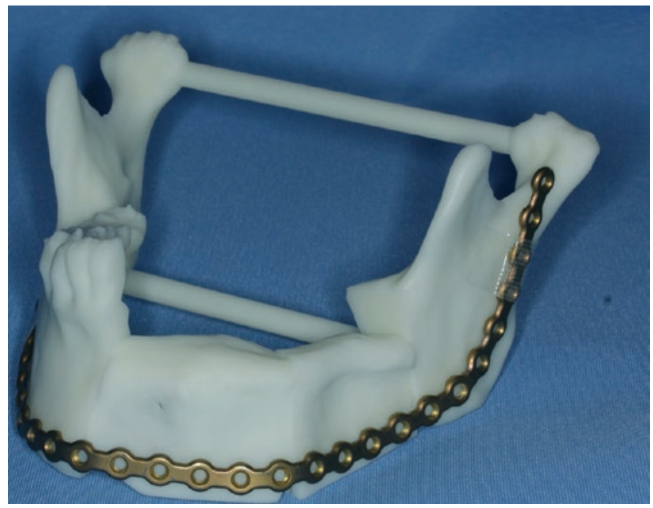


Fig. 42.4 3D-printed mandible model and pre-bended titanium plate

Fig. 42.5 3D-printed mandibular osteotomy surgical guide with retention hole and titanium plate information

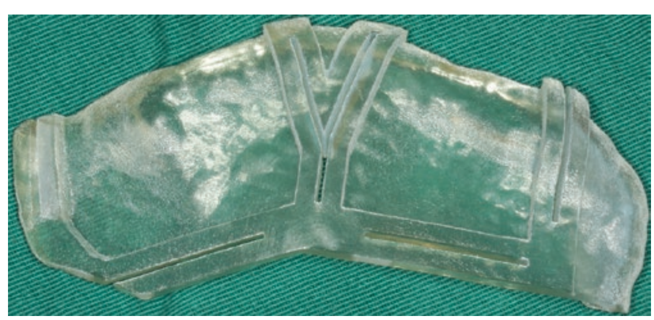


Fig. 42.6 3D-printed iliac bone surgical guide

Fig. 42.7 Submandibular incision to perform mandibular osteotomy under the guidance of a surgical guide

Fig. 42.8 Fixed pre-bended titanium plate

Fig. 42.9 DCIA flap with facial paddle harvested under the guidance of a surgical guide

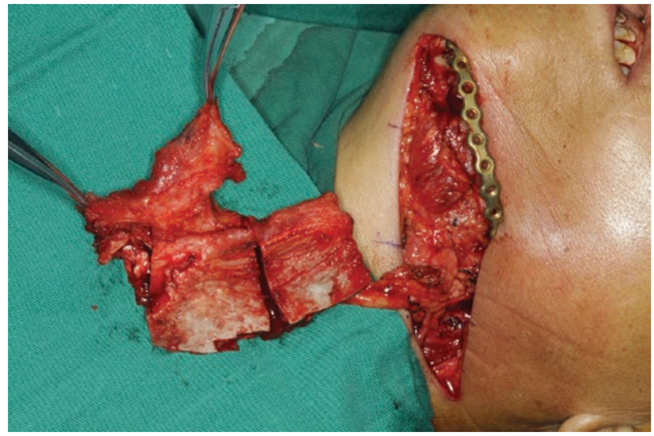


Fig. 42.10 Vascular anastomosis in an end-to-end way

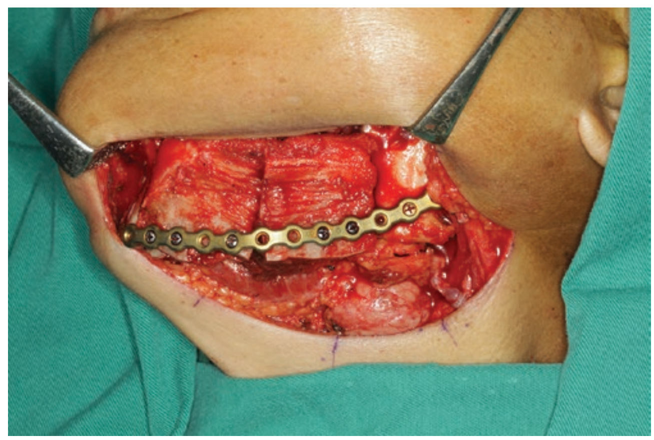


Fig. 42.11 DCIA flap fixed in place

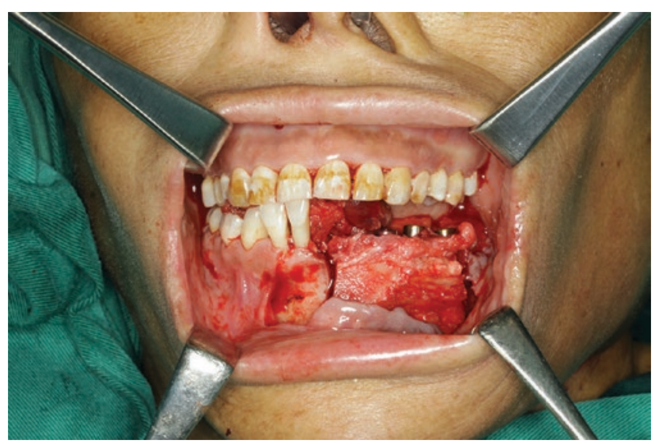


Fig. 42.12 Four implants were inserted in the iliac crest at the same time

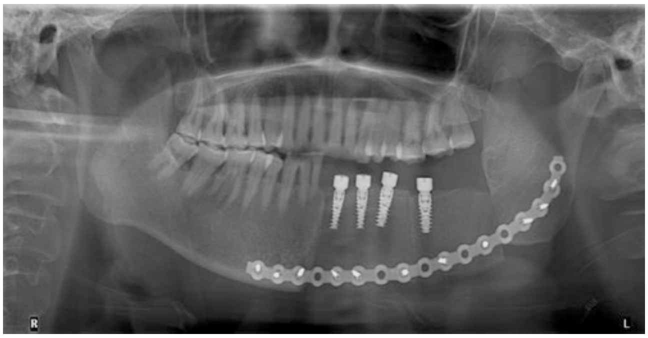


Fig. 42.13 Postoperative OPG showed well the position of implants and DCIA flap

Fig. 42.14 One-month postoperative facial profile

42.4 Clinical Implication

Mandibular reconstruction with iliac flap and dental implant under a precise surgical guide is an effective way to rehabilitate oral function and face contour at the same time.

Fig. 42.15 One-year postoperative facial profile

Fig. 42.16 Postoperative occlusion after implant denture rehabilitation

References

1. Mucke T, Holzle F, Loeffelbein DJ, et al. Maxillary reconstruction using microvascular free flaps. Oral Surg Oral Med Oral Pathol Oral Radiol. 2011;111:51–7.
2. Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. Plast Reconstr Surg. 1989;84:71–9.
3. Taylor GI, Townsend P, Corlett R. Superiority of the deep circumflex iliac vessels as the supply for free groin flaps. Clinical work. Plast Reconstr Surg. 1979;64:745–59.
4. Chang YM, Tsai CY, Wei FC. One-stage, double-barrel fibula osteoseptocutaneous flap and immediate dental implants for functional and aesthetic reconstruction of segmental mandibular defects. Plast Reconstr Surg. 2008;122:143–5.

43 Case of Facial Nerve Rehabilitation

Zhigang Cai, Shijun Li, Zimeng Li, and Xiaofeng Shan

43.1 Case Presentation

A 29-year-old female was referred for a recurrence of a right parotid gland malignant tumor. The primary lesion was myoepithelial carcinoma, treated by the local hospital with parotid gland tumor resection. The admission physical examination showed a large mass on the right face, with poor mobility and hard texture. She had normal facial nerve function preoperatively.

43.2 Choice of Treatment

Most surgical techniques for the treatment of parotid disease involve removal of the lesion while preserving the facial nerve, as any damage to it leads to severe functional deficits. There are many reconstructive methods for facial nerve reconstruction, such as facial nerve end-to-end anastomosis, the great auricular nerve graft, the sural nerve graft, or hypoglossal-facial nerve anastomosis [1].

When the proximal stump of the facial nerve is available but without enough length for direct neurorrhaphy, the method of cable nerve grafting interposition using the great auricular nerve, sural nerve, and lingual nerve could be performed [2, 3]. In consideration of surgical area at oral and maxillofacial regions, the great auricular nerve is a better choice compared to others because of the location near the facial nerve, which can provide a smaller surgical field in surgery [4–6].

43.3 Operative Technique

During the operation, part of the facial nerve was found surrounded by the tumor, and then the tumor was resected completely and the facial nerve was sacrificed. The greater auricular nerve was found on the surface of the sternocleidomastoid muscle and was harvested as a donor nerve. The distal end of the greater auricular nerve was sutured with temporo-facial division. The proximal end of the greater auricular nerve was end-to-end sutured with the mandibular margin branch and end-to-side anastomosed with temporal branch and zygomatic branch. The cervico-facial division is directly anastomosed with the buccal branch (Figs. 43.1-3, 43.4, 43.5, 43.6-7, 43.8, 43.9, and 43.10-12).

43.4 Clinical Implication

End-to-end anastomosis is the prior principle of facial nerve injury. However, in cases of facial nerve cut injury, end-to-end anastomosis must reroute the facial nerve as the nerve stump tensioning present or hardly be adopted as facial nerve damaged seriously. In this way, great auricular-facial nerve neurorrhaphy could be employed as one-stage surgery or for primary function recovery [1, 7]. Great auricular nerve, a branch of the superficial cervical plexus, which is neighbored to the facial nerve and has a similar cross-sectional trunk area with the facial nerve is becoming a common choice in facial nerve repair.

Z. Cai (✉) · S. Li · Z. Li · X. Shan
Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_43

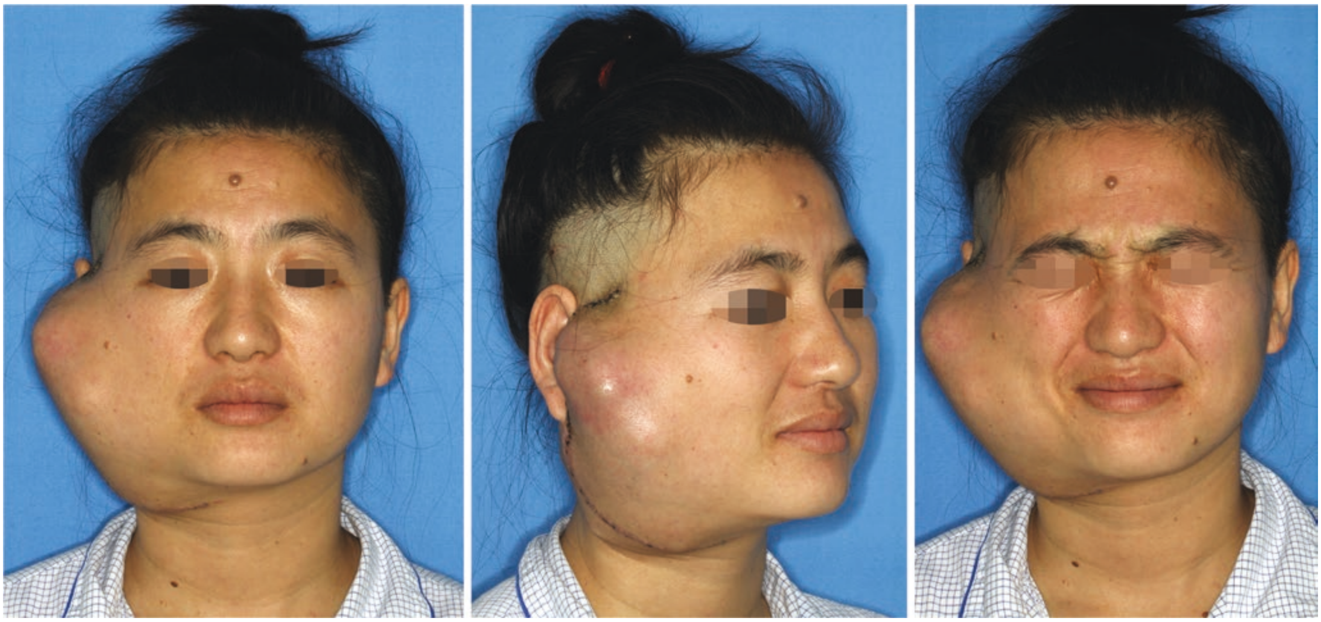


Fig. 43.1-3 Pre-operation situation

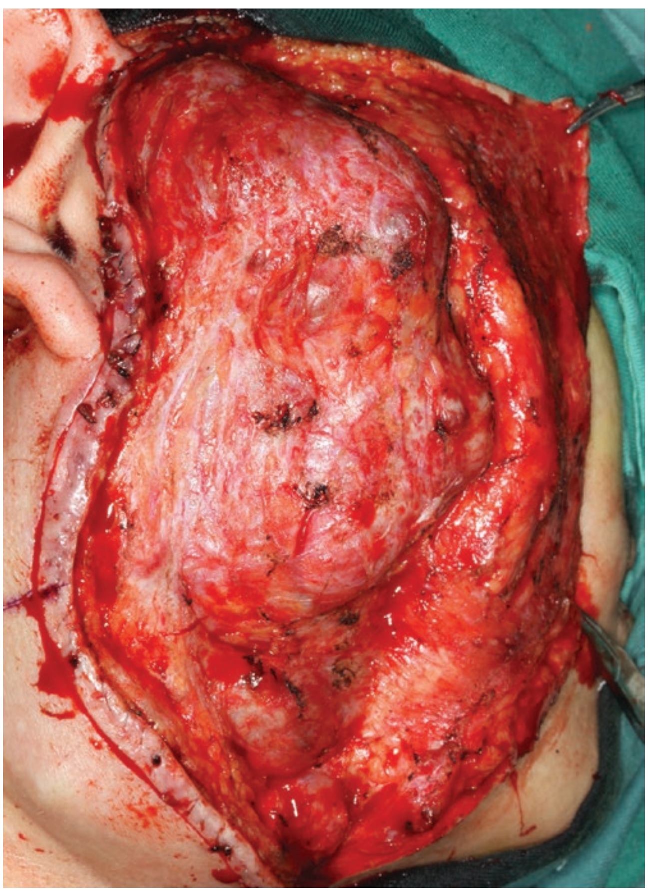


Fig. 43.4 The exploration of the tumor

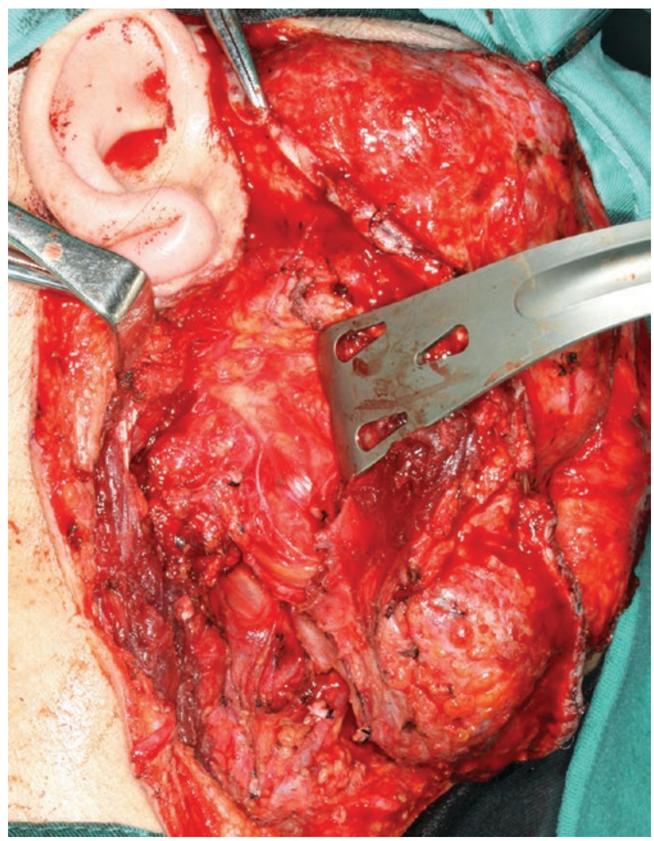


Fig. 43.5 The facial nerve was surrounded by the tumor

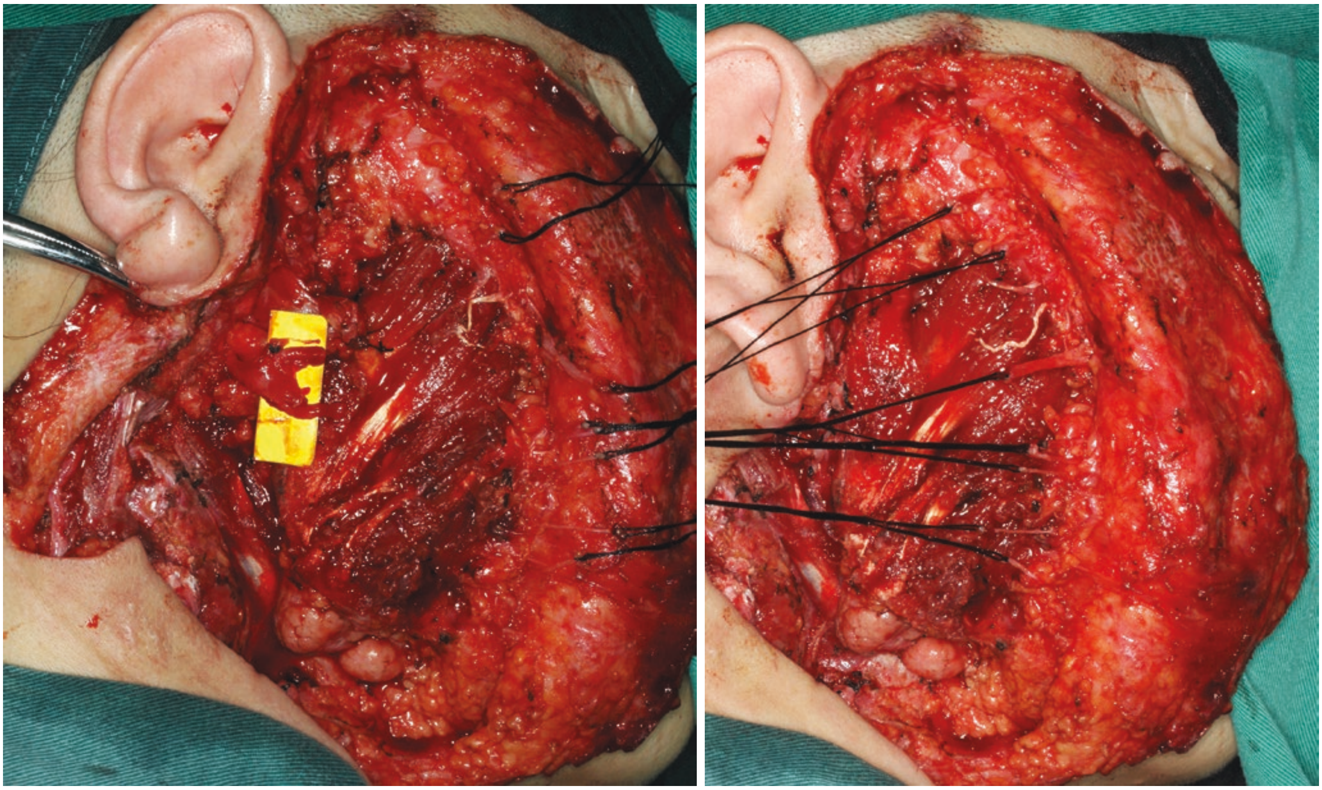


Fig. 43.6-7 Recognition of branches

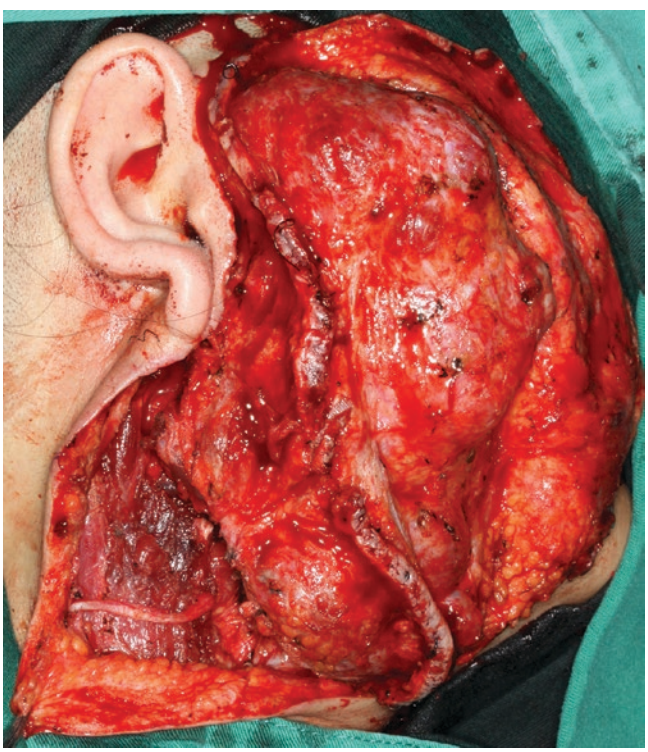


Fig. 43.8 Recognition of the great auricular nerve

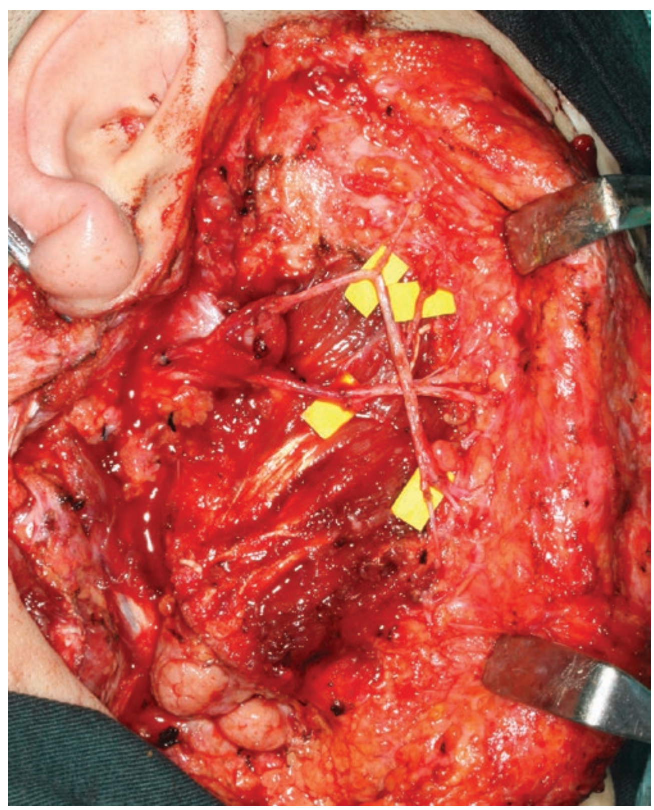


Fig. 43.9 The distal end of the greater auricular nerve was sutured with temporo-facial division, the proximal end of the greater auricular nerve was end-to-end sutured with the mandibular margin branch, and end-to-side anastomosed with temporal branch and zygomatic branch. The cervico-facial division directly anastomosed with the buccal branch

Fig. 43.10-12 Situation at follow-up

References

1. Reddy PG, Arden RL, Mathog RH. Facial nerve rehabilitation after radical parotidectomy. Laryngoscope. 1999;109:894.
2. Sun Y, Liu L, Han Y, et al. The role of great auricular-facial nerve neurorrhaphy in facial nerve damage. Int J Clin Exp Med. 2015;8:12970.
3. Humphrey CD, Kriet JD. Nerve repair and cable grafting for facial paralysis. Facial Plast Surg. 2008;24:170.
4. Renkonen S, Sayed F, Keski-Säntti H, et al. Reconstruction of facial nerve after radical parotidectomy. Acta Otolaryngol. 2015;135:1065.
5. Yla-Kotola T, Goldstein D, Hofer S, et al. Facial nerve reconstruction and facial disfigurement after radical parotidectomy. J Reconstr Microsurg. 2015;31:313.
6. Koshima I, Nanba Y, Tsutsui T, et al. New one-stage nerve pedicle grafting technique using the great auricular nerve for reconstruction of facial nerve defects. J Reconstr Microsurg. 2004;20:357.
7. Bascom DA, Schaitkin BM, May M, et al. Facial nerve repair: a retrospective review. Facial Plast Surg. 2000;16:309.

44

Mandibular Reconstruction with Vascularized Fibular Flap in Double-Barrel Technique

Zhigang Cai, Xiaofeng Shan, Yifan Kang, and Jie Liang

44.1 Case Presentation

A 34-year-old female was referred for a left mandibular myofibrosarcoma recurrence. She received tumor ablation surgery at a local hospital 1 year ago. Her chief complaint was left lower lip numbness. Most left lower teeth were lost. Preoperative OPG showed the invasion and destruction of the left mandibular body (Figs. 44.1 and 44.2).

44.2 Choice of Treatment

Mandibular reconstruction after tumor resection is challenging for functional and esthetic reasons. Several techniques are available. The most popular approach is the use of vascularized fibular flap [1] because of the long vascular pedicle, wide diameter of peroneal vessels, and types and volumes of tissues, and the fibular flap was the first choice in the last decades.

Compared to iliac flap, a single-barrel fibula can provide an aesthetic inferior mandibular margin or a functional alveolar ridge height for osseointegrated dental implants but not both [2]. Several techniques were raised to enhance the fibular height, such as vertical distraction osteogenesis, double-barrel, vascularized fibular flap with non-vascularized fibular bone graft. The distraction has some disadvantages. It may require an additional 4 months to finish therapy. It may also cause inferior margin of fibular flap fracture and wound dehiscence [2].

Thus, a new approach was presented to solve this problem. Vascularized fibular bone is used for alveolar reconstruction, and non-vascularized fibular bone graft is used for mandibular margin reconstruction. Lee et al. [3] reported mandibular reconstruction with vascularized fibular flap and non-vascularized fibular bone graft first. However, in their study, the onlay bone graft was used to reconstruct the alveolar. According to other studies, the non-vascularized bone graft might have up to 50% resorption rate [4]. It was not healthy for implantation.

Fig. 44.1 Preoperative facial profile

Z. Cai (✉) · X. Shan · Y. Kang · J. Liang
Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_44

Fig. 44.2 Preoperative OPG showed the tumor occupied left the mandibular body, causing the loss of teeth

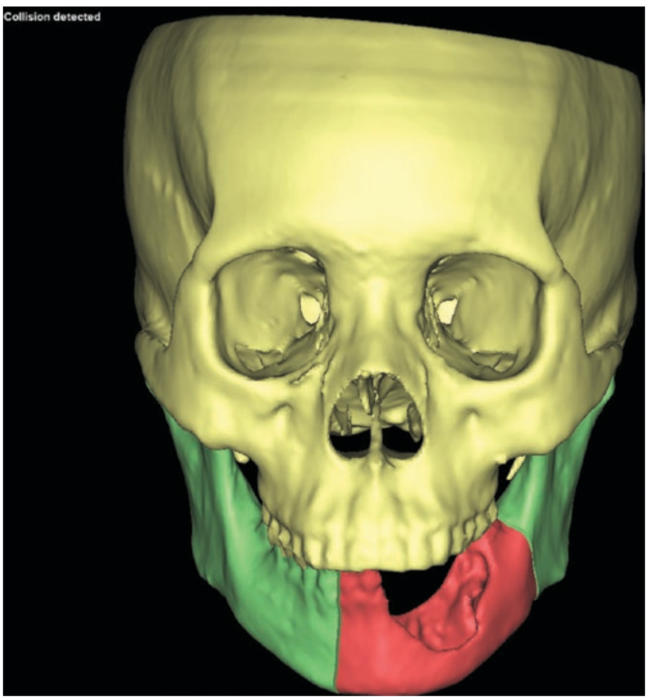


Fig. 44.3 Preoperative digital design showed the range of mandibulectomy

The double-barrel technique was first described by Horiuchi [5]. It could enhance two times height compared to the original fibula, which reconstructs the mandibular margin and alveolar bone at the same time. However, the double-barrel technique needs a fibula long enough. It may not be suitable for large mandibular defect. Fibula height is about 1.3–1.5 cm in Chinese people. The double-barrel technique may cause shortening of occlusion distance which is not convenient for prosthesis. Thus, preoperative digital design was important to simulate surgery process (Fig. 44.3) and measure the postoperative occlusion distance (Fig. 44.4). 3D-printed mandibular model was used for pre-bending the titanium plate (Fig. 44.5).

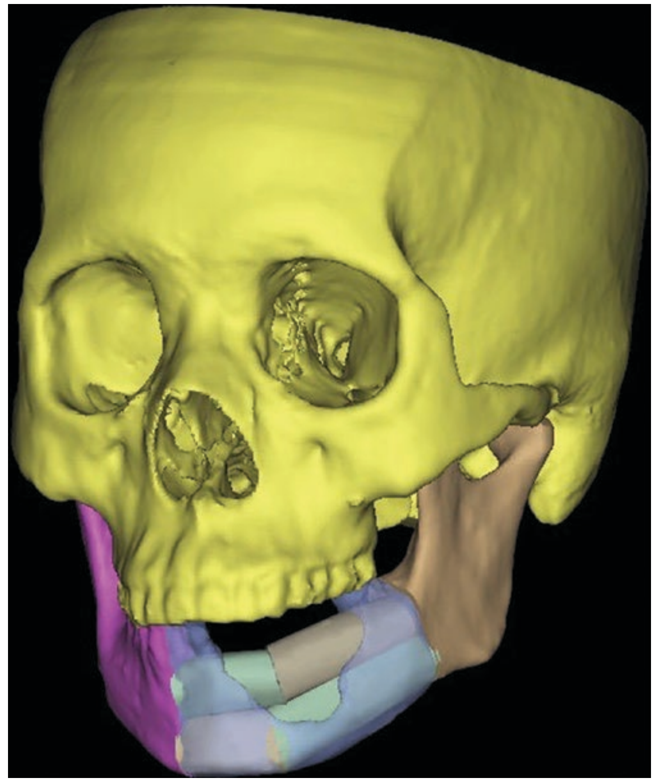


Fig. 44.4 Preoperative digital design showed the length of each fibular segment using a double-barrel technique

Fig. 44.5 3D-printed model and pre-bended titanium plate

44.3 Operative Technique

During the operation, two-team surgery was performed. Before the tumor ablation, a titanium plate was placed for keeping the residual mandible and occlusion relationship (Fig. 44.6). Team A performed tumor ablation through submandibular incision under the guidance of a computer-assisted navigation system

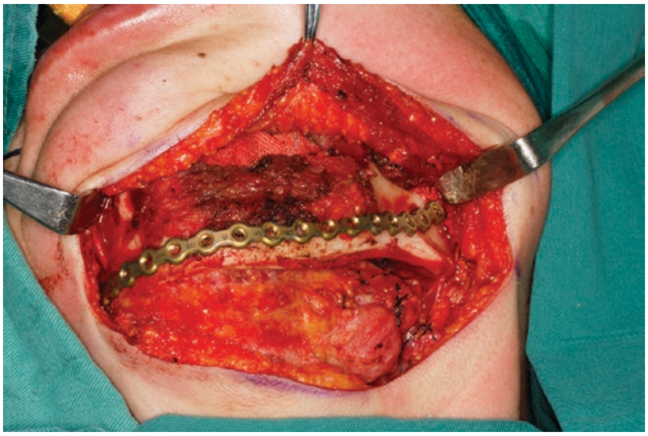


Fig. 44.6 Exposure of tumor and placing plate for keeping residual mandible and occlusion relationship

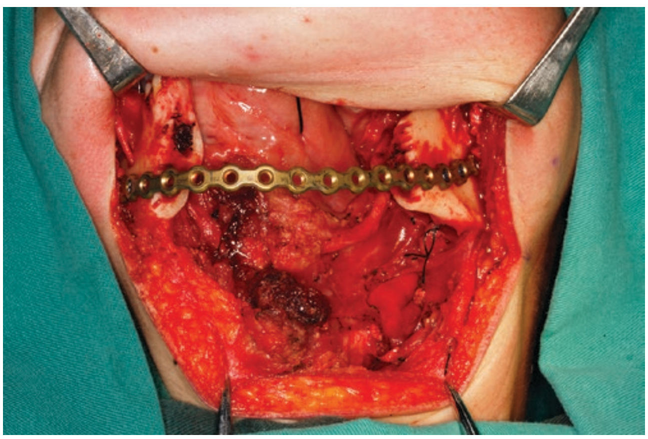


Fig. 44.7 Tumor ablation

(Fig. 44.7). And team B harvested the fibular flap. The fibular flap was shaped into four segments according to preoperative design. The fibular segments were numbered from 1 to 4 according to the proximal order. The No.1 was the proximal segment and the No.4 was the distal segment. Two of them were for mandibular inferior margin (1 and 2 in Fig. 44.8), and the others were for alveolar bone (3 and 4 in Fig. 44.8).

Under the guidance of a computer-assisted navigation system, the fibular flap was placed precisely and fixed by a titanium plate. Then, the vascular anastomosis was performed in an end-to-end way. The facial feature was well reconstructed and flap survived (Figs. 44.9, 44.10, and 44.11). The patient received implantation under the guidance of a surgical guide (Fig. 44.12). The postoperative position of implants and occlusion were good after prosthesis (Figs. 44.13 and 44.14). The patient's appearance and function were both well reconstructed (Fig. 44.15).

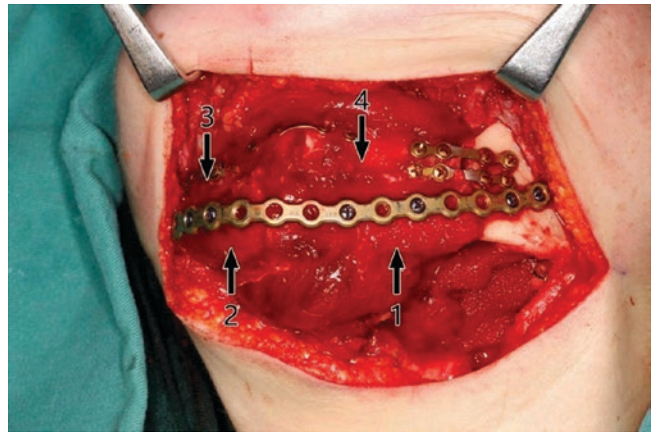


Fig. 44.8 Double-barrel fibular flap reconstruction of both mandibular inferior margin and alveolar bone

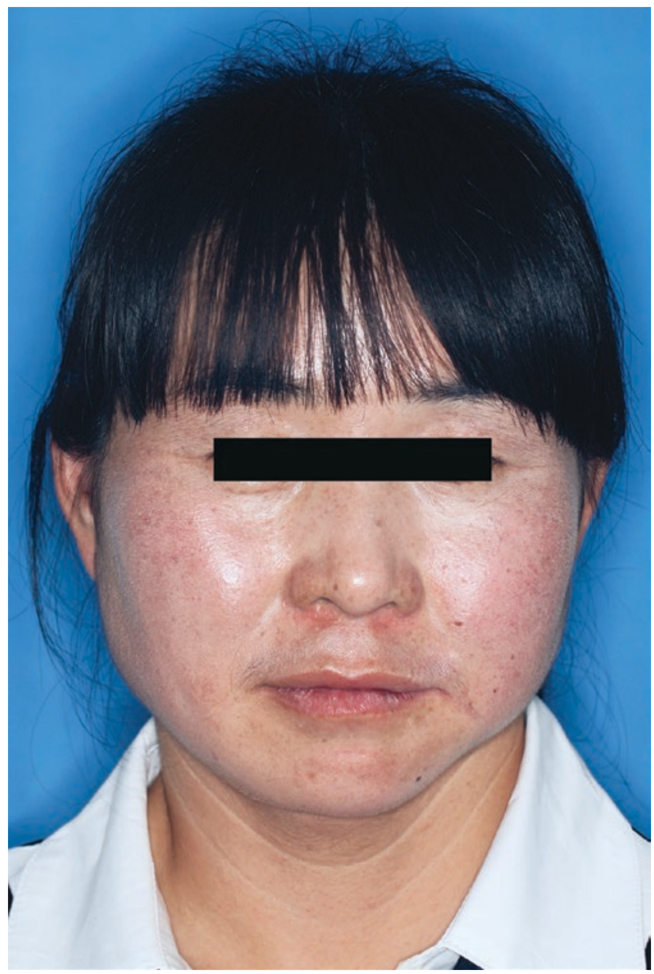


Fig. 44.9 Postoperative facial profile

Fig. 44.10 Flap survived well and the height of the alveolar bone was reconstructed well

Fig. 44.11 Postoperative OPG showed the morphology and the height of the mandible were reconstructed well

Fig. 44.12 Three dental implants were inserted using an implantation surgical guide

Fig. 44.13 Post-implantation OPG showed a good position of implants

Fig. 44.14 Removed partial denture rehabilitated occlusion relationship well

44.4 Clinical Implication

Mandibular reconstruction with double-barrel vascularized fibular flap is a safe and effective way to enhance the fibular height and reconstruct the mandibular defect.

Fig. 44.15 Both appearance and function were well reconstructed postoperatively

References

1. Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. Plast Reconstr Surg. 1989;84:71–9.
2. Chang YM, Wallace CG, Hsu YM, Shen YF, Tsai CY, Wei FC. Outcome of osseointegrated dental implants in double-barrel and vertically distracted fibula osteoseptocutaneous free flaps for segmental mandibular defect reconstruction. Plast Reconstr Surg. 2014;134:1033–43.
3. Lee JH, Kim MJ, Choi WS, et al. Concomitant reconstruction of mandibular basal and alveolar bone with a free fibular flap. Int J Oral Maxillofac Surg. 2004;33:150–6.
4. Li L, Blake F, Heiland M, Schmelzle R, Pohlenz P. Long-term evaluation after mandibular reconstruction with fibular grafts versus microsurgical fibular flaps. J Oral Maxillofac Surg. 2007;65:281–6.
5. Horiuchi K, Hattori A, Inada I, et al. Mandibular reconstruction using the double barrel fibular graft. Microsurgery. 1995;16:450–4.

45 Oromandibular Reconstruction with Intraoral Anastomosis of a Deep Circumflex Iliac Artery Perforator Fascial Flap with Iliac Crest

Lei Zheng, Xiaoming Lv, and Wenjie Wu

45.1 Case Presentation

A young female was referred for a lesion of the right mandible without any symptoms. The lesion is located in the body of the right mandible. The diagnosis of a suspected low-graded malignant tumor was confirmed by pathology before tumor ablation was performed, which resulted in a segmental mandible defect with 6 cm in length (Figs. 45.1, 45.2, 45.3, 45.4, and 45.5).

Fig. 45.1 Preoperative facial profiles

45.2 Choice of Treatment

The conventional treatment of this case was a segmental mandibulectomy and simultaneous reconstruction of oromandibular defects using vascularized bone graft, such as free fibula flap. Extraoral approaches can routinely be applied to vessel preparation and anastomoses during jaw reconstruction. However, this patient had high aesthetic and functional requirements as a young female. In consideration of the characters of the mandible tumor and the patient's requirements, we offered a different treatment, which was resection of mandibular tumor by transoral approach and use of intraoral anastomosis for mandibular reconstruction with DCIAPFF (deep circumflex iliac artery perforator fascial flap with iliac crest). All the operative procedures including the segmental mandibulectomy and simultaneous reconstruction of oromandibular defects were in the oral cavity.

Gaggl et al. [1] reported intraoral microvascular anastomosis first. The advantages of the intraoral anastomosis can be seen as follows: (1) avoiding the extraoral scar [1, 2]; (2) preventing facial nerve branch paralysis [3]; and (3) this technique is minimally invasive and safe [4].

Less donor-site morbidity was the criteria used as well as the esthetic demand in planning the treatment. The DCIAPFF was the flap of choice for this type of reconstruction. The rationale for the choice of the DCIAPFF was as follows. First, it could provide a suitable perforator fascial flap and sufficient bone. Second, a discreetly hidden donor-site scar and less donor-site morbidity justified this choice [5]. The wound of donor-site could be closed directly without a skin graft or mesh [6, 7].

L. Zheng (✉) · X. Lv · W. Wu
Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_45

Fig. 45.2 Preoperative occlusion

Fig. 45.3 Preoperative panoramic radiograph showing the lesion of the mandible

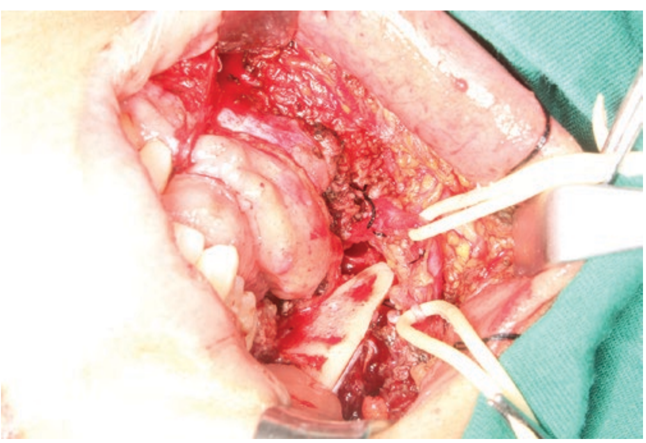


Fig. 45.4 The mandibular defect after mandibulectomy by transoral approach. The facial artery (↑) and vein (▲) were prepared by the transmucosal approach

Another advantage of intraoral anastomosis with DCIAPFF is avoiding pedicle elongation with vein grafts. The pedicle of DCIAPFF with approximately 5 cm in length is too short to reach the submandibular vessels. The facial vessels preparation through the intraoral approach is close to the defect site to avoiding pedicle elongation.

Fig. 45.5 The specimen after mandibulectomy

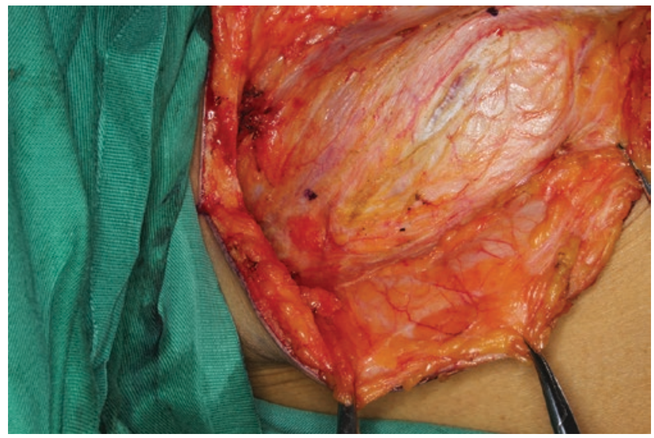


Fig. 45.6 The terminal musculocutaneous perforator of the deep iliac circumflex artery (←)

45.3 Operative Technique

The location of the terminal cutaneous perforators was detected by using a Doppler flowmeter preoperatively. The DCIAPFF harvest and tumor ablation were performed synchronously.

An initial incision was performed interior the iliac crest from the middle of the inguinal crease to the upper border of the fascial paddle centered on the perforator. The skin flaps were elevated toward both sides of the incision. The origin of the DCIA underneath the abdominal musculature was identified near the mid-point of the line between pubic tubercle and ASIS. Following the course of DCIA, meticulous dissection is made. Leaving a small cuff of abdominal muscle attached to the inner lip of the iliac crest helped protect the minute branches of the parent DCIA. DCIA was found to end as a musculocutaneous perforator, which was nourishing the overlying fascial tissue. Then, the dominant perforator was meticulously dissected (Fig. 45.6). After isolating the perforator, the border of the fascial tissue was cut to elevate the fascial flap. The iliac crest bone was harvested in the usual fashion (Fig. 45.7). The donor site was directly closed layer by layer without mesh.

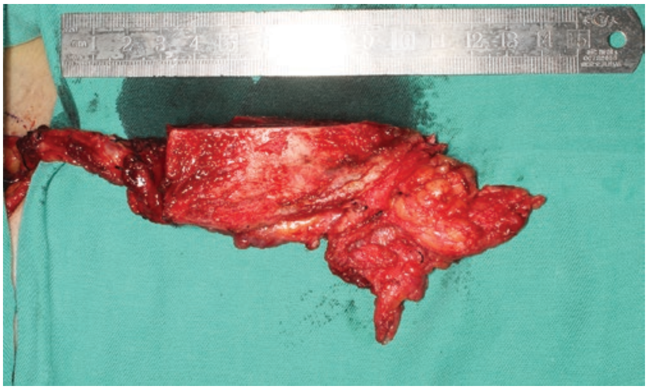


Fig. 45.7 The harvested deep circumflex iliac artery perforator fascial flap with iliac crest

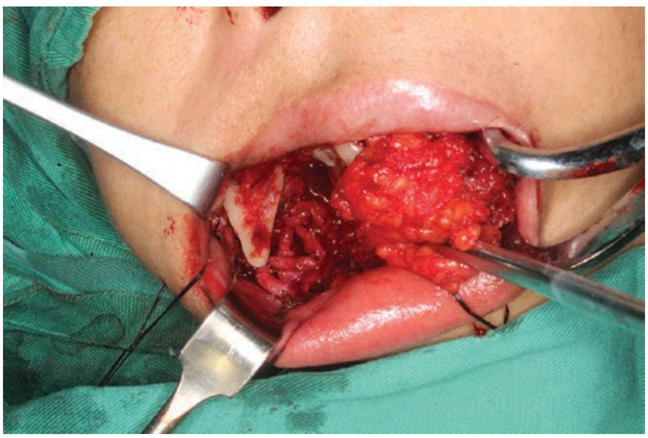


Fig. 45.8 Vascular anastomosis to the facial artery (←) and vein (→) was performed in an end-to-end fashion

After removing the submandibular gland, the facial vessels were prepared. The marginal mandibular branch of the facial nerve was protected carefully near the inferior margin of the removed mandible through the incision of the resection of the mandibular tumor by transoral approach. The facial vessels were dissected over a length of 4 cm to anastomosis (Fig. 45.4).

The harvested iliac flap was re-shaped to the required dimensions of the mandible. After fixation of the bone segment with a plate and screw, vascular anastomosis to the facial artery and vein was performed in an end-to-end fashion. Excellent inflow and outflow were checked. The fascial flap was used to reconstruct the soft-tissue defect as well as be a monitor (Figs. 45.8 and 45.9).

45.4 Clinical Implications

Oromandibular reconstruction with intraoral anastomosis of a deep circumflex iliac artery perforator fascial flap with iliac crest is an innovative technique for reconstruction of mandible defects less than 8 cm and a small amount of soft-tissue defect (Figs. 45.10, 45.11, 45.12, 45.13, and 45.14).

Fig. 45.9 Iliac bone graft in the final position fixed with a plate and screw after intraoral anastomosis

Fig. 45.10 Postoperative view of intraoral fascial flap at the 3-day examination

Fig. 45.11 Postoperative view of intraoral fascial flap at the 7-day examination

Fig. 45.12 Postoperative occlusion and intraoral appearance

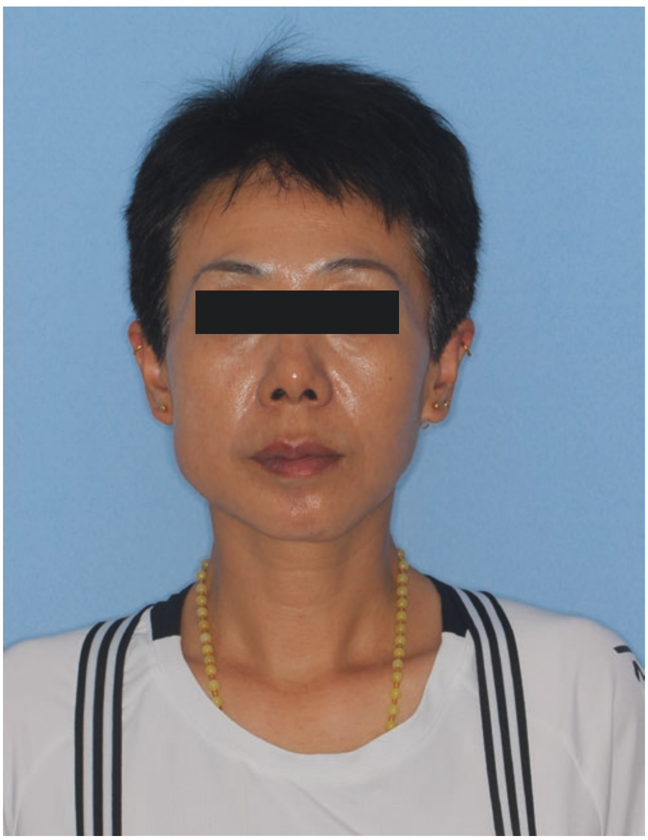


Fig. 45.13 Postoperative facial profiles

Fig. 45.14 Postoperative panoramic radiograph showing good mandibular configurations

References

1. Gaggl A, Bürger H, Virnik SA, et al. An intraoral anastomosing technique for microvascular bone flaps in alveolar ridge reconstruction: first clinical results. Int J Oral Maxillofac Surg. 2009;38:921–7.
2. Gaggl A, Bürger H, Virnik S, et al. The microvascular corticocancellous femur flap for reconstruction of the anterior maxilla in adult cleft lip, palate, and alveolus patients. Cleft Palate Craniofac J. 2012;49:305–13.
3. Sosin M, Sinada GG, Rodriguez ED, et al. Intraoral microvascular anastomosis of an iliac free flap for maxillary fibrous dysplasia. J Oral Maxillofac Surg. 2015;2068(73):e1–5.
4. Brandtner C, Bürger H, Hachleitner J, Gaggl A. The intraoral anastomosing technique in reconstructive surgery of the face - a consecutive case series of 70 patients. J Craniomaxillofac Surg. 2015;43:1763–8.
5. Schultz BD, Sosin M, Nam A, et al. Classification of mandible defects and algorithm for microvascular reconstruction. Plast Reconstr Surg. 2015;135:743e–54e.
6. Bitter K, Schlesinger S, Westerman U. The iliac bone or osteocutaneous transplant pedicled to the deep circumflex iliac artery. II. Clinical application. J Maxillofac Surg. 1983;11:241–7.
7. Ting JW, Rozen WM, Niumsawatt V, et al. Developments in image-guided deep circumflex iliac artery flap harvest: a step-by-step guide and literature review. J Oral Maxillofac Surg. 2014;72:186–97.

46 Bilateral Submandibular Gland Transplantations for Pediatric Several Dry Eye Disease

Guangyan Yu, Zhigang Cai, and Jiazeng Su

46.1 Case Presentation

A 9-year-old female patient was referred for severe dry eye disease for 3 years. The disease was caused by Steven-Johnson syndrome, and the patient complained of dryness, burning, foreign body sensation, itching, and red-eye of both eyes (Fig. 46.1).

46.2 Choice of Treatment

Ophthalmologic treatments including artificial tear substitutes and occlusion of tear drainage were both failed for her. An interdisciplinary team of oral and maxillofacial surgeons, ophthalmologists, and microsurgeon was built, and a treatment plan of bilateral microvascular autologous submandibular gland transplantations was made.

46.3 Operative Technique

A curved incision was made in the temporal region, and the superficial temporal artery and vein were carefully dissected (Fig. 46.2). The submandibular gland, including the facial artery, anterior facial vein, and Wharton's duct, was harvested first from the submandibular triangle through a conventional cervical approach. The chorda tympani supplying the submandibular gland was severed, whereas the lingual nerve was carefully protected (Fig. 46.3). Then, the remaining part of Wharton's duct was dissected and harvested via an incision of the mouth floor. The totally freed submandibular gland was transferred to the temporal region with facial artery, anterior facial vein, and Wharton's duct. The superficial temporal vessels were cut and prepared for anastomosis. The superficial temporal artery was anastomosed with the facial artery.

Fig. 46.1 Preoperative image

Fig. 46.2 Dissection of superficial temporal artery and vein

G. Yu (✉) · Z. Cai · J. Su
Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China
e-mail: gyyu@263.net

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_46

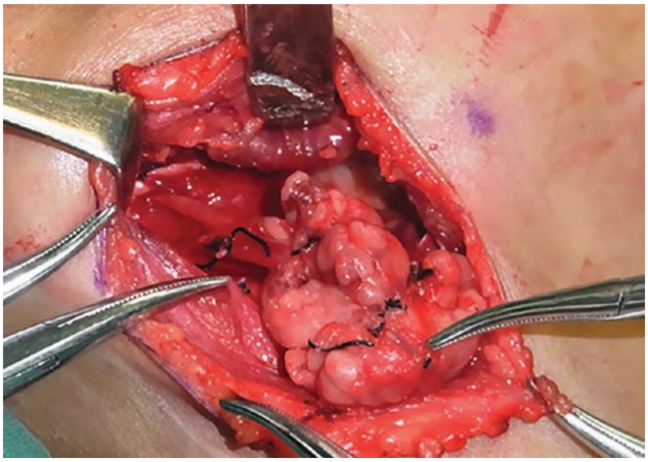


Fig. 46.3 Harvest of the submandibular gland, facial artery, anterior facial vein, and Wharton's duct

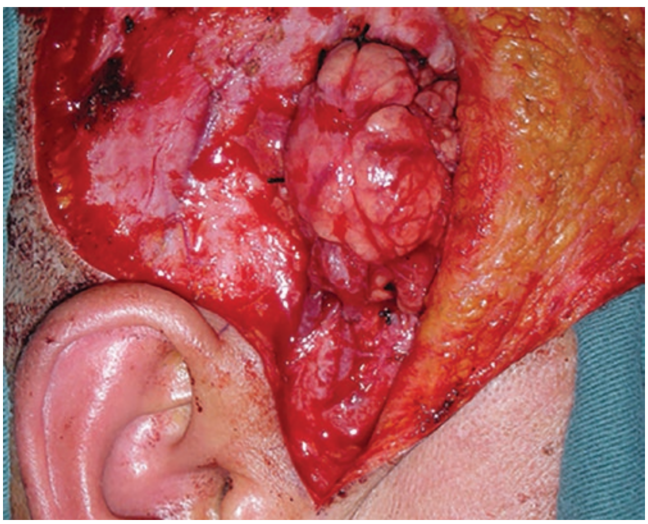


Fig. 46.4 Vessels anastomosis

Because the anterior facial vein didn't collect the venous drainage of the gland. The superficial temporal vein had to be anastomosed with the accompanying vein of the facial artery (Fig. 46.4). At last, Wharton's duct was passed through a tunnel prepared subcutaneously to the upper lateral conjunctival fornix by blunt dissection. The distal end of Wharton's duct was sutured to form an opening in the upper lateral conjunctival fold. The procedures of contralateral side transplantation were similar (Figs. 46.5 and 46.6). Postoperative ^{99m}Tc-pertechnetate examination showed that both transplanted glands were viable with good secretory function (Fig. 46.7). Two-year follow-up showed that the lubricant effect of saliva from transplanted glands was satisfactory with the disappearance of symptoms resulting from dry eye. The patient was able to stop the application of artificial tear substitutes. Objective examination showed improvement in Schirmer's test, best-corrected visual acuity, break-up time of tear film, and corneal staining (Fig. 46.8).

Fig. 46.5 Superficial temporal vessels dissection of the contralateral side

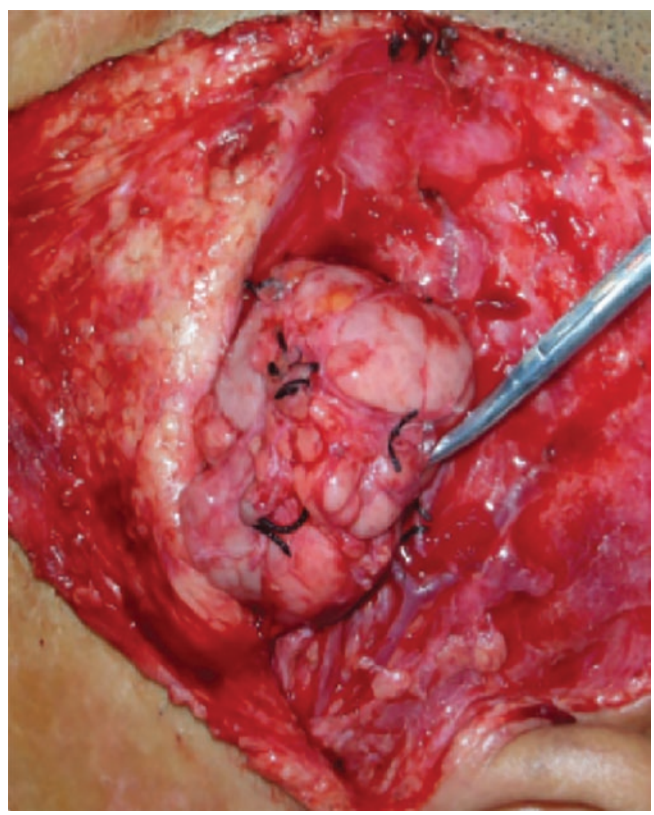


Fig. 46.6 Vessels anastomosis of the contralateral side

Fig. 46.7 Postoperative ^{99m}Tc-pertechnetate examination

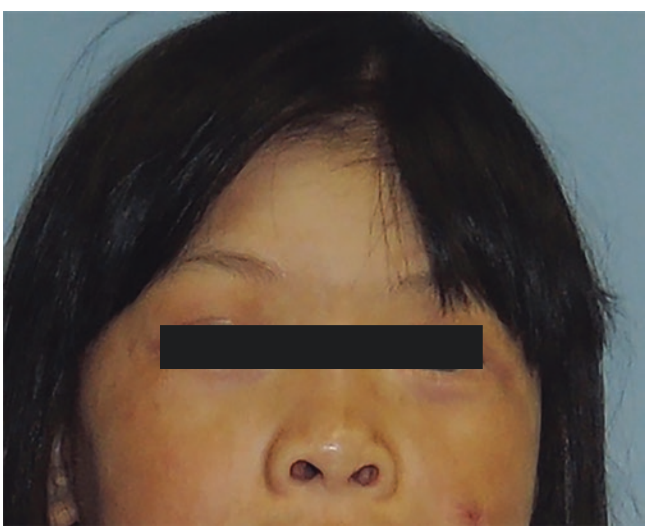


Fig. 46.8 Postoperative image of 2-year follow-up

46.4 Clinical Implication

Bilateral small organ transplantations were successfully performed in the head and facial region of a child and treated the severe dry eye disease [1–6].

References

1. Yu GY, Zhu ZH, Mao C, Cai ZG, Zou LH, Lu L, et al. Microvascular autologous submandibular gland transfer in severe cases of keratoconjunctivitis sicca. Int J Oral Maxillofac Surg. 2004;33:235–9.
2. Yu GY, Wu LL, Liu XJ. Microvascular autologous submandibular gland transfer in severe cases of keratoconjunctivitis sicca: a 10-year experience. Chin J Dent Res. 2009;12:79–82.
3. Zhang L, Su JZ, Cai ZG, Lv L, Zou LH, Liu XJ, et al. Factors influencing the long-term results of autologous microvascular submandibular gland transplantation for severe dry eye disease. Int J Oral Maxillofac Surg. 2019;48:40–7.
4. Geerling G, Sieg P, Bastian GO, Laqua H. Transplantation of the autologous submandibular gland for most severe cases of keratoconjunctivitis sicca. Ophthalmology. 1998;105:327–35.
5. Su JZ, Cai ZG, Yu GY. Microvascular autologous submandibular gland transplantation in severe cases of keratoconjunctivitis sicca. Maxillofacial Plast Reconstr Surg. 2015;37:5.
6. Paniello RC. Submandibular gland transfer for severe xerophthalmia. Laryngoscope. 2007;117:40–4.

47 Chimeric Thoracoacromial Artery Perforator Flap for One-Staged Reconstruction of Complex Pharyngoesophageal Defects

Xiao Zhou, Zan Li, and Dajiang Song

47.1 Case Presentation

A 52-year-old male was referred for a suspected local recurrence of laryngeal carcinoma. The primary lesion was a T4N2M0 squamous cell carcinoma treated by the referring hospital with prior laryngectomy with bilateral neck dissections, free anterolateral thigh flap transferring, tracheostomy, and radiotherapy. Tumor ablation resulted in bilateral neck dissection, a totally circumferential defect of the hypopharynx, 6 cm in length, and a lower neck skin defect (Fig. 47.1a, b).

47.2 Choice of Treatment

Oncological hypopharyngeal complex resections represent a unique reconstructive challenge [1]. Conventional techniques offer local and free tissue transfer options, such as pedicled pectoralis major myocutaneous flap [2], deltopectoral flap [3, 4], free radial forearm flap [5], free jejunal interposition flap [6], and anterolateral thigh flap [7]. However, clinical outcomes due to disease recurrence and long-term complications such as oesophageal fistula formation, severe skin contracture, and post-radiotherapy chronic wound make

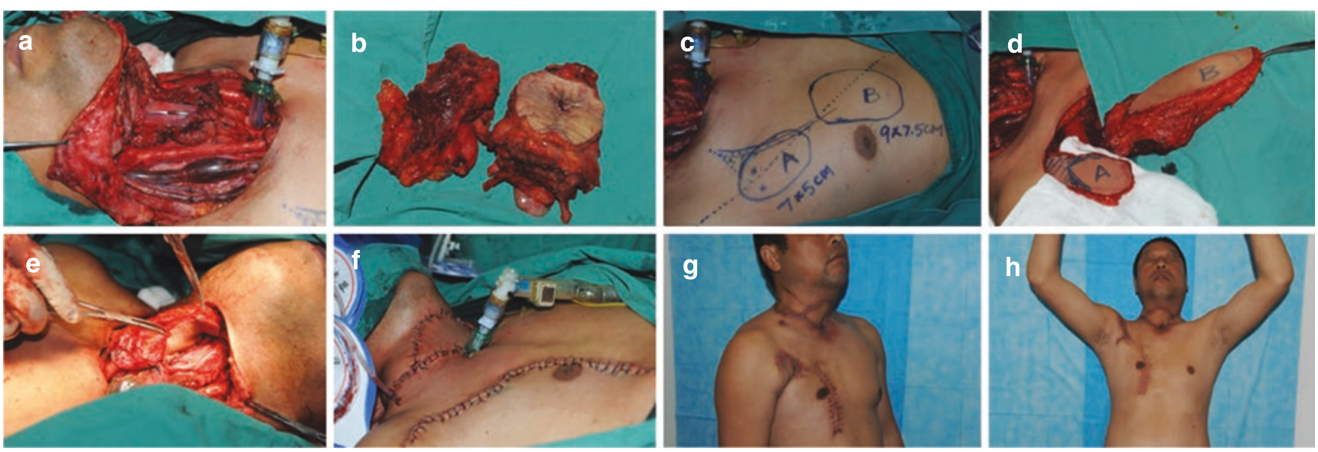


Fig. 47.1 (**a**) Defect after total laryngectomy and partial pharyngectomy in a previously irradiated patient. (**b**) Resected specimen. (**c**) Outline of the chimeric TAAP flap. (**d**) The chimeric TAAP flap was elevated. (**e**) Inset of the flap. Two skin paddles showing common vascular pedicle and side-by-side stacking, effectively doubling the width of the flap. (**f**) Closure of cervical wound with PM skin, repaired the neck necrosis skin, and for flap monitoring and direct closure of the donor site. (**g**) Follow-up at 8 months showing healing of the neck wound with no evidence of fistula and viable flap. (**h**) The flap healed successfully and the symmetry of the nipple and the pectoral major function was completely preserved at 20 months of follow-up

X. Zhou · Z. Li (✉) · D. Song
Department of Oncology Plastic Surgery, Hunan Cancer Hospital, Changsha, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_47

this reconstructive modality extremely difficult to manage [8]. Furthermore, complex anterior neck defects require a combination of two free flaps, or even two-staged reconstruction to achieve good clinical outcomes, especially when conventional pedicled flaps are contraindicated. When common practice "gold standard" free flaps are contraindicated due to lack of suitable recipient vessels [7], pedicle flaps offer a lifeboat option [9].

Circumferential hypopharyngeal defects associated with anterior neck defect have always been complex, requiring multiple staged procedures to establish sufficient oesophageal reconstruction and anterior neck coverage. We extensively evaluated the utilization of TAAP flap, pedicled or chimeric, with a focus on its design, defects location, clinical outcomes, and indication according to comorbidities to demonstrate that reconstruction of complex circumferential hypopharyngeal defects with anterior neck skin defect can be achieved reliably with TAAP flap.

A chimeric TAAP flap, including a 9.0 × 7.5 cm^2 standard PM flap and a 7.0 × 5.0 cm^2 TAAP flap, was designed and elevated (Fig. 47.1c, d). The two flaps were then transferred via the subclavian route to the defect; the perforator flap was fashioned into a tube connecting the oropharynx above and the esophagus below to achieve total circumferential hypopharyngeal reconstruction (Fig. 47.1e, f). A well-healed pharyngoesophageal and anterior neck reconstruction with the chimeric TAAP flap at 42-month follow-up is shown (Fig. 47.1g), and pectoralis major muscle function was completely preserved (Fig. 47.1h).

47.3 Operative Technique

A two-team approach was followed. Team A performed meticulous debridement of the defect or total resection of the tumor, and team B elevated the TAAP flap and dissected the pedicle. Simultaneously, precision assessment of the defect size and the required pedicle length (distance between the thoracoacromial trunk and the perforator) was utilized to adjust the preoperative flap design, if necessary [12, 13].

47.3.1 Flap Design and Harvesting

In all cases, the flap was designed via surface markings according to the cutaneous perforators from the pectoral branch of TAA, using a handheld Doppler. Along the line joining the acromion to the xiphoid process intersection with the perpendicular line drawn from the midclavicular line, the 4-cm^2 area around the located perforator was drawn [10, 11] (Fig. 47.2a).

The chimeric TAAP flap always was elevated in a medial-to-lateral fashion until the detection of the TAAP. Constantly emerged from the septum between the clavicular and the sternocostal heads of PM muscle, the TAA perforator was visualized. Following the perforator course toward the source vessels until the flap was completely islanded, dissection proceeded along the subfascial plane (Fig. 47.3). Longer pedicle of the TAA could be achieved by superior retraction of the PM muscle, and when the origin of the TAA from the subclavicular artery was encountered, dissection ended. To harvest a standard PM myocutaneous flap, the pectoral branch of TAA nourishing the PM muscle was preserved during the dissection (Fig. 47.1b). Passing under the clavicular head of the PM muscle and through either a subcutaneous tunnel or under the clavicle bone, the two flaps inset into the pharyngoesophageal defect (Fig. 47.2c). To avoid any pedicle compression or kinking during the flap insert, the authors made sure that the tunnel was large enough in every case. If it was required, the perforator flap was primarily thinned using tissue scissors at the peripheries. To achieve a 3-cm-diameter hypopharyngeal reconstruction, the chimeric flap was then stacked side-by-side in 12 total circumferential pharyngeal defect cases without skin compromise (Figs. 47.2d, 47.4, and 47.6), with a second layer closure of fascia and muscle over the mucosal flap suture line for more secure closure of flap junction and the PM muscle to obliterate the dead space to minimize fistula formation (Fig. 47.5). All anastomoses and the longitudinal side seam were completed with 3–0 polyglactin sutures in an interrupted fashion. To achieve pharyngeal reconstruction and the PM flap for replacement of neck skin simultaneously, the perforator flap was used in four total circumferential pharyngeal defect and three near-circumferential pharyngeal defect cases with extensive anterior neck defect (Fig. 47.5b). The near-circumferential pharyngeal defect cases without anterior neck defect were excluded from this series.

47.4 Clinical Implications

When free tissue transfer is contraindicated or neck vessels are depleted, the chimeric TAAP flap is an innovative local alternative solution for the reconstruction of complex circumferential hypopharyngeal defects (Fig 47.6).

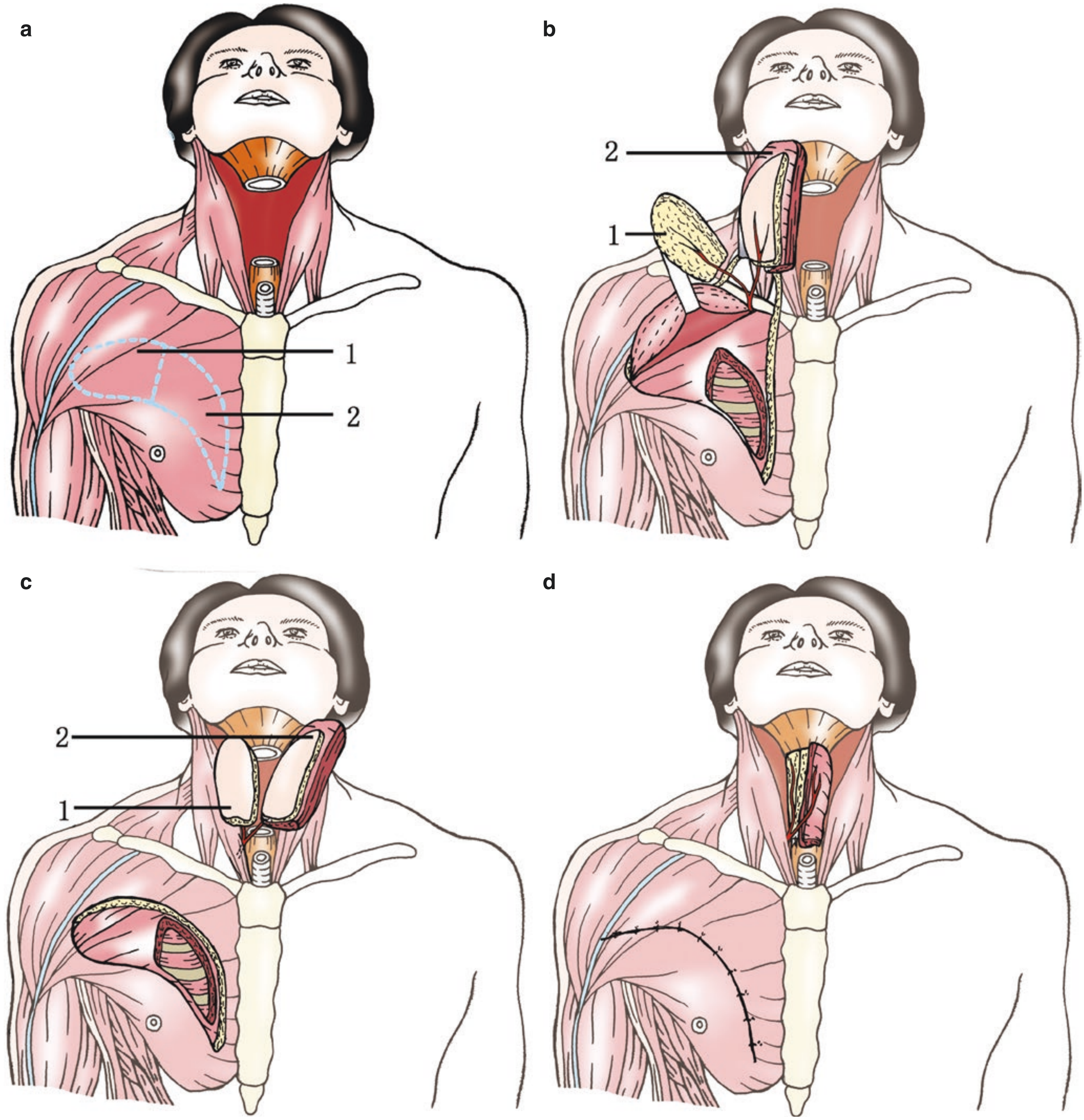


Fig. 47.2 (**a**) Circumferential hypopharyngeal and anterior neck skin defect and outline of the chimeric TAAP flap skin paddle. (**b**) Completed elevation of the chimeric TAAP flap. (**c**) Transfer of the chimeric TAAP flap. (**d**) Completed inset of the chimeric TAAP flap. 1: TAAP flap; 2: PM flap

Fig. 47.3 Chimeric TAAP flap harvesting. The flap is divided into two parts, perforator flap and PM flap

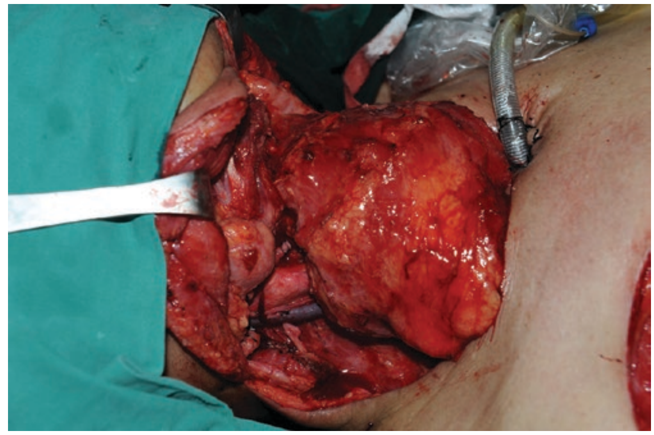


Fig. 47.5 Completed flap insetting. The fascia and muscle are wrapped around the tubed flap to reinforce the suture line

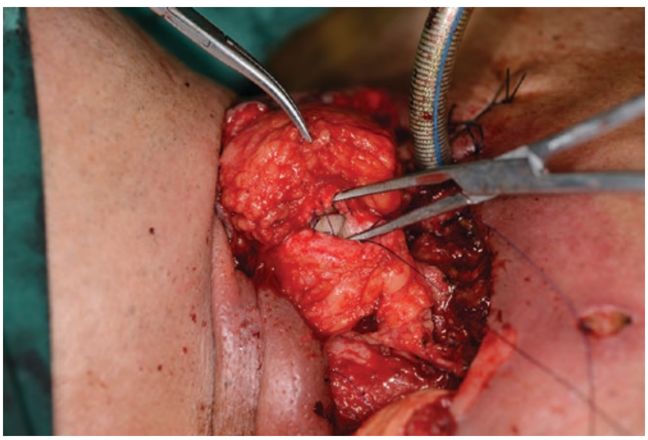


Fig. 47.4 Tubing of the flap

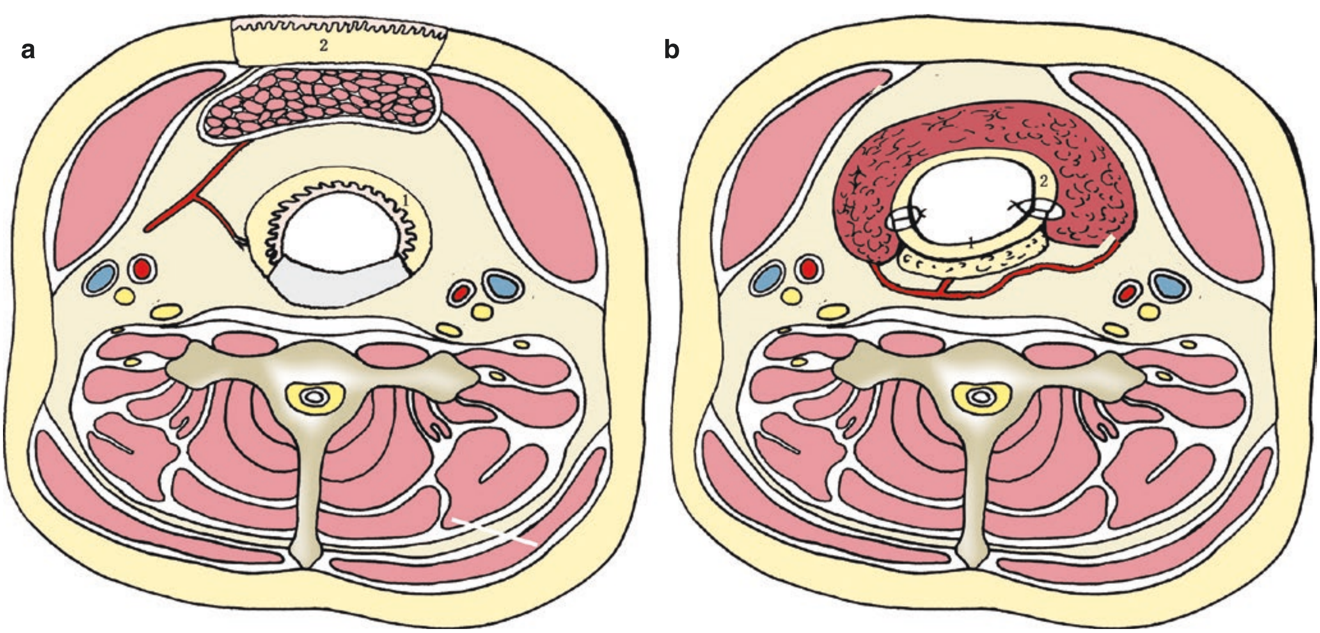


Fig. 47.6 Cross-section through the operative site after chimeric TAAP flap inset, showing its relationship with the prevertebral fascia and great vessels. 1: TAAP perforator flap; 2: Standard PM myocutaneous flap

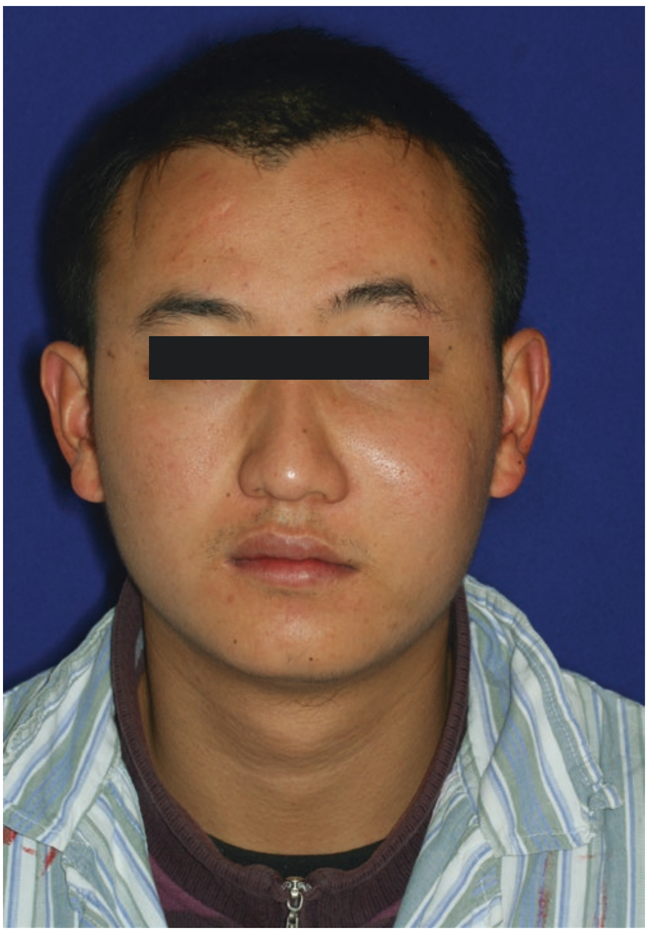
References

1. Yu P. One-stage reconstruction of complex pharyngoesophageal, tracheal, and anterior neck defects. Plast Reconstr Surg. 2005;116:949–56.
2. Burke MS, Kaplan SE, Kaplowitz LJ, et al. Pectoralis major myocutaneous flap for reconstruction of circumferential pharyngeal defects. Ann Plast Surg. 2013;71(6):649–51.
3. Bakamjian VY. Total reconstruction of pharynx with medially based deltopectoral skin flap. N Y State J Med. 1968;68:2771–8.
4. Nishi Y, Rikimaru H, Kiyokawa K, Watanabe K, Koga N, Sakamoto A. Development of the pectoral perforator flap and the deltopectoral perforator flap pedicled with the pectoralis major muscle flap. Ann Plast Surg. 2013;71:365–71.
5. Bootz F, Weber A, Oeken J, Keiner S. Reconstruction of hypopharynx after pharyngolaryngectomy with U-shaped radial forearm flap. Laryngorhinootologie. 2002;81:17–21.
6. Yu P, Lewin JS, Reece GP, Robb GL. Comparison of clinical and functional outcomes and hospital costs following pharyngoesophageal reconstruction with the anterolateral thigh free flap versus the jejunal flap. Plast Reconstr Surg. 2006;117:968–74.
7. Selber JC, Xue A, Liu J, et al. Pharyngoesophageal reconstruction outcomes following 349 cases. J Reconstr Microsurg. 2014;30:641–54.
8. Briant TD. Spontaneous pharyngeal fistula and wound infection following laryngectomy. Laryngoscope. 1975;85:829–34.
9. Amin AA, Rifaat M, Ellabban MA, Zedan M, Kamel M, Bassiouny M. Transaxillary thoracodorsal artery perforator flap: a versatile new technique for hypopharyngeal reconstruction. J Reconstr Microsurg. 2014;30:397–404.
10. Zhang YX, Li Z, Grassetti L, et al. A new option with the pedicle thoracoacromial artery perforator flap for hypopharyngeal reconstructions. Laryngoscope. 2015;126:1315.
11. Ariyan S. The pectoralis major myocutaneous flap. A versatile flap for reconstruction in the head and neck. Plast Reconstr Surg. 1979;63:73–81.
12. Li Z, Cui J, Zhang YX, et al. Versatility of the thoracoacromial artery perforator flap in head and neck reconstruction. J Reconstr Microsurg. 2014;30:497–503.
13. Zhang YX, Yongjie H, Messmer C, et al. Thoracoacromial artery perforator flap: anatomical basis and clinical applications. Plast Reconstr Surg. 2013;131:759e–70e.

48 Maxillary Reconstruction with Vascularized Fibula Osteomyocutaneous Flap Using Virtual Surgical Planning

Jian Sun, Jun Li, and Yi Shen

48.1 Case Presentation



A 28-year-old male suffered swelling in L maxilla and palate, which is diagnosed as an ossifying fibroma. The patient should undergo total maxillectomy and maxillary reconstruction with vascularized fibula osteomyocutaneous flap in combination with titanium mesh in the guidance of virtual surgical planning.

48.2 Choice of Treatment

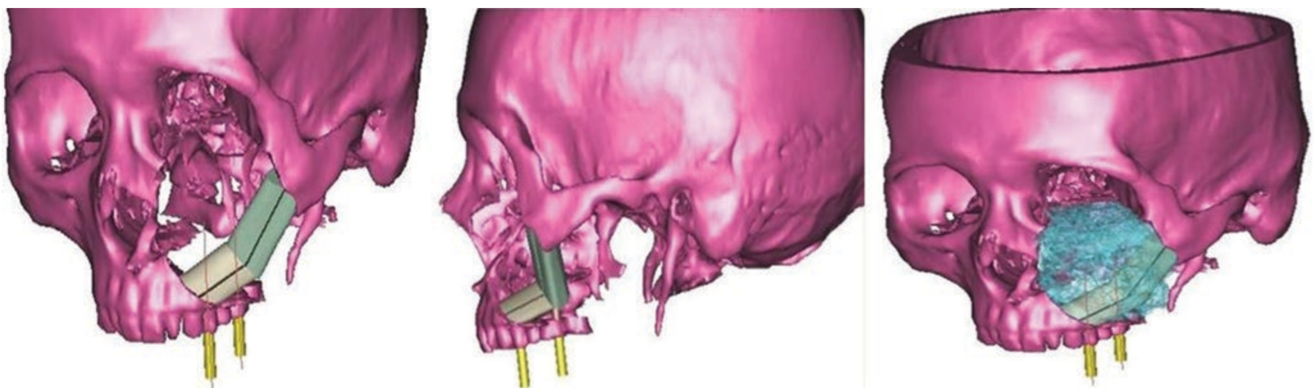
The goals of maxillary reconstruction are to reconstruct the maxillary buttress and produce optimal aesthetic form and to supply suitable conditions for dental rehabilitation. The use of maxillary prosthesis, locoregional pedicled flaps, and revascularized soft tissue flaps can only complete the goals in small maxillary defects. In large defects, these treatment options are no longer the optimal indication. For such defects, the application of revascularized composite osteocutaneous flaps, including the radial forearm flap, the scapular system flaps, the iliac crest flap, and fibula flap, is able to reconstruct the mid-facial skeletal buttress, minimize soft-tissue descent, and improve the post-reconstructive functions with dental rehabilitation [1–4]. Sufficient soft and hard tissue can be harvested with few limitations of vascular pedicle length, flap shape, and tissue position. In our department, we

J. Sun (✉) · J. Li · Y. Shen
Department of Oral and Maxillofacial-Head and Neck Oncology, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine, Shanghai, China

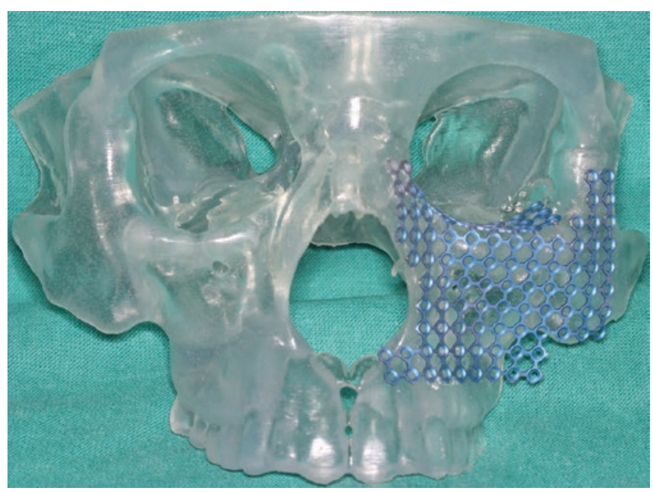
C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_48

prefer the fibula composite flap for reconstruction of class II defects and fibula composite flap in combination with titanium mesh for restoration of class III defects in immediate and delayed maxillary reconstruction [5]. In our planning for maxillary reconstruction, the fibula is osteotomized into several segments to reconstruct the alveolar ridge and the pterygomaxillary buttress. Titanium mesh can restore the infraorbital rim, the orbital floor, and the anterior wall of the maxilla in case of class III defect.

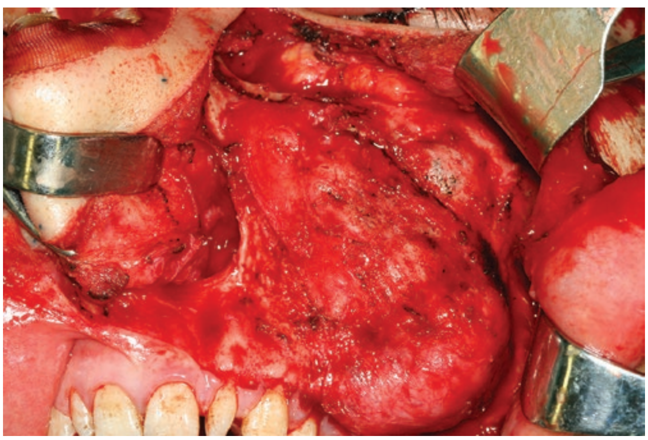
48.3 Operative Technique



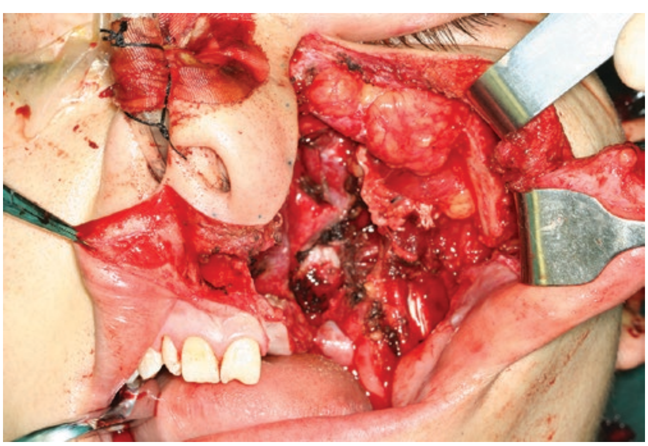
1. The virtual surgical planning at three planes.

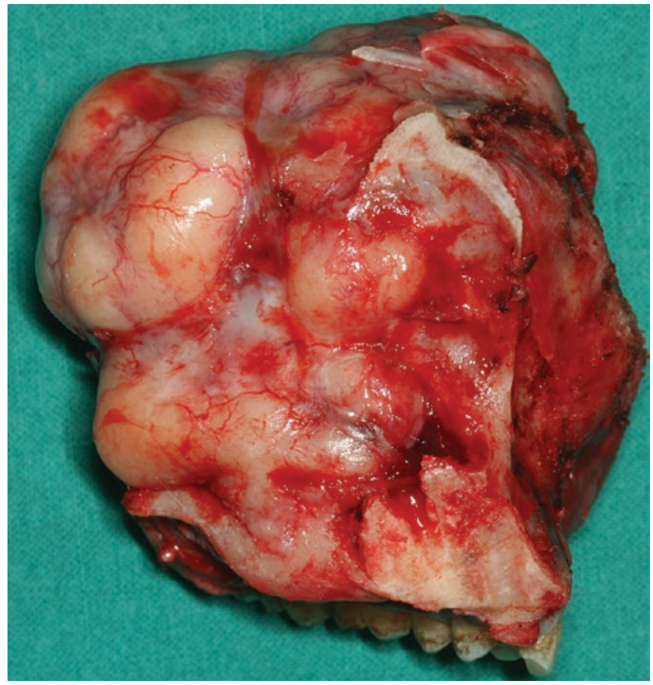


2. The stereo models and guide templates were produced according to the virtual planning. The titanium mesh and plate were pre-bended preoperatively on the models.

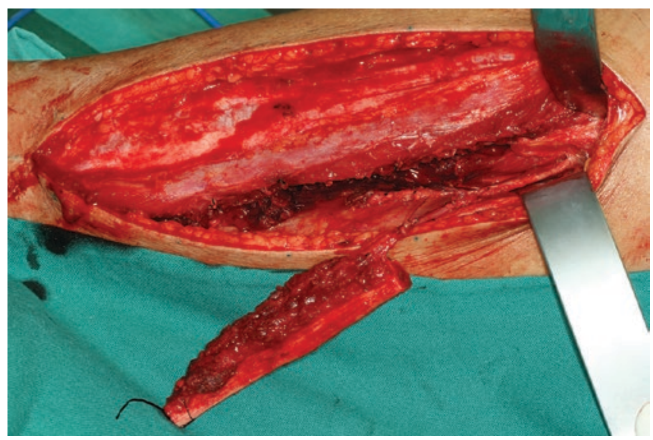


3. A lateral rhinotomy incision was cut and raised to expose the lesion in the maxilla.





4. Total maxillectomy was performed to resect the tumor. The defect and the specimen are shown in the Fig. 48.1.



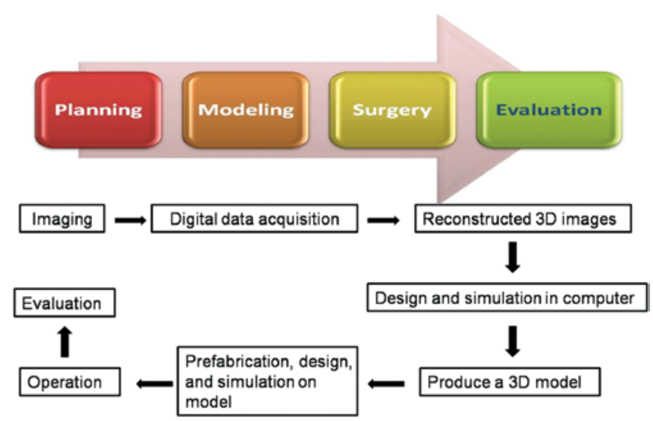
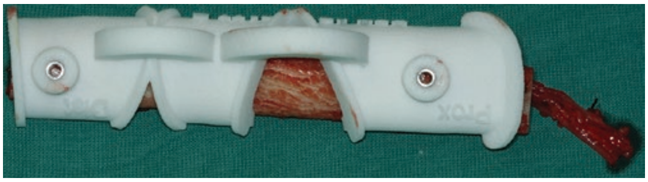
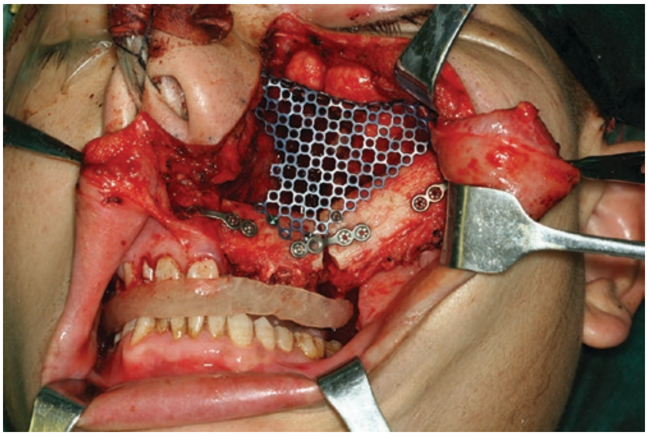


Fig. 48.1 The clinical steps of computer-aided cranio-maxillofacial surgery include planning, modeling, surgery, and evaluation

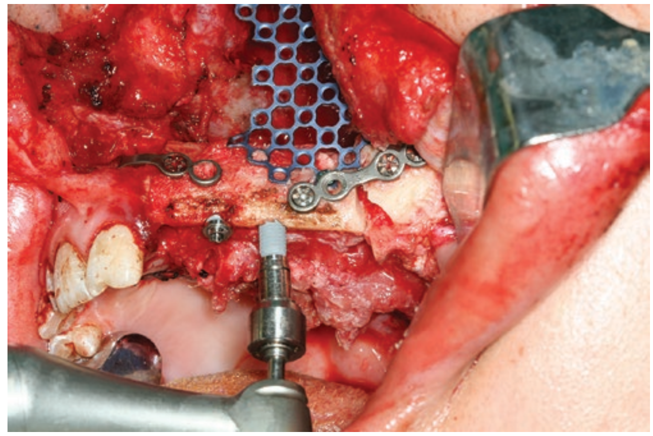
5. The vascularized fibula osteomyocutaneous flap was harvested by a second team simultaneously.





6. The fibula was osteotomized using a fibular osteotomy guide template to restore the maxillary alveolar ridge and pterygomaxillary buttress. The length of each fibular segment was not shorter than 1.5 cm to maintain the vascularity of each fibular segment. Titanium mesh was applied to restore the infraorbital rim, the orbital floor, and the anterior wall of the maxilla.

7. The ipsilateral superficial temporal artery and vein was used as the recipient vessels for anastomoses using microscope.



8. Three osseointegrated implants were inserted simultaneously in this patient according to the virtual surgical planning.

9. The facial and intraoral wounds were closed.


RA
10 cm
R
10 cm

10. Good facial appearance and occlusion were showed at postoperative 1-year follow-up, and three-dimensional CT reconstruction showed bilateral midfacial structures were symmetrical.

48.4 Clinical Implications

Cranio-maxillofacial surgery and computer-aided surgery technology have developed simultaneously. To decrease the stigmata and functional compromise of cranio-maxillofacial deformities and lesions, cranio-maxillofacial surgeons should first break and then restore the facial hard and soft tissues so that detailed anatomical and pathological information is required. Digital CT scan data with 3D surface-rendered and volume-rendered images supplies required anatomical detail in formats for surgeons to interpret and apply readily. The 3D rendered images facilitate preoperative diagnosis and planning, operation, and postoperative assessment as well as physician and patient education. In a word, the clinical steps of computer-aided cranio-maxillofacial surgery include planning, modeling, surgery, and evaluation (Fig. 48.1). The challenges of cranio-maxillofacial surgery do not have animal models and happen infrequently in patients. At present, it nearly takes a surgeon's career to extend the depth of knowledge and experience to perform operations safely, efficiently, and accurately. Computer-aided surgical education helps the promise of easing the learning curve through computerized anatomical libraries and surgical simulators. Computer simulation and rapid prototyping modeling technology allow the surgeon to perform accurate resection and restoration and to shorten the operating time, particularly in reconstructing the neo-maxilla. Using computer simulation, the entire process of resection and reconstruction can be preoperatively made and compared to opt for the best plan and indicate the postoperative outcome. Stereo models of post-reconstructive model and cutting guide template can be used to preoperatively pre-bend the reconstruction plate and intraoperatively recreate the planning. As a result, three-dimensionally reliable, efficient, and reproducible resection and reconstruction could be performed intraoperatively [6–8]. By comparing preoperative simulation with postoperative result, a more critical evaluation of the postoperative result could be made to improve the quality of operation. The potential shortcomings of computer simulation include cost and difficulty changing the surgical planning intraoperatively. For the latter, modification of the preoperative planning depends on the surgeon's experience.

References

1. Brown JS, Jones DC, Summerwill A, et al. Vascularized iliac crest with internal oblique muscle for immediate reconstruction after maxillectomy. Br J Oral Maxillofac Surg. 2002;40:183.
2. Uglesic V, Virag M, Varga S, et al. Reconstruction following radical maxillectomy with flaps supplied by the subscapular artery. J Craniomaxillofac Surg. 2000;28:153.
3. Clark JR, Vesely M, Gilbert R. Scapular angle osteomypgenous flap in postmaxillectomy reconstruction: defect, reconstruction, shoulder function and harvest technique. Head Neck. 2008;30:10.
4. Brown JS, Shaw RJ. Reconstruction of the maxilla and midface: introducing a new classification. Lancet Oncol. 2010;11:1001.
5. Sun J, Shen Y, Li J, et al. Reconstruction of high maxillectomy defects with the fibula osteomyocutaneous flap in combination with titanium mesh or a zygomatic implant. Plast Reconstr Surg. 2011;127:150.
6. Shen Y, Sun J, Li J, et al. Special considerations in virtual surgical planning for secondary accurate maxillary reconstruction with vascularized fibula osteomyocutaneous flap. J Plast Reconstr Aesthet Surg. 2012;65:893.
7. Shen Y, Li J, Ow A, et al. Acceptable clinical outcomes and recommended reconstructive strategies for secondary maxillary reconstruction with vascularized fibula osteomyocut. J Plast Reconstr Aesthet Surg. 2017;70:341–51.
8. Li J, Shen Y, Wang L, et al. Superficial temporal versus cervical recipient vessels in maxillary and midface free vascularized tissue reconstruction: our 14-year experience. J Oral Maxillofac Surg. 2018;76:1786–93.

49 Transoral Segmental Mandibulectomy and Intraoral Anastomosis for Mandibular Reconstruction Guided by Virtual Surgical Planning and Intraoperative Navigation

Jian Sun, Jun Li, and Mingming Lv

49.1 Case Presentation

A 40-year-old female was referred with mild swelling on the left side of the mandible for 6-month duration with no complaint of pain, tenderness, dysphagia, dysphonia, or dyspnoea and no history of any trauma to the face (Fig. 49.1). CT scan and panoramic radiograph showed a well-circumscribed multilocular mass in left body of the mandible (Fig. 49.2).

49.2 Choice of Treatment

Ameloblastoma is a benign odontogenic tumor that represents 1% of all tumors in the oral cavity. The elective treatment of ameloblastoma is surgery. The optimal surgical treatment of ameloblastoma should minimize recurrences, restore function and aesthetics, and leads to minimal morbidity in the donor area. Radical surgery is suggested to be the most recommended option in multicystic/solid and advanced unicystic tumors.

In conventional radical surgery, segmental mandibulectomy and immediately mandibular reconstruction are usually performed through an extraoral approach. In the present case, the segmental mandibulectomy and vessel anastomosis was performed intraorally without any extraoral incision, and mandibular reconstruction was performed with vascularized osseous flap using virtual surgical planning (VSP) and intraoperative navigation. In the outcome, we were able to achieve the desirable results by keeping the procedure minimally invasive and avoiding any external scar.

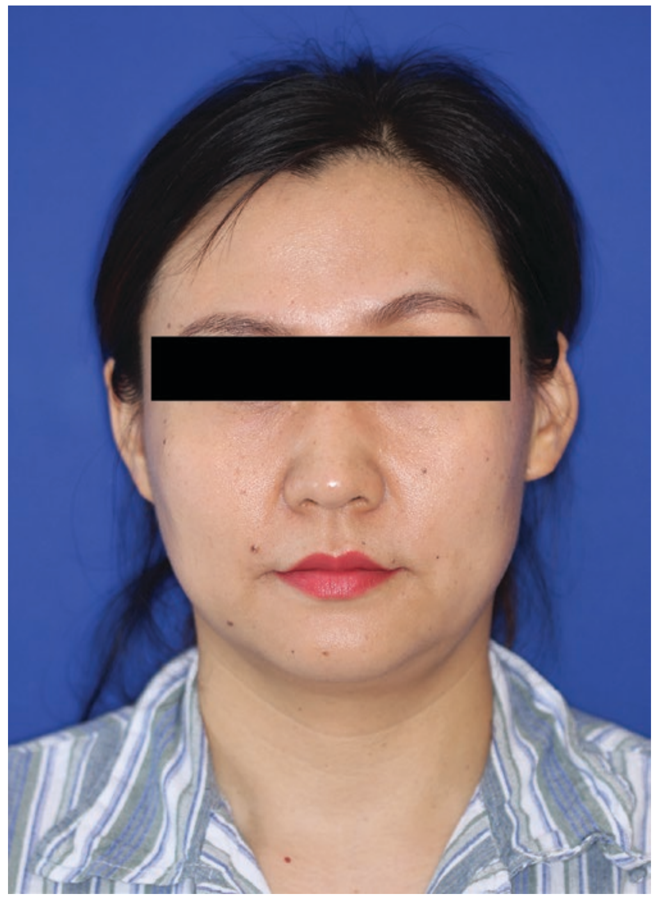


Fig. 49.1 Preoperative frontal facial photograph of the patient with ameloblastoma in the left mandible

49.3 Operative Technique

49.3.1 Virtual Surgical Planning (VSP)

In virtual surgical planning, the DICOM (Digital Imaging and Communication in Medicine) data of the patient are transferred to the software, where determination of the resection

J. Sun (✉) · J. Li · M. Lv
Department of Oral and Maxillofacial-Head and Neck Oncology, Shanghai Ninth People's Hospital, College of Stomatology, Shanghai Jiao Tong University School of Medicine, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_49

Fig. 49.2 Preoperative panoramic radiograph of the patient showing radiolucency at the left body of the mandible

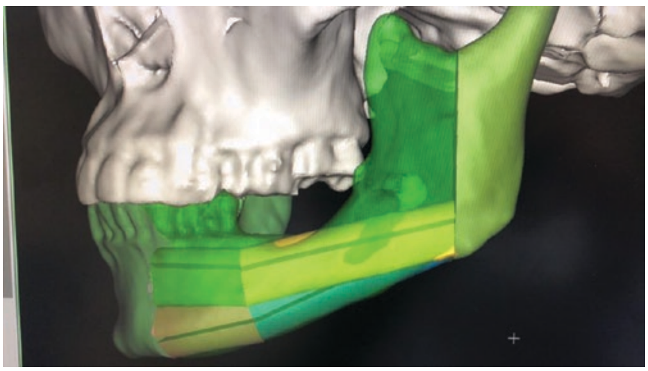


Fig. 49.3 Virtual surgical planning

margins and virtual mandibulectomy can be performed. Then, the DICOM data of donor site bones were imported and superimposed on the mandibular defect to recreate the native mandibular contour and geometry in the neo-mandible (Fig. 49.3). In this case, we used an important technique where occlusion-oriented reconstruction was done. The titanium reconstruction plate was prebent using 3D compression molding technology.

49.3.2 Surgical Procedure

As described in detail in our previous published paper [1], the patient underwent osteotomy and bone grafting via transoral approach by giving incision at the attached gingiva. When the mandible and tumor site were adequately exposed, the cutting guide for proximal osteotomy was positioned through the teeth and fixed by placing screws through the holes on the guide, and proximal osteotomy was performed (Fig. 49.4). Then, the bone segment (to be removed) was pulled anteriorly and medially to expose the distal part of the mandible to fix the distal osteotomy cutting guide (Fig. 49.5). After the distal osteotomy, segmental mandibulectomy is completed transorally, and the cutting guides were removed. The pre-bent reconstruction plate was then screwed onto the remnant mandible using the predrilled holes of cutting guides (Fig. 49.6). The order of reconstruction plate fixation is just

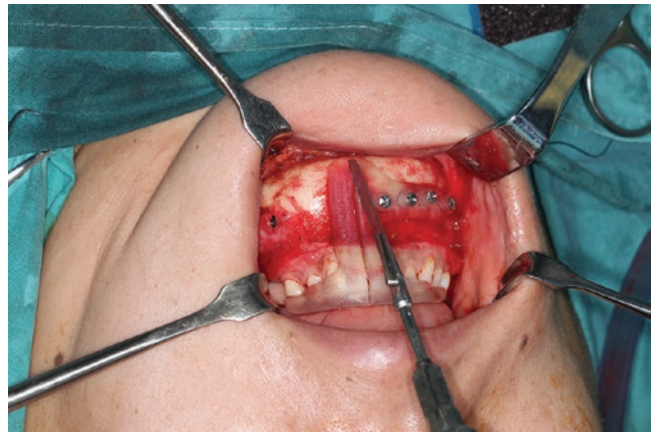


Fig. 49.4 Intraoperative photograph showing the cutting guide for proximal osteotomy positioned through the teeth and fixed with screws placed through the holes on the guide and use of surgical reciprocating saw for performing proximal osteotomy

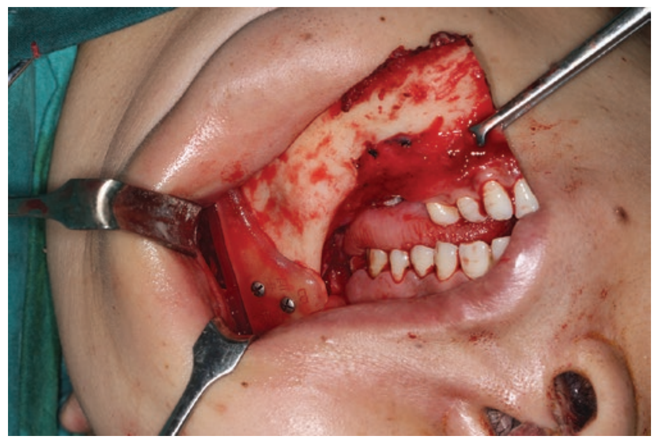


Fig. 49.5 Intraoperative photograph showing the exposed bone segment, pulled anteriorly and medially to expose for distal osteotomy site, and fix the cutting guide

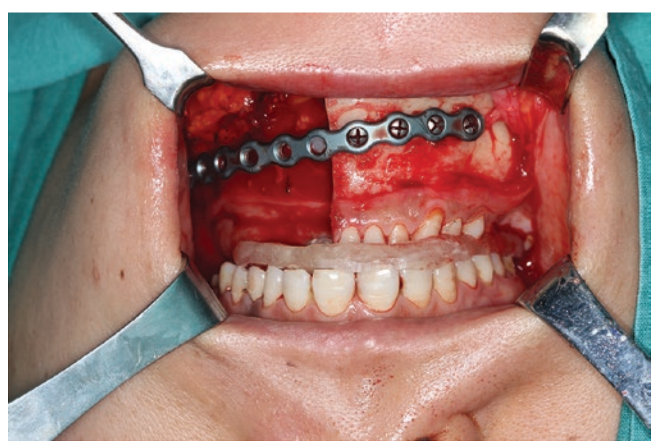


Fig. 49.6 Intraoral photograph showing pre-bent reconstruction plate screwed onto the remnant mandible using the predrilled holes of cutting guides

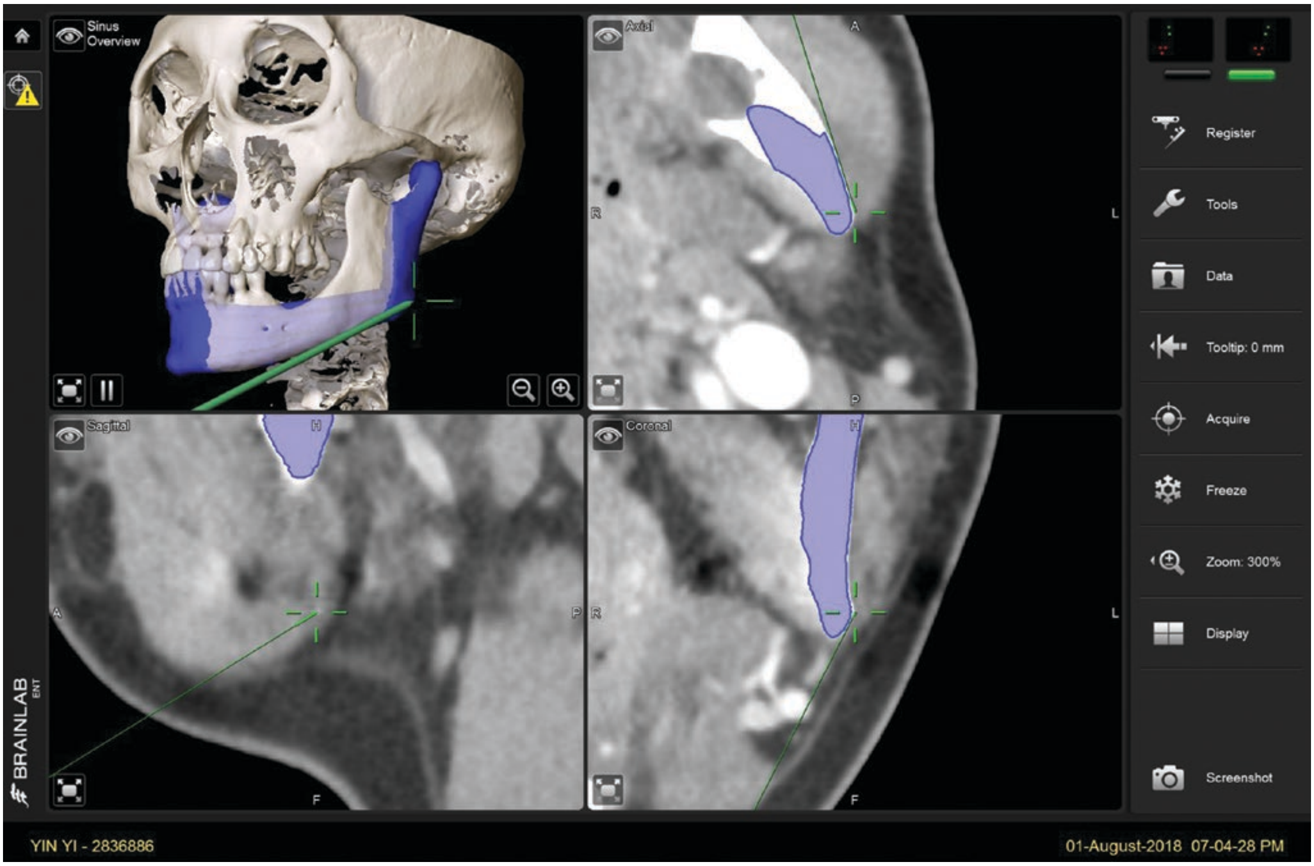


Fig. 49.7 Photograph showing real-time intraoperative navigation used to confirm and correct the spatial position of the neo-mandible

reverse to that of osteotomy procedure. Due to this technique, the spatial relationship of the mandible remains unchanged after the mandibulectomy and reconstruction procedure. At the same time, the osseous flap was harvested and contoured in accordance with the shaping guide. Then, the harvested bone segments were inserted into the defect and anchored to the reconstruction plate. The real-time navigation system was used to ascertain the correct spatial position of the neo-mandible by comparing it with the actual position of condyle, angle, body, and symphysis on the VSP (Fig. 49.7). After the position of neo-mandible was confirmed, intraoral anastomosis was performed in an end-to-end fashion using the surgical microscope (Fig. 49.8). The patient had a good bone union, aesthetic, and occlusion at 6-month follow-up (Figs. 49.9 and 49.10).

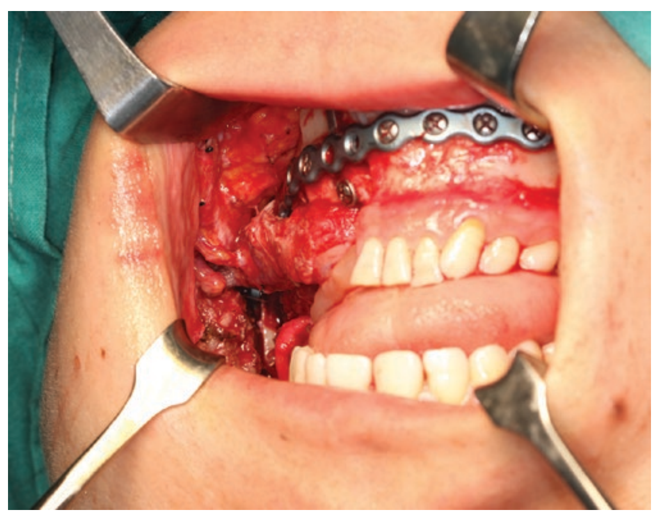


Fig. 49.8 Intraoperative photograph showing intraoral anastomoses performed between facial and peroneal vessels in an end-to-end fashion. The Coupler Microvascular Anastomat (Synovis Micro Companies Alliance, USA) was used for vein anastomosis (yellow circle)

49.4 Clinical Implications

Our group found it feasible to perform transoral segmental mandibulectomy and intraoral anastomosis without any extraoral incision, for mandibular reconstruction in patients with benign lower jaw tumors [2]. Application of VSP in combination with intraoperative real-time navigation following the guidance of occlusion allows completion of functional mandibular reconstruction with accurate results of symmetric

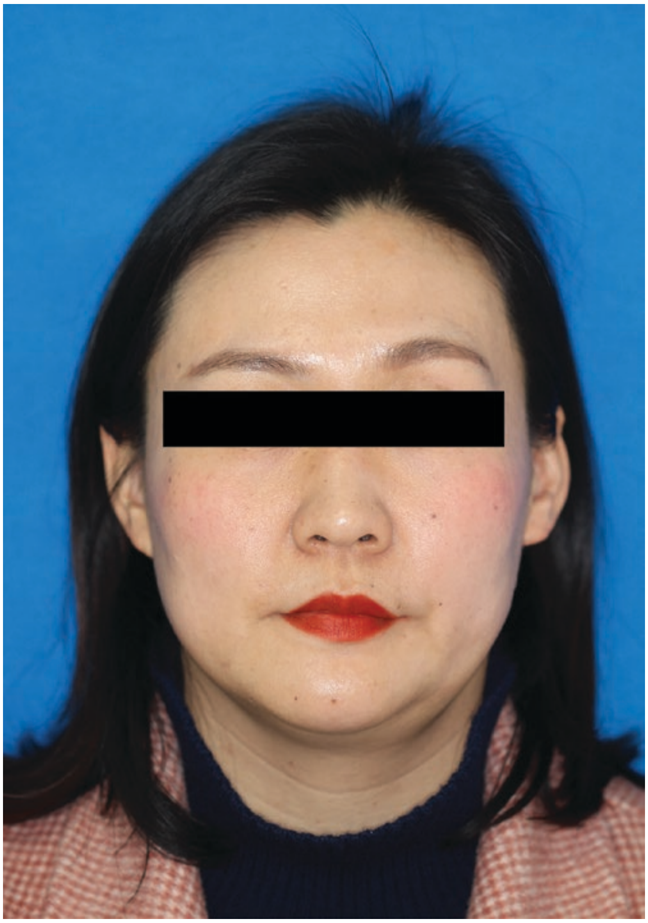


Fig. 49.9 Postoperative frontal facial photograph showing good symmetry and esthetics at 6-month follow-up

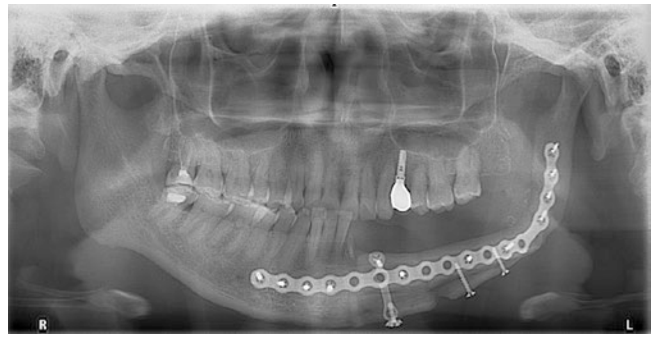


Fig. 49.10 Postoperative panoramic radiograph of the patient showing good osseous flap take up and stable mandibular position

appearance and the good spatial relationship between neomandible and adjacent soft and hard tissues [3, 4].

References

1. Lv M, Yang X, Gupta A, Shen Y, Li J, Sun J. Sequential application of novel guiding plate system for accurate transoral mandibular reconstruction. Oral Oncol. 2020;111:104846. https://doi.org/10.1016/j.oraloncology.2020.104846. Epub ahead of print
2. Sun J, Li J, Lv MM, Wang L, Gupta A, Shen Y. Expanded Transoral microvascular mandibular reconstruction: a scar-free approach. J Oral Maxillofac Surg. 2019;S0278-2391(19):31337-0.
3. Shen Y, Sun J, Li J, Ji T, Li MM. A revised approach for mandibular reconstruction with the vascularized iliac crest flap by virtual surgical planning. Plast Reconstr Surg. 2012;129(3):565e–6e.
4. Shen Y, Sun J, Li J, Ji T, Li MM, Huang W, Hu M. Using computer simulation and stereomodel for accurate mandibular reconstruction with vascularized iliac crest flap. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012;114(2):175–82.

Reconstructed Bladder Innervation Above the Level of Spinal Cord Injury to Produce Urination by Abdomen-to-Bladder Reflex Contractions

50

Chunlin Hou and Haodong Lin

50.1 Case Presentation

In June 2000, a 38-year-old female patient with bladder dysfunction due to conus medullaris injury came to our hospital for treatment. She was completely paraplegia due to a compression fracture of the L1-level spine due to a fall from a height. She complained of urinary retention and inability to urinate and placed an indwelling catheter. Urinary tract infections often occurred and can only be treated with antibiotics. The results of the urodynamic examination showed that the maximum flow rate was 2.2 ml/s; residual urine volume was 570 ml; bladder pressure was 30.2 cm H_2O; abdominal pressure was 29 cm H_2O; and detrusor pressure was 1.3 cm H_2O.

50.2 Choice of Treatment

Spinal cord injury often leads to urinary system dysfunction [1]. It was still a great challenge for clinicians and reconstructive surgeons to develop an ideal urinary function treatment strategy for patients with spinal cord injury. In a series of recent studies, it has been reported that stimulating the artificial somatic-CNS autonomic reflex pathway can trigger bladder contraction, but this pathway was only useful in the case of spasm bladder caused by spinal cord injury above the conus [2–6]. Spinal fracture and dislocation mainly occurred in the thoracolumbar segment (T12-L1), which was more likely to cause the injury of conus medullaris, leading to the decrease in bladder tension and bladder contractility.

In our previous animal experiments, we successfully established an abdomen-to- bladder reflex pathway and restored the controlled urination of the atonic bladder [7–9]. The right T-12 ventral root and S-2 ventral root were anastomosed in the dura mater to establish a new neural pathway. According to our preclinical trial results, we chose to perform abdomen-to-bladder pathway reconstruction surgery for the patient 8 months after injury.

After the surgery, the indwelling catheter remained in place for 1.5 years. During this period, the patient had multiple urinary tract infections, which may be due to the indwelling catheter. Two years after the operation, the bladder storage and urination function were restored. She could urinate by abdomen-to-bladder reflex contractions, which was caused by scratching T-10 skin, and the catheter was removed. No further urinary tract infections occurred since then.

50.3 Operative Technique

The patient was placed in a prone position and underwent standard L5–S3 laminectomy. The dura mater was cut through a paramedian incision to expose the ventral and dorsal roots of S-3 nerve. The right S-3 ventral root was separated from the dorsal root by microanatomy. After the location was determined, the ventral root of S-3 was cutoff. Additional standard T9–11 laminectomy was performed.

We determined the T-10 segment of the spinal cord by the entrance of the T-10 spinal nerve root. The right ventral root of T-10 was cut with an operation microscope and identified to be normal function. The sural nerve with a length of about 30 cm was taken as the graft nerve.

Using 10–0 absorbable suture, one end of nerve graft was anastomosed with the proximal end of T-10 ventral root; the other end of nerve graft was put into the plastic tube and fixed with suture.

C. Hou
Department of Orthopedic Surgery, Changzheng Hospital, Second Military Medical University, Shanghai, China

H. Lin (✉)
Department of Orthopedic Surgery, Shanghai General Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_50

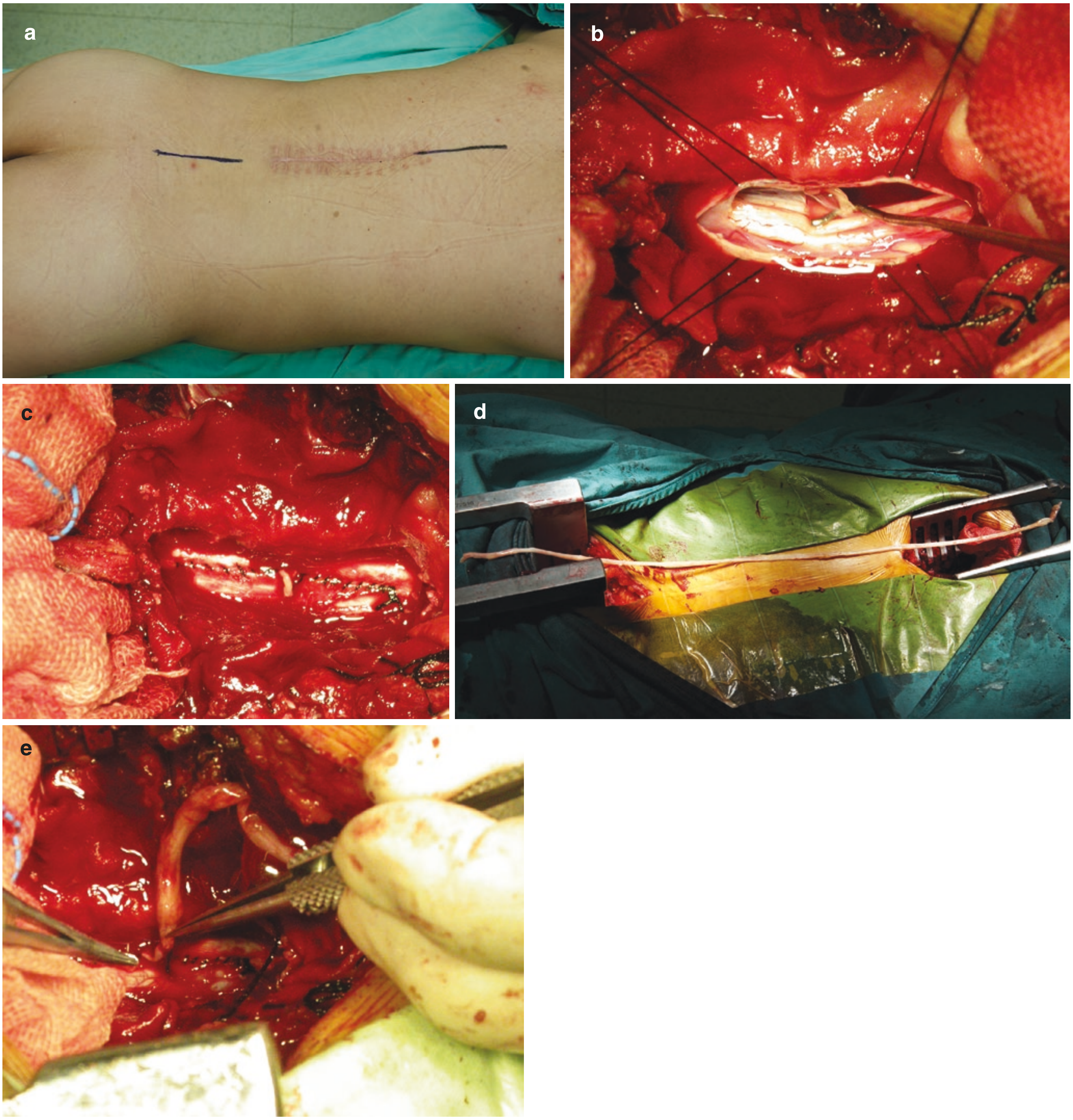


Fig. 50.1 Reconstruction of bladder urination reflex pathway. (**a**) Patients were placed in a prone position and underwent standard laminectomy from L5 to S3 and T10 to T12. (**b**) After the ventral root of T11 was identified and found to be functional, it was cut off. (**c**) The ventral root of T11 was left outside, and the dura was closed. (**d**) The length of the sural nerve was about 30 cm. (**e**) The ventral roots of T11 and S2 were anastomosed by a nerve graft. Adapted from Lin et al. [8];with permission

The plastic tube was then passed through the skin tunnel, and the nerve graft is inserted into another incision. The distal end of the nerve graft was then released from the plastic tube and sutured to the ventral root of S-3 (Fig. 50.1). The wound was sutured layer by layer, and a drainage tube was placed.

50.4 Clinical Implications

The results showed that the artificial bladder reflex arc can be established by intradural nerve transplantation and sacral ventral root anastomosis in patients with lumbosacral spinal cord injury so as to realize the autonomy of urination. This technique uses intact abdominal reflex above the paraplegia level to reconstruct bladder voiding function. This may be a new method for the treatment of atonic bladder caused by thoracolumbar fracture.

References

1. Brindley GS. The frst 500 patients with sacral anterior root stimulator implants: general description. Paraplegia. 1994;32:795–805.
2. Chang SM, Hou CL. The frequency and effcacy of differential sacral roots innervation to bladder detrusor in Asian people. Spinal Cord. 2000;38:773.
3. Chuang DC, Chang PL, Cheng SY. Root reconstruction for bladder reinnervation: an experimental study in rats. Microsurgery. 1991;12:237–45.
4. Fujishiro T, Takahashi S, Enomoto H, Ugawa Y, Ueno S, Kitamura T. Magnetic stimulation of the sacral roots for the treatment of urinary frequency and urge incontinence: an investigational study and placebo controlled trial. J Urol. 2002;168:1036–9.
5. Gasparini ME, Schmidt RA, Tanagho EA. Selective sacral rhizotomy in the management of the reflex neuropathic bladder: a report on 17 patients with long-term followup. J Urol. 1992;148:1207–10.
6. Xiao CG, Du MX, Dai C, Li B, Nitti VW, de Groat WC. An artifcial somatic-central nervous system-autonomic reflex pathway for controllable micturition after spinal cord injury: preliminary results in 15 patients. J Urol. 2003;170:1237–41.
7. Lin H, Hou C, Chen A, Xu Z. Innervation of reconstructed bladder above the level of spinal cord injury for inducing micturition by contractions of the abdomen-to-bladder reflex arc. Neurosurgery. 2010;66:948–52.
8. Lin H, Hou C, Chen A. Reconstructed bladder innervation above the level of spinal cord injury to produce urination by abdomen-to-bladder reflex contractions. J Neurosurg Spine. 2011;14(6):799–802.
9. Lin H, Hou C, Chen A, Xu Z. Reinnervation of atonic bladder after conus medullaris injury using a modified nerve crossover technique in canines. World Neurosurg. 2010;73(5):582–6.

51 Reconstructed Bladder Innervation Below the Level of Spinal Cord Injury to Produce Urination by Achilles Tendon-to-Bladder Reflex Contractions

Chunlin Hou and Haodong Lin

51.1 Case Presentation

In September 1998, a male patient was treated with neurogenic bladder due to spinal cord injury. He was 20 years old, with stable nerve injury and no contraindications for general anesthesia and surgery. The cause of spinal cord injury is a traffic accident. The patient received open reduction and internal fixation in the early stage of spinal cord injury but sustained dysuria and defecation dysfunction without bladder reflex. The patient was treated with indwelling catheterization. He had five urinary tract infections, characterized by fever and purulent urine, which was controlled by antibiotic therapy and bladder irrigation.

51.2 Choice of Treatment

At present, there are many methods for the treatment of bladder dysfunction, including the application of neuromuscular flap for detrusor magnetic stimulation reconstruction and selective sacral nerve root resection [1–4]. However, these methods rarely achieve satisfactory results.

We conducted a series of experiments with Achilles tendon-bladder-reflex arc to verify the effectiveness of the reflex pathway. The artificial bladder reflex arc of Achilles tendon in dogs was successfully established by right L-5 to S-2 ventral root intradural anastomosis. Based on the results of these preclinical experiments, we attempted to reconstruct the bladder innervation below the level of spinal cord injury to produce urination by contraction of Achilles tendon-bladder-reflex in paraplegic patients [5, 6].

Ten months after the operation, the bladder storage and urination function gradually recovered, and no nocturnal urinary incontinence was found. He urinated by stimulating the Achilles tendon-spinal cord-bladder reflex (hitting the Achilles tendon) and which became functional about 12 months after the operation. About 5–10 s after the start of Achilles tendon stimulation, the patient began to void. Urodynamic and electromyographic of the external urethral sphincter showed that the bladder activity changed from hypersensitivity with DESD to almost normal. Some dysfunctions found in EMG were improved.

51.3 Operative Technique

A three-channel Foley catheter was inserted into the bladder, one channel connected to a drainage bag and the other connected to a pressure sensor leading to the urodynamic unit.

The patients were placed in a prone position and underwent standard laminectomy from L-5 to S-3. The dura was opened through a paracentral incision to expose the dorsal and ventral roots of S1–4 nerve.

The S-1 nerve root was located by L5/S1 intervertebral space, and S2–4 nerve roots were arranged in descending order. At the dural incision, the ventral and dorsal roots of spinal nerve were identified according to their anatomical characteristics: the smaller and darker medial lateral roots (usually single) were the ventral root, while the larger and lighter lateral posterior roots (usually double) were the dorsal root.

C. Hou
Department of Orthopedic Surgery, Changzheng Hospital, Second Military Medical University, Shanghai, China

H. Lin (✉)
Department of Orthopedic Surgery, Shanghai General Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_51

The ventral and dorsal roots were carefully separated and marked with rubber strips. After the ventral roots of S-1, S-2, and S-3 were identified, they were separated from their respective dorsal roots by microanatomy, and their positions were confirmed by electrical stimulation. Electrical stimulation of the ventral roots of S-2 and S-3 should cause bladder contraction and an increase in intravesical pressure. The nerve root whose intravesical pressure increased the quickest and with the highest pressure was the main nerve root that innervates the bladder.

The unilateral S-1 (or L-5) ventral root and the dominant nerve roots at the same level were resected microsurgically and anastomosed with 9–0 suture to form the "Achilles tendon-spinal cord-bladder" reflex arc (Figs. 51.1 and 51.2). The wound was sutured in three layers, and the external drainage tube was placed. The patients were given broad-spectrum antibiotics for 3 days after surgery.

51.4 Clinical Implications

This study suggests that the residual tendon reflexes (such as Achilles tendon reflex) below the paraplegic level can be used to reconstruct the voiding function of spastic bladder in patients with complete suprasacral spinal cord injury who have a hyperreflexic bladder and detrusor external sphincter dyssynergia.

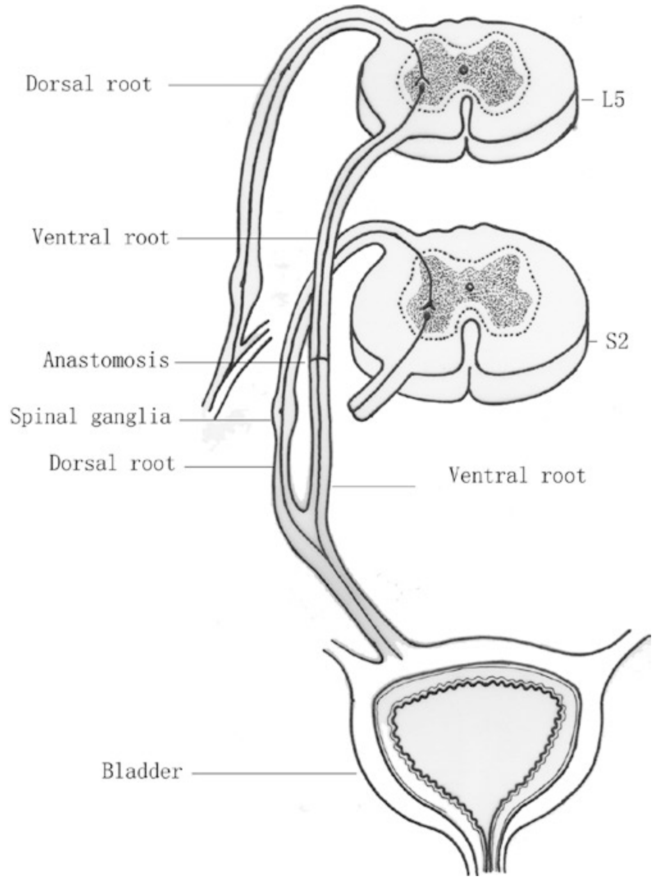


Fig. 51.1 Microsurgical anastomoses between S-1 (or L-5) and S-2 and/or S-3 ventral roots

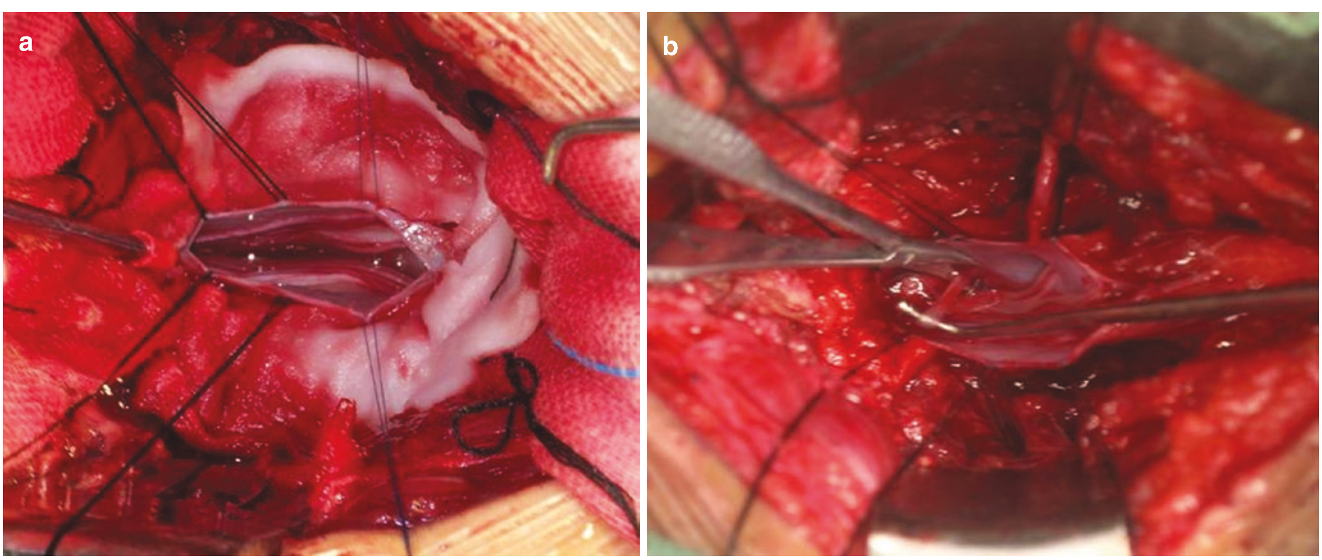


Fig. 51.2 Surgical procedure for reconstruction of a bladder reflex pathway. (**a**) With the patient lying prone, standard laminectomies from L-5 to S-3 were performed. The dura mater was opened through a paramedian incision, and the dorsal and ventral roots of the S-1, S-2, S-3, and S-4 nerves were exposed. (**b**) The ventral roots of S-1, S-2, and S-3 were identified and separated from their respective dorsal roots by microdissection. (**c**) The S-1 ventral root were anastomosed to S2/3 ventral roots. Adapted from Lin et al. [6]; with permission

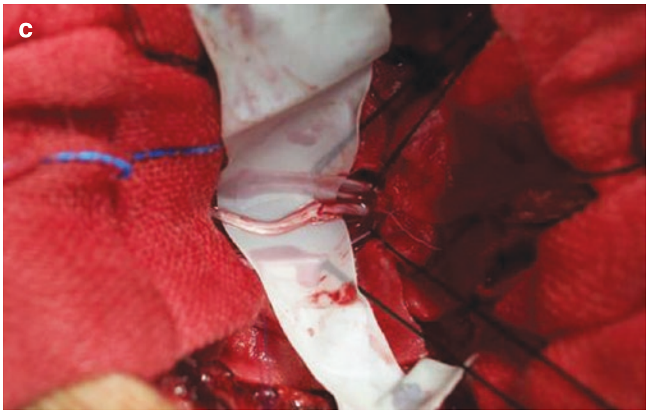


Fig. 51.2 (continued)

References

1. Carlsson CA, Sundin T. Reconstruction of efferent pathway to the urinary bladder in a paraplegic child. Rev Surg. 1967;24:73–6.
2. Gasparini ME, Schmidt RT, Tanagho EA. Selective sacral rhizotomy of the reflex neuropathyic bladder: a report on 17 patients with long-term follow-up. J Urol. 1992;148:1207–10.
3. Xiao CG, de Groat WC, Godec CJ, Dai C, Xiao Q. "Skin-CNS-bladder" reflex pathway for micturition after spinal cord injury and its underlying mechanisms. J Urol. 1999;162:936–42.
4. Xiao CG, Godec CJ. A possible new reflex pathway for micturition after spinal cord injury. Paraplegia. 1994;32:300–7.
5. Zheng XY, Hou CL, Zhong HB, Xu RS, Chen AM, Xu Z. Reconstructed bladder innervation below the level of spinalcord injury: the knee-tendon to bladder artifcial reflex arc. J Spinal Cord Med. 2009;32:79–85.
6. Lin H, Hou C, Zhen X, Xu Z. Clinical study of reconstructed bladder innervation below the level of spinal cord injury to produce urination by Achilles tendon-to-bladder reflex contractions. J Neurosurg Spine. 2009;10(5):452–7.

52 Transfer of Normal S1 Nerve Root to Reinnervate Atonic Bladder Due To Conus Medullaris Injury

Chunlin Hou and Haodong Lin

52.1 Case Presentation

A 25-year-old male patient with atonic bladder after conus medullaris injury was referred for treatment. His lower limb motor function was near normal. The preoperative diagnosis was L1 vertebral fracture. Physical examination showed that the muscle strength of both lower limbs was near normal and could walk smoothly. Both spontaneous voiding and the sense of bladder fullness were absent in the patient. Cystometrography showed that the patient had a reflexic bladder. When the residual urine volume was over 100 ml, the patient urinated after the application of abdominal pressure.

52.2 Choice of Treatment

Electrical stimulation has been used to restore the function of the spastic bladder caused by spinal cord injury above the conus medullaris [1, 2]. In our earlier studies, we demonstrated that the residual tendon reflexes below the paraplegic level, such as the Achilles tendon reflex, can be used to reconstruct spastic bladder voiding function in patients with complete suprasacral spinal cord injury [3, 4]. In this study, the S1 ventral root was anastomosed with S2 and/or S3 ventral roots to reconstruct the bladder reflex arc. For atonic bladders caused by conus medullaris injury, the nerve innervation of the bladder after spinal cord injury can be reconstructed to produce urination by abdomen-to-bladder reflex contractions. However, sural nerve transplantation was needed to bridge T10/T11 and S2/3 nerve roots, with a maximum length of 30 cm in this procedure. We tried to reinnervate the atonic bladder of patients with conus medullaris injury by ipsilateral S1 root transfer.

On the second day after the operation, the muscle strength of S1 nerve innervated muscles was decreased by 1 grade (MRC) compared to preoperative levels. However, at 3 months after the operation, the muscle strength of S1 nerve innervated muscles returned to the preoperative level. Twelve months after the operation, the patient recovered the function of urination and was able to urinate autonomously without incontinence. Interestingly, the patient also recovered the bladder sensory function, which was characterized by the ability to sense a full bladder and perceive the desire to void.

52.3 Operative Technique

The operation was performed under general anesthesia. The patient was placed in a prone position and underwent standard laminectomy from L5 to S3. The dura was opened through a paramedian incision to expose the dorsal and ventral roots of S1–4 nerves. The S1 nerve root was located by using the L5/S1 intervertebral space as a marker, and the S2–4 nerve roots were arranged in descending order.

The ventral and dorsal roots of the spinal nerve were distinguished by their anatomical characteristics in the dural incision. The ventral roots of S1, S2, and S3 were identified and separated from their dorsal roots by microanatomy. When the function of S1 nerve root was confirmed to be normal, the unilateral S1 ventral root and S2/3 ventral roots on the same side were cutoff by microsurgical technique and anastomosed with 9–0 suture (Fig. 52.1). The wound was sutured in three layers with an external drainage tube.

52.4 Clinical Implications

In this trial, we have demonstrated that the normal S1 nerve roots can be used to successfully reconstruct atonic bladder function in patients with low medullary cone (S2–5) injury

C. Hou
Department of Orthopedic Surgery, Changzheng Hospital, Second Military Medical University, Shanghai, China

H. Lin (✉)
Department of Orthopedic Surgery, Shanghai General Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China

C. Hou et al. (eds.), *Practical Microsurgery Cases*, https://doi.org/10.1007/978-981-15-9716-9_52

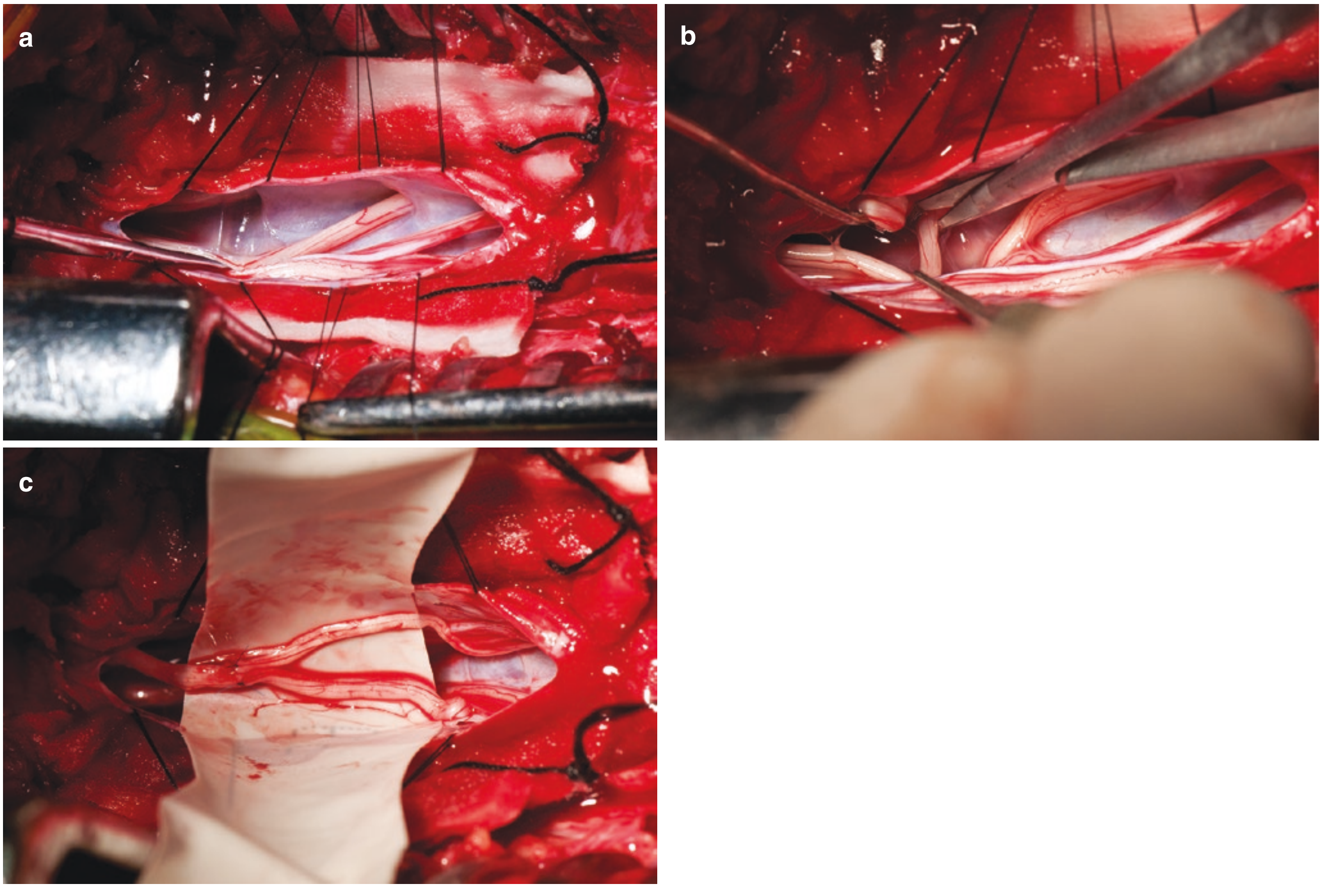


Fig. 52.1 Surgical procedure for reconstruction of bladder reflex pathway. (**a**) The patient was placed in the prone position and underwent standard laminectomy from L5 to S3. The dura was opened through a paramedian incision to expose the dorsal and ventral roots of S1–4 nerves. (**b**) The ventral roots of S1, S2, and S3 were identified and separated from their dorsal roots by microdissection. (**c**) The S1 and S2/3 ventral roots were anastomosed with 9–0 suture

and associated with bladder dysfunction but preservation lower extremity motor function.

References

1. Brindley GS, Polkey E, Rushton DN, et al. Sacral anterior root stimulators for bladder control in paraplegia: the first 50 cases. J Neurol Neurosurg Psychiatry. 1986;49(10):1104–14.
2. MacDonagh RP, Sun WM, Smallwood R, et al. Control of defecation in patients with spinal injuries by stimulation of sacral anterior nerve roots. Br Med J. 1990;300(6738):1494–7.
3. Lin H, Xu Z, Liu Y, Chen A, Hou C. The effect of severing L6 nerve root of the sacral plexus on lower extremity function: an experimental study in rhesus monkeys. Neurosurgery. 2012;70:170–7.
4. Lin H, Hou C. Transfer of normal S1 nerve root to reinnervate atonic bladder due to conus medullaris injury. Muscle Nerve. 2013;47(2):241–5.