

Customized Reconstruction of Complex Soft Tissue Defect Around the Knee with Individual Design of Free Perforator Flap

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Abstract

Background Reconstruction of complex soft tissue defect around the knee, particularly in involving with large soft tissue defect or disruption of extensor mechanism, always is a challenging problem. The purpose of this study was to introduce our clinical experience on using individual design of free perforator flap for complex soft-tissue reconstruction around the knee.

Methods Between June 2010 and March 2017, 16 patients underwent the reconstruction of complex soft tissue defect in the knee region with free perforator flap, Various flap designs was performed basing on the location of wound, the require pedicle length, the tissue components that are deficient, the volume of such components and the risk of donor site morbidity.

Results Complex soft tissue defect of the knee was reconstructed with anteriorlateral thigh perforator (ALTP) flap in 5 cases, modified ALTP flap in 2 cases, chimeric ALTP flap in 4 cases, dual skin paddles ALTP flap in 2 cases and chimeric thoracodorsal artery perforator (TDAP) flap in 2 cases. Multiple perforator flaps and vascularized fascia lata in combination were performed in one case. All flaps survived postoperative. None vascular congestion was observed. Only one case suffered partial necrosis. Primary closure of donor site was performed for all patients. The mean follow-up time was 16.5 months. Most cases showed satisfactory flap contour and acceptable function outcome.

Conclusions Free perforator flap is a reliable option for repairing complex soft tissue defect in the knee region, especially when local and pedicled flaps are unavailable. Various flap designs allow for more individualized treatment approaches.

Introduction

One-stage reconstruction of complex soft tissue defect in the knee region, particularly in involving with large soft tissue defect or disruption of extensor mechanism, always is a challenging problem for reconstructive surgeons.^{1,2} Previous several strategies have been described in the literature for the reconstruction of soft tissue defect around the knee, including local flap, pedicle flap, muscle flap with skin grafting or musculocutaneous flap.³⁻⁷ However, local flap and pedicled flap would not adequately to reconstruct a complex soft tissue defect because of its limitation of soft-tissue volume and less flexible design⁸. Some authors reported that complex soft tissue defect around the knee can be resurfaced by using muscle flap with skin grafting, but the muscle flap with skin graft often resulted in bulky appearance, unsatisfactory color match and unstable surface⁹. The musculocutaneous flap also has been widely used for the reconstruction of complex tissue defect in the extremities. However, the problem of donor site morbidity and bulkiness contour of the flap was remaining.

In the era of well-developed microsurgery technology and perforator flap technology, free perforator flaps have become the first choice in treatment of large lower-extremity wounds, where the local flap is unavailable. Free perforator flap gained popular because of its large cutaneous area, less donor site morbidity, aesthetically appearance, adjustable donor-sites, long vascular pedicle and flexible design with adjacent structure.¹⁰ However, there was little knowledge for the reconstruction of complex soft tissue defect of the knee with free perforator flap in the literature.

High energy trauma and soft tissue tumor excisions surgery often causes complex extremity defects, individualized reconstruction of complex tissue defect in the knee region is essential to salvage the extremity and restore its

function. However, harvesting free perforator flap by using a traditional fashion was unable to repair precisely and efficiently. An ideal reconstructive procedure should not only cover soft tissue defect but also restore the function of the knee in a single procedure and reduce the donor site morbidity as well. Therefore, in this study, we presented a case series of complex soft tissue defects reconstruction around the knee using various flap designs which allow for more individualized treatment approaches. To our knowledge, the concept and practice of using individual design of free perforator flap for reconstruction of complex soft tissue defects in the knee regions have not been described in the literature before.

Patients And Methods

From June 2010 to March 2017, 16 patients (3 females and 13 males) underwent the reconstruction of complex soft tissue defect in the knee region with free perforator flap.. Patient ages ranged from 5 to 64 years (mean, 36.1 years). Of the 16 cases, one had a chronic ulcer, one had post-burn contracture, two had a skin necrosis after total knee arthroplasty, and 12 had post-traumatic injuries. Patient details are shown in Table 1. The study followed the ethical guidelines of the Hospital Ethical Committee of the Xiangya Hospital. Protocol was performed in accordance with the ethical standards of the Helsinki Declaration of 1975 and all subsequent revisions.

Surgical Technique

A hand-held Doppler probe was routinely used to preoperatively map the perforators on the donor site. A pinch test was performed on the donor site to evaluate the available width of the flap. After radical debridement, a paper template was prepared according to the shape of the soft-tissue defect. Our surgery team preoperatively assessed and classified the soft tissue defects to provide individual patients with a specific customized reconstruction. Various flap designs were performed for the reconstruction of complex soft tissue of the knee. Flap choice was based on the location of the soft tissue defect, the requirement length of the pedicle, characteristics of the defect, the tissue components that are deficient and the risk of donor site morbidity.

For the reconstruction of simple soft tissue defect in the knee region, a free anterior lateral thigh perforator (ALTP) flap was designed (*Supplement materials* Fig. 1). However, when the extensor mechanism or joint capsule of the knee was damage, a modified design was performed for the defect reconstruction by preserving a part of fascia late in the flap which was enabled to resurface the superficial skin defect and simultaneous restore the extensor mechanism or joint capsule of the knee (Fig. 1, *Supplement materials video. 1*). This procedure could harvest the ALTP flap with a selective size of fascia lata based on characterizes of the soft tissue defect, and provide individual patients with a specific customized reconstruction which avoided the waste of the tissue and minimized the donor site morbidity. When the fascia lata component was required more freedom inserting for repairing the extensor apparatus of knee, free perforator flap combination with a vascularized fascia lata flap could also be performed for the reconstruction of complex soft tissue defect (Fig. 2, 3).

To reconstruct very large soft tissue defect and achieve the primary closure of donor site as well, the dual skin paddles perforator flap was performed (Fig. 2, *Supplement materials* Fig. 2). A single unified narrow flap was harvested, and then was split into two skin paddles between the perforator vessels. The dual skin paddles were stacked each other side-by-side to effectively enlarge the width of the flap. This approach was enabled to cover greater width of soft tissue defect in the knee region and directly close the wound of donor site without tension as well. When the dual skin paddle perforator flap was designed to repair the greater width soft tissue defect, the major

of principles in the dual skin paddle perforator flap is the conversion of flap length into the desired shape. A part of fascia late also can be preserved in this flap to repair joint capsule of the knee or restore the extensor function of the knee.

For the reconstruction of large and deeper wound in the knee region, the chimeric perforator flap could be designed to achieve three-dimensional reconstruction of soft tissue defect. the skin paddle was used to cover the surface soft tissue defect, and the muscle paddle was performed to obliterate the dead space (Fig. 4). Each component can be precisely inserted to reconstruct the wound with more degree of freedom. Most importantly, the muscle paddle also could be used to restore the extensor mechanism of knee and cover the explore knee joint at a single stage (Fig. 5, 6, *Supplement materials video.2*).

Results

A total of 17 perforator flaps was successfully harvested in this series of cases. Five cases were repaired with anterior lateral thigh perforator (ALTP) flaps, two cases were repaired with modified ALTP flaps, four cases were repaired with chimeric ALTP flaps, two cases were repaired with dual skin paddles ALTP flaps, and the other two cases were repaired with chimeric thoracodorsal artery perforator (TDAP) flaps. In addition, multiple perforator flaps and vascularized fascia lata flap in combination were performed in one case. The size of the soft tissue defects range from 72 cm² to 503 cm² (mean, 196.8 cm²).

The use of recipient vessels varied widely. According on the location of the knee defect and available vascular supply, Seven (43.75%) arterial anastomoses were performed distal to the knee (posterior tibia artery (PTA) and anterior tibia artery (ATA)), eight (50%) around the knee (the superior medial genicular artery (SMGA) and medial sural artery (MSA)), and one (6.25%) proximal to the knee (descending branch of the lateral circumflex femoral artery (LCFA)).

All flaps survived at postoperative. None vascular congestion was observed. Only one case suffered partial necrosis (cases 15). Necrotic tissues were debrided, and the resulting defects were repaired with thickness split skin grafting. Primary closure of donor sites we successfully achieved for all patients. The mean follow-up time was 16.5 months (range 8~35 months). Most cases showed satisfactory contour, and there was no excessive bulk. Those patients could walk normally without any assistance. The knee range of motion was available for 15 (94%) patients except one case underwent a knee fusion procedure. Mean active range of motion was 110.4 degrees (range, 60~130 degrees).

Discussion

Complex soft tissue defect in the knee regions often was caused by multiple previous operation, high energy trauma and large soft tissue tumor excisions, those always resulted in various tissue defects, including bones, skin, and extensor mechanism. Soft-tissue reconstruction in the knee regions requires thin, flexible, large cutaneous area and multiple components. It was commonly considered that the local or pedicled flap was the optimal choice in many cases of soft-tissue reconstruction around the knee.¹¹ Recently, Ling et al¹² recommended the medial sural artery perforator (MSAP) flap as the first choice for soft-tissue defect reconstruction around the knee. However, the local flaps and pedicled flaps were only the optimal choice for repairing a small to medium-sized defects of the knee because of limitation of the volume soft tissue. Descending branch of anterior lateral thigh perforator (dbALTP) also have been reported as a reconstructive solution for soft tissue defects of the knee¹³. But it has never gained

popularity among reconstructive surgeons because of venous congestion and difficult flap dissection in the presence of a variable anatomy of the vascular pedicle.¹⁴ In addition, Limited arc of rotation and reach of those flap are major disadvantages. Those were the impetus to look for an alternative flap.

Previous study showed that free flap would be an ideal choice when local tissue options are unavailable or inadequate, specially, when the vascular web around the knee has been damaged. Free muscle flap such as latissimus dorsi and gracilis muscle flaps has been reported as a reliable alternative approach for reconstruction of the complex tissue defect in the knee region, because of its rich blood supply and large area.^{15,16} Those advantages are specifically indicated more complex soft defects with joint and/or prosthesis exposure. However, problems of donor-site morbidity and bulkiness of flaps remain. In this study, we presented a case series of complex soft tissue defects reconstruction in the knee region by using various flap designs, including free ALTP flap, ALTP flap with partial fascia lata, chimeric ALTP flap, dual skin paddles ALTP flap, chimeric TDAP flap and multiple perforator flaps combination with vascularized fascia lata. To our knowledge, this is the largest series to date reporting microvascular reconstruction of complex soft-tissue defects in the knee region by using the free perforator flap. Our report focuses on the individual flap design for customized reconstruction of complex soft tissue defects in the knee region to minimize the donor site morbidity and gain acceptable knee function recovery, that have rarely been addressed before.

Recently, the flap donor site as limited resources has attracted the attention of reconstructive surgeons.¹⁷ One of the most important goals of modern reconstructive microsurgery is to minimize donor-site morbidity. Reconstructive surgeon has shifted their focus from pure coverage of soft tissue defect to now include the functional donor site issues and aesthetic appearance of the donor site as well. In this context, harvesting a free perforator flap by using a traditional fashion design may be not suitable to reconstruct very large soft tissue defect because of the limitation of soft-tissue amount which will result in a nonaesthetic donor-site skin graft.⁸ Recently, dual skin paddles perforator flap was introduced as an ideal approach to reconstruct very large soft tissue defect and maintain the primary closure of donor site.^{18,19} Zhang et al¹⁷ have reported that dual skin paddles perforator flap allows dual skin paddles to be placed side by side and effectively doubling the width of the flap by using a kiss technique. Our previous study also demonstrated that the dual skin paddles ALTP flap was an alternative option to repair extensive soft tissue defect in the foot and ankle.²⁰ However, to our knowledge, there is no literature which has described the use of the dual skin paddle perforator flap for repairing the complex tissue defect in the knee region. In the present cases, the double skin paddle ALTP flap was successfully used to cover very large soft tissue defect in two cases, and the donor site were achievement of primary closure of donor site.

High energy trauma and soft tissue tumor excisions surgery often causes complex three-dimensional extremity defects, which can be accompanied by large surface soft tissue defect, dead space, disruption joint capsule and/or extensor apparatus of the knee, and are challenging to repair precisely and efficiently. One-stage reconstruction of soft tissue defect and lost extensor mechanism in the knee region could provide a reasonable functional outcome.²¹ In the present series, six patients companied with disruption of joint capsular or extensor mechanism of the knee. The ALTP flap with partial fascia lata was performed on two cases to restore the joint capsule of the knee and simultaneous repair soft tissue defect. However, we also found that it is difficultly to use this approach to cover very large soft tissue defect, because the fascia lata was not completely separated from the skin paddle, and not facilitated to precisely inset in the wound. To overcome those disadvantages, vascularized fascia lata flap combination with free perforator flap was designed to cover the large soft tissue defect, restore extensors apparatus of the knee, and achieve the primary closure of donor site as well. In this case, a contralateral double skin paddles

ALTP flap and bilateral superior lateral genicular artery perforator (SLGAP) flap was obtained to cover the soft tissue defect. The vascularized fascia lata flap was harvested to repair the patella tendon. This method provided sufficient soft tissue and double-vascularised layers for the reconstruction of large surface soft tissue defect and restoring the extensor mechanism of the knee at a single stage.

There are several extensor apparatus reconstruction procedure also have been reported in the literature before, such as a gastrocnemius transposition flap²², quadriceps advancement^{23,24} and tendon graft²⁵. However, multiple operative procedures were required for those methods. Recently, chimeric flap has become one of the most popular procedures for reconstruction of three-dimensional defects because of its more degree freedom and flexible design.^{17,26-28} Chimeric MSAP flap have been reported as a valuable option for the reconstruction of composite and three-dimensional knee defects,²⁹ However, the problems of donor-site morbidity and inability to repair very large defects at one-stage remain.³⁰ According to our experience, both TDAP chimeric flap and ALTP chimeric flap were reliable option for the reconstruction of complex tissue defect in the knee region, those flaps can provide a large skin area and enough muscle volume.²⁸

Selection of appropriate recipient vessels is essential for successful free flap transfer in the knee region. The size, shape, location and depth of soft tissue defect will affect the normal anatomy of the region and will drive the surgeon to different options according to the quality of the available vessels. Park et al³¹ recommended that the medial genicular artery (MGA) was an excellent alternative because of its proximity to the knee and its reliability, versatility and suitable caliber. Hong and koshima³² have presented a reliable approach which can use the perforator vessels as a recipient vessel for free flap transfer in the knee region, but the perforators are not always reliable in caliber and location. According to our experience, the vascular near the knee should be considered as the first choice for free flap transfer. If vessels near the recipient site were damage and microsurgical anastomosis must be performed outside of the zone of injury, The LCFA, PTA or ATA may be available to choose. In this present series cases, 43.75% arterial anastomoses were performed distal to the knee (PTA or ATA), 50% around the knee (SMGA or MSA), and 6.25% proximal to the knee (LCFA).

Conclusion

Free perforator flaps transfer plays an importantly role in the reconstruction of the complex soft tissue in the knee regions, when local and pedicled flaps are unavailable. Various flap designs was enabled to be performed basing on the location of the wound, the require pedicle length, wound characteristics, the tissue components that are deficient, the volume of such components, the donor site and the risk of donor site morbidity. Those design provided with more individualized treatment approaches. Despite almost of previous studies have focused on the local flaps and pedicled flaps for the reconstruction of soft tissue defect of the knee, and less frequently applied in the knee regions with free perforator flap, in the era of well-developed microsurgery technology and perforator flap technology, free perforator flap should not be used as the second choice.

List Of Abbreviations

ALTP, anteriorlateral thigh perforator; TDAP, thoracodorsal artery perforator; MSAP, medial sural artery perforator; SLGAP, superior lateral genicular artery perforator; LCFA, lateral circumflex femoral artery; PTA, posterior tibial artery; ATA, anterior tibial artery; SMGA, superior medial genicular artery; MSA, medial sural artery

Declarations

Ethical Approval and Consent to participate

This study was approved by the Ethics Committee of Xiangya Hospital, Central South University.

Consent for publication

Not applicable

Competing Interest

The authors declare that they have no competing interest.

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Authors' contributions

JF and LQ designed the study, analysed the data and wrote the manuscript. PW, ZZ and FY collected the data. JT revised the manuscript and supervised the project.

Acknowledgments

None

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Table

Table 1.
The detail information of the patients

Patients	Age (y)/ Sex	Cause injury	Type of the flap	Size of the flap(cm)	Restoring knee function or joint capsular	Recipient vessels	Complication	Follw-up(Mo)
1	25M	Traffic injury	Dual skin paddle ALTP with a part of FL	15 × 7 and 15 × 7	FL for joint capsular repairing	MGA	None	18
2	40F	Traffic injury	Dual skin paddle ALTP	16 × 10 and 13 × 8	None	ATV	None	14
3	52M	Ulcer with knee infect	Chimeric ALTP	21 × 9 for skin paddle and 12 × 5 for the muscle paddle	None	ATV	None	18
4	59M	Traffic injury	Chimeric ALTP	24 × 8.5 for skin paddle and 10 × 5 for the muscle paddle	None	PTV	None	9
5	31M	Traffic injury	ALTP	20 × 10	None	ATV	None	15
6	27M	Traffic injury	ALTP with a part of FL	29 × 10	FL for joint capsular repairing	ATV	None	24
7	64M	Skin Necrosis after TKA	ALTP	12 × 6	None	MSA	None	6
8	26F	Traffic injury	ALTP	14.9 × 9	None	ATV	None	10
9	65M	Skin Necrosis after TKA	Chimeric ALTP	15 × 7 for skin paddle and 6 × 5 for the muscle paddle	None	MGA	None	12

Patients	Age (y)/ Sex	Cause injury	Type of the flap	Size of the flap(cm)	Restoring knee function or joint capsular	Recipient vessels	Complication	Follow-up(Mo)
10	7M	Traffic injury	ALTP with a part of FL	16 × 7	FL for joint capsular repairing	MSA	None	18
11	5M	Scar contracture after burn	ALTP	14 × 6.5	None	MSA	None	24
12	25F	Traffic injury	Chimeric TDAP	25 × 10 for skin paddle and 17 × 4 for the muscle paddle	Function restoring with muscle paddle	MSA	None	24
13	39M	Traffic injury	Chimeric TDAP	15 × 9 for skin paddle and 6 × 12 for the muscle paddle	None	LCFV	None	8
14	36M	Traffic injury	Chimeric ALTP	25 × 9	FL for function restoring	MGA	None	12
15	45M	Traffic injury	Dual skin paddle ALTP and SLGA flap and Vascular FL	18 × 9 and 9 × 20 for dual skin ALTP and 23 × 7 for SLGA flap and 18 × 7 for Vascular FL	Vascularized FL for function restoring	MSA	Partial Necrosis	35
16	32M	Traffic injury	ALTP	24 × 8	None	ATV	None	18

F: Female M: Male TKA: total knee arthroplasty ALTP: anterolateral thigh perforator flap TDAP: thoracodorsal artery perforator flap SLGA: superior lateral genicular perforator flap MGA: medial genicular artery MSA: medial sural vessel ATV: anterior tibial vessel PTV: posterior tibial vessel LCFV: lateral circumflex femoral vessel FL: fascia lata

Figures

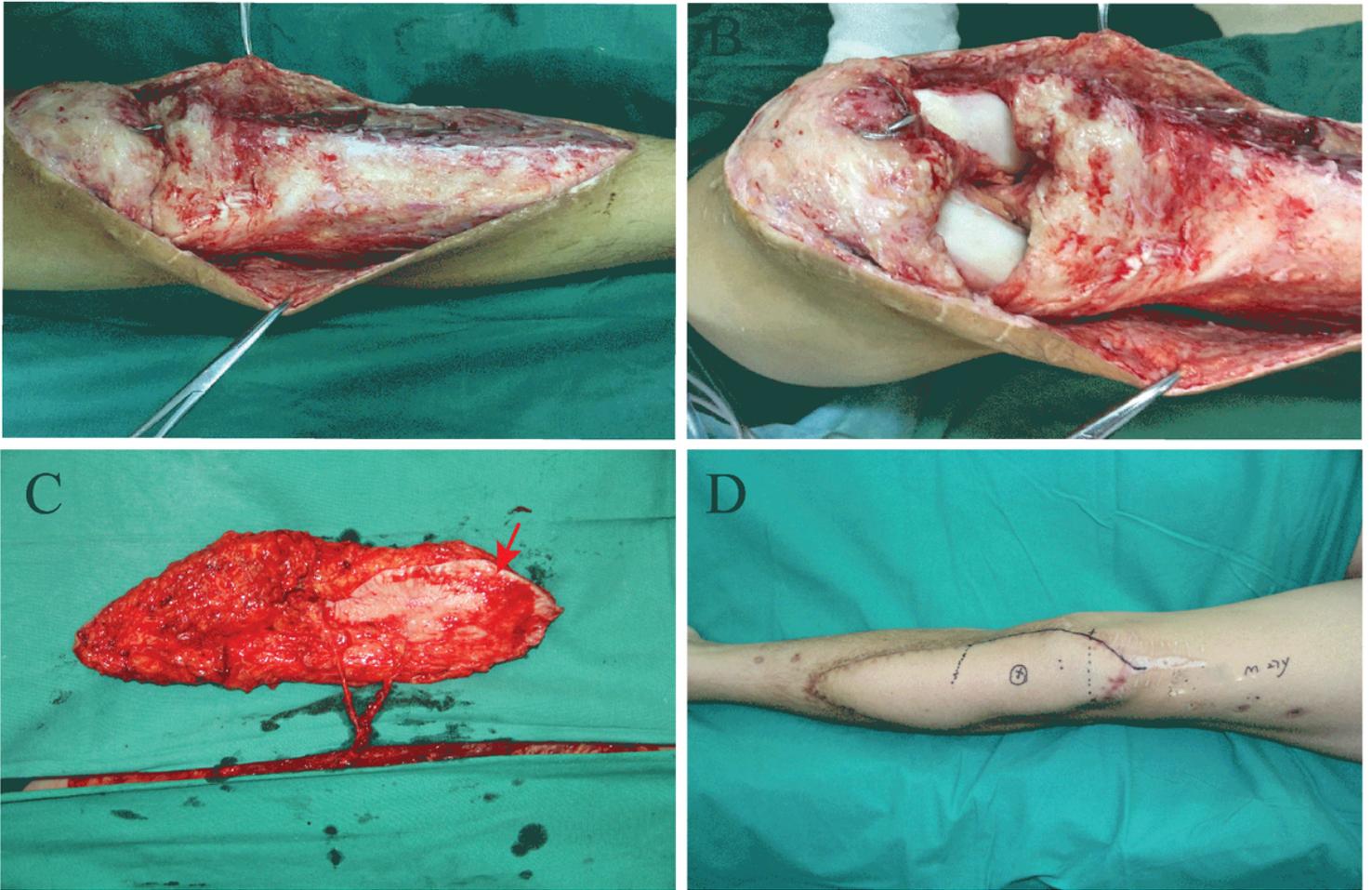


Figure 1

A, B: A 27-year-old male sustained with large soft tissue defect, exposure of the knee joint and disturb the extensor mechanism of the knee; C: ALTP flap with a part of fascia lata (Red arrow) was elevated to reconstruct the soft tissue defect and restore the extensor mechanism of the knee; D: At the 12-month follow-up, the appearance of the recipient site contour was acceptable. The patient gained good recovery with functional outcome.

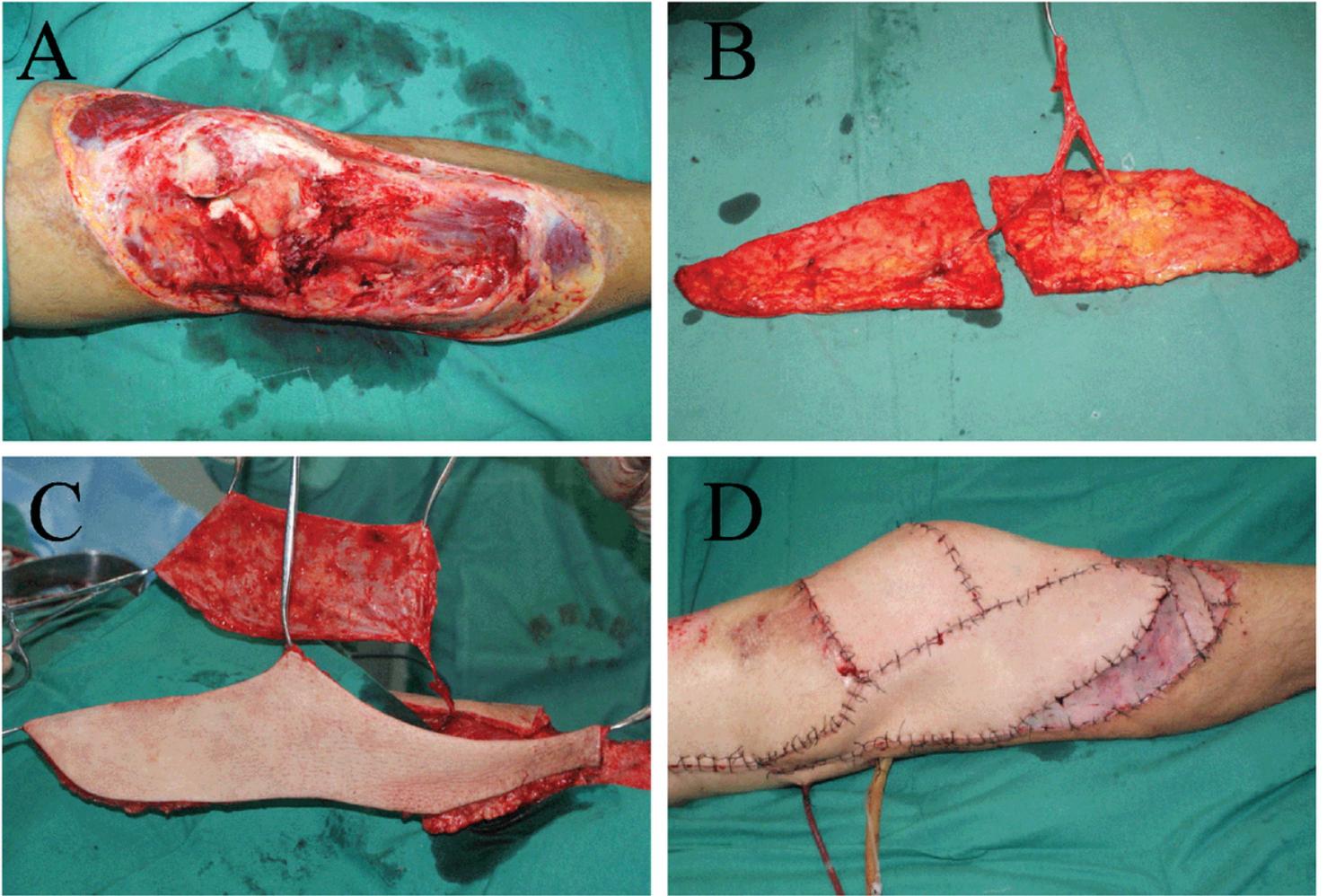


Figure 2

A: A 45-year-old male suffered with a traffic accident which resulted in a very large soft tissue defect and disruption of extensor apparatus and partial joint capsule of the knee; B: A free double skin paddle ALTP flap was harvested from the contralateral thigh; C: the SLGA flap and a vascularized fascia late flap was harvested from the bilateral thigh; D: Postoperative view of the recipient site.



Figure 3

The appearance of the knee contour was acceptable at the 35-month follow-up. The patient could stand and walk without any assistance.

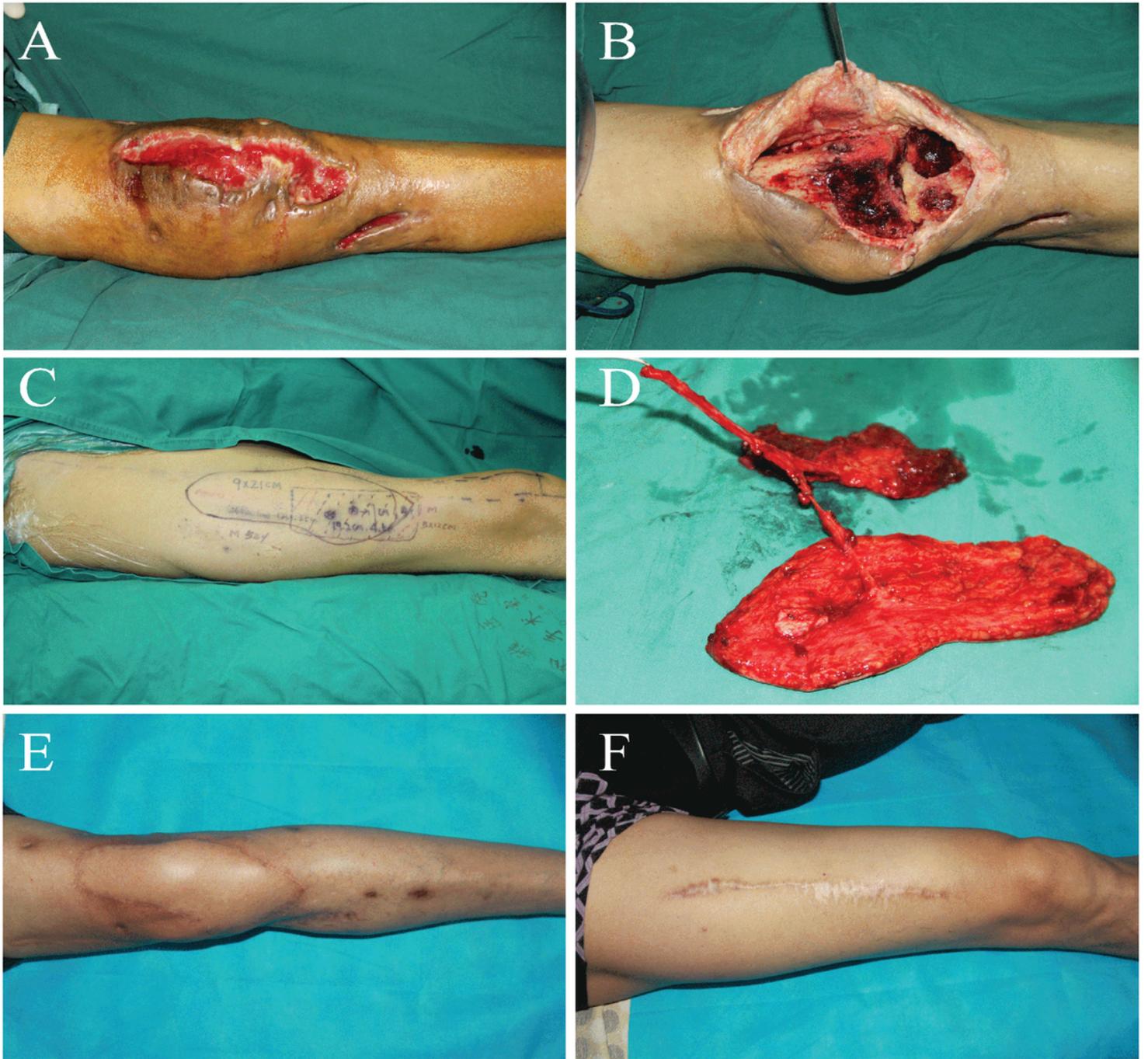


Figure 4

A: A 52-year-old male suffered with chronic ulcer in the knee regions; B: Radical debridement left a large soft tissue defect and a dead space; C: the ALTP chimeric flap was designed to reconstruct the defect. D: Intraoperative view of the flap; E, F: Postoperative view of the recipient site and the donor site.

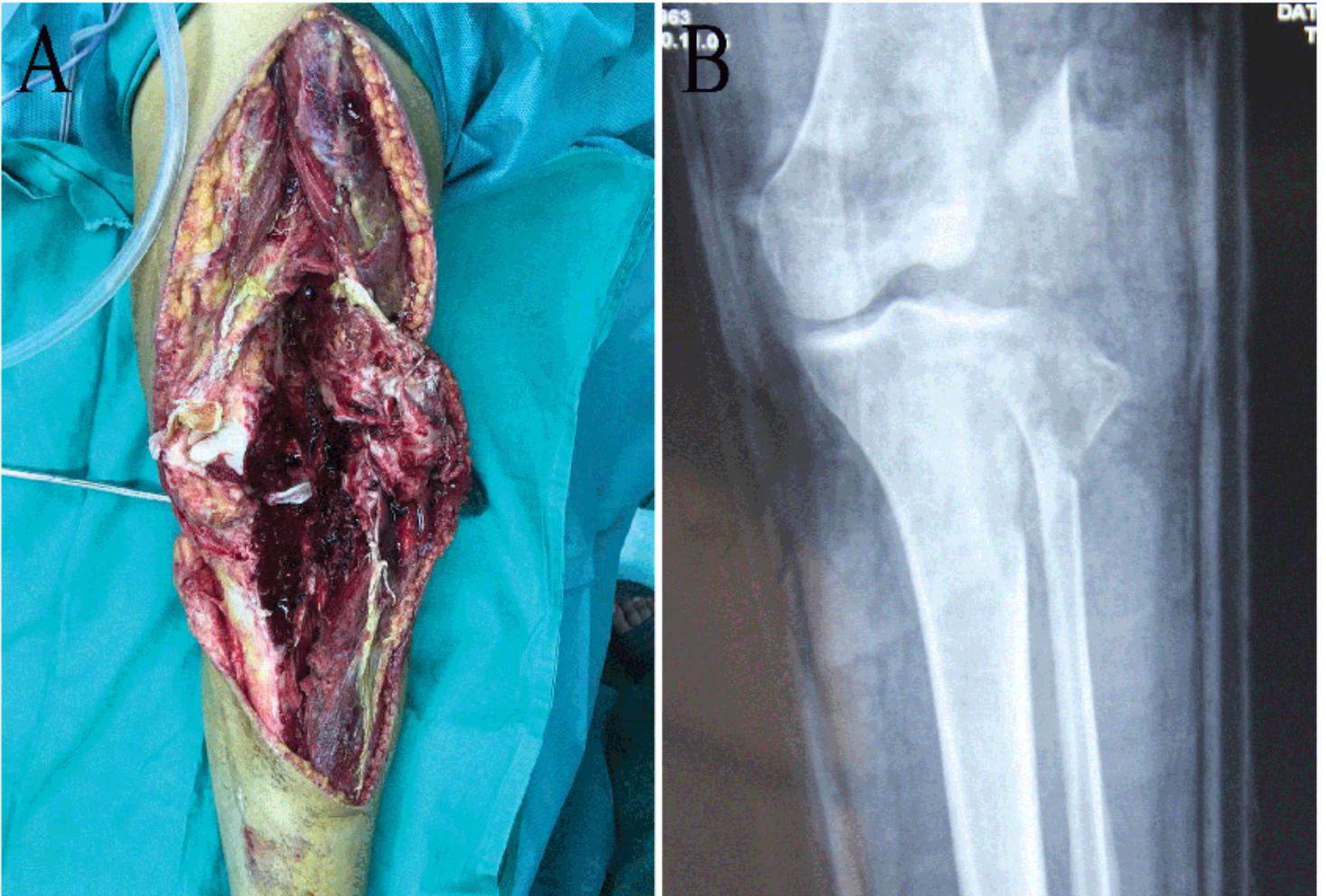


Figure 5

A, B: A 25-year-old female suffered with a huge soft tissue defect, fracture of the lateral femoral condyle and exposure of the knee joint.

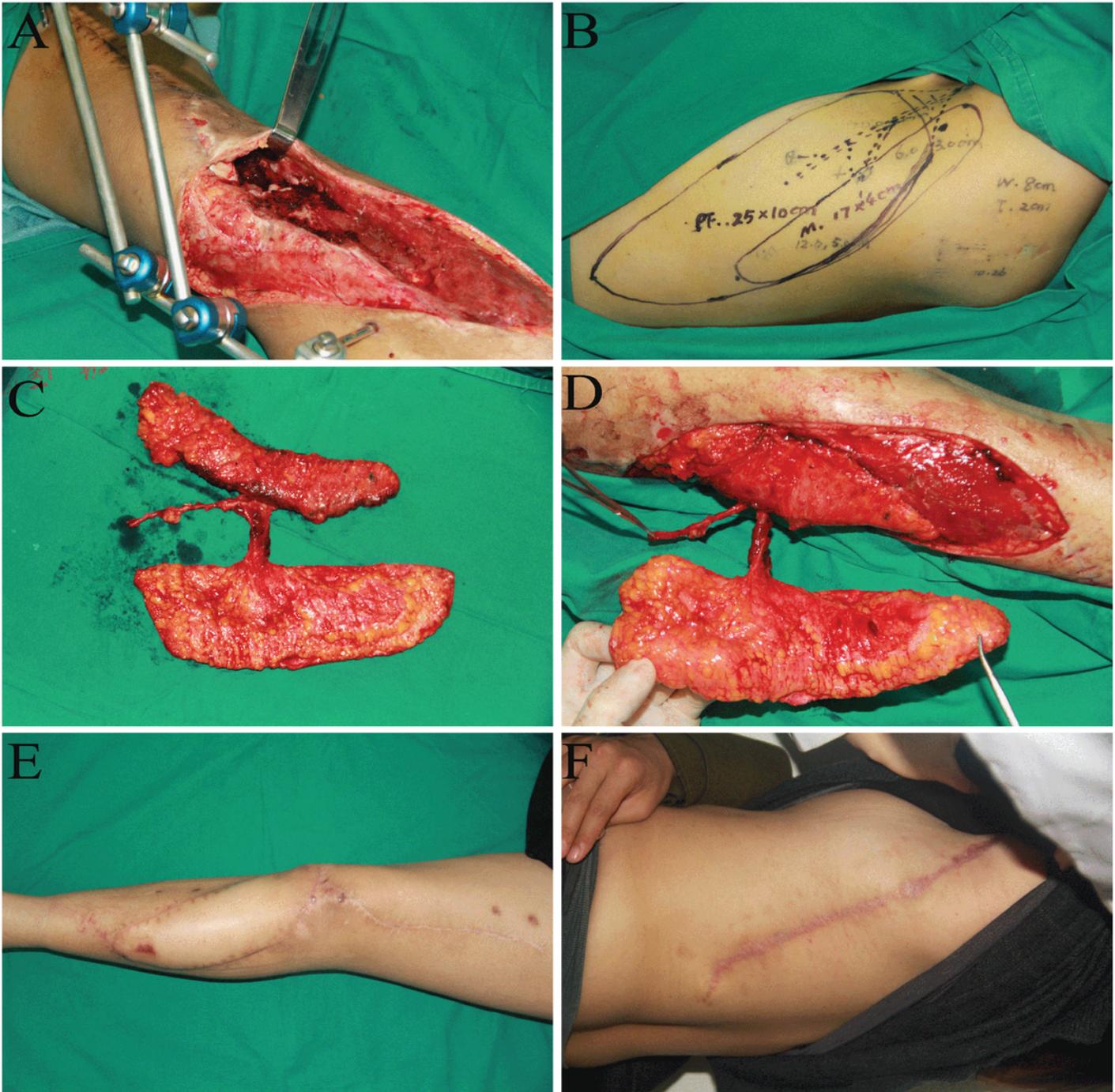


Figure 6

A: Radical debridement left a large soft tissue defect with a dead space, and the lateral extensor mechanism of the knee was deficient; B: A TDAP chimeric flap was designed to obliterate the dead space, restore the extensor mechanism and recover the soft tissue defect at one stage; C: Intraoperative view of the flap; D: The muscle paddle was inserted into the dead space and was used to restore the extensor mechanism as well; E, F: Postoperative view of the recipient site and the donor site. The patient could walk normally without any assistance.

Supplementary Files

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- video.2.MOV
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