Clinical Case Report

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Three-dimensional virtual planning in precise chimeric fibula free flap for metacarpal defects

A case report

Hui Shen, MD[a], Xiang-qian Shen, MD[a], Ying Lv, PhD[b], Hui Lu, MA[a], Jing-hong Xu, MD[c,*], Shou-Cheng Wu, MA[a]

Abstract

Rationale: Metacarpal and phalanx defects with soft tissue loss were suggested to be reconstructed by vascularized bone flap. The fibular osteocutaneous flap is a preferred method. Three-dimensional virtual planning has successfully applied in mandibular reconstruction with fibular free flap. We applied three-dimensional virtual planning in precise fibula flap harvest to maintain the continuity of the fibula and to achieve accurate metacarpal and phalanx reconstruction.

Patient concerns: A 35-year-old male presented with extensive soft tissue defects and first metacarpal defect involving the first metacarpophalangeal joint.

Diagnoses: There were 4 cm of first metacarpal defect involving the first metacarpophalangeal joint and soft tissue defects of 5cm × 3cm + 3cm × 2cm.

Interventions: By combining three-dimensional virtual planning, we harvested a chimeric fibular flap. The precise fibula partial osteotomies were performed with cutting guides designed in virtual planning.

Outcomes: All the chimeric flaps survived and no significant donor-site morbidity was noted. Michigan Hand Outcome Questionnaire scores indicated acceptable functional results.

Lessons: Our preliminary experience with the approach of three-dimensional virtual planning in precise chimeric fibula free flap is practical and efficient. Although more cases and follow-up are needed to evaluate it, this approach is expected to benefit patients.

Keywords: fibula osteocutaneous flap, metacarpal reconstruction, virtual planning

1. Introduction

High-energy trauma to the hand often causes damage to bone, tendons, and soft tissue. Metacarpal and phalanx defects with soft tissue loss usually were suggested to be reconstructed by vascularized bone flap.[1] The iliac flap, the serratus anterior-rib composite flap, the medial femoral condyle flap, and the scapula flap have been described for the reconstruction of the metacarpal defect.[2–5] The fibular osteocutaneous flap has a similar shape to a metacarpal. It is easier to be dissected and may be the best option for metacarpal reconstruction.[6] However, the size of the fibular is still a bit larger for metacarpal reconstruction. Recently, complications related to harvest of the osteocutaneous fibula flap are of concern,[7] including gait abnormality, ankle instability, and limited range of ankle motion. Thus, we attempt to retain the fibular continuity while harvesting the individualized fibular osteocutaneous flap with preoperative virtual planning.

Three-dimensional virtual planning has successfully applied in mandibular reconstruction with fibular free flap. This approach leads to greater precision of the surgical procedure and reduction of surgical time.[8–10] Recently, virtual surgical planning has applied in metatarsal defect reconstruction and metatarsal osteotomy.[11,12]

By combining 3-dimensional virtual planning, we harvested 3 fibular flaps on the posterior margin of fibula for reconstruction of metacarpal and phalanx defects (Table 1). We describe our early experience with this technical approach and illustrate the technique a typical case.

2. Case report

Informed consent was obtained from each patient preoperatively after they were given a detailed explanation of the operative procedures. This study was approved by our ethics institutional review board (First Affiliated Hospital, College of Medicine, ZheJiang University).

A 35-year-old male patient sustained a right-hand crush injury (Fig. 1A). In the debridement, the stump revisions of 3 to 5 fingers were performed. In the emergency 1-stage operation, osteotomies of the remnants of metacarpal and distal phalange were

Editor: Jianxun Ding.

HS and X-qS contributed equally to the work.

Funding/support: This research was supported by the National Natural Science Foundation of China (81471874 and 81501293).

The authors have no conflicts of interest to disclose.

Supplemental Digital Content is available for this article.

[a] Department of Hand Surgery and Microsurgery Center, The First Affiliated Hospital, College of Medicine, ZheJiang University, [b] The Children's Hospital, Zhejiang University School of Medicine, [c] Department of Plastic Surgery, The First Affiliated Hospital, College of Medicine, ZheJiang University, HangZhou, ZheJiang Province, China.

[*] Correspondence: Jing-hong Xu, Department of Plastic Surgery, The First Affiliated Hospital, College of Medicine, ZheJiang University, HangZhou, ZheJiang Province 310003, PR China (e-mail: xujinghong2008@outlook.com).

Medicine (2017) 96:31(e7364)

Received: 2 April 2017 / Received in final form: 28 May 2017 / Accepted: 31 May 2017

http://dx.doi.org/10.1097/MD.0000000000007364

Table 1

Summary of defects and results.

Case	Age, y	Sex	Defects*	Skin island, cm^2	Bone segment, cm	Complications	MHQ score
1	58	M	1 DP, PP	8×2	3	None	77
2	35	M	1 M	$5 \times 3+3 \times 2$	4	None	66
3	41	M	5 M	4×5	3	None	82

* DP = distal phalanx, M = metacarpal, PP = proximal phalanx.

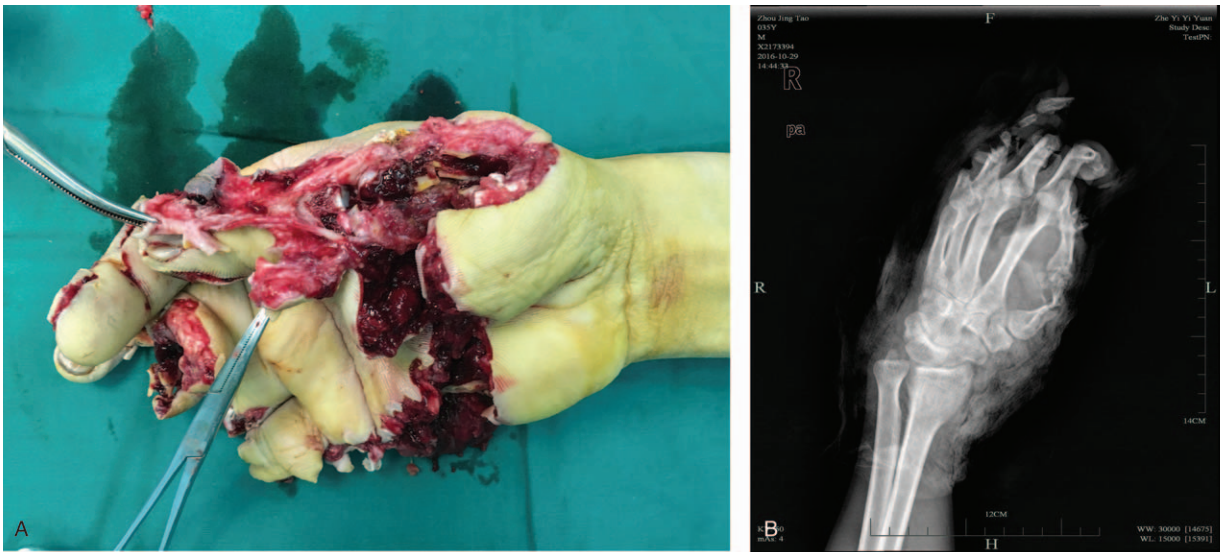

Figure 1. (A) A 35-year-old male patient sustained a right-hand crush injury. (B) There were more than 4 cm defect of the first metacarpal, involving the 1st metacarpophalangeal joint.

performed to obtain smooth osteotomy planes for reconstruction. There were extensive soft tissue defects on the palmar hand and right dorsal hand. There were more than 4 cm defect of the 1st metacarpal, involving the 1st metacarpophalangeal joint (Fig. 1B).

A chimeric fibula skin flap was designed to reconstruct the defect. Perforator mapping showed 2 perforators of the peroneal artery. A double paddled perforator flap was designed to cover the defect of the palmar hand and right dorsal hand simultaneously (Fig. 2A)

2.1. Three-dimensional virtual planning

Preoperative high-resolution computed tomographic angiography (1-mm fine cuts) scans of the lower extremity were performed for both virtual planning and perforator mapping. The lower extremity was surveyed by color Doppler imaging to identify the location of the perforators. High-resolution computed tomographic scan of the hand is also performed for 3-dimensional rendering using Magics19.01 (Materialis). In the 3-dimensional hand model, the shape of bone segment was determined by superimposing the patient's contralateral 1st metacarpal. The length of the segment was

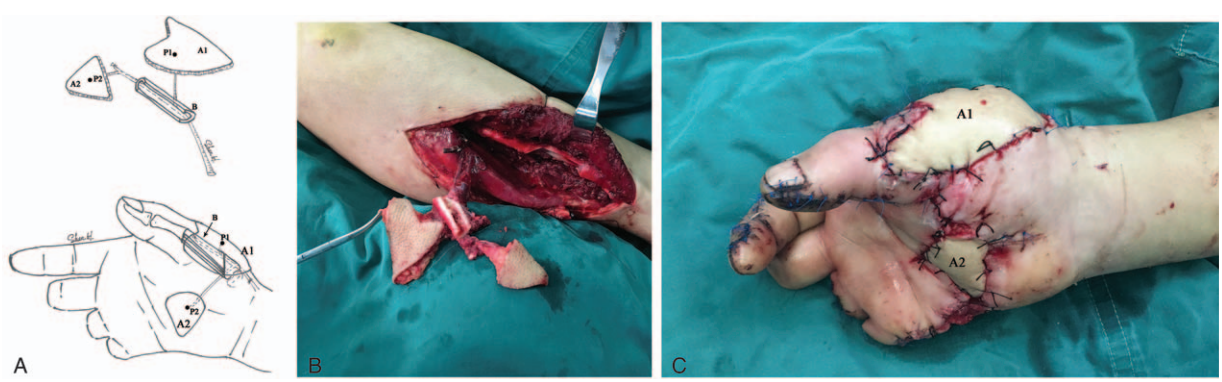

Figure 2. (A) The fibular chimeric flap was designed (A1 and A2, skin paddles for soft tissue defects; P1 and P2, perforators for skin paddle A1 and A2; and B, bone flap). (B, C) The chimeric fibular osteocutaneous flap is carefully harvested and positioned.

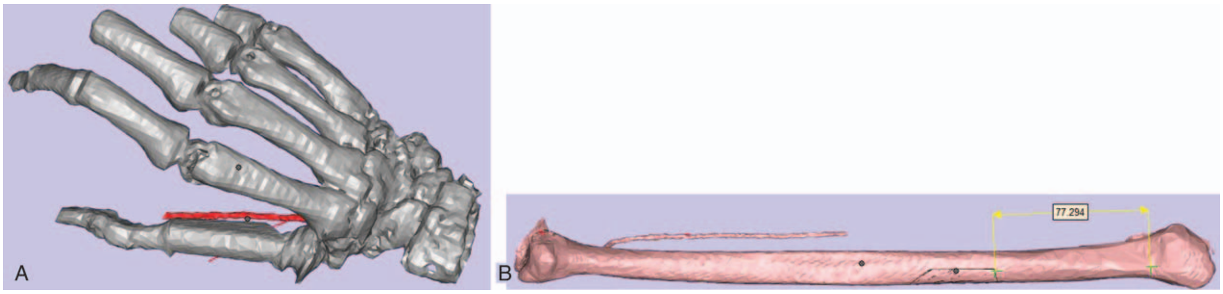

Figure 3. (A, B) According to the virtual planning, the fibula bone segment was designed on the posterior margin of fibula.

about 4 cm. The degree of both distal and proximal obliquity of the segment were also determined. Then, according to the position of the perforator, the fibula bone segment was designed on the posterior margin of fibula (Fig. 3A and B). The reconstruction plate and cutting guide were designed and prepared accordingly. Here, our team designed a fibula partial osteotomy cutting guide (Fig. 4A) (Video1, http://links.lww.com/MD/B769).

2.2. Reconstruction

Through a standard lateral approach, the fibula and peroneal artery was exposed. The osteotomies were completed with a reciprocating and sagittal saw through the cutting slots (Figs. 2B and 4B). The peroneal artery was exposed and protected during the harvesting of the fibula. The fibular cutting guide was secured to the fibula segment to replicate the cuts that were planed previously. Two skin islands were included with the fibula segment. The fibula segment was placed in the planned position and fixed to the bone remnants using 1.5 mm locking plate. The soft tissue defects were covered by the skin paddle after the repair of the extensor tendon (Fig. 2C).

The hand was immobilized for 2 weeks when postoperative exercise started. The thumb tactile sensation and function were found satisfactory in the 3 months follow-up (Fig. 5A and B). The Michigan Hand Outcome Questionnaire scores was 66 (Video 2, http://links.lww.com/MD/B770).

3. Discussions

Vascularized bone flaps have better healing quality and higher resistance to infections than nonvascularized bone grafts in metacarpal defects reconstruction.[13] The free fibular bone flap initially described by Taloy to reconstruct bony defects of the long bones.[14] Since then, many cases involving metacarpal and phalangeal defects have been reported reconstructing with this method.[1,6,15–17] The fibular osteocutaneous flap has a similar shape to a metacarpal. And it can provide a fasciocutaneous flap for soft tissue reconstruction. However, the fibular segment is still thicker than metacarpal and phalanx. In our measurement, metacarpal bone defects only need half the thickness of the fibula to reconstruct. The monolayer fibula cortex is also thick enough to provide sufficient strength. So in this method, we take only the necessary amount of fibula, leaving the rest to maintain the ankle stability. By this method, the fibular graft can be designed sizable even for phalanx reconstruction.

It has been commonly recommended to preserve 5 to 7 cm of distal fibula at the ankle and 4 to 6 cm at the knee to avoid donor site related complications.[18] However, complications related to osteotomy of the fibula are of concern recently.[7,19] In 6-month follow-up, there were no complications related to osteotomy of the fibula in the 3 cases. This method may improve to maintain the ankle stability to reduce complications. However, we still need more cases and longer follow-up to evaluate the incidence of complications. And it is possible to harvest bone graft lower than 7 cm of distal fibular without breaking the ankle stability by this method.

Three-dimensional virtual planning has been widely used in reconstructive and orthopedics surgery. The computer-planned fibular osteotomy can produce adequate margins without the need for intraoperative changes in surgical plan.[20] Fibular osteotomy is greatly accelerated because the need for intraoperative freehand contouring is eliminated.[20] However, despite widely used in mandibular reconstruction, virtual planning is rarely reported for

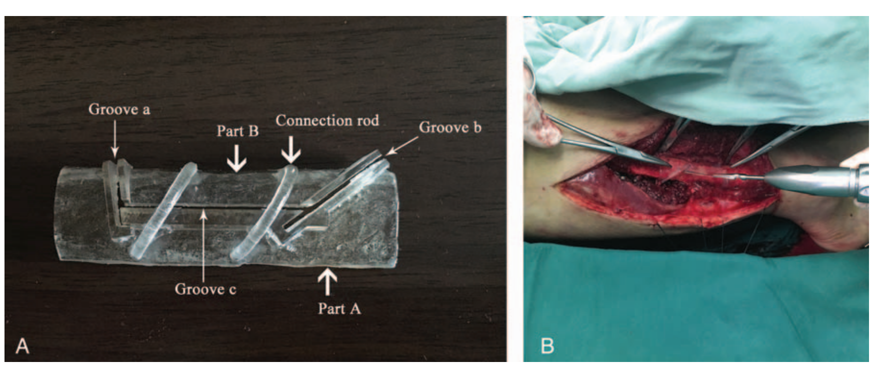

Figure 4. (A) Fibula partial osteotomy cutting guide is designed in 2 parts (part A and B). (B) The cutting guide is locked to the anterior and posterior margin of fibula. Precise osteotomies are performed through groove a and b with a reciprocating saw. Then part B is removed and osteotomy of groove c is performed. The 1st layer of cortex is sawn with a reciprocating saw. The 2nd layer of cortex was carefully sawn with a sagittal saw to avoid injury to the peroneal artery.

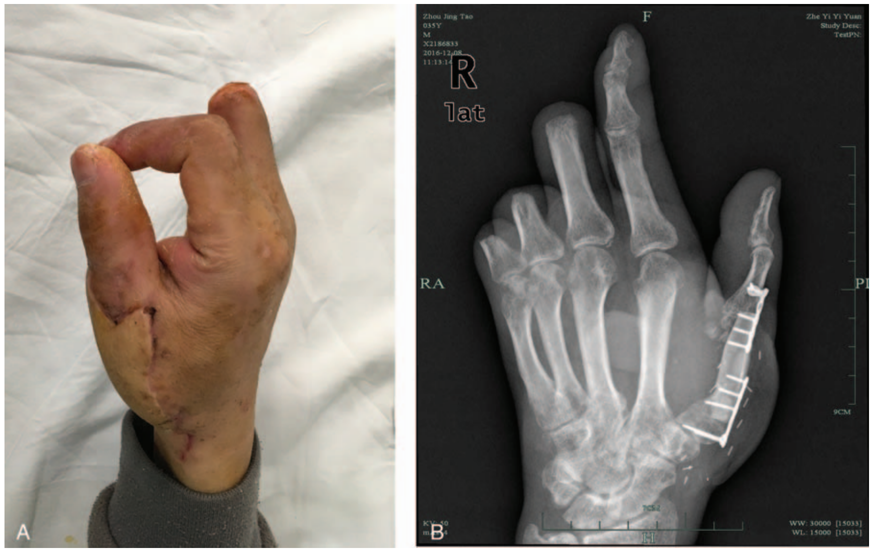

Figure 5. (A, B) The thumb tactile sensation and function were found satisfactory in the 3 months follow-up.

the metacarpal reconstruction. By this method, the fibular segment and metacarpal remnant are assembled with excellent bone-to-bone approximation. The thickness of the fibular segment is designed according to the metacarpal of the contralateral hand. So, the thickness of the fibular segment is consistent with physiological thickness. The virtual planning also includes the cutaneous flap. The distance between the perforator and the fibular segment will affect the pedicle length.

Fibular osteotomy of this method seems complicated. In fact, by using the cutting guide, the fibular osteotomy takes approximately 10 minute. The harvest of the cutaneous flap may take more time, because the peroneal artery is under the fibular. However, there is still sufficient space to expose the peroneal artery through the notch of the fibular bone. And the virtual planning minimized the adjustments needed for intraoperative inset. Finally, this method still saves considerable intraoperative time.

Our preliminary experience with the approach of 3-dimensional virtual planning in precise chimeric fibula free flap is practical and efficient. Although more cases and follow-up are needed to evaluate it, this approach is expected to benefit patients.

Acknowledgments

The authors thank National Natural Science Foundation of China (81471874 and 81501293) for the support.

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