OPEN

PRS GLOBAL OPEN

SPECIAL TOPIC
Reconstructive

Medial Femoral Condyle Free Flap: A Systematic Review and Proportional Meta-analysis of Applications and Surgical Outcomes

Matteo Scampa, MD*
Vladimir Mégevand, MD*†
Jérôme Martineau, MD*
Dirk J. Schaefer, MD‡
Daniel F. Kalbermatten, MD, PhD*
Carlo M. Oranges, MD, PhD*

Background: Recalcitrant bone nonunion and osseous defect treatment is challenging and often requires vascularized bone transfer. The medial femoral condyle flap has become an increasingly popular option for reconstruction. The study aims at reviewing its different applications and synthesizing its surgical outcomes.
Method: A systematic review including all studies assessing surgical outcomes of free medial femoral condyle flap for bone reconstruction in adults was conducted on January 31, 2023. Flap failure and postoperative complications were synthesized with a proportional meta-analysis.
Results: Forty articles describing bony reconstruction in the head and neck, upper limb, and lower limb areas were selected. Indications ranged from bony nonunion and bone defects to avascular bone necrosis. Multiple flaps were raised as either pure periosteal, cortico-periosteal, cortico-cancellous-periosteal, or cortico-chondro-periosteal. A minority of composite flaps were reported. Overall failure rate was 1% [95% confidence interval (CI), 0.00–0.08] in head & neck applications, 4% in the lower limb (95% CI, 0.00–0.16), 2% in the upper limb (95% CI, 0.00–0.06), and 1% in articles analyzing various locations simultaneously (95% CI, 0.00–0.04). Overall donor site complication rate was 4% (95% CI, 0.01–0.06). Major reported complications were: femoral fractures (n = 3), superficial femoral artery injury (n = 1), medial collateral ligament injury (n = 1), and septic shock due to pace-maker colonization (n = 1).
Conclusion: The medial femoral condyle flap is a versatile option for bone reconstruction with high success rates and low donor site morbidity. *(Plast Reconstr Surg Glob Open 2024; 12:e5708; doi: 10.1097/GOX.0000000000005708; Published online 5 April 2024.)*

INTRODUCTION

The treatment of bone defects or nonunion presents a significant challenge for the reconstructive surgeon, often requiring multiple surgical revisions to obtain satisfying results. Various strategies have been described, among which the use of vascularized bone grafts has gained popularity due to advances in microsurgery.[1] Although fibula, iliac crest, and scapula vascularized bone grafts have been thoroughly studied and their efficacy demonstrated, no comprehensive studies have been performed on the medial femoral condyle free flap (MFC-FF) despite its increasing use.

First described by Sakai et al in 1991, the MFC-FF is based on the medial bony surface of the femoral condyle, perfused by the descending genicular artery (DGA), and the supero-medial genicular artery.[2] Multiple uses have been described in the literature affirming versatility with applications in different regions of the body.[3–5] This study aims at reviewing all retrospective and prospective studies on the application of MFC-FF in bone reconstruction to assess safety by performing a meta-analysis of reconstructive failure rates and donor site complications. A previous review focused exclusively on the head and neck, but this review aims at illustrating and expanding the different applications of this flap.[3]

*From the *Department of Plastic, Reconstructive, and Aesthetic Surgery, Geneva University Hospitals, Geneva University, Geneva, Switzerland; †Department of Plastic surgery, Guy's and St Thomas' NHS Foundation Trust, St Thomas' Hospital, London, United Kingdom; and ‡Department of Plastic, Reconstructive, Aesthetic, and Hand Surgery, Basel University Hospital, Basel, Switzerland.*

Received for publication October 9, 2023; accepted February 12, 2024.

DOI: 10.1097/GOX.0000000000005708

Disclosure statements are at the end of this article, following the correspondence information.

METHOD

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Guidelines were followed to perform this analysis.[6] The study protocol was prospectively registered on PROSPERO: CRD42023395348.

Search Strategy

PubMed/MEDLINE, Embase/MEDLINE/Preprint, Web of Science, and Cochrane library were searched on January 31, 2023 with a combination of Mesh terms and keyword synonyms of "medial femoral condyle" and "flap" linked with Boolean operators. Details on search queries are provided in Table 1. No publication date or language restrictions were applied. The articles were screened independently, in a blind fashion, by two authors (M.S. and V.M.) using the Rayyan web app (https://www.rayyan.ai/; accessed on February 2, 2023). Initially, all articles were screened by title and abstract. In case of a divergent opinion, the selection of the concerned article was discussed with the senior author (C.M.O.). Selected articles were then fully read and incorporated into a standardized spreadsheet provided they matched selection criteria. A secondary manual search was conducted by screening the selected articles' references to identify additional studies. These retrieved articles were then added to the "to be screened article pool" and reviewed with a similar protocol for selection decision.

Article Selection

Population, intervention, comparator, outcomes and study design (PICOS) criteria were used to define the selection criteria before conducting the systematic review (Table 2). All prospective and retrospective studies including a number of cases equal to or superior than five MFC-FFs used for bony reconstruction in adult patients were selected. All recipient sites were included, to offer an overview of the flap applications. Reconstructive failure, defined as loss of free flap, nonunion, no resolution of bony defect or loss of limb, was considered the primary outcome. Failure rate was then stratified by recipient site (head & neck; trunk-abdomen; upper limb; lower limb, multiples sites). The secondary outcome was donor site complications. An overall donor site complication rate was computed, including all complications described as nontransient.

Takeaways

Question: What are the applications of the free medial femoral condyle free flap? Is it a safe procedure?

Findings: With a systematic review and meta-analysis of donor site complications and reconstructive failure rate, we demonstrated that the medial femoral condyle free flap can be safely used in small bone defects or bone nonunion. Overall failure rate is low at 2%. Overall donor site complication is 4%, with only six major complications over 582 flaps.

Meaning: We offer an overview of major indications of the medial femoral condyle free-flap highlighting potential complications.

Data Extraction

Study characteristics and primary and secondary outcomes were then incorporated independently on two Excel spreadsheets (version 16.30; Microsoft Corp., Redmond, Wash.) by two authors (M.S. and V.M.) and the results were compared with detect potential reporting errors. Failure rate and donor site complication rate were reported on a per-patient basis. Overall donor site complication rate was computed by adding all donor site complications reported. Transient resolutive symptoms such as paraesthesia, knee pain, or mobility restriction were not included in the calculation. When mean values of population characteristics

Table 1. Research Strategy

Database	Date	Search Query	No. Articles
PubMed, MEDLINE	Jan 2023	(free flap) AND (medial condyle OR medial femoral condyle)	252
Embase, Preprints	Jan 31, 2023	("medial femoral condyle"/exp OR "medial femoral condyle") AND ("free tissue graft" OR "free flap reconstruction")	69
Web of Science	Jan 31, 2023	(ALL=(medial condyle flap)) OR ALL=(medial femoral condyle) AND (ALL=(free flap)) OR ALL=(free tissue transfer)	126
Cochrane Library	Jan 31, 2023	ID search hits #1MeSH descriptor: [free tissue flaps] explode all trees95 #2free flap811 #3medial condyle215 #4medial femoral condyle149 #5(#1 OR #2) AND (#3 OR #4)1	1

Table 2. Selection Criteria according to PICOS

	Inclusion	Exclusion
Population	Adults	Pediatric patients, cadaveric studies, animal studies
Intervention	Medial femoral condyle free flap	Pedicled flap
Comparator	None	
Outcomes	Primary: reconstructive failure Secondary: donor site postoperative complications	Studies not reporting the main outcome
Study design	Prospective, retrospective, comparative	Case reports, case series (<5 cases), reviews

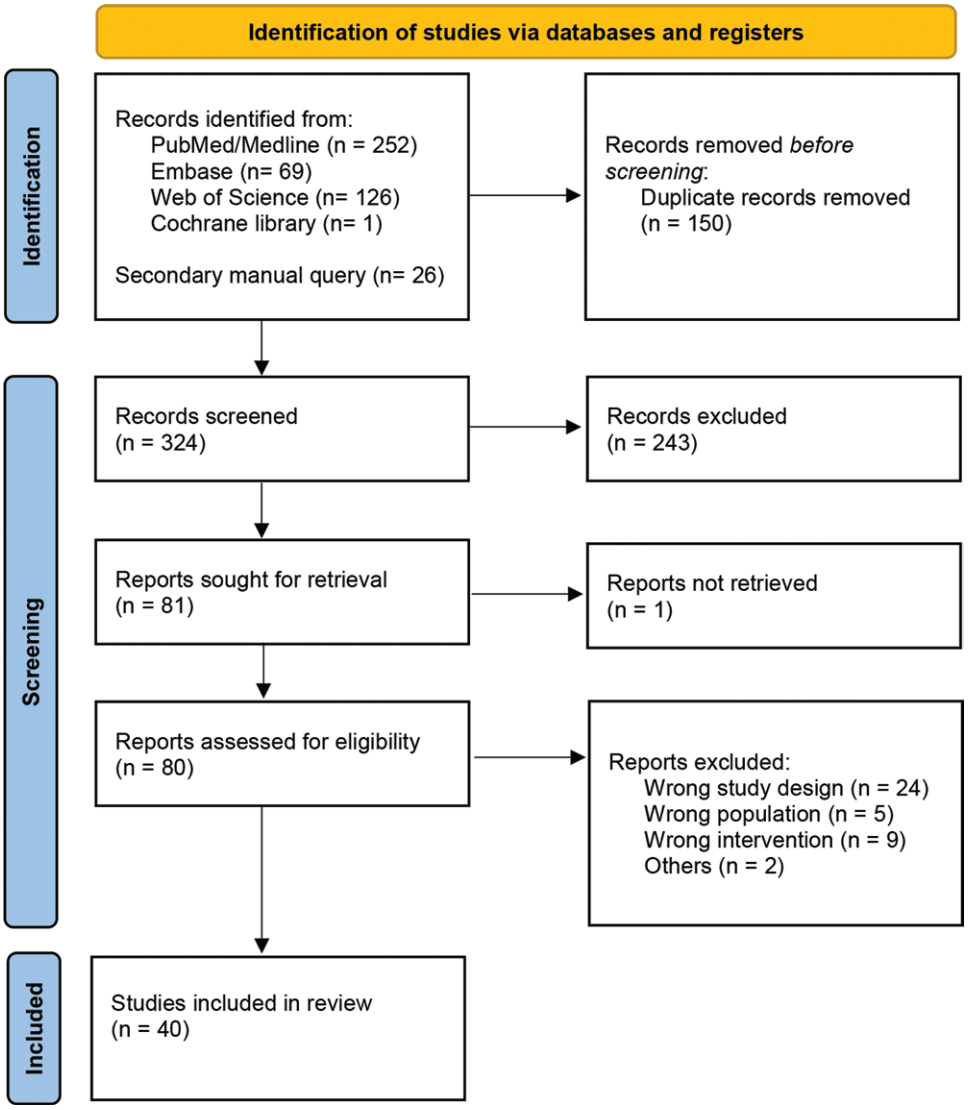

Fig. 1. PRISMA flow chart.

were not readily available from the study, they were calculated with an SD, based on the data available in the study. If ranges were given, no mean was calculated.

Statistical Analysis

A proportional meta-analysis of the primary and secondary outcome was conducted using R software version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria) and its meta-package. A random effect DerSimonian–Laird model was used to obtain pooled complication rates. Heterogeneity between studies was evaluated with the I^2 statistic along with the Q-statistic P value, with I^2 with values below 30% considered as low heterogeneity and those over 70% as significant heterogeneity. Results are presented as forest plots with proportions and their 95% confidence intervals (CIs).

RESULTS

Forty articles representing a total of 582 flaps were retrieved[2,4,5,7–43] (Fig. 1). Nine studies assessed MFC-FF use in the head and neck region, 19 in the upper limb, six in the lower limb, and six in various sites. Different types of tissues were used to raise the flap in the selected studies, including pure periosteal, cortico-periosteal, cortico-cancellous periosteal, osteo-cartilaginous, as well as associations of the MFC-FF with a skin paddle, saphenous subcutaneous flap, vast medialis or sartorius muscle segment. The mean pedicle length range was between 5.4 cm and 6.9 cm.[2,7,10,20–22,36] Flap size was described in square centimeters (cm^2) and cubic centimeters (cm^3), limiting comparability but the mean flap surface ranged from 4.9 to 25.5 cm^2, and the mean flap volume ranged from 3.6 to 36.1 cm^3.[2,4,5,10,14,16,18,20–22,28,29,33,36,38,41,42] The mean procedure time ranged from 243 to 540 minutes.[7,8,23,24,29,30,36,37]

The overall flap failure rate was 2% (95% CI, 0%–4%; Fig. 2). Overall heterogeneity was low with an I^2 of 23%. After excluding three patients from the study by Stranix et al that did not have adequate follow-up to allow for flap failure assessment, 30 failures among 579 patients

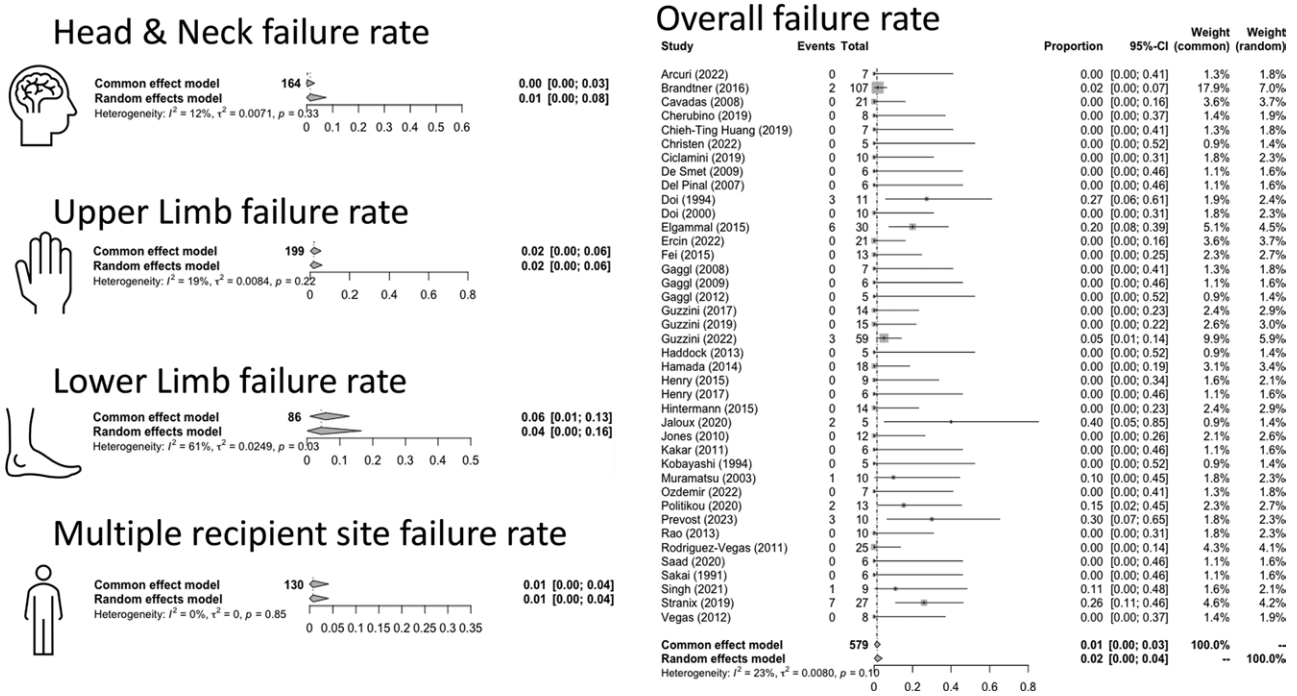

Fig. 2. Flap failure rate overall and according to different regions.

were described.[42] Only six cases of pedicle revision were described among the studies.[8,16,34,41,42]

The main indications in the head and neck region were segmental mandibular, maxillary, alveolar ridge, and orbital bone defects.[7,8,20–22,37,41] For subtotal nasal defects, the MFC-FF bony flap was used as a scaffold to support a frontal flap.[10] Brandtner et al described further applications with facial bone, calvaria, skull base, and partial laryngeal defects reconstruction.[8] A total of 164 procedures were described with a mean patient age ranging from 31.6 to 55.7 years. The head and neck studies included 29 men and 23 women, but the sex of 112 patients was not specified. The pooled flap failure rate in the head and neck region was found to be 1% (95% CI, 0%–8%; Fig. 2) with a low heterogeneity (I^2 = 12%).

In the upper limb, the main indications were bony nonunion, avascular necrosis (AVN) of carpal bones and traumatic bone loss.[4,11,13–19,24,25,28,30–32,34,35] The treated bones included the clavicle, humerus, radius, ulna, carpal bones, metacarpal bones, and phalanx. Henry et al described the use of MFC-FF for replacing bone loss due to osteomyelitis in the distal fingers.[27] The studies included a total of 199 procedures, with a mean patient age ranging from 25.3 to 51.7 years. Of these 199 cases, 147 patients were men and 52 were women. The pooled flap failure rate of MFC-FF for upper limb reconstruction was 2% (95% CI, 0%–6%; Fig. 2) with a low heterogeneity (I^2 = 19%).

In the lower limb, the main indications for MFC-FF were bony nonunion, AVN, and osteochondral lesions.[5,9,29,36,40,42] The treated bones were the tibia, hindfoot, and midfoot bones. Eighty-six procedures were performed on 56 men and 30 women with a mean age ranging from 34.8 to 48 years. The pooled flap failure rate in this region was 4% (95% CI, 0%–16%; Fig. 2) with mid heterogeneity (I^2 = 61%).

Six studies evaluated MFC-FF use for multiple recipient sites within the same cohort, hence not allowing for inclusion in one of the three location categories above.[12,23,26,38,39,43] Indications were nonunions, traumatic bone loss, and septic bone loss. The affected bones were the clavicle, humerus, radius, ulna, carpal and metacarpal bones, phalanx, femur, tibia, and calcaneum. In total, 130 procedures were performed on 107 men and 23 women, with a mean age ranging from 41.6 to 48.9 years. In these six studies, the pooled flap failure rate was 1% (95% CI, 0%–4%; Fig. 2) with low heterogeneity (I^2 = 0%).

No study assessing MFC-FF use in trunk and abdomen was selected.

Donor site morbidity was reported in 36 studies.[2,4,5,7–11,13–15,17–26,28–42] The most reported postoperative symptoms were transient paresthesia, knee pain, and/or decreased knee mobility. Major complications were rare, with only three cases of femoral fractures, one case of superficial femoral artery injury, one case of medial collateral ligament of the knee injury, and one septic shock due to postoperative pacemaker colonization reported. Minor complications such as seroma (n = 7), superficial infection (n = 7), hematomas (n = 4), persistent donor site paresthesia (n = 6), persistent knee pain (n = 4), hypertrophic scar (n = 1) and genicular nerve neuroma (n = 1) were described. In one study by Del Pinal et al, an infected hematoma was described, and this event was counted as a single event under superficial infection.[14] The pooled overall donor site complication rate was 4% (95% CI, 1%–6%; Fig. 3) with low heterogeneity (I^2 = 4%).

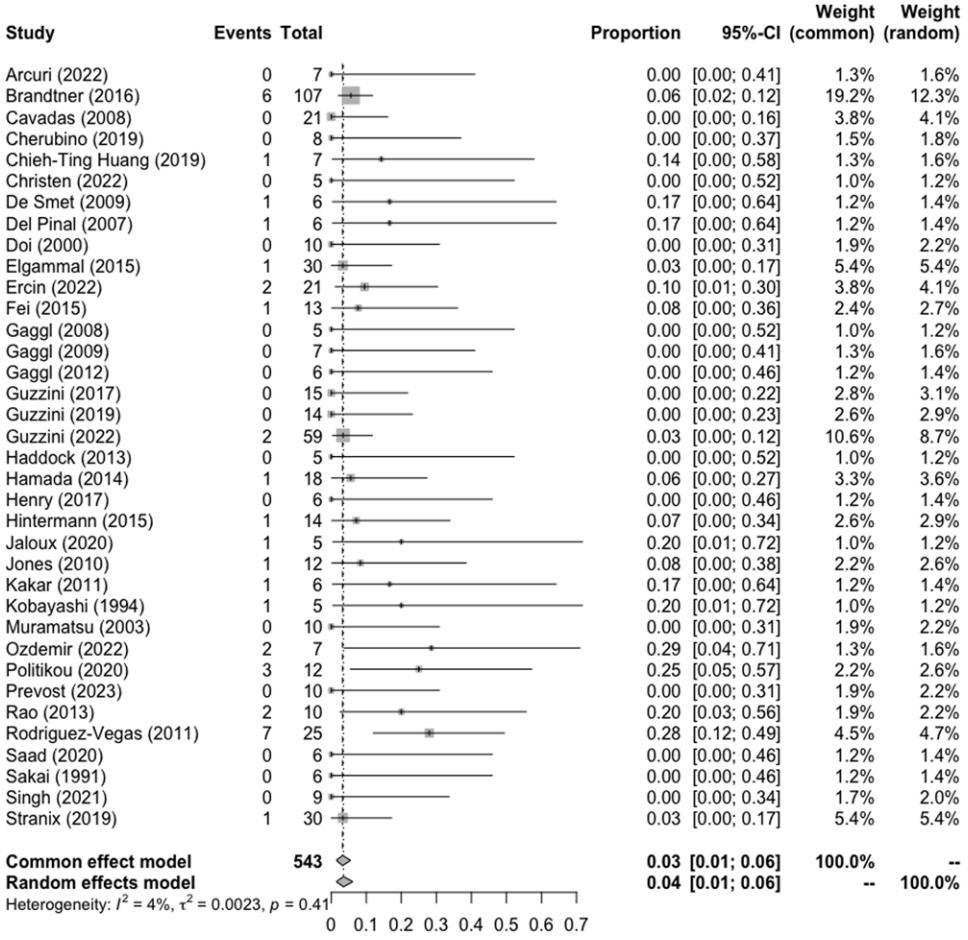

Fig. 3. Forest plot of overall donor site complication rate.

DISCUSSION

This meta-analysis represents the first attempt, to our knowledge, to synthesize success rates of all MFC-FF applications for bony reconstruction. Indications covered small bone defects, bony nonunion, and the need to offer structural support in diverse reconstructions. The overall success rate was high, with a flap failure rate of less than 2% and donor site morbidity rate as low as 4%.

However, we noted a higher rate of flap failure in the lower limb region compared with the other sites. This result may have been influenced by one of the studies that reported a substantially higher rate of complications in comparison with the others (seven nonunion or partial nonunion out of 27 reconstructions).[42] Their cohort was described as including multiple patients that had complex hindfoot pathologies, with 83% AVN rate and 67% of patients with failed previous operations. Furthermore, distal third lower limb reconstruction can be especially challenging due to peripheral arterial disease, venous stasis, and the paucity of soft tissue, making tension-free closure difficult.

The MFC-FF is a versatile bony flap with relatively consistent anatomy and a straightforward surgical approach. All articles describe an approach between the adductor magnus and vastus medialis tendon, offering exposition of the medial femoral condyle and the DGA pedicle accompanied by two concomitant veins, as described by Sakai et al in 1991.[2] When reported in selected studies, the pedicle length remained relatively consistent, with mean lengths varying between 5.4 and 6.9 cm.[2,7,10,20–22,36] However, the DGA diameter may be small in some cases, requiring flap elevation on the supero-medial genicular artery in one-fourth of the cases according to Oh et al, thus providing a shorter pedicle.[44] Additionally, the pedicle offers multiple periosteal branches supplying the underlying bone, allowing for the raise of various flap sizes, as big as 8×13 cm, according to Kakar et al.[32] Anatomic limitations are the medial patellar facet, the medial femoral collateral ligament, and the posterior border of the femur.[32] Flap composition was variable across the selected studies, including a pure periosteal flap as described for AVN or above a cancellous bone autograft or allograft, such as the cambium layer of the periosteum that has osteogenic properties.[4,40,43] However, some authors advocate the raise of a periosteal flap with a thin layer of cortex to avoid injury to the cambium layer.[2] Vegas et al did not find significant statistical differences between pure periosteal and cortico-periosteal in terms of osteogenic capacities, and prefer the ease of use of periosteal flap, as they are thin and pliable.[43] When raised as a thin cortico-periosteal flap, the MFC-FF also remains easily pliable and can be

used as a scaffold to offer structural support, as described by Cherubino et al.[10] Some authors prefer to obtain periosteal-cortico-cancellous flaps, given they provide all the structures needed to replace the bone loss. The flaps can also include part of the femoral cartilage to provide reconstruction for articular defects.[38] If a larger cartilage surface is required, the medial femoral trochlea flap remains an alternative flap, also based on the DGA.[45–48] In cases where a skin paddle is needed, the dissection should encompass the saphenous pedicle that emerges from the DGA and reaches the skin paddle.[2] This skin paddle can also be used as a flap monitor; however, skin paddle monitoring may be unreliable. For instance, Stranix et al describe two cases of skin paddle necrosis where during debridement the bony flap was viable, meaning that a compromised vascularization in the skin part of a compound flap does not necessarily mean that the bony part is also necrotic. Ercin et al present alternative techniques with adipofascial and periosteal monitors.[18]

In the current practice, fibula bone free flap, deep circumflex iliac artery bone flap, and scapula bone flap are commonly used bone flaps. Although the fibula bone free flap remains the workhorse flap for large bone defects such as mandibular reconstruction, it is associated with notable donor site morbidity and involves losing one of the three main vascular axis of the leg.[49,50] MFC-FF has been highlighted for its minimal donor site morbidity and ease of dissection, making it an optimal bone flap for small bony defects.[51] In this meta-analysis, the pooled overall donor site complication rate remained low at 4% with a relatively consistent rate across studies. Although transient symptoms such as paraesthesia, knee pain, and decreased range of motion were often reported in studies, they usually resolved in a few weeks after surgery. Patient reported outcomes were deemed acceptable, slightly below general population scores.[52] On the other hand, major complications remained rare. Three cases of postoperative femoral fracture were reported, and occurred in cases of larger flaps extending on the femoral shaft, or in patients with a history of previous trauma with bone fixation in the knee area.[8,13,26] Use of MFC-FF for small bone defects and avoidance of injured limbs as donor site may limit this surgical risk.

The definition of flap failure varied among studies and could constitute a limitation in the interpretation of the success rate of the procedure. Although bone flap perfusion monitoring was scarcely described, the osseous integration or union needed to be assessed for the study to be selected. However, bone union achievement or osseous integration does not necessarily signify that the bone flap was successfully perfused because nonvascularized bone grafts can also lead to successful bone union in small defects.[53,54] Even though MFC-FF monitoring can be difficult, it would be of great interest to document the anastomosis patency to confirm that the flap behaves as a vascularized bone flap.

Another limitation of this meta-analysis is the choice of case series describing five or more patients, resulting in the exclusion of case reports describing experimental applications of the MFC-FF. Therefore, this review is not exhaustive of all of its potential applications. Indeed, ear, temporomandibular-joint, tracheal, and cricoid reconstruction are examples of possible MFC-FF applications that were found during the systematic review but did not match the inclusion criteria.[55–58] Furthermore, no publication bias assessment method was conducted, as results were relatively homogeneous and close to the standard free flap failure rate.

CONCLUSIONS

The MFC-FF is a versatile flap with many applications in head and neck and extremity reconstruction, allowing for the inclusion of various tissues to reconstruct bone defects, eventually associated with tendon or soft tissue loss. Mostly used for small lesions, bone paddles as big as 8 × 13 cm can also be raised for larger defects. Given its low donor site morbidity and straightforward surgical dissection, it has the potential to become a workhorse flap for bone nonunions and small bone defects.

Carlo M. Oranges, MD, PhD
Department of Plastic, Reconstructive and Aesthetic Surgery
Geneva University Hospitals
Rue Gabrielle-Perret-Gentil 4
1205 Geneva, Switzerland
E-mail: carlo.oranges@hcuge.ch

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. Dimitriou R, Jones E, McGonagle D, et al. Bone regeneration: current concepts and future directions. *BMC Med.* 2011;9:66.
2. Sakai K, Doi K, Kawai S. Free vascularized thin corticoperiosteal graft. *Plast Reconstr Surg.* 1991;87:290–298.
3. Banaszewski J, Gaggl A, Andruszko A. Medial femoral condyle free flap for head and neck reconstruction. *Curr Opin Otolaryngol Head Neck Surg.* 2019;27:130–135.
4. Christen T, Krähenbühl SM, Müller CT, et al. Periosteal medial femoral condyle free flap for metacarpal nonunion. *Microsurgery.* 2022;42:226–230.
5. Haddock NT, Alosh H, Easley ME, et al. Applications of the medial femoral condyle free flap for foot and ankle reconstruction. *Foot Ankle Int.* 2013;34:1395–1402.
6. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* 2021;372:n71.
7. Arcuri F, Innocenti M, Menichini G, et al. Microvascular reconstruction of the mandible with medial femoral condylar flap for treatment of mandibular non-union. *Int J Oral Maxillofac Surg.* 2022;51:175–181.
8. Brandtner C, Hachleitner J, Bottini GB, et al. Microvascular medial femoral condylar flaps in 107 consecutive reconstructions in the head and neck. *Br J Oral Maxillofac Surg.* 2016;54:614–618.
9. Cavadas PC, Landín L. Treatment of recalcitrant distal tibial nonunion using the descending genicular corticoperiosteal free flap. *J Trauma.* 2008;64:144–150.
10. Cherubino M, Stocco C, Tamborini F, et al. Medial femoral condyle free flap in combination with paramedian forehead flap for total/subtotal nasal reconstruction: Level of evidence: IV (therapeutic studies): level of evidence: IV (therapeutic studies). *Microsurgery.* 2020;40:343–352.

11. Chieh-Ting Huang T, Sabbagh MD, Lu CK, et al. The vascularized medial femoral condyle free flap for reconstruction of segmental recalcitrant nonunion of the clavicle. *J Shoulder Elbow Surg.* 2019;28:2364–2370.
12. Ciclamini D, Tos P, Guzzini M, et al. The medial femoral condyle free corticoperiosteal flap versus traditional bone graft for treatment of nonunions of long bones: a retrospective comparative cohort study. *Injury.* 2019;50:S54–S58.
13. De Smet L. Treatment of non-union of forearm bones with a free vascularised corticoperiosteal flap from the medial femoral condyle. *Acta Orthop Belg.* 2009;75:611–615.
14. Del Piñal F, García-Bernal FJ, Regalado J, et al. Vascularised corticoperiosteal grafts from the medial femoral condyle for difficult non-unions of the upper limb. *J Hand Surg Eur Vol.* 2007;32:135–142.
15. Doi K, Oda T, Soo-Heong T, et al. Free vascularized bone graft for nonunion of the scaphoid. *Jl Hand Surg.* 2000;25: 507–519.
16. Doi K, Sakai K. Vascularized periosteal bone graft from the supracondylar region of the femur. *Microsurgery.* 1994;15:305–315.
17. Elgammal A, Lukas B. Vascularized medial femoral condyle graft for management of scaphoid non-union. *J Hand Surg Eur Vol.* 2015;40:848–854.
18. Erçin BS, Tatar BE, Cavadas PC. Monitor selection according to the defect location in the medial femoral condyle flap. *Injury.* 2022;53:4139–4145.
19. Fei W, Danmou X, Dong R, et al. Free vascularized medial femoral condyle corticocancellous flap for treatment of challenging upper extremity nonunions. *J Reconstr Microsurg.* 2015;31:124–131.
20. Gaggl A, Bürger H, Virnik SA, et al. An intraoral anastomosing technique for microvascular bone flaps in alveolar ridge reconstruction: first clinical results. *Int J Oral Maxillofac Surg.* 2009;38:921–927.
21. Gaggl A, Bürger H, Virnik S, et al. The microvascular corticocancellous femur flap for reconstruction of the anterior maxilla in adult cleft lip, palate, and alveolus patients. *Cleft Palate-Craniofac J.* 2012;49:305–313.
22. Gaggl AJ, Bürger HK, Chiari FM. Free microvascular transfer of segmental corticocancellous femur for reconstruction of the alveolar ridge. *Br J Oral Maxillofac Surg.* 2008;46:211–217.
23. Guzzini M, Ciclamini D, Arioli L, et al. Correlation between risk factors and healing times in long bone nonunions treated with corticoperiosteal flap from the medial femoral condyle. *J Reconstr Microsurg.* 2023;39:502–507.
24. Guzzini M, Lanzetti RM, Perugia D, et al. The treatment of long bones nonunions of upper limb with microsurgical corticoperiosteal free flap. *Injury.* 2017;48:S66–S70.
25. Guzzini M, Lanzetti RM, Proietti L, et al. The role of vascularized flaps in the treatment of proximal pole avascular necrosis in scaphoid non-unions. *Acta Bio-medica: Atenei Parmensis.* 2019;90:64–68.
26. Hamada Y, Hibino N, Kobayashi A. Expanding the utility of modified vascularized femoral periosteal bone-flaps: an analysis of its form and a comparison with a conventional-bone-graft. *J Clin Orthop Trauma.* 2014;5:6–17.
27. Henry M. Free vascularized medial femoral condyle structural flaps for septic terminal digital bone loss. *J Hand Microsurg.* 2015;7:306–313.
28. Henry M. Vascularized medial femoral condyle bone graft for resistant nonunion of the distal radius. *J Hand Surg Asian Pac Vol.* 2017;22:23–28.
29. Hintermann B, Wagener J, Knupp M, et al. Treatment of extended osteochondral lesions of the talus with a free vascularised bone graft from the medial condyle of the femur. *Bone Jt J.* 2015;97-B:1242–1249.
30. Jaloux C, Bettex Q, Levadoux M, et al. Free vascularized medial femoral condyle corticoperiosteal flap with non-vascularized iliac crest graft for the treatment of recalcitrant clavicle non-union. *J Plast Reconst Aesthet Surg.* 2020;73:1232–1238.
31. Jones DB, Moran SL, Bishop AT, et al. Free-vascularized medial femoral condyle bone transfer in the treatment of scaphoid nonunions. *Plast Reconstr Surg.* 2010;125:1176–1184.
32. Kakar S, Duymaz A, Steinmann S, et al. Vascularized medial femoral condyle corticoperiosteal flaps for the treatment of recalcitrant humeral nonunions. *Microsurgery.* 2011;31:85–92.
33. Kobayashi S, Kakibuchi M, Masuda T, et al. Use of vascularized corticoperiosteal flap from the femur for reconstruction of the orbit. *Ann Plast Surg.* 1994;33:351–357; discussion 357–358.
34. Muramatsu K, Doi K, Ihara K, et al. Recalcitrant posttraumatic nonunion of the humerus: 23 patients reconstructed with vascularized bone graft. *Acta Orthop Scand.* 2003;74:95–97.
35. Özdemir A, Odabaşı E, Acar MA. The free medial femoral condyle periosteal flaps for the treatment of recalcitrant upper limb long bones nonunion. *Ulusal travma ve acil cerrahi dergisi [Turkish Journal of Trauma & Emergency Surgery]* 2022;28:1347–1352.
36. Politikou O, Wirth S, Giesen T, et al. Corticoperiosteal medial femoral condyle flap for recalcitrant nonunion in ankle and foot: outcomes and radiological evaluation of donor site morbidity. *Foot Ankle Surg.* 2020;26:918–923.
37. Prevost A, Poulet V, Delanoe F, et al. Merits of the free periosteal femoral condyle flap in the management of advanced mandibular osteoradionecrosis. *Int J Oral Maxillofac Surg.* 2023;52:175–180.
38. Rao SS, Sexton CC, Higgins JP. Medial femoral condyle flap donor-site morbidity: a radiographic assessment. *Plast Reconstr Surg.* 2013;131:357e–362e.
39. Rodríguez-Vegas JM, Delgado-Serrano PJ. Corticoperiosteal flap in the treatment of nonunions and small bone gaps: technical details and expanding possibilities. *J Plast Reconstr Aesthet Surgy.* 2011;64:515–527.
40. Saad A, Jimenez ML, Rogero RG, et al. Medial femoral condyle periosteal free flap for the treatment of talus avascular necrosis. *Foot Ankle Int.* 2020;41:728–734.
41. Singh K, Huang TCT, Meaike JD, et al. The medial femoral condyle free flap for reconstruction of recalcitrant defects in the head and neck. *Ann Plast Surg.* 2021;87:291–297.
42. Stranix JT, Piper ML, Azoury SC, et al. Medial femoral condyle free flap reconstruction of complex foot and ankle pathology. *Foot Ankle Orthop.* 2019;4:2473011419884269.
43. Vegas MR, Delgado P, Roger I, et al. Vascularized periosteal transfer from the medial femoral condyle: is it compulsory to include the cortical bone? *J Trauma Acute Care Surg.* 2012;72:1040–1045.
44. Oh C, Pulos N, Bishop AT, et al. Intraoperative anatomy of the vascular supply to the medial femoral condyle. *J Plast Reconstr Aesthet Surg.* 2019;72:1503–1508.
45. Pet MA, Assi PE, Giladi AM, et al. Preliminary clinical, radiographic, and patient-reported outcomes of the medial femoral trochlea osteochondral free flap for lunate reconstruction in advanced Kienböck disease. *J Hand Surg.* 2020;45:774.e1–774.e8.
46. Pet MA, Assi PE, Yousaf IS, et al. Outcomes of the medial femoral trochlea osteochondral free flap for proximal scaphoid reconstruction. *J Hand Surg.* 2020;45:317–326.e3.
47. Bürger HK, Windhofer C, Gaggl AJ, et al. Vascularized medial femoral trochlea osteocartilaginous flap reconstruction of proximal pole scaphoid nonunions. *J Hand Surg.* 2013;38:690–700.
48. Windhofer CM, Orthner E, Bürger HK. Vascularized osteochondral free flaps from the femoral trochlea as versatile procedure for reconstruction of osteochondral lesions of the talus. *Foot Ankle Surg.* 2022;28:935–943.
49. Ling XF, Peng X. What is the price to pay for a free fibula flap? A systematic review of donor-site morbidity following free fibula flap surgery. *Plast Reconstr Surg.* 2012;129:657–674.

50. Rogers SN, Lakshmiah SR, Narayan B, et al. A comparison of the long-term morbidity following deep circumflex iliac and fibula free flaps for reconstruction following head and neck cancer. *Plast Reconstr Surg.* 2003;112:1517–1525.
51. Mehio G, Morsy M, Cayci C, et al. Donor-site morbidity and functional status following medial femoral condyle flap harvest. *Plast Reconstr Surg.* 2018;142:734e–741e.
52. Miles MR, Jacobson L, Hill JB, et al. Patient-reported lower extremity outcomes following fibula or medial femoral condyle free flaps for upper extremity defects. *Hand N Y N.* 2023;18:1005–1011.
53. Moura LB, Carvalho PH de A, Xavier CB, et al. Autogenous non-vascularized bone graft in segmental mandibular reconstruction: a systematic review. *Int J Oral Maxillofac Surg.* 2016;45:1388–1394.
54. Allsopp BJ, Hunter-Smith DJ, Rozen WM. Vascularized versus nonvascularized bone grafts: what is the evidence? *Clin Orthop Relat Res.* 2016;474:1319–1327.
55. Xia L, Jie B, Zhang Y, et al. Temporomandibular joint reconstruction with medial femoral condyle osseocartilaginous flap: a case series. *Int J Oral Maxillofac Surg.* 2021;50:604–609.
56. di Summa PG, Sapino G, Zaugg P, et al. The periosteal-cutaneous chimeric medial femoral condyle free flap for subtotal ear reconstruction: a case report. *Microsurgery.* 2020;40:814–817.
57. Ninkovic M, Buerger H, Ehrl D, et al. One-stage reconstruction of tracheal defects with the medial femoral condyle corticoperiosteal-cutaneous free flap. *Head Neck.* 2016;38:1870–1873.
58. Banaszewski J, Gaggl A, Buerger H, et al. Functional results after total cricoidectomy with medial femoral condyle free flap reconstruction. *Eur Arch Otorhinolaryngol.* 2016;273:3869–3874.