



Sequential chimeric deep circumflex iliac artery perforator flap and flow-through anterolateral thigh perforator flap for one-stage reconstruction of complex tissue defects

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KEYWORDS

Anterolateral thigh perforator flap;
Deep circumflex iliac artery;
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Perforator flap;
Soft-tissue defect

Summary

Background: Simultaneous reconstruction of composite bone and large soft-tissue defect areas is challenging for reconstructive surgeons. This study presents a microsurgical sequential chimeric flap composed of a flow-through anterolateral thigh perforator (ALTP) flap and a deep circumflex iliac artery perforator (DCIAP) chimeric flap for one-stage reconstruction of a complex tissue defect in limbs.

Methods: A retrospective analysis was performed among patients who underwent reconstruction of bone composite and large soft-tissue defect areas in limbs using a sequential chimeric flap. A flow-through ALTP flap and a DCIAP chimeric flap were microsurgically fabricated as sequential chimeric flaps.

Results: Ten patients were successfully treated with the sequential chimeric flaps. All components of the flaps survived in all patients. Primary closure of the donor site was achieved in all cases. The sizes of the flow-through ALTP flaps ranged from 16 × 6 cm to 27 × 8 cm. The size of the cutaneous portion of the DCIAP chimeric flap ranged from 11 × 4 cm to 20 × 9 cm, and bone flap sizes ranged from 1 × 3 × 2 cm to 2.5 × 8 × 3 cm. A vascular compromise was observed postoperatively in one case. Only one case suffered minor wound-edge necrosis. Mean follow-up time was 13.1 months. Most cases showed a satisfactory contour, and no fracture of transferred iliac segments occurred.

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Conclusion: The sequential chimeric ALTP-DCIAP flap is a valuable alternative for one-stage reconstruction of composite bone and large soft-tissue defects in limbs. This approach is flexible and provides a large cutaneous area with primary closure of the donor site.

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Introduction

Extensive resection of a tumor or a complex high-energy traumatic injury often causes large soft-tissue losses and bone defects.^{1,2} One-stage reconstruction of composite bone and soft-tissue defects is essential to salvage an extremity and restore its function. However, it is often a challenging problem for reconstructive surgeons. The challenge in these types of reconstruction is to repair bone and large soft-tissue defects in a single procedure, as well as to cover a large soft-tissue defect with primary closure of the donor site.^{3,4}

A one-stage reconstruction strategy with chimeric flaps has become the mainstream treatment for such complex tissue defects.^{5,6} The use of several chimeric flaps such as the deep circumflex iliac artery perforator (DCIAP) chimeric flap,^{7,8} the scapula osteomyocutaneous flap,⁹ and the fibular artery perforator chimeric flap¹⁰ for one-stage restoration of complex tissue defects has been reported. The DCIAP chimeric flap has become a workhorse in the reconstruction of composite bone and soft-tissue defects in the extremities because it affords more degrees of freedom and flexibility in such complex tissue defects.^{7,11} This flap also reduces donor site morbidity and further improves the esthetics at the recipient site. However, it also has some disadvantages when used to reconstruct a complex wound in a large defect area. For example, the dimensions of the skin paddles may be insufficient to repair an extensive soft-tissue defect.

To overcome this drawback, we propose a sequential chimeric perforator flap design, in which a flow-through anterolateral thigh perforator (ALTP) flap and a DCIAP chimeric flap were microsurgically fabricated as sequential chimeric perforator flaps. Although the concept and practice of using sequential chimeric flaps have been developed in recent years and have further extended the indication for free flap transfers in reconstructive surgery,¹² the use of a sequential chimeric perforator flap comprising a flow-through ALTP flap and a DCIA chimeric flap for the reconstruction of composite bone and soft-tissue defects in limbs has not been widely reported.

Patients and methods

A retrospective analysis was performed among patients who underwent reconstruction of composite bone and large soft-tissue defect area in limb using sequential chimeric flaps between August 2009 and March 2017. The sequential chimeric perforator flap consisted of a flow-through ALTP flap and a DCIAP chimeric flap. The flap was used in one female and nine males. Patients' age ranged from 18 to 64 years (mean, 34.2 years). One defect was caused by a crushing injury, and nine injuries were caused by traffic

accidents. The patients' details are shown in [Table 1](#). The manuscript was performed according to the *STROBE guidelines* (<http://www.strobe-statement.org/>). The study followed the ethical guidelines of the Ethical Committee of the Xiangya Hospital. The protocol was designed in accordance with the ethical standards of the Helsinki Declaration of 1975 and all subsequent revisions.

Surgical technique

All patients underwent preoperative computed tomography-assisted angiography (CTA) to assess the vascular anatomy of the recipient and donor sites. The complex tissue defect was carefully evaluated and classified in detail by our surgical team to provide each individual patient with a specific customized reconstruction. After radical debridement, a paper template was created according to the shape of the tissue defect. A pinch test was performed to assess the available maximum skin size at the donor site. According to wound shape and the available maximum skin size at the donor site, the paper template was split into two narrow parts, which can serve as a guide for designing the width of the flaps less than the maximum available skin size, thus assuring primary closure of the donor sites with low skin tension ([Figure 1](#)).

Harvest of the traditional DCIA osteocutaneous flap has widely included a large muscle cuff to preserve subsequent skin paddle viability. The iliac crest osteocutaneous flap has limited indications for compound defect reconstruction because the subcutaneous components, which include a large amount of abdominal musculature, are bulky and immobile ([Figure 2A](#)). To overcome the disadvantage of the traditional DCIA osteocutaneous flap, the following three different designs of the DCIAP chimeric flap were used in this study ([Supplementary material Figure 1](#)).

Type I, in which the perforators are numerous and tiny and could not be freely dissected with the skin flap, and a small facial pedicle with a width of 2–3 cm is required to ensure a sufficient blood supply. The skin component is nourished by the same osteomusculocutaneous perforators that nourish the bone block. This type reduces the large muscle cuff and increases the skin paddle mobility.^{11,13,14} The major advantage of this type of design was the ability to shorten operative time for dissection of perforators and reduce the donor site morbidity. However, this type of design has a shorter vascular pedicle between the skin paddle and the bone component, which results in a limitation of the degree of freedom ([Figure 2B](#)).

Type II, in which the skin paddle was nourished by the terminal musculocutaneous perforator of the deep circumflex iliac artery. The difference between this type of DCIAP chimeric flap and the type I design lies in the fact that the

Table 1 Detailed information of the patients.

Case	Age (year) /sex	Cause of injury	Location of the wound	Dimensions of the flap (cm)		Type of DCIAP	Second procedure	Donor site	Complications	Follow-up (mo)
				DCIAP chimeric flap	ALTP					
1	37/M	Traffic accident	Right leg and distal tibial bone defect	Flap:20×8; Bone:1.8×7×3	16×6	Type I	None	DC	None	12
2	31/M	Traffic accident	Left leg and proximal tibial bone defect	Flap:19×10; Bone:2×6×2	25×8.5	Type II	None	DC	Small-edge necrosis	11
3	49/M	Traffic accident	Right leg and distal tibial bone defect	Flap:12×7; Bone:2×4×3	26×8	Type II	None	DC	Venous crisis	14
4	42/M	Traffic accident	Right leg and distal tibial bone defect	Flap:10×9; Bone:1.5×5×2	27×8	Type III	None	DC	None	9
5	21/M	Crush injury	Right hand and metacarpal bone defect	Flap:11×4; Bone:1×7×4	24×7	Type II	Reconstruct extensor function	DC	None	18
6	40/M	Traffic accident	Left foot and the second metatarsal defect	Flap:18×8; Bone:1×4×2	25×8	Type II	Flap debulking	DC	None	18
7	61/M	Traffic accident	Left leg and distal tibial bone defect	Flap:20×9; Bone:1.5×6×3	21×9	Type II	None	DC	None	13
8	28/M	Traffic accident	Left leg and tibial bone defect	Flap:10×9; Bone:2.5×8×3	23×10	Type III	None	DC	None	12
9	18/M	Traffic accident	Left thigh and femoral bone defect	Flap:15×7; Bone:2×7×3	23×7	Type I	None	DC	None	14
10	56/F	Traffic accident	Left foot and first metatarsal bone defect	Flap:15×5; Bone:1×3×2	19×7	Type II	None	DC	None	10

F: female; M: male; DCIAP chimeric flap: deep circumflex iliac artery perforator chimeric flap; ALTP: anterolateral thigh perforator flap; DC: directly closed.

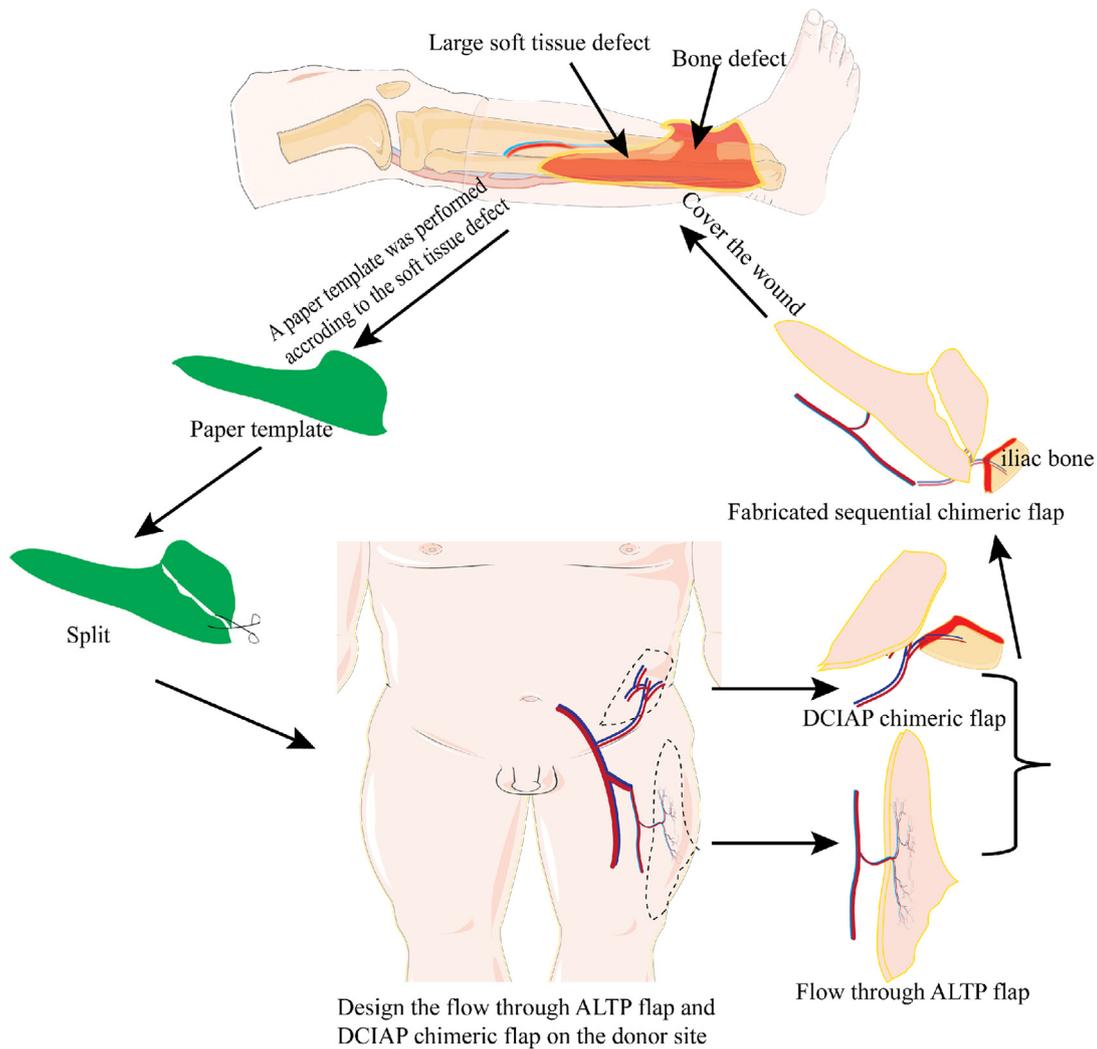


Figure 1 Diagram illustrating the design of the sequential chimeric flap for the reconstruction of a complex soft-tissue defect in the extremities. A paper template was created according to the shape of the tissue defect. To achieve primary closure of the donor site, the paper template was split into two narrow parts to navigate the design of the flow-through ALTP flap and DCIAP chimeric flap at the donor site. After elevation of the two flaps, the flow-through technique was used to microsurgically fabricate the sequential chimeric flap. The skin paddles were placed side by side at the recipient site to exactly match the size of the large defect. The iliac crest was designed to restore the bone defect.

skin portion in the composite flap is not nourished by the osteomusculocutaneous branches nourishing the iliac bone but by the terminal musculocutaneous perforator of the deep circumflex iliac artery.^{8,15} This type of design provides longer vascular pedicle of skin paddle. Notably, although this type design has longer vessel pedicle between the skin paddles and bone component, tedious intramuscular dissection and high donor site morbidity were unavailable (Figure 2C).

Type III, according to our ten-year clinical experience, we developed a novel deep iliac circumflex artery perforator chimeric flap, in which the bone component and the skin paddle are supplied with one independent vascular pedicle, and each pedicle is linked to the deep iliac circumflex vessel. The skin paddle was nourished by the ascending branch of the deep circumflex iliac artery. These vascular

branches can be of appropriate length to allow for inseting with more freedom (Figure 2D).

The surgical technique used to harvest the DCIAP chimeric flap was performed by a method as described elsewhere.^{7,11,16} Briefly, initially, only one side of the skin paddle was incised to avoid failure of flap elevation because the location of a perforator may vary, and this approach allowed us to readjust the location of the skin paddle. The flap was dissected in the suprafascial plane. Several additional perforators were preserved until the main perforator was identified. Then, the vascular pedicle was meticulously dissected from the abdominal musculature. A small soft-tissue cuff was included with the vascular pedicle for protection during flap dissection. The perforator was traced back to the main trunk of the deep circumflex iliac vessel. The bone portion was dissected after detaching the

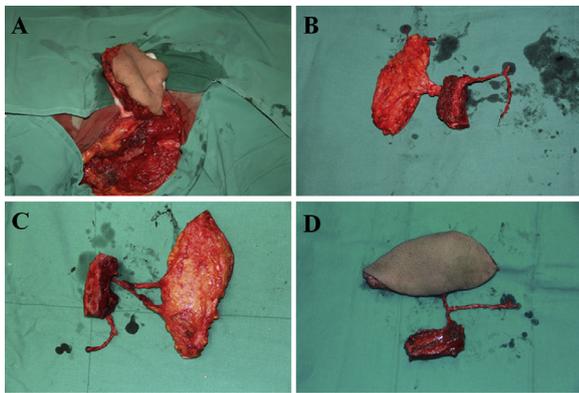


Figure 2 Three different designs of the DCIAP chimeric flap were used in this study: A Traditional iliac crest osteocutaneous flap; B, C, D Deep iliac circumflex artery perforator chimeric flap (B, Type I; C, Type II; D, Type III).

abdominal musculature along the superior edge of the iliac crest. A small muscular cuff was held between the deep circumflex artery and the iliac crest to protect the branches of the deep circumflex artery that supplied the bone flap.

The surgical technique to harvest the flow-through ALTP flap was similar to that used in our previous work.¹⁷ Some tips should be considered during dissection of the flap. Sufficient perforators (diameter > 0.5 mm) should be preserved. A vascular clamp was used to confirm perforator territory and to choose a suitable perforator. The large muscle branch derived from the main trunk vasculature should be preserved to bridge vessels for the DCIAP chimeric flap.

Subsequently, the flow-through ALTP and DCIAP chimeric flaps were placed side by side to exactly match the size of the large soft-tissue defect. The flow-through technique was performed to microsurgically fabricate a sequential chimeric perforator flap. The distal end of the descending branch or a large muscle branch of the lateral circumflex femoral vein (LCFV) was anastomosed to the pedicle of the DCIAP chimeric flap. After the flap was transferred to the defect, the proximal end of the descending branch of the LCFV was anastomosed to the recipient vessel (*Supplementary material Figure 2*). The donor site wound was closed directly after complete hemostasis and reliable drainage.

Results

Ten patients were successfully treated with sequential chimeric perforator flaps. A vascular compromise was observed postoperatively in one case (case 3), and one case suffered minor wound-edge necrosis (case 2). All components of the sequential chimeric flaps survived in all patients. The donor site was successfully closed in all patients. The sizes of the flow-through ALTP flaps ranged from 16 × 6 cm to 27 × 8 cm. The size of cutaneous portions of the DCIAP chimeric flap ranged from 11 × 4 cm to 20 × 9 cm, and the bone flap sizes ranged from 1 × 3 × 2 cm to 2.5 × 8 × 3 cm. The mean operative time was 431.1 min (range, 350-520 min). The mean follow-up time was 13.1 months (range, 9-18 months). Most of the cases showed a satisfactory contour; only one ALTP flap (case 6) presented



Figure 3 A: A 49-year-old male sustained a huge soft-tissue defect and tibial bone defect on the right lower leg. B: Preoperative radiographic view. C: Postoperative plain radiographic view of the recipient site, donor site, and iliac bone graft at the 12-month follow-up.

mild bulkiness, which was treated by a debulking procedure. The average bone union time was 5.5 months (range, 4-8 months), and no fracture of transferred iliac segments occurred.

Case report

Case 3

A 49-year-old male was involved in a traffic accident, which caused huge soft-tissue and tibial bone defects on the right lower leg. To reconstruct the large soft-tissue defect and bone defect simultaneously, the microsurgeon fabricated a sequential chimeric flap consisting of a flow-through ALTP flap and a DCIAP chimeric flap. The skin paddle dimensions of the DCIAP chimeric flap were 12 × 7 cm, the volume of the iliac bone was 2 × 4 × 3 cm, and the size of the flow-through ALTP flap was 26 × 8 cm. The skin paddles for the flaps were placed side by side to cover the surface skin of the soft-tissue defect. The iliac bone component was inserted to restore the bone defect (*Supplementary material Figure 3*). The donor sites were closed directly. Although a postoperative re-exposure procedure was required for the flap because of a venous crisis, all flaps survived completely. The recipient site showed a satisfactory contour. A radiograph showed that the bone graft was well united (*Figure 3*). Excessive functional recovery was observed after 12 months of follow-up (*Supplementary Video 1*).

Case 6

A 40-year-old male sustained a traffic accident that caused a damage injury with amputation of the lateral three toes of the left foot. After radical debridement, we were left with a defect in the second metatarsal bone and a large soft tissue defect. A flow-through ALTP flap and DCIAP chimeric flap

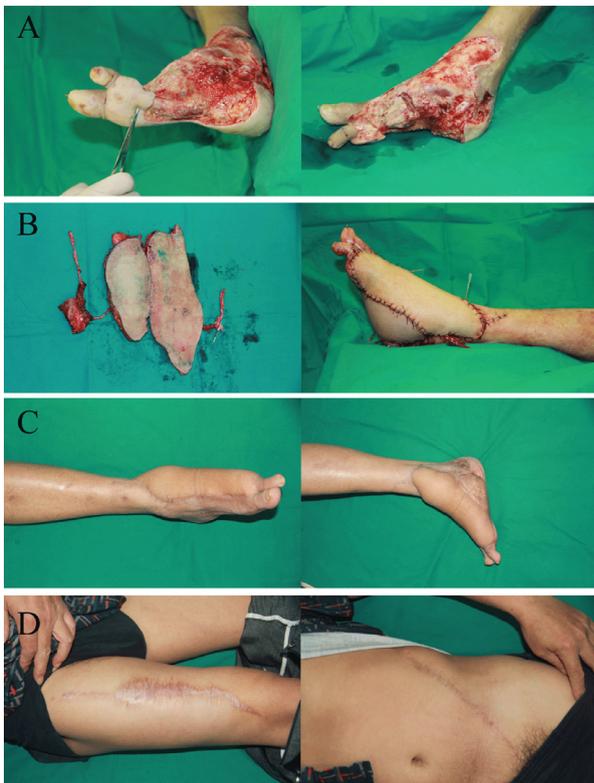


Figure 4 A: Preoperative view of a left foot injury. B: Intraoperative view of the sequential chimeric flap. C, D: Postoperative views of the recipient and donor sites at the 12-month follow-up.

were microsurgically fabricated as a sequential chimeric flap to reconstruct the complex tissue defect in one stage. The skin paddle dimensions of the DCIAP chimeric flap were 18×8 cm, the volume of iliac bone was $1 \times 4 \times 2$ cm, and the size of the flow-through ALTP flap was 25×8 cm. The skin paddles of the flaps were placed side by side to cover the surface skin of the soft-tissue defect. The iliac bone component was inserted to restore the bone defect. The donor sites were closed (*Supplementary material Figure 4*). The postoperative course was uneventful. The recipient site showed a satisfactory contour, and the ALTP flap showed mild bulking. Thus, a second debulking procedure was performed after 12 months of follow-up (*Figure 4*). A radiograph showed that the bone graft was well united (*Figure 5*). The patient was able to stand and walk without assistance at the 6-month follow-up (*Supplementary Video 2*).

Discussion

Complex limb injuries often result in defects in various tissues including bone, skin, tendons, and neurovascular structures.^{3,18} The simultaneous reconstruction of different components, particularly those involving composite bone defect and large soft-tissue loss, is always challenging for reconstructive surgeons. A chimeric perforator flap consists of multiple independent tissue flaps such as skin flaps, muscle flaps, and vascularized bone grafts, and each has



Figure 5 Postoperative radiographic view at the 12-month follow-up.

its independent vascular supply, but all flaps are linked to a common vascular source.^{19,20} This chimeric style is a subtype of compound flaps and provides many advantages when repairing complex tissue defects. However, conventional chimeric flaps lack the versatility to offer adequate tissue volume and allow precise tissue positioning to optimally cover the wound.²¹

Recently, the sequential chimeric flap has been described to cover extensive tissue defect and offers more freedom in the flap setting for complex tissue defects.^{1,12} Koshima et al.^{22,23} first described the fabricated chimeric flap as a mosaic flap used to reconstruct massive cervical defects; it consisted of two adjacent flaps that are simultaneously harvested, and the vascular pedicles of these flaps are fabricated together into a single vascular source by micro-anastomosis, and it was used as a bridge flap. Tang et al.¹ also reported a combined multilobed flap consisting of a multilobed dorsum of the foot flap and an ALT flap joined through microvascular anastomosis. This flap formed a complex micro-anastomosed chimeric flap system to precisely match the complex soft-tissue defect. However, the use of a sequential chimeric flap consisting of a flow-through ALTP flap and a DCIAP chimeric flap joined through microvascular anastomosis to reconstruct composite bone and soft-tissue defects in the extremities has not been widely reported. In the present series, we reported our clinical experience on one-stage reconstruction of composite bone and large soft-tissue defects using this sequential chimeric flap.

A T-type vessel pedicle is requisite for the successful design and completion of a sequential chimeric flap.¹² Our previous studies showed that a flow-through ALTP flap may be a good option to revascularize an additional free flap.¹⁷ Moreover, the flow-through ALTP flap provided a long vascular pedicle, large dimensional skin area, acceptable donor site morbidity, and adjustable thickness.²⁴⁻²⁶

The fibular osteocutaneous flap,²⁷⁻²⁹ scapular osteomyocutaneous flap,^{9,30,31} and iliac osteomyocutaneous flap have been commonly harvested to reconstruct composite bone and soft-tissue defects simultaneously. The literature reports that fibular flaps are useful for the reconstruction of bone defects because of its structural characteristics such as straightness, length, and the possibility to be divided into segments to reconstruct long bone defects.²⁹

However, the skin paddles of chimeric flaps harvested from the fibular vessel system at the donor site have limited dimensions; thus, they are not suitable for reconstruction of very large soft-tissue defects.²⁷ Moreover, some authors also have illustrated a relatively high stress fracture rate when fibula was used as a sole bony replacement in lower extremity reconstruction.³² The scapular osteocutaneous flap also has a versatile bone stock and can be harvested in different manners to fit a wide range of bone defects.^{5,31} Recently, Azouz et al.³³ have reported that the chimeric latissimus dorsi-scapula flap is a good option for large soft tissue defect reconstruction. However, a nonesthetic skin graft, bulky appearance, unsatisfactory color match, and function loss of donor site may be unavoidable for the limb reconstruction. Furthermore, an intraoperative readjusted position is also required.

The chimeric perforator flap based on the deep circumflex iliac vessel system is widely used to reconstruct composite bone and soft-tissue defects of the extremities and mandible because it provides a large concave segment of bone and a thick skin paddle.^{11,34-36} Taylor et al.³² have presented their 40 years of experiences in the free vascularized bone transfer and stated that this donor site was a good alternative for repairing short, straight, 6- to 8-cm-long bone defects in the lower limb. Liu et al.⁷ showed that the DCIAP chimeric flap technique enhances flap safety, reduces donor site morbidity, and improves the recipient site contour compared with the traditional iliac osteocutaneous flap technique. In the present series of cases, the flow-through ALTP flap and DCIAP chimeric flap were designed and harvested to restore composite bone and soft-tissue defects.

The advantages of simultaneously harvesting ALTP and DCIAP chimeric flap and microsurgical fabricating a sequential chimeric flap to reconstruct a complex tissue defect in a limb are as follows. The sequential chimeric flap provided a large amount of soft tissue and multiple components that individual flaps cannot offer. Primary closure was possible at both donor sites, producing an esthetic result and minimizing donor site morbidity. DCIAP chimeric flap transfer often results in poor restoration of sensation; however, the lateral femoral cutaneous nerve can be preserved in the ALTP flap to restore sensation. The length of the flap pedicle is adjustable, allowing more versatility to reconstruct complex defects without ending up with excess wasted tissue. Furthermore, the distal end or muscle branch of the descending branch of the lateral femoral circumflex vessel is a good match for the deep circumflex iliac vessel. Double flaps can also be elevated without the need for patient re-positioning. In addition, only a pair of recipient vessels was required to supply the entire sequential chimeric flap, and this procedure can reduce the risk of limb damage. *Although previous studies presented that end-to-side anastomosis was a good alternative for free flap transfer,³⁷ more than one of pair of recipient vessels was required to supply the two free flaps. It also requires major considerations related to the anastomosis angle or traumatic arteriotomy.^{25,38}*

Although the sequential chimeric perforator flap offers many merits for the complex tissue defect reconstruction, several disadvantages exist. First, the curvatures of the bone component can sometimes result in an unsatisfactory

outcome of extremity reconstruction because of the resultant unsmooth contour. Second, this approach depends on a T type of vascular pedicle to revascularize the additional free flap. Third, the additional microsurgical anastomosis is more time consuming and technically demanding. Use of the sequential chimeric flap requires a longer learning curve and skillful microsurgical technique. In this series, senior surgeons in a team of highly experienced microsurgicians performed the procedures. Finally, in this technique, more than one donor site is involved.

Some authors have claimed that multiple perforator flaps in combination resulted in an additional scar at the recipient site, an increased risk of kinking or twisting of the vascular pedicle, and a higher rate of flap-related complications.^{4,39} However, in this series, only one case developed a venous crisis. All flaps survived. According to our experience, several tips and tricks for the design and harvesting of the sequential chimeric perforator flap can be shared. On the one hand, successful harvesting of the DCIA chimeric flap and flow-through ALTP flap depends on the identification of reliable perforator vessels, which requires detailed knowledge of LCFV and deep circumflex iliac vein anatomy. Unfortunately, the perforators for the ALTP and DCIA chimeric flaps often have different origins, locations, volumes, and courses, thereby making dissection challenging. CTA was performed in all patients to assess the vascular anatomy of the lateral femoral circumflex and deep circumflex iliac systems. This examination is part of our routine preoperative workup for free tissue transfer on limbs. Some authors have reported that CTA can be used to accurately map the entire courses of the perforating vessels and to identify their exact diameters, enabling preoperative development of a more concrete surgical approach.⁴⁰ On the other hand, the superficial circumflex vessel should be included in the flap. If the perforator vessels have small diameters, the superficial circumflex vessel can be anastomosed to the recipient vessels to avoid insufficient blood supply and venous drainage. Furthermore, a large muscle branch derived from the main trunk vasculature should be preserved to revascularize the DCIA chimeric flap when the distal LCFV has a small diameter.

In summary, a sequential chimeric flap using flow-through ALTP and DCIA chimeric flaps combined into a “chain-linked” flap may be a valuable alternative for the simultaneous restoration of bone and large soft-tissue defects of the extremities. This approach is flexible and provides a large cutaneous area with primary closure of the donor site.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2019.02.029.

References

1. Tang L, Pafitanis G, Yang P, et al. Combined multi-lobed flaps: a series of 39 extensive hand and multi-digit injuries one-staged reconstructions using modified designs of ALT, DPA and chimeric linking flaps. *Injury* 2017.
2. Zheng X, Zheng C, Wang B, et al. Reconstruction of complex soft-tissue defects in the extremities with chimeric anterolateral thigh perforator flap. *Int J Surg* 2016;**26**:25-31.
3. 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**:1018-30.
4. Song B, Chen J, Han Y, et al. The use of fabricated chimeric flap for reconstruction of extensive foot defects. *Microsurgery* 2016;**36**:303-9.
5. Ozcan Akcal A, Unal K, Gorgulu T, Akif Akcal M, Bigat Z. Reconstruction of midfoot bone and soft tissue loss with chimeric partial scapula and latissimus dorsi muscle flap and short perforator-based skin flap following gunshot injuries: report of two cases. *Microsurgery* 2016;**36**:598-603.
6. Kheradmand AA, Garajei A, Kiafar M, Nikparto N. Assessing the Anatomical Variability of Deep Circumflex Iliac Vessels in Harvesting of Iliac Crest-Free Flap for Mandibular Reconstruction. *J Craniofac Surg* 2016;**27**:e320-3.
7. Liu J, Song D, Li J, Xu J, Lv H. Modified osteomyocutaneous iliac crest flaps transplantation. *J Plast Surg Hand Surg* 2015;**49**:102-6.
8. Zheng HP, Zhuang YH, Zhang ZM, Zhang FH, Kang QL. Modified deep iliac circumflex osteocutaneous flap for extremity reconstruction: anatomical study and clinical application. *J Plast Reconstr Aesthet Surg* 2013;**66**:1256-62.
9. Akcal A, Gorgulu T, Savas SA, et al. Circumflex scapular artery myocutaneous and/or vascularized scapular chimeric flap. *J Surg Res* 2016;**206**:126-32.
10. Mei J, Wu S, Yang Z, et al. Functional total heel reconstruction with a fibular osteomyocutaneous flap. *J Reconstr Microsurg* 2010;**26**:367-73.
11. Bisase B, Sloane J, Coombes DM, Norris PM. The deep circumflex iliac artery perforator flap (DCIAP)-a reconstructive option for the large composite oro-mandibular cutaneous defect. *Br J Oral Maxillofac Surg* 2013;**51**:962-4.
12. Yoshimatsu H, Yamamoto T, Hayashi N, et al. Reconstruction of the ankle complex wound with a fabricated superficial circumflex iliac artery chimeric flap including the sartorius muscle: a case report. *Microsurgery* 2015.
13. Kimata Y. Deep circumflex iliac perforator flap. *Clin Plast Surg* 2003;**30**:433-8.
14. Kimata Y, Uchiyama K, Sakuraba M, et al. Deep circumflex iliac perforator flap with iliac crest for mandibular reconstruction. *Br J Plast Surg* 2001;**54**:487-90.
15. Bergeron L, Tang M, Morris SF. The anatomical basis of the deep circumflex iliac artery perforator flap with iliac crest. *Plast Reconstr Surg* 2007;**120**:252-8.
16. Zheng HP, Zhuang YH, Zhang ZM, Zhang FH, Kang QL. Modified deep iliac circumflex osteocutaneous flap for extremity reconstruction: anatomical study and clinical application. *J Plast Reconstr Aesthet Surg* 2013 May 27 [Epub ahead of print].
17. 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.
18. 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**:200-8.
19. Hallock GG. Further clarification of the nomenclature for compound flaps. *Plast Reconstr Surg* 2006;**117**:151e-160e.
20. Hallock GG. The complete nomenclature for combined perforator flaps. *Plast Reconstr Surg* 2011;**127**:1720-9.
21. Tang J, Fang T, Song D, et al. Free deep inferior epigastric artery perforator flap for reconstruction of soft-tissue defects in extremities of children. *Microsurgery* 2013;**11**:22127.
22. Koshima I, Fukuda H, Soeda S. Free combined anterolateral thigh flap and vascularized iliac bone graft with double vascular pedicle. *J Reconstr Microsurg* 1989;**5**:55-61.
23. Koshima I, Yamamoto H, Hosoda M, et al. Free combined composite flaps using the lateral circumflex femoral system for repair of massive defects of the head and neck regions: an introduction to the chimeric flap principle. *Plast Reconstr Surg* 1993;**92**:411-20.
24. Hsiao YC, Yang JY, Chang CJ, et al. Flow-through anterolateral thigh flap for reconstruction in electrical burns of the severely damaged upper extremity. *Burns* 2013;**39**:515-21.
25. Sananpanich K, Tu YK, Kraissarin J, Chalidapong P. Flow-through anterolateral thigh flap for simultaneous soft tissue and long vascular gap reconstruction in extremity injuries: anatomical study and case report. *Injury* 2008;**39**(Suppl 4):47-54.
26. Bullocks J, Naik B, Lee E, Hollier L Jr. Flow-through flaps: a review of current knowledge and a novel classification system. *Microsurgery* 2006;**26**:439-49.
27. Wang CY, Chai YM, Wen G, Han P. One-stage reconstruction of composite extremity defects with a sural neurocutaneous flap and a vascularized fibular graft: a novel chimeric flap based on the peroneal artery. *Plast Reconstr Surg* 2013;**132**:428e-437e.
28. Kuo YR, Shih HS, Chen CC, et al. Free fibula osteocutaneous flap with soleus muscle as a chimeric flap for reconstructing mandibular segmental defect after oral cancer ablation. *Ann Plast Surg* 2010;**64**:738-42.
29. Vrabec E, Kosutic D, Krajnc A, Arnez ZM. Fibula osteocutaneous free flap for tertiary reconstruction of a segmental diaphyseal femoral defect. *J Reconstr Microsurg* 2007;**23**:115-17.
30. Wilkman T, Tornwall J, Vuola J, Lassus P. The free scapular flap with latissimus muscle reduces fistulas in mandibular reconstruction. *J Plast Reconstr Aesthet Surg* 2016;**69**:802-8.
31. Kosutic D, Uglesic V, Knezevic P, Milenovic A, Virag M. Latissimus dorsi-scapula free flap for reconstruction of defects following radical maxillectomy with orbital exenteration. *J Plast Reconstr Aesthet Surg* 2008;**61**:620-7.
32. Taylor GI, Corlett RJ, Ashton MW. The evolution of free vascularized bone transfer: a 40-year experience. *Plast Reconstr Surg* 2016;**137**:1292-305.
33. Azouz SM, Castel NA, Vijayasekaran A, Rebecca AM, Lettieri SC. Lower-limb reconstruction with chimeric flaps: the quad flap. *Microsurgery* 2018.
34. Grinsell D, Catto-Smith HE. Modifications of the deep circumflex iliac artery free flap for reconstruction of the maxilla. *J Plast Reconstr Aesthet Surg* 2015;**68**:1044-53.
35. Brandtner C, Hachleitner J, Buerger H, Gaggli A. Combination of microvascular medial femoral condyle and iliac crest flap for hemi-midface reconstruction. *Int J Oral Maxillofac Surg* 2015;**44**:692-6.

36. Vanmierlo B, Craggs B, Van Eeckhout G, Zeltzer A, Hamdi M. Sequential chimeric anterolateral thigh flap for reconstruction of through-and-through oropharyngeal defects with no suitable neck recipient vessels. *Plast Reconstr Surg* 2013;**131**:1087-90.
37. Godina M. Preferential use of end-to-side arterial anastomoses in free flap transfers. *Plast Reconstr Surg* 1979;**64**:673-82.
38. Kim JT, Kim CY, Kim YH. T-anastomosis in microsurgical free flap reconstruction: an overview of clinical applications. *J Plast Reconstr Aesthet Surg* 2008;**61**:1157-63.
39. Jia YC, Chen HH, Kang QL, Chai YM. Combined anterolateral thigh and anteromedial thigh flap for extensive extremity reconstruction: vascular anatomy and clinical application. *J Reconstr Microsurg* 2015;**31**:674-80.
40. Zhang Y, Pan X, Yang H, et al. Computed tomography angiography for the chimeric anterolateral thigh flap in the reconstruction of the upper extremity. *J Reconstr Microsurg* 2017;**33**:211-17.