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# The medial femoral condyle free flap: An excellent option for difficult cases: case series

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**Abstract**

The use of the medial femoral condyle free flap is a versatile option for the treatment of upper extremity non unions and reconstructive procedures associated with bone loss or osteonecrosis. The benefit of this type of flap is the viability of the bone which favors primary ossification and increases bone density. Vascularized free bone flaps are especially useful for the treatment of recalcitrant nonunions, or nonunions that have failed three or more treatments to obtain consolidation. We present a case series of three patients treated with medial femoral condyle free flap for reconstruction of the upper extremity of different etiologies at the level of the distal humerus, distal radius and distal phalanx of the thumb.

**Keywords**

Medial femoral condyle free flap, recalcitrant nonunion, thumb reconstruction, knee, upper extremity reconstruction

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## Introduction

The use of the medial femoral condyle free flap (MFCF) is a versatile option for the treatment of upper and lower extremity nonunions and reconstructive procedures associated with bone loss or avascular necrosis.[1,2] The benefit of this type of flap is the viability of the bone which favors primary ossification and increases bone density.[1,3] Atrophic nonunions are associated with poor bone vascularity at the fracture site. Effective treatments provide not only bone, but also restore healthy blood flow to the area. The sites where vascularized bone grafts can be harvested are the fibula, radius, scapula, iliac crest and the medial aspect of the knee.[4] Vascularized free bone flaps are especially useful for the treatment of nonunions and recalcitrant nonunions, meaning nonunions that have failed three or more treatments to obtain consolidation.[5,6] If the recipient site is irregular, the MFCF is indicated due to the versatile anatomy of this flap.[7]

In 1991, Doi and Sakai[8] demonstrated the use of the vascularized supracondylar region of the femur with vascular supply through the descending genicular artery (DGA), a branch of the superficial femoral artery and the superomedial genicular artery (SMGA).[9] The SMGA offers the greatest vascularity of the medial condyle of the femur.[4,10] This versatile flap can be used as an osteocutaneous flap if a skin paddle is needed and can be incorporated to address a tendon, muscle and chondral defect as well.[2,6,11–13] Donor site morbidity is limited and primarily relates to sensory disturbances in the distribution of the saphenous nerve.[14–16] The purpose of this case series is to demonstrate the versatility of the MFCF in the management of different types of nonunion for various anatomical levels of the upper extremity.

## Case section

### *Subjects*

Three patients were treated with MFCF. Case 1 is a supracondylar humerus fracture initially treated with open reduction internal fixation (ORIF) and autologous non-vascularized bone graft which presented with an infected nonunion requiring hardware removal. Case 2 is a patient who failed to heal after

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of the management of a distal metaphyseal giant cell tumor treated with excision, autologous bone grafting and a wrist fusion. Case 3 involves a reconstructive option for the distal phalanx of the thumb in a patient suffering a crush injury.

All patients were treated with the same surgical technique, by the same senior author and the approach to the knee was ipsilateral to the affected upper limb. The disabilities of the arm, shoulder and hand (DASH)[17] score is a validated upper extremity outcome questionnaire used to assess functional outcomes which was performed in the three patients presented.

## Surgical technique

The patient is placed in supine position, the ipsilateral leg to the affected upper extremity is prepped circumferentially from the ankle to the groin. A sterile tourniquet is applied high at the thigh and the lower extremity is then externally rotated and flexed at the hip and knee to assume a frog-leg position.

A curvilinear incision of approximately 12 cm is made from the level of the adductor hiatus to the midpoint of the medial patella. Dissection is performed through the subcutaneous tissue until the fascia of the vastus medialis is identified. The vastus medialis is retracted anteriorly and the adductor tendon is identified and retracted posteriorly. The medial femoral condyle is then exposed and the transverse and longitudinal branches of the DGA are visualized. The periosteum was incised leaving the central pedicle attached. Attention was then directed to harvesting the graft in a rectangular manner with small, posterior and anterior segments. The proximal and posterior portions were isolated with a key elevator leaving the central pedicle with periosteum still adherent. At this point, an osteotomy through the cancellous portion under the pedicle was performed. The graft was then released with an osteotome on all four sides and elevated. After this was done, the tourniquet was deflated to confirm the graft had adequate blood supply. Ligation of the graft pedicle was performed 5 cm proximally using ligaclips. The graft was then transferred to the repair site. Suture repair of the fascia was performed with absorbable 2–0 suture, subcutaneous tissue was closed with interrupted absorbable 4–0 and the skin was closed with subcuticular 4–0 absorbable suture.

*Case 1.* A 58-year-old female with a past medical history of hypertension presented after a fall where she sustained a supracondylar fracture of the left elbow. Initial surgery consisted of ORIF of the medial and lateral columns through a chevron osteotomy of the ulna. She failed to show signs of union at 5 months postoperatively and underwent bone stimulator therapy for 4 months. Radiographs showed loosening of hardware and a persistent nonunion. The patient then underwent removal of hardware, repeat fixation with 90/90 plating and iliac crest bone graft (ICBG). Unfortunately, she developed a deep surgical site infection 4 weeks postoperatively necessitating debridement, removal of hardware and 6 weeks of antibiotic therapy followed by repeat ORIF with contralateral ICBG. Six months postoperatively she fails to demonstrate union and to avoid yet another failure of fixation the decision was made to use a MFCF.

A para-tricipital and anteromedial approach was performed, with dissection and exposure of the brachial artery, median nerve and ulnar nerve. The fracture site at the medial column was debrided and cancellous graft was placed without removing the plate. After harvest of the MFCF as described above, the graft was placed in the medial column crossing the fracture site and secured with two 2.0 mm cortical screws after elevating the periosteum about 5 mm at both ends of the graft. The pedicle was anastomosed to the brachial artery in end-to-side fashion. Five months after surgery, there was no pain, elbow flexion of 110 degrees and her elbow extension lag of 30 degrees. Her left-hand strength was 30 pounds compared with the right side that was 40 pounds. Subsequent radiographs demonstrated signs of consolidation with bone bridging at the medial column and residual radiolucency at the lateral column. The patient reported no complaints, with flexion of 110 degrees, extension lag of 30 degrees and complete prono-supination at the time of her final follow-up visit. The result of a DASH score performed 2 years after her last surgery was 0.8 (Figure 1).

*Case 2.* A 59-year-old male patient, with a history of diabetes, hypertension and hypercholesterolemia, presented with pain in the left wrist. He reported no history of trauma and a De Quervain's release done by another surgeon 3 months prior without improvement of his pain after this procedure. The patient complained of pain at the radial and dorsal aspect of the wrist with mild edema and severe tenderness at the level of the distal radius and radial styloid. anteroposterior (AP) and lateral x-rays of the wrist revealed a large area of radiolucency at the metaphysis of the radius suggestive of a giant cell tumor with cortical breakthrough of the lesion. The patient was treated surgically with en bloc excision of the tumor, tricortical bone grafting of 4 cm and wrist fusion with a 3.5/2.7 metaphyseal Synthes plate (West Chester, PA, USA). A giant cell tumor of the radius was confirmed by pathology. Nine months after surgery, x-rays show clear radiolucency at the interval of the graft and proximal aspect of the radius shaft. The decision was made to perform an MFCF without removal of hardware as this appeared to be intact.

A rectangular cortico-cancellous graft from the medial femoral condyle was harvested and it was carved in a "C" shape carrying out two controlled fractures of the cortical graft, but maintaining the periosteum intact. The nonunion site at the shaft of the radius was debrided and excision of fibrous tissue was done. The site was packed with cancellous graft taken from the medial femoral condyle area and the flap was placed circumferentially around the radial, volar and ulnar cortices of the radius at the proximal segment of the fusion. The pedicle was sutured end-to-side to the radial artery and to

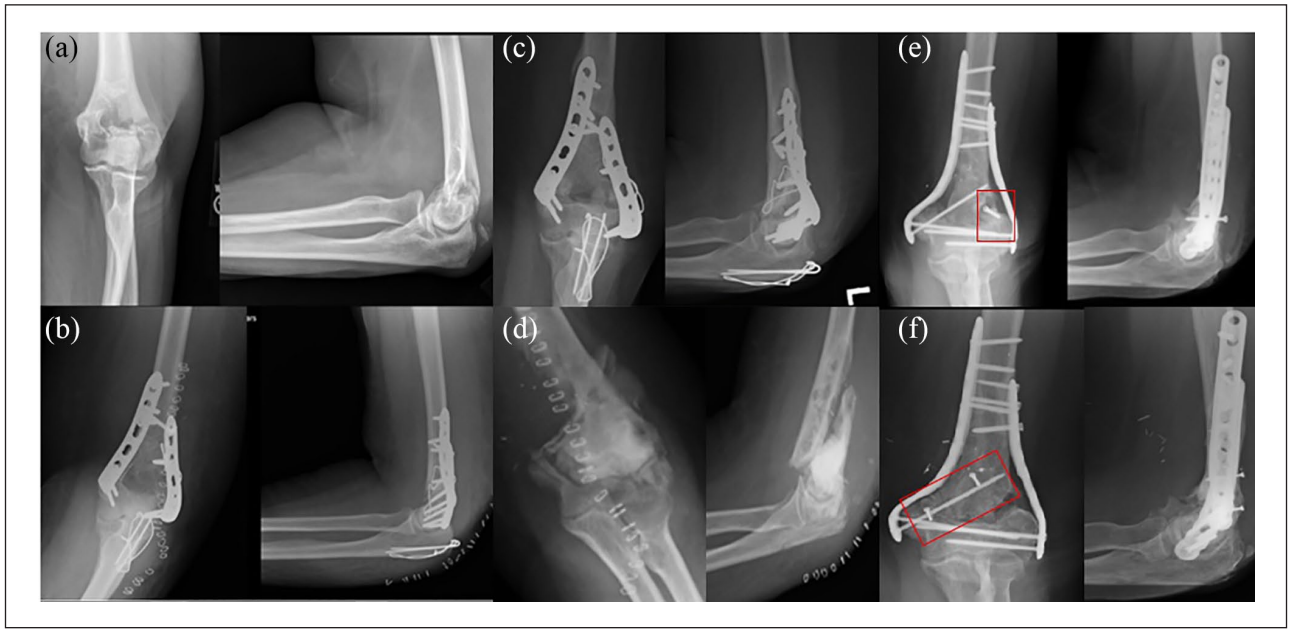


**Figure 1.** (a) Supracondylar fracture, (b) ORIF, (c) nonunion 5 months, (d) hardware removal, (e) ORIF and iliac bone graft, and (f) final consolidation after MFCF. Red: bone graft MFCF.

the venae comitantes. Monthly evaluation was performed after the surgery, with slow bone bridging observed on x-rays. Twelve months after the MFCF was done, complete consolidation of the radius was observed. At this time, the patient demonstrated grip strength in the right hand of 100 and 75 lbs in the affected hand. Supination was 70 degrees with pronation of 80 degrees. A DASH questionnaire, 2 years after the surgical intervention, showed a score of 36.7 (Figure 2).

*Case 3.* A 31-year-old healthy male presented with a crush injury to the right thumb. On physical examination the interphalangeal joint and pulp of the thumb were exposed with complete loss of the distal phalanx. Through the wound, we were able to see the volar surface of the nailbed was intact. The wound was primarily at the volar aspect of the distal phalanx with ragged edges and questionable blood supply of the skin flaps.

Initial debridement of the thumb was performed, and a cement spacer replicating the distal phalanx was placed to build an induction membrane, applying the principals of the Masquelet technique for the management of long segmental defects. The spacer also supported the nailbed which avoids a progressive hook nail deformity. Stabilization of the bone cement spacer was done. The severely mangled skin was monitored with evidence of partial epidermal skin necrosis, but at 10 weeks, the pulp of the thumb was completely healed with no soft tissue defects.

Reconstruction of the distal phalanx was accomplished with a rectangular $3 \times 1$ cm MFCF.

Exposure of the thumb was performed through a Brunner incision and fixation was performed using a 90/90 technique with #0 malleable wires to fuse this to the interphalangeal joint of the thumb. Examination of the digital arteries of the thumb revealed both arteries were severed at the interphalangeal joint level. The digital arteries were identified at the level of the palm and after tourniquet was deflated the blood flow of both digital arteries was poor. The pedicle of the graft was anastomosed to the radial artery at the snuffbox with a vein graft harvested from the volar forearm. The vein graft was anastomosed with the radial artery in an end-to-side fashion. The vein was sutured to the venae comitantes of the radial artery. The upper limb was immobilized in a thumb spica splint. At the 2-month postoperative visit, the patient complains of mild knee discomfort while playing soccer or after prolonged standing. Five months after surgery, radiographs showed stable fusion. The patient reported no pain and demonstrated grip strength of 85lbs in the affected right hand with a left-hand grip strength of 100 lbs. DASH score was 12.5 (Figure 3).

Postoperative treatment included 81 mg of aspirin daily for 30 days. The flap was assessed using Doppler 2 weeks after surgery, and the donor site was examined as well. All patients were allowed to bear weight and ambulate as tolerated after surgery.

Three patients were included in this case series: a recalcitrant nonunion of the distal humerus, nonunion of a wrist fusion secondary to a distal radius giant cell tumor en bloc excision and a thumb distal phalanx reconstruction due to complete distal phalanx loss. Average age was 49 years old (31–59), one female, two males, one right upper limb and two left upper limbs, one right knee donor site and two left knee donor sites (see Table 1). None were smokers, two were

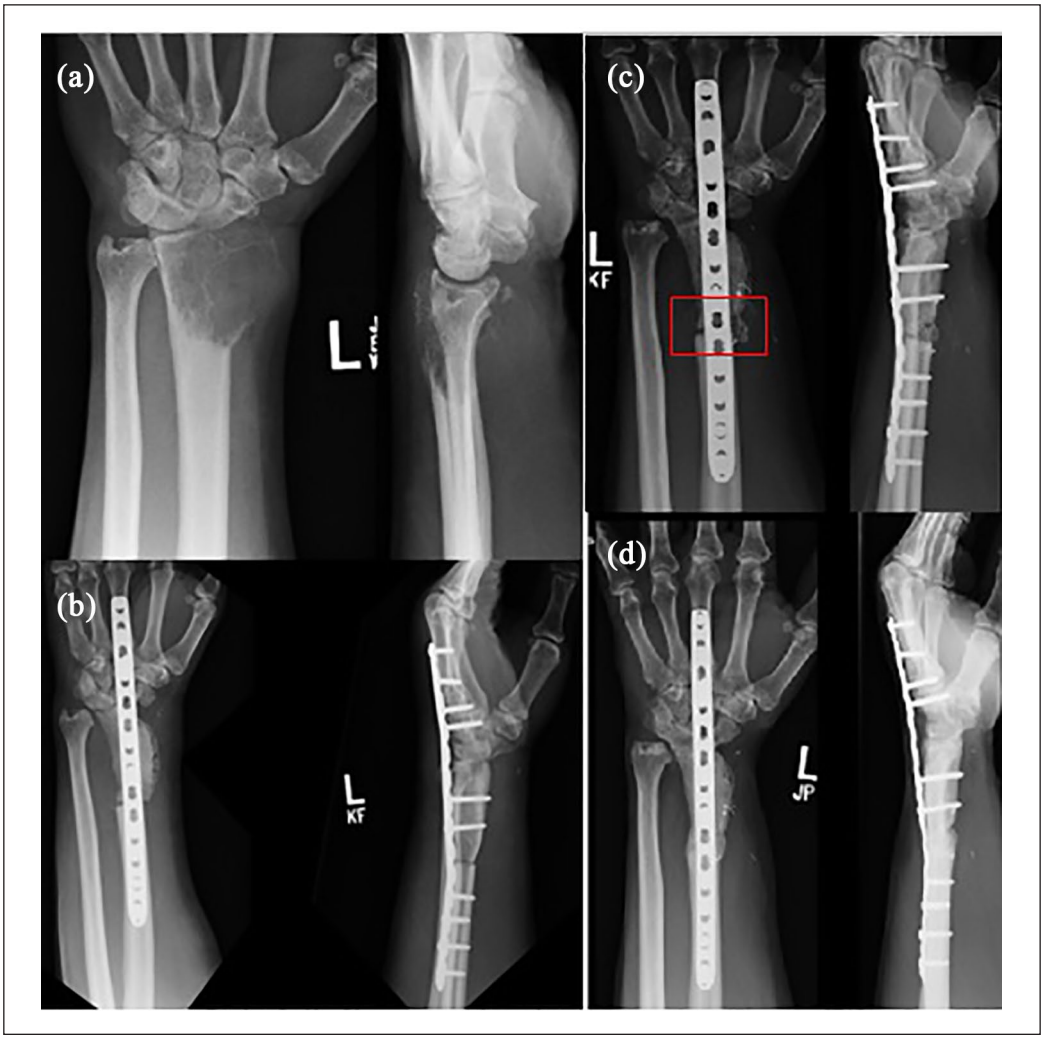


**Figure 2.** (a) Distal radius x-ray giant cell tumor, (b) wrist fusion iliac bone graft, (c) nonunion, and (d) final result after MFCF. Red: bone graft MFCF.

diabetic and one patient had hypertension. All patients underwent prior surgery before the MFCF (Table 2). Two patients were admitted overnight for pain control.

Patients were evaluated for flexion, extension and grip strength of the recipient site and compared with the contralateral extremity (Table 3). Donor site was evaluated for flexion and extension of the knee as well as occult fracture or sensory loss. Average time to consolidation after the MFCF was 7.3 months (5–12 months). No final pain at the donor site was reported, all patients had full range of motion of the knee and no complications were identified with a mean follow-up of 8.6 months (5–12 months; Table 4).

## Discussion

The cases detailed above illustrate the broad utility of the MFCF where moderate size cortico-cancellous bone is required. In a hostile wound bed that requires free tissue transfer due to inadequate vascularity, the MFCF provides versatility and reliability with acceptable donor site morbidity. Overall, a 100% consolidation was achieved. Recent literature reports eight thumb reconstructions using the MFCF demonstrating the versatility and reliability of this flap.[18] On the distal humerus fracture, final DASH score of 0.8 demonstrates good outcomes compared with the literature (27.8), however, we are aware that this is only one case and further patients would need to be evaluated to confirm this result. Our time for consolidation after the MFCF was similar to previously published averages.[19]

Bakri et al.[20] performed a revision reconstruction with the MFCF in 46 cases of nonunion in the upper and lower limbs. In 87% ($n=40$), consolidation was achieved with a mean time of 3.5 months, while three fractures consolidated in 12 months, two fractures failed and one flap died. Cavadas and Landín[21] demonstrated the final consolidation in recalcitrant nonunion of the tibia in a time-lapse of 3.1 months. In

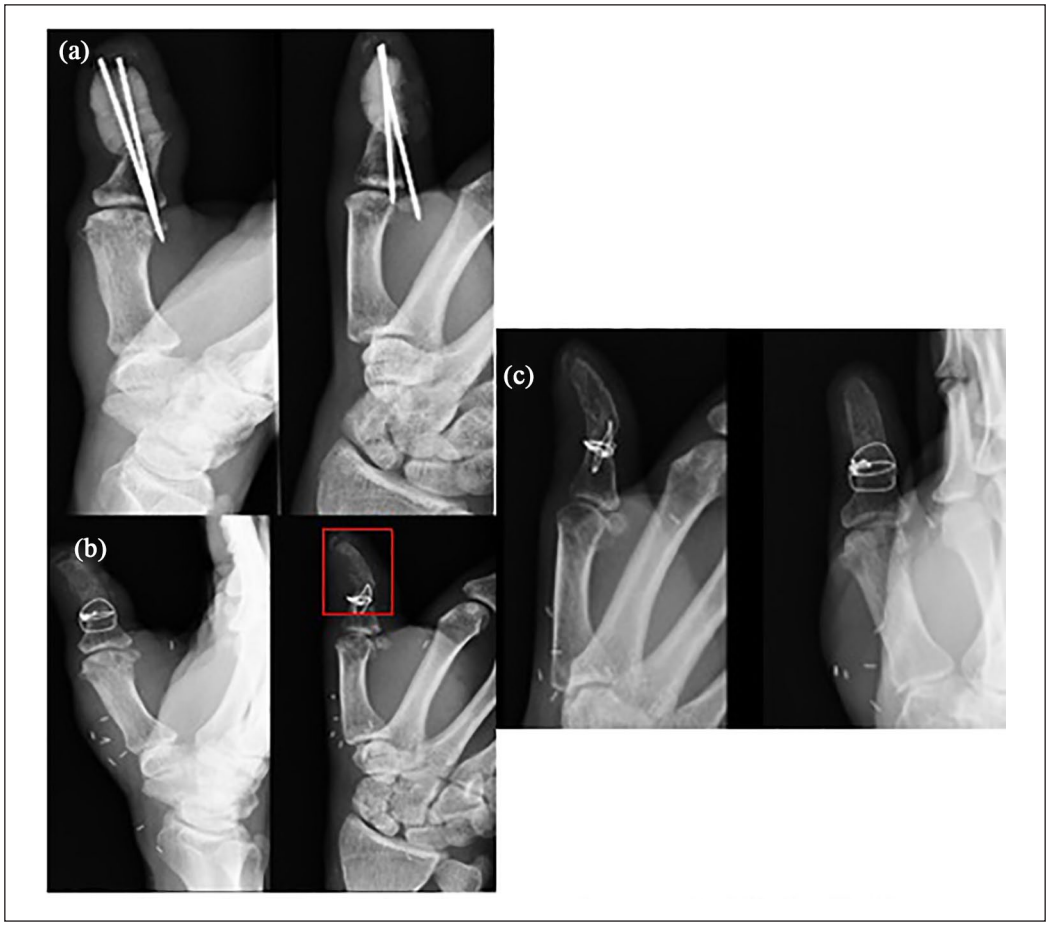


**Figure 3.** (a) Thumb with bone cement spacer, (b) MFCF, and (c) final x-ray. Red: bone graft MFCF.

**Table 1.** Demographics.

| Patient | Age | Gender | Diagnosis | Treated site | Knee |
|---|---|---|---|---|---|
| 1 | 58 | Female | Recalcitrant nonunion distal humerus | Left distal humerus | Left |
| 2 | 59 | Male | Distal radius giant cell tumor | Left distal radius | Left |
| 3 | 31 | Male | Right thumb distal phalanx bone defect | Right thumb | Right |

**Table 2.** Associated risk factors.

| Patient | Prior surgery | Surgery | Smoking | Diabetes | Hypertension |
|---|---|---|---|---|---|
| 1 | Yes | ORIF/ICBG | No | Yes | Yes |
| 2 | Yes | Arthrodesis/ICBG | No | Yes | No |
| 3 | Yes | Irrigation and debridement | No | Yes | No |

ORIF: open reduction internal fixation; ICBG: iliac crest bone graft.

our cases, we defined definitive healing as consolidation in four cortexes confirmed by x-ray.

In our case of radius nonunion, we identified atherosclerosis on the intima of both the donor and recipient vessels. Henry[22] demonstrated nonunion of the distal radius with 100% consolidation in a time of 6.1 weeks with the MFCF; this report also concluded that the benefits of this graft are a greater layer of cancellous and cortical bone, molding the graft for length and width and robust blood supply.

The DGA was used in all of our cases. Iorio et al.[23] reported 100% presence of the DGA in 12 fresh cadavers. Literature supports the evidence that the SMGA is seen in

**Table 3.** Final range of motion and grip strength.

| Patient | Flexion | Extension | Jamar right (lbs) | Jamar left (lbs) | DASH |
|---|---|---|---|---|---|
| 1 | 110° | 30°lag | 40 | 30 | 0.8 |
| 2 | None ( full pronation) | None ( full supination) | 100 | 75 | 36.7 |
| 3 | Full MCP range of motion | Full MCP range of motion | 80 | 100 | 12.5 |

DASH: disabilities of the arm, shoulder and hand score; MCP: metacarpophalangeal.

**Table 4.** Final follow-up, consolidation, knee function and complication.

| Patient | Consolidation | Month | Knee fracture | Knee pain | Knee flexion | Knee extension | Complication |
|---|---|---|---|---|---|---|---|
| 1 | Yes | 9 | No | No | Full | Full | No |
| 2 | Yes | 12 | No | No | Full | Full | No |
| 3 | Yes | 5 | No | No | Full | Full | No |

the majority of the cases, the DGA can be absent in 10%–15% cases.[11,10,24] Anatomic variability should be accounted for and alterations to flap harvest should be included in preoperative planning.

During the reconstruction of the phalanx, the size of the graft that can be used is about 5 × 7 cm and for forearm nonunion up to 5 cm.[2]

Although the vascularized free fibular graft[25] is an acceptable option, it comes with complications, such as instability of the ankle joint, pain due to the vast anatomic dissection and neurological injury of the common peroneal nerve, venous thromboembolism, muscle weakness indicated also in defects more than 5 cm which makes it a less desirable option when compared with the MFCF in the three cases that we presented.

Regarding the medical advances, until this date, we do not know how to assess the integrity of the vascularized flap and the healing process besides the clinical and radiological follow-up. Further studies should be done to have the correct interpretation of the bone healing after a free vascularized bone graft.

No complications were identified at the donor site at final follow-up. Windhofer et al.[26] evaluated postoperative knee x-ray and magnetic resonance imaging without osteochondral pathology and normal patella alignment. Other complications that have been reported when using the MFCF graft include pain of the donor site, seroma, saphenous nerve paraesthesia and distal femur fracture.[2] Minimal bone regeneration has been observed in the donor area of the medial condyle after harvesting the graft, leading some to advocate for the use of allograft bone grafting to promote regeneration of bone in the donor site.[27]

Some disadvantages of the procedure include the longer operative time required for the harvest and fixation of the flap, and the requirement for microsurgical skills for the harvest and anastomosis of the flap.[5] While the vascularity of the SMGA and DGA is consistent, individual variability can exist and requires a learning curve for flap elevation.[11]

In most studies where incomplete consolidation or failure of the graft was found, the patients were smokers, confirming the observation that smoking interferes with the consolidation process.[28]

## Conclusion

In conclusion, the MFCF graft can be used to manage large bone defects, small bone defects, recalcitrant nonunion and osseous reconstructions secondary to bone loss. It is a versatile option for irregular defects and the anatomical structure of the donor site allows to use cortical, cancellous or periosteal flap for bone reconstruction. The consistent anatomy in the knee makes the MFCF easily identifiable, resulting in low morbidity at the donor site. For these reasons, the authors consider the MFCF an excellent treatment option for a wide array of nonunion and reconstructive procedures.

### Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

### Ethics approval

Our institution does not require ethical approval for reporting individual cases or case series. All procedures were in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration on 1975, as revised in 2008.

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### Informed consent

Written informed consent was obtained from the patient(s) for their anonymized information to be published in this article.

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