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The osteocutaneous SCIP flap: A detailed description of the surgical technique and retrospective cohort study of consecutive cases in a tertiary European centre

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Summary *Introduction:* In the era of increasing popularity of the superficial circumflex iliac perforator (SCIP) flap, osteocutaneous variants of the flap have been described as well. Despite their benefits such as customizability and low donor site morbidity, these flaps have not yet gained broad acceptance. By reviewing our case series, we aim to promote the safe application of this promising new tool in osteoplastic reconstructions.
Patients and methods: We performed a single-centre, retrospective chart review of all cases in which osteocutaneous SCIP-flaps were used. We describe our surgical technique and present the surgical, functional and aesthetic outcomes of the patients in our cohort.
Results: Since September 2019, we have used osteocutaneous SCIP flaps in six patients, five in the extremities and one for the head and neck region. The vascularised bone segment was measured on average 4.9 cm (range 4-7 cm) x 3 cm (range 1.5-4 cm) and was combined with a skin paddle of a mean length of 14.3 cm (range 8-20 cm) and width of 6.3 cm (range 5-8 cm). One flap underwent emergency revision due to venous congestion. All flaps survived and healed uneventfully. Long-term follow-up shows adequate bony integration and stable soft tissue coverage with good functional restoration and minimal donor site morbidity.

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Conclusion: The osteocutaneous SCIP flap provides a large and thin skin island and a "moderately sized" vascularised bone segment with minimal donor site morbidity and can be successfully used in selected cases of osteoplastic reconstruction.

Introduction

The superficial circumflex iliac artery perforator (SCIP) flap was first described by Koshima et al.[1] in 2004 as a technical evolution of the groin flap, the first reported free flap in plastic surgery literature.[2] It overcomes some of the drawbacks of the groin flap such as its bulkiness and short pedicle. The superficial circumflex iliac artery (SCIA), on which these flaps are based, divides into a superficial and a deep branch. This deep branch ends by running along the iliac crest and giving off nutrient vessels to the bone. Based on this fact, Iida first described an osteocutaneous variant of the SCIP flap including vascularised iliac bone in 2013.[3] Since then, varying types of osteocutaneous SCIP flaps have successfully been used in the reconstruction of a number of body regions, including head, neck,[4,5] hands,[6] and feet.[7]

Despite its advantages, this promising flap has not yet gained broad acceptance outside the pioneering Asian units, not least because of uncertainties regarding anatomical variations and changing descriptions of surgical procedure. Given the initial experience in our centre, we hypothesised that the osteocutaneous SCIP flap offers a valuable and versatile option for osteoplastic reconstructions, also in the Western population. In reviewing our series of consecutive patients, describing our preferred technique incorporating the newest anatomical insights and discussing the relevant surgical considerations and potential pitfalls, we aim to improve the understanding and further promote the safe application of this recent addition to the reconstructive surgeon's armamentarium.

Patients and methods

Chart review

We performed a single-centre, retrospective chart review of all free flaps performed in our unit between September 2019 and September 2021. Eligible for inclusion in this study were all patients that underwent reconstructions with a free osteocutaneous SCIP flap. No cases were excluded. This window of time was selected to reflect the experience gathered during the two years following the first use of this flap. Follow-up data were extracted from the hospital's internal information system. All documents and radiological images were reviewed by a surgeon who was unfamiliar with the cases to avoid bias. Primary outcome measurements were free flap and reconstructive success, bone healing as well as complications and secondary interventions. Bone healing was assessed based on sequential radiographs and CT images, depending on the type of defect and its location. Furthermore, specific information concerning the surgical technique (plane of elevation, size of the soft tissue and bone components, flap design, number and origin of perforators, vessel diameter, etc.) were collected from the surgical notes. Missing outcome data in any of the cases resulted in exclusion of this specific measurement in the final manuscript. By our unit's standard, free flap patients are followed up on an outpatient basis 1 week, 3 weeks, 2 months, 6 months and one year after hospital discharge and later depending on individual needs. At the time of the review, no patients were lost to follow-up. This study was approved by the local ethics committee (BASEC-Nr: Req-2022-00179). The STROBE guidelines for cohort studies were followed in the preparation of this manuscript.

Surgical technique

As a standard, we run a preoperative Angio-CT of the donor site to exclude any disadvantageous anatomical varieties or plaques. Whenever possible, we prefer the contralateral side to the defect, aiming to facilitate a two-team approach during flap harvest and preparation at the recipient site. Both branches of the SCIA as well as regional superficial veins are then mapped on the day before the operation guided by duplex ultrasound using an 18 MHz linear array transducer (L18-5 probe; Affiniti 70G Ultrasound Machine, Philips Healthcare, Andover, MA, USA). The examination is always performed by the surgeon in charge of the case and provides them with first-hand, dynamic information of the vascular anatomy. Starting at the origin from the femoral artery, the superficial and deep branches are tracked, marking the location where they penetrate the superficial (Scarpa) fascia. The presence of the bone branch can be confirmed as well. The necessary skin paddle is marked according to the perforator location and the safe zones of perfusion.[8]

Flap harvest starts at the inferolateral border of the planned skin paddle. The Scarpa fascia is identified, and the flap is elevated on this superficial plane in a cranio-medial direction (Figure 1A). After encountering and dissecting the main perforator from the deep branch to the skin, the soft tissue skin island can be fully mobilized. A superficial vein, usually found in the medial aspect of the skin paddle, is included to improve venous drainage. This is done as a safety measure and has been recommended by Koshima et al. in the original description of the SCIP flap because the concomitant vein of the arterial pedicle tends to be small.[1] By backtracking from the perforator, the deep branch and its final course as bone branch towards the iliac crest can now easily be identified and dissected (Figure 1B). Next, the bone branch is bluntly elevated from the anterior superior iliac spine (ASIS) and the harvest of the required bone

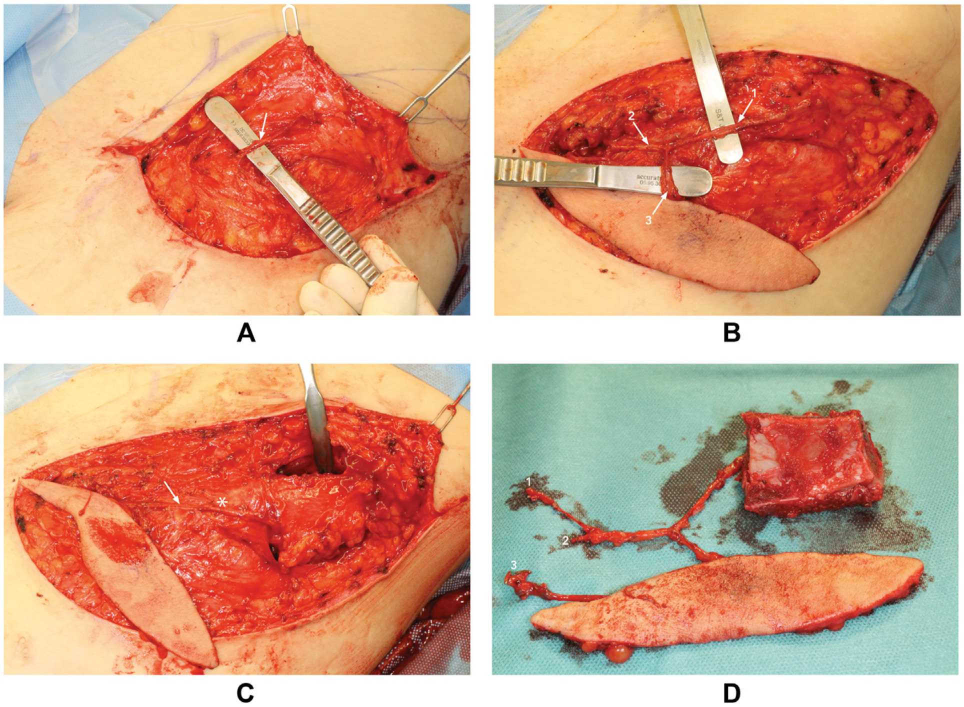


Figure 1 Surgical technique. (A) elevation of the flap on the superficial plane starting at the inferolateral border with identification of the main deep branch perforator to the skin (arrow). (B) Complete mobilization of the skin paddle and identification of the bone branch (1) originating from the deep branch (2). (3) indicates the perforator from the deep branch to the skin. C) harvesting of the bone component, 2 cm posterolateral to the ASIS (asterisk indicating the location of the ASIS; arrow highlighting the bone branch). D) Final design of the chimeric osteocutaneous SCIP-flap: (1) Accompanying vein of the deep branch, (2) deep branch of the SCIA, and (3) additional superficial vein for improved drainage of the soft tissue component.

segment started 1.5–2 cm posterior to the ASIS, therefore leaving the origin of the inguinal ligament and the sartorius muscle in place (Figure 1C). Vitality of the bone segment is confirmed by continuous bleeding from the osteotomy sites. Depending on the requirements at the recipient site, the pedicle can be traced further towards the femoral vessels as to obtain adequate length before being divided (Figure 1D).

The resulting bone defect is filled with Spongostan (Ethicon Inc., Somerville, NJ) for haemostasis, and Ropivacaine is applied locally for postoperative pain control. Alternatively, especially in larger defects, a bone allograft (Tutoplast, Tutogen Medical GmbH, DE) can be used to fill the dead space and restore iliac contour. The donor site is then closed in a multilayer fashion, with special attention being paid to the closure of the deep fascia over the osteotomy site to prevent potential herniation. In all cases, the skin itself was closed primarily, aided by further mobilization of the surrounding soft tissues on the superficial fascia if needed.

The inset of the flap begins with trimming and osteosynthesis of the bone component followed by partial fixation of the skin island. In general, we prefer end-to-side anastomoses in the extremities in order not to compromise the blood supply of the limb. Furthermore, this also overcomes the potential issue of size discrepancy between donor and recipient vessels as the pedicle vessels of a SCIP are of smaller calibre in comparison to other flaps. In the head and neck regions, adequately sized recipient vessels for an end-to-end anastomosis are usually readily available. After performing the microvascular anastomoses, the inset of the skin paddle is completed, ensuring compression free soft tissue coverage over the pedicle.

Results

Between September 2019 and September 2021, a total of 6 patients (4 males and 2 females) underwent reconstructions with a free osteocutaneous SCIP flap in our unit. Mean age was 52 years (range 26 - 75 years), and average BMI was 24.7 kg/m^2 (range 21 - 31 kg/m^2). Indication for the reconstruction was given primarily due to trauma, except for one oncological case. The defects were located in the hand, foot, lower leg as well as in the face (see Table 1).

The vascularised iliac bone included in the flaps measured on average 4.9 cm (range 4 – 7 cm) in length and 3.0 cm (range 1.5 – 4 cm) in width perpendicular to the iliac crest. All bone components were harvested as full thickness iliac crest segments. The mean skin paddle length was 14.3 cm (range 8 – 20 cm), and its average width was 6.3 cm (range 5 – 8 cm). The mean vessel diameter was 2 mm (range 1.5 – 2.3 mm) for the pedicle artery, 1.3 mm (range 1 – 1.5 mm) for the concomitant vein and 2.25 mm (range 2 - 2.5 mm) for the superficial vein. All flaps were elevated on the superficial plane between the deep and superficial fat compartments. A bone branch originating from the deep branch was always found and subse-

Table 1 Summary of patient demographics and flap characteristics. SCIA = superficial circumflex iliac artery.

Age at surgery / Sex	BMI (kg/m2)	Indication	Bone defect	Size of skin paddle (cm)	Size of bone segment (cm)	SCIA branch used for bone perfusion	SCIA branch used for skin perfusion	Recipient vessel	Suture tech-nique	Number of venous anastomoses performed	Follow-up (months)
31 / male	25	Trauma	Calcaneus	16 × 7	7 × 3	Deep branch	Deep branch	Posterior tibial artery	End-to-side	2	29
61 / male	31	Trauma	Metacarpal IV + V (right hand)	16 × 6	5 × 4	Deep branch	Deep and superficial branch	Ulnar artery	End-to-side	2	22
64 / female	20	Trauma	Metatarsal I	13 × 7	4 × 1.5	Deep branch	Deep branch	Dorsalis pedis artery	End-to-side	2	21
75 / female	23	Malignant tumour	Orbital floor and maxilla	8 × 5	4 × 3.5	Deep branch	Deep branch	Facial artery	End-to-end	2	20
26 / male	21	Trauma	Metacarpal II + III (right hand)	13 × 5	4 × 3	Deep branch	Deep branch	Radial artery	End-to-end	2	6
54 / male	28	Post-traumatic osteomyelitis	Tibia	20 × 8	5.5 × 3	Deep branch	Deep and superficial branch	Side branch of posterior tibial artery	End-to-end	2	6

Figure 2 Clinical (A) and radiological (B) appearances after debridement illustrating the significant bone and soft tissue defect as well as the destruction of the Achilles tendon.

quently used for the perfusion of the bone segment. The skin component was supplied by perforators from the deep branch in all cases. In two of the larger flaps, perforators from the superficial branch were also included in order to ensure adequate perfusion of the entire skin paddle (Table 1). No vein grafts were used in any of the cases.

One flap underwent emergency revision within 24 h for venous congestion due to kinking of the venous pedicle, which was resolved successfully and the flap salvaged. Besides that, all flaps healed completely, without the need for any secondary interventions.

All donor sites healed uneventfully by primary intention. No cases of herniation, haematoma or seroma formation were observed. In one case, the lateral femoral cutaneous nerve was severed in order to facilitate flap harvest and primarily readapted, resulting in transient numbness in the upper lateral thigh. The affected patient reported complete sensory recovery after eight months.

The mean follow-up period was 17.3 months (range 6 – 29 months). Regular radiological and clinical follow-ups confirmed adequate, progressive osteointegration, stable soft tissue coverage and overall successful reconstructive outcome in all cases. In an effort to improve the aesthetic outcome, secondary corrections were performed in two cases, in the hand and face, respectively.

Case examples

Case 1

A 31-year-old male patient presented to us after sustaining an accidental, self-inflicted shotgun injury on a hunting trip. He suffered a grade 3 open, comminuted calcaneus fracture with a sizable soft tissue defect and complete destruction of the Achilles tendon, resulting in the defect shown in Figure 2 with loss of a large portion of the calcaneal bone (Figure 2). Fortunately, the tibial nerve remained intact.

The case was discussed in a multidisciplinary conference with orthopaedic and trauma surgeons. Since the loss of the calcaneus was extensive, the main reconstructive aim was considered bone length restoration to allow for an adequate lever arm for the Achilles tendon to be reconstructed. The option of a free ALT with rolled up vascularised fascia lata was considered but finally discarded in favour of tendon reconstruction with an allograft in combination with vascularised autologous bone and soft tissue coverage. Therefore,

Figure 3 Radiological follow-up (A) 6 weeks postoperative (B) late follow-up, 17 month postoperative illustrating complete bony union.

Figure 4 Clinical result 20 months postoperative.

Figure 5 Initial presentation after circular saw injury.

the defect was reconstructed using an osteocutaneous SCIP flap as described above. The required skin paddle measured 16 × 7 cm, and the iliac bone component was 7 × 3 cm. Perforators from both the superficial and deep branch were included, and anastomosis was performed onto the posterior tibial system, in an end-to-side fashion for the artery and end-to-end for the veins. An allograft was used to reconstruct the missing Achilles tendon.

Initially, an external fixator was installed to ensure compression free immobilization. Full-weight bearing was recommenced 14 weeks postoperatively. Regular radiologic follow-up showed progressive bony hypertrophy and osteointegration (Figure 3).

Long-term follow-up confirmed a satisfactory functional result (See Videos, Supplemental Digital Content 1 and 2, which show the patient 20 month postoperative). The patient can walk barefoot free of complaints, has returned to his job as a carpenter working full-time and does not desire any secondary contouring procedures (Figure 4).

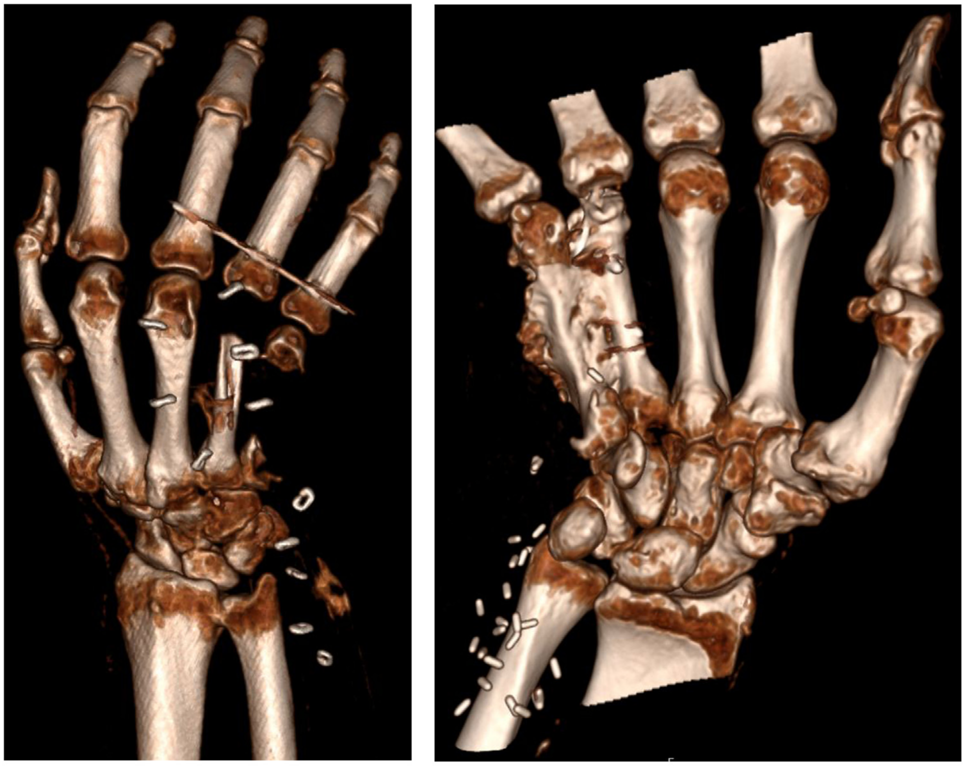
Case 2

A 61-year-old male patient was referred to us after injuring his right, dominant hand with a circular saw. In addition to the severe soft tissue and bony defects on the dorso-ulnar aspect of the hand shown in Figures 5 and 6A, he sustained defect lesions of his extensor tendons (extensor digiti minimi, extensor digitorum communis III-V) and dorsal branch of the ulnar nerve. After initial debridement and temporary fixation, the definitive reconstruction was performed within 48 h after the accident using an osteocutaneous SCIP flap. A 5 × 4 cm segment of vascularised iliac bone was inset to reconstruct and retain the length of the fourth and fifth metacarpal. The skin component measured 16 × 6 cm, and the anastomoses were performed end-to-side onto the ulnar artery and end-to-end to the ulnar vein and a dorsal forearm vein. In addition, palmaris longus tendon autografts were used to reconstruct the extensor tendons, while nerve allografts (Avance nerve graft, Axogen, Alachua FL) were employed to bridge the defect of the dorsal branch of the ulnar nerve.

About one year later, the metalwork was removed, and tenolysis of the extensor digitorum communis tendons II-V as well as an arthroplasty of the fourth metacarpophalangeal joint were performed to improve the functional result. As the flap needed to be raised for surgical access, it was slightly thinned in the same operation. Currently, the patient is free of pain and has resumed his employment in a factory without any limitations, despite physically demanding labour. Figure 7 illustrates the clinical findings 17 months after the initial trauma (for specific functional results see Supplemental Digital Content 3).

Discussion

The concept of harvesting vascularised iliac bone perfused by the SCIA system is not new. In 1978, Taylor et al. described a composite groin - vascularised iliac bone free flap.[9] Although initially described based on the SCIA system, the authors soon abandoned it in favour of the deep



A B

Figure 6 3D CT reconstruction of the affected hand. (A) appearances after initial debridement and temporary fixation with a marked defect of the head and shaft of the 4th metacarpal as well as almost complete destruction of the 5th metacarpal bone. (B) Result 11 months postoperative illustrating bony union as well as adequate metacarpal length retention.

A B C

Figure 7 Clinical result 17 months after the accident.

circumflex iliac artery (DCIA)-based iliac bone flap, which allowed for a bigger bone component to be harvested and offered a larger calibre pedicle.[10] In 2013, the idea was revived in the form of the osteocutaneous SCIP flap,[3,7] combining the advantages of the SCIP with the potential for vascularised bone transfer.

The following year, the superficial plane between superficial and deep fat (Scarpa fascia) was established as a new plane of elevation for SCIP flaps in an effort to obtain even thinner flaps and reduce donor site morbidity by leaving the inguinal lymph nodes in place.[11] Therefore, the options for elevating the flap have expanded to three planes: sub- or supra-fascial to the fascia lata (deep plane) and superficial.

Plane of elevation and pedicle selection

The plane of elevation is seldomly clearly stated in reports about osteocutaneous SCIP flaps and in general the deep plane seems to be favoured.[7,12] We prefer the superficial plane due to the above-mentioned considerations about the donor site. Furthermore, this plane not only provides a thinner but also more homogeneous flap.[8] This technique also allows the harvest of thin skin flaps even in adipose patients, which is often an issue in the Western population. Nevertheless, secondary flap thinning might still be necessary to achieve an optimal contour, depending on the recipient region (see case 2 which corresponds with Supplemental Digital Content 4 Fig. B).

In contrast to most reports, the deep branch is our preferred pedicle for the skin paddle, as not only does it supply the bone, but according to our previous anatomical study, it also provides a longer pedicle as well as a larger angiosome when it comes to the soft tissue component.[8] The mean pedicle length that can be achieved with this technique is 9.1 ± 1 cm[8]. While this is still rather short in comparison to other perforator flaps, it is sufficient for most reconstructive situations. If necessary, the superficial branch is included, especially in cases where a large skin paddle is needed or when the perforators originating from the deep branch are rather hypoplastic. Whenever this is done, one should keep in mind that there are rare anatomical variations where no common trunk of the SCIA exists but both the superficial and deep branch originate independently from the femoral system,[13] which would therefore require two separate anastomoses.

In general, the flap can be designed in a composite or chimaeric fashion, depending on requirements at the recipient site. The proposed surgical technique and chimeric deep branch design allow for optimized, independent inset of the bone and soft tissue components, yet still only require one microvascular anastomosis.

Bone harvest

Our standard technique is to harvest the full thickness of the iliac bone. If a thinner bone component is sufficient for the reconstructive situation, the medial cortex can be left in place with the aim of further reducing donor site morbidity.[7]

The size of vascularised bone that can be harvested based on the SCIA system certainly represents one important limitation of this flap. Based on clinical experience[5] and experimental findings in cadavers,[14] about 8×3 cm is assumed to be safe. Although in some cases we harvested bone segments measuring more than 3 cm in depth from the iliac crest, we tend to adhere to these parameters. Ultimately, the extent of vascularisation of the bone remains a surgical decision based on the individual anatomy, and adequate perfusion of the bone segment can be verified intraoperatively by active bleeding at the osteotomy sites. Alternatively, ICG (indocyanine green) fluorescence angiography can be employed for further reassurance.

On the other hand, a clear advantage of the osteocutaneous SCIP is its reliable and customizable soft tissue component and low donor site morbidity. Depending on the plane of elevation, it can be harvested from bulky to very thin and still has the potential to cover even large defects.[15] While the osteoseptocutaneous fibula flap also allows for sizable and very thin skin islands to be harvested in conjunction with the bone,[16,17] these components tend to be less independent, which can hamper optimal inset. Furthermore, such donor sites usually require skin grafting and are associated with potentially significant morbidity for the patient.[18,19]

The DCIA flap is another obvious alternative option for an osteocutaneous flap. While it offers a larger bone component and a pedicle of larger size, the skin paddle is significantly bulkier, offers less flexibility of inset and comes with increased morbidity as described below.

The scapular / parascapular osteocutaneous flap also offers a reliable and potentially large skin island with a bone flap of a maximum around 12 cm length but limited width and especially thickness as the scapula becomes thin medially from the lateral edge.[20,21] The unsightly, often wide scars after harvesting large skin paddles and the potential need for repositioning in the OR are some disadvantages compared to the SCIP flap.

Other options such as the radial forearm osteocutaneous flap, the lateral arm osteocutaneous flap or the medial femoral condyle flap offer only limited volumes of vascularised bone compared to the osseous component of the SCIP flap.

Ultimately, the decision which flaps to use for complex defects requiring combined osteocutaneous reconstruction will need to be made on an individual basis, with all available options having advantages as well as disadvantages that need to be considered in order to find the best suited option for the individual patient.

Donor site

The SCIP flap is well appreciated for its minimal morbidity of the donor site. Harvesting iliac bone in addition to the traditional skin paddle seems to only moderately increase that risk. The most common complaint is increased postoperative pain,[7] which is to be expected, given the experience with iliac crest bone grafting. As it has been shown to have a long-term effect, we advise addressing this issue intraoperatively.[22,23] Using the technique described above, we did not experience any such issues in the long term.

Besides that, lateral femoral cutaneous nerve injury (most often cause by traction) can occur due to the dissection close to the ASIS, leading to transient numbness in the lateral thigh region.[7] In cases where perforators from the superficial branch are included in addition to the deep branch, a further issue that can arise is that the deep branch travels underneath the lateral femoral cutaneous nerve, sometimes giving of his perforators laterally, while the superficial branch perforators are medial. This essentially creates a loop around the nerve, trapping the pedicle. Potential solutions to this are: creating two independent skin islands, dividing the pedicle and performing two separate anastomoses or sectioning the nerve and microsurgical neurorrhaphy after harvesting the flap.

Although direct comparative studies are lacking, abdominal wall herniations, which are known to occur after harvest of DCIA flaps,[24] have not been observed after osteocutaneous SCIP flaps.[5,6,12] This might be an effect of the smaller volume of bone that is usually included in an osteocutaneous SCIP flap. Yet, it seems reasonable to assume that the donor site morbidity is also lowered by reducing the disruption of the abdominal wall to the minimum, the area of bone that is harvested, and not having to open more for the dissection of the DCIA pedicle. Regardless, adequate fascial closure remains essential for successful long-standing repair.

Furthermore, although the scar tends to be longer in cases where iliac bone was harvested in addition to the soft tissues, the donor site is typically inconspicuous and easily concealed by the normal undergarments of the patients (for clinical examples see Supplemental Digital Content 4).

Patient selection

Of course, the decision which flap is used always must be made in an individualised approach based on the specific reconstructive situation, patient characteristics and other relevant factors. In general, we believe that the osteocutaneous SCIP flap is ideally suited for cases, where thin soft tissue coverage is needed in addition to a small to "moderately sized" vascularised bone segment. Given the shorter pedicle length, we recommend clarifying preoperatively whether adequate recipient vessels are available in the vicinity. Additionally, CT angiographic imaging of the donor site helps identify potentially disadvantageous anatomical variations or significant calcifications.

Limitations

The main limitation of this paper is the low numbers of cases performed. Nevertheless, we feel that our initial experience offers a valuable perspective on the current surgical developments, especially given the context of the low number of overall published cases and lack of dedicated reports in the Western world. In addition, the time needed to harvest the flaps was not uniformly measured and documented, and therefore it had to be excluded as the documented operation time included other procedures such as tumour ablation or osteosynthesis.

Conclusion

We present a series of consecutive cases in which free osteocutaneous SCIP flaps were successfully used for combined bone and soft tissue reconstructions in the extremities and the face. The advantages of the flap are the large and thin skin island and a "moderately sized" vascularised bone segment harvested with minimal donor site morbidity and an easily concealed scar. If the disadvantage of a comparatively short and small calibre pedicle is taken into careful consideration, the osteocutaneous SCIP flap has the potential to be an excellent solution for selected cases of osteoplastic reconstruction.

Ethical approval

This study was approved by the responsible ethics committee of the Canton of Bern (BASEC-Nr: Req-2022-00179).

Declaration of Competing Interest

None declared.

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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.2022.10.056.

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