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# Expanding Indications of the Medial Femoral Condyle Free Flap: Systematic Review in Head and Neck Reconstruction

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**Background:** The medial femoral condyle free flap serves as an attractive reconstructive option for small- to intermediate-sized bony defects. It is commonly applied in the extremities with limited reports in the head and neck.

**Methods:** A systematic review of the literature was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

**Results:** Seventeen articles met inclusion criteria, yielding 166 cases for analysis, with a majority of the cohort from a single study (n = 107; 64.4%). However, all included studies represented novel reconstructive sites and surgical indications. Flap components were described in 157 cases; periosteum was used only in four cases (2.5%), whereas all others are composed of cortical bone combined with periosteum, cancellous bone, and/or cartilage (97.5%). Additionally, a skin island was used in 43 cases (25.9%). Flap measurements were reported in 51 cases, averaging 4.5 ± 2.7 cm in length. Seven cases listed skin island dimensions, averaging 20.2 ± 12.8 $cm^2$. The descending genicular artery was the primary pedicle employed (n = 162; 97.6%), while the superior medial genicular was used in the descending genicular artery's absence (n = 4; 2.4%). Descending genicular artery pedicle length from 15 reporting cases averaged 6.4 ± 1.2 cm. Successful reconstructions totaled 160 cases (96.4%). Recipient complications were seen in 16 cases (9.6%) with six constituting flap failures (3.6%). Donor site complications were minimal (n = 6; 3.6%); however, this included one major complication of femoral shaft fracture.

**Conclusion:** The medial femoral condyle free flap is an effective reconstructive option for the head and neck due to its versatile nature, low complication profile at both recipient and donor site, ease of harvest, and two-team approach. *(Plast Reconstr Surg Glob Open 2023; 11:e4925; doi: 10.1097/GOX.0000000000004925; Published online 5 April 2023.)*

## INTRODUCTION

The advent of vascularized bone flaps, beginning with work on free fibula flaps by Taylor et al, in 1975, revolutionized the treatment of osseous defects.[1] Since then, free vascularized bone flaps from the fibula, radial forearm, scapula, and iliac crest have been well described and are at the forefront of osseous flaps for head and neck reconstruction.[2–5] Each provides its own unique advantages and ample coverage for defects of varying sizes.[2–5] The free fibula is the gold standard osseous flap of craniofacial surgery, especially the mandible, as it provides ample bone stock, segmental vascular supply allowing for multiple osteotomies, a long pedicle, and multiple skin islands.[6] The free scapula flap, first conceptualized in 1978, is known for its abundant soft tissue supply, whereas the vascularized iliac free flap, first introduced in 1979, features a large volume of high-quality corticocancellous

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bone stock and a cartilage cap.[5,6] The radial forearm osteocutaneous free flap, first used in 1983, emerged as another workhorse flap that is thin, pliable, and delivers a long vascular pedicle with reliable anatomy.[3,7] Nonetheless, each of these osseous free flaps exhibit drawbacks, such as the high rates of delayed donor site wound healing seen in the fibula and radial forearm, the increased risk of donor site fracture in the radial forearm, the lack of segmental vascularity in the scapula, and the short pedicle length and high donor site morbidity (DSM) in the iliac crest.[3,6,8]

In 1988, Masquelet et al discussed a flap using the descending genicular artery (DGA), which actualized the advent of the free medial femoral condyle flap (MFC).[9,10] First performed by Sakai et al in 1991, the MFC flap has since undergone numerous revisions, evolving into a highly adaptable option for cases requiring small amounts of vascularized bone.[1,10,11] MFC flap characteristics can be tailored to the reconstructive task at hand, expanding the possible indications for its use.[1,10–13] Earlier variations of the MFC flap focused on harvesting the periosteum and underlying cambium to generate a flexible, osteogenic flap ideal for treating bony nonunion, among other applications.[1,10,12] The MFC flap can also be harvested as a corticocancellous or corticochondral flap, with the latter option well suited for temporomandibular joint reconstruction.[1,10–13] When bone and soft tissue are both needed in the reconstruction of a defect, the MFC can also be harvested as an osteocutaneous flap, with the skin island supplied by the saphenous artery branch, or a myo-osseus flap including a segment of vastus medialis.[1,10,14] Such flexibility in flap design lends itself to numerous applications. Its most popular usage has been in cases of avascular necrosis or bony nonunion of the wrist and hand, as well as in pathologies of the lower extremity.[1,10–13,15] Recently, the free MFC flap has been increasingly reported in cases of head and neck reconstruction as well. Its use in this region was first described in the orbit in 1994 and has since then expanded across regions of the head and neck.[16]

This systematic review aims to evaluate the free MFC flap as a reconstructive option for the head and neck. Pooling reported data to summarize indications, outcomes, and adverse events will allow for more thorough understanding of the MFC flap compared with the other widely utilized vascularized bone free flaps.

## METHODS

### Search Strategy

Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines,[17] a systematic review of the literature was performed in June 2022 by two independent reviewers. A search of the literature was conducted using PubMed and OVID for relevant studies from 1994 to June 2022. Key search phrases included "medial femoral condyle flap," "medial femoral condyle flap head and neck," "MFC flap head and neck," and "MFC head and neck."

> **Takeaways**
>
> **Question:** Should the medial femoral condyle (MFC) free flap be recognized as a reconstructive option for the head and neck, along with other popular vascularized osseous free flaps?
>
> **Findings:** This systematic review provides a descriptive analysis on the use of the MFC flap in head and neck reconstruction. Findings suggest it to be an attractive option for small- to intermediate-sized defects, given its high success rate, minute complication profile, long-term stability, and simultaneous two-team approach.
>
> **Meaning:** The MFC flap should be viewed as a potential reconstructive option for small-to-intermediate defects of the head and neck, as it possesses robust regenerative bone potential, versatility, and minimal donor site morbidity.

### Study Selection

Study eligibility criteria included articles describing use of the free MFC flap in the management of head and neck reconstruction. This included prospective studies, retrospective studies, case series, or case reports. Further inclusion criteria consisted of human only studies with extractable data and postoperative outcomes. Exclusion criteria included (1) studies reporting only on recipient sites other than the head and neck region, (2) studies reporting only on the use of flaps other than the free MFC flap for head and neck reconstruction, (3) studies without extractable data or postoperative outcomes, (4) review articles, and (5) technique only articles. Within the search strategy, no restrictions were placed on language. After removal of duplicate papers, identical cases, and irrelevant studies, a full-text review of the remaining articles was performed to match inclusion and exclusion criteria.

### Data Extraction and Management

Data were collected by two independent reviewers based upon eligibility and inclusion criteria as discussed above. Any discussions or disagreements were resolved via consultation with the senior author. Extracted data were collected and organized in a spreadsheet and included study authorship, year of publication, study design, patient cohort and demographics (age and sex), insult, indication, recipient site, MFC flap characteristics, length to follow-up, recipient and donor site complications, key findings and outcomes, and study limitations.

### Quality Assessment

The plastic and reconstructive surgery level of evidence pyramid was used to categorize each included study.[18]

## RESULTS

### Study Selection

Using key search phrases, the initial electronic database search yielded 328 articles with 287 articles removed

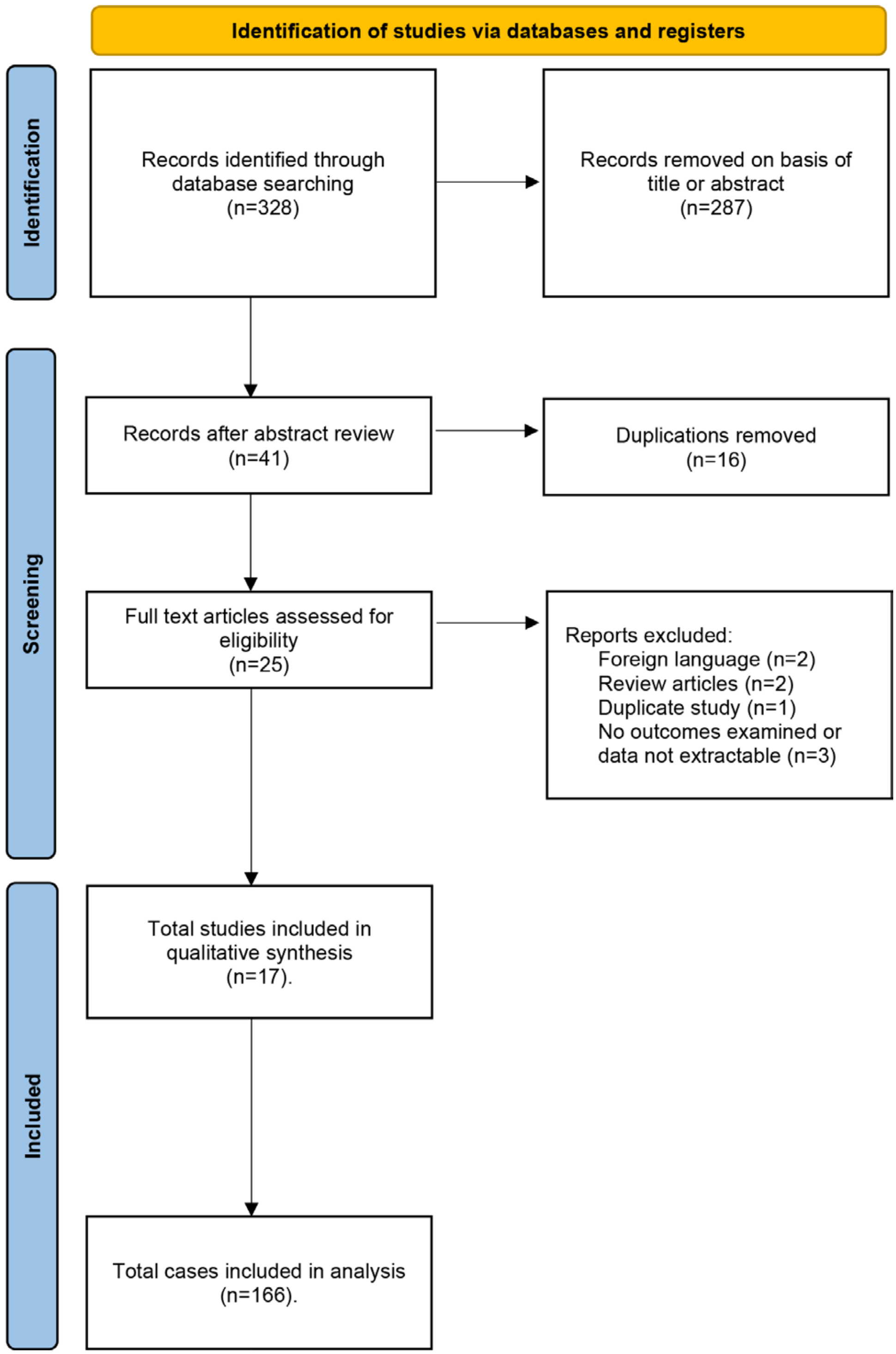


**Fig. 1.** Study selection flowchart based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[17]

based on title and abstract. After removal of duplications, a total of 25 studies were assessed based on inclusion and exclusion criteria. Eight studies failed to meet inclusion criteria. Two studies were in a foreign language, two were review articles, three articles did not have extractable data or outcomes, and one report included a duplicate case. Ultimately, 17 studies were included for qualitative analysis. A flowchart based on the the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement is provided to illustrate the selection process (Fig. 1).

### Study Characteristics

Included studies were published between 1994 and 2022, with seven identifying as case reports (41.2%), four as case series (23.5%), and six as retrospective cohort studies (35.3%). There was a 15-year gap from the first reported case in 1994 to the next reported case in 2009.

### Quality of Included Studies

Based on the plastic and reconstructive surgery level of evidence pyramid, the retrospective cohort studies were categorized as level III, case series as level IV, and case reports as level V evidence.[18] (**See table 1, Supplemental Digital Content 1,** which displays the study characteristics. **http://links.lww.com/PRSGO/C497**.)

### Patient Demographics and Characteristics

The 17 studies constituted a total of 166 patients, with a majority of the patient cohort coming from one single study (n = 107; 64.4%).[19] However, novel reconstructive sites not discussed in this single study were found in the other included reports. Overall recipient sites included the orbit, maxilla, palate, mandible, nose, ear, frontal sinus, calvaria, and larynx and tracheal regions (Table 1). The number of patients in each study ranged from one to 107, and patient age ranged from 7 to 83 years. Follow-up times varied among studies, ranging from 2.5 to 145 months.

### Donor Site Characteristics

The MFC free flap components were documented in 157 cases; periosteum only was used in four cases (2.5%), whereas all other patients had cortical bone combined with periosteum, cancellous bone, and/or cartilage (97.5%). The addition of a skin island was reported in 43 cases (25.9%). A total of 51 cases documented MFC flap measurements; the dimensions varied, with flap length averaging 4.5 ± 2.7 (range 1–15) cm. Skin island dimensions were reported in seven cases and averaged 20.2 ± 12.8 (range 3–35) $cm^2$. The DGA was the primary pedicle employed (n = 162; 97.6%), whereas the superior medial genicular artery (SGA) was used in the DGA's absence (n = 4; 2.4%). The average DGA pedicle length from 15 reporting cases was 6.4 ± 1.2 (range 4–9.4) cm. (**See table 2, Supplemental Digital Content 2,** which displays the patient demographics and flap characteristics. **http://links.lww.com/PRSGO/C498**.)

**Table 1. Recipient Sites**

| Region | Site |
|---|---|
| Orbit | Supraorbital rim<br>Orbital wall<br>Infraorbital rim<br>Orbital floor |
| Maxilla | Alveolar ridge |
| Palate | Premaxillary alveolus<br>Anterior palate and alveolus<br>Hard palate<br>Entire palate |
| Mandible | Body<br>Posterior body<br>Parasymphysis/body<br>Symphysis/body<br>Condyle<br>Condyle/ramus |
| Neck | Cricoid cartilage<br>Cervical trachea<br>Laryngotracheal region<br>Larynx |
| Other | Anterior frontal sinus<br>Nose<br>Ear<br>Calvaria |

### Adverse Events

Postoperative major and minor complications at the recipient site were seen in 16 cases (9.6%). Flap failures constituted six cases (3.6%) and were due to venous congestion (n = 2), flap necrosis (n = 2), infection (n = 1), and inadequate blood supply resulting in an oroantral fistula (n = 1). Salvageable recipient site complications included minor bony necrosis (n = 3), arterial thrombosis (n = 1), infection (n = 1), submental abscess (n = 1), wound dehiscence resulting in recurrent oronasal fistula (n = 1), and moderate dyspnea and bilateral vocal cord paresis (n = 1). In the case of wound dehiscence, the complication was not due to the MFC flap, but rather due to dehiscence of the superimposed buccal myomucosal flaps for fistula closure.[20] Self-limiting complications included chemosis (n = 1) and temporary subcutaneous emphysema (n = 1).

At the donor site, six cases (3.6%) noted complications other than self-limiting pain, paresthesia, or hyposensitivity. Those cases included hypertrophic scar (n = 2), seroma (n = 2), prolonged pain (n = 1), and femoral shaft fracture (n = 1). In the case of femoral shaft fracture, the patient had a large bone procurement of 15 cm in length that included the medial condyle and segment of femoral shaft.[19]

### Outcomes

Reported outcomes were significantly heterogenous, as reconstruction sites and surgical indications differed among studies, and objective measures were not always used. Nonetheless, successful reconstructions using the free MFC flap totaled 160 cases (96.4%) with six failures (3.6%). Of the 17 studies analyzed, the overarching theme emphasized was the stability of the reconstructions noted during the follow-up periods, the minimal DSM, the ease of harvest, and the simultaneous two-team approach reducing operative time. Considering other commonly used vascularized bone flaps, each study found the free MFC flap to be a reliable option in the reconstruction of small- to medium-sized defects of the head and neck. For instance, mandibular defects have traditionally been reconstructed using the free fibula flap; however, the studies here found the free MFC flap to be an excellent alternative for smaller scale defects. Furthermore, in cases requiring dental implants postreconstruction, the MFC flap was found to provide adequate bone quality when a suitable amount of cortical bone was procured.[13,19,21,22] In the studies discussing palatal reconstruction, the MFC free flap was found to be an effective reconstructive option for recalcitrant wounds.[13,19,20] **(See table 3, Supplemental Digital Content 3,** which displays the recipient and donor site outcomes and complications. **http://links.lww.com/PRSGO/C499**.)

## DISCUSSION

Since the first description of the free MFC flap for head and neck reconstruction by Kobayashi et al,[16] its use has expanded into the other craniofacial bones and neck structures. This study aimed to provide a comprehensive analysis on the published literature to define the role of the free MFC flap in head and neck reconstruction among the other widely known vascularized osseous flaps. The literature defines the free MFC flap as a highly reliable tool, given the high success rate (96.4%) found in the analyzed studies, stability of the reconstruction over long-term follow-up, minimal donor site complications with relatively quicker recovery, straightforward dissection, and simultaneous approach in harvesting the flap and preparing the recipient site. One of the MFC flap's distinctive qualities is its robust ability to introduce periosteum, which possesses high bone regenerative potential. Overall, the free MFC flap demonstrates more benefits than downfalls compared with its counterparts, with the main limitation being its restriction to smaller scaled defects (Table 2).

The benefits of the free MFC flap gives its edge over other commonly used osseous flaps, as it provides advantages in areas of versatility, pliability, structural strength, and long-term stability.[23] In terms of vascularity, the MFC free flap is typically supplied by the DGA (97.6%) and the SGA (2.4%).[1,12,13] The DGA branches off the superficial femoral artery proximal to the adductor hiatus, then giving rise to a muscular branch, a saphenous branch, and an articular branch that directly supplies the bone of the medial condyle.[1] The DGA pedicle length averages 6.6 cm.[6,10] The SGA emerges medially from the popliteal artery to perfuse the medial condyle and consists of a shorter vascular leash of approximately 4.1 cm[1] (Fig. 2). The mean caliber of the DGA is 1.8 mm and 1.75 mm for the vein.[24] Therefore, in our experience, end-to-side anastomoses are sometimes required when plugging into large recipient head and neck vessels. Additionally, there are considerable anatomical variations in the branching patterns of the vascular network, and in some instances, the DGA may be insufficient or entirely absent.[1,12] This poses a limitation, as the SGA's shorter pedicle leads to higher risk of flap complications and failure, much like the iliac crest.[1,12,13,25,26]

**Table 2. Common Indications of the Free MFC Flap in Head and Neck Reconstruction**

| Factors | Defect Indication |
|---|---|
| Size | Small (1–2 cm)<br>Intermediate (3–5 cm) |
| Region | Calvaria[19]<br>Laryngotracheal region[19,32–34]<br>Mandible[6,13,22,24,35,36]<br>Maxillary alveolus[13,19–21,37]<br>Orbit[16,20]<br>Palate[13,20]<br>Other facial bony structures[19,38–40] |
| Other | Problematic nonunions[6,20,36]<br>Failed nonvascularized bone grafts[13,19,20,37]<br>Recalcitrant defects[19,20,37]<br>Osteoradionecrosis[13,16,20,22,24] |

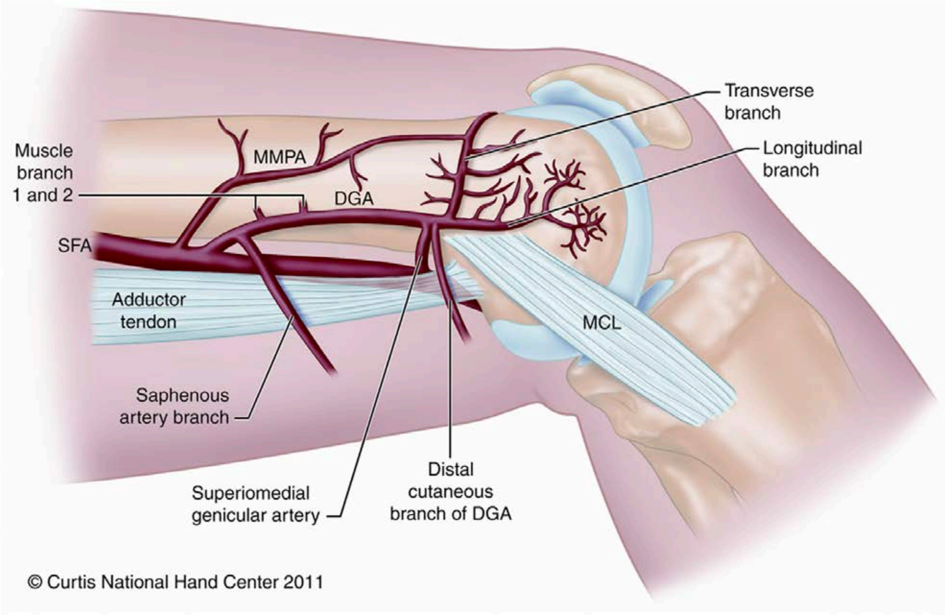


**Fig. 2.** Medial femoral condyle vascular anatomy.[31] Reprinted from *The Journal of Hand Surgery*, 37(5), Matthew L. Iorio, Derek L. Masden, James P. Higgins, Cutaneous Angiosome Territory of the Medial Femoral Condyle Osteocutaneous Flap, 1033-1041, Copyright 2012, with permission from Elsevier.

**Table 3. Comparisons of the Free MFC Flap to Other Commonly Used Free Osseous Flaps**

| Free Flap Type | Pedicle (Artery) | Pedicle Length (cm) | Approximate Maximum Bone Harvest Length (cm) | Advantages | Limitations |
|---|---|---|---|---|---|
| Medial femoral condyle[1,6,10–14,20,23,27–29] | Descending genicular | 6.6 (range 3.5–9.0) | 6 | Minimal donor site morbidity<br>Suitable for pediatric population<br>Cartilage | Cannot be used in large reconstructions<br>Risk of femur fracture in large bone harvests, including femur shaft |
| Fibula[6,8,20,25,41] | Peroneal | 11.2 (range 10–13) | 25 | Ample bone stock<br>Segmental vascular supply<br>Long pedicle<br>Multiple skin islands<br>Suitable for pediatric population | No cartilage<br>High rate of delayed donor site wound healing, specifically in osteocutaneous flaps |
| Radial forearm[3,7,8,42,43] | Radial | 18.0 (range 14–22) | 12 | Thin, pliable<br>Long pedicle | No cartilage<br>High rate of donor site wound breakdown<br>High fracture rate without plating |
| Iliac crest[5,6,8,44] | Deep circumflex iliac | 5.0 (range 5.0–7.0) | 6 | High-quality bone stock<br>Cartilage | Short pedicle<br>Rigid structure making sculpting difficult<br>Highest rate of complications at recipient and donor site<br>Increased harvest time |
| Scapula[5,6,8,30] | Circumflex scapular<br>Angular | 7.5 (range 6.7–9.0)<br>14.1 (range 13.0–15.0) | 14 | Abundant soft tissue supply<br>Two available pedicles<br>Low donor site morbidity<br>Early ambulation<br>Suitable for geriatric population | Lack of segmental vascularity<br>Lack of quality bone stock<br>Difficulty in flap harvest due to patient positioning |

The hallmark feature of the free MFC flap is its ease of harvest and DSM.[27–29] In the author's experience, the MFC flap harvest is just slightly more technically demanding than the radial forearm osteocutaneous flap, but much less complex and extensive than the free fibula flap. In terms of the DSM, the authors have found the best outcomes with the MFC compared with the other vascularized free flaps. The analyzed cases compliment the author's findings in that the majority of patients experienced self-limiting pain, paresthesia, or hyposensitivity. Zeman-Kuhert et al assessed donor site outcomes for facial reconstruction patients using subjective and objective measures, such as the Tegner Lysholm Knee Scoring Scale, the Knee Society Score, and the Patient and Observer Scar Assessment Scale.[28] The results found no knee joint instability or limited range of motion, and on Patient and Observer Scar Assessment Scale analysis, observer scores were significantly higher for scarring in osteocutaneous versus nonosteocutaneous flaps.[28] However, as seen in one case by Brandtner et al, large harvests including the femoral shaft can lead to increased risk of femoral shaft fracture.[19,29] This typically begins at lengths of approximately 6 cm or more.[29]

The iliac crest free flap experiences the highest rate of complications at not only the recipient site, but also the donor site.[5,6] This, in combination with the increased harvest time, has added to its decline in use over recent years.[5] For instance, patients report dissatisfaction with the aesthetic outcome of the donor site scar (20%) and anatomic hip contour (39%).[8] Functionally, 25% experience antalgic gait and reduced hip mobility, and 27% lack sensation in the lateral femoral cutaneous nerve distribution.[8] The radial forearm osteocutaneous flap presents with high rates of donor site wound breakdown with tendon (5%–46%) and metal hardware (1%–15%) exposure and chronic pain on long-term follow-up (16.7%).[8] Before plating, the fracture rate of the radial forearm osteocutaneous flap was as high as 18% and 32% in women; however, with prophylactic plating being the standard, this risk has been significantly reduced.[3,8] The free fibula flap is associated with varying levels of DSM in terms of sensory deficits (21%), chronic pain (6.5%), and reduced ankle function (41%).[8,25] Both the radial forearm and the fibula, specifically osteocutaneous flaps, exhibit higher rates of delayed wound healing (20%) compared with the scapula (<10%) and iliac crest (5%).[8] The free scapula flap demonstrates the least DSM and provides opportunity for early ambulation, which is beneficial for the older population.[6,8] However, flap harvest may prove to be difficult in terms of patient positioning in the operating room[30] (Table 3).

Among the pediatric group, the free fibula flap has been deemed the safest option for reconstruction using a vascularized osseous flap.[6] Due to the Innocenti technique, the MFC free flap may also be used safely among the skeletally immature population.[20] Before this description, the MFC free flap was not an option among the skeletally immature due to fear of disruption of the distal femoral growth plate.[20] However, with the use of fluoroscopic guidance and Kirschner wires, the Innocenti technique frameshifts the entire flap design proximally onto the medial femoral metaphysis, with the distal osteotomy still proximal to the distal femoral physis.[20] Results of this technique demonstrated no injuries to the distal femoral physis, limb length discrepancies, or gait disturbance.[20]

### Limitations

This systematic review has inherent limitations, as the available literature on the free MFC flap for head and neck reconstruction consists mainly of single case reports and retrospective, descriptive studies. Additionally, a majority of the cohort in this review is pooled from one single study. This demonstrates predominantly low-level evidence, limiting both power and generalizability. Nonetheless, the MFC flap is a relatively newer flap with indications for the head and neck continuously being discovered, as seen in this review. The authors of the included studies do not support the free MFC flap as a replacement to the more popular vascularized bone free flaps; however, they do agree the free MFC flap should be recognized as an option where applicable. Therefore, summarizing the variety of indications allows for a better depiction on the overall use of the MFC flap in the head and neck. Future prospective studies are required to objectively evaluate outcomes and better elucidate indications for the use of the MFC flap in head and neck reconstruction. Although the MFC flap proves to be a promising option for small- to intermediate-sized defects of the head and neck, many of the bone gaps in this region are large and will continue to require larger vascularized bone flaps, such as the fibula.

## CONCLUSIONS

The aim of this study was to provide an up-to-date review on the free MFC flap as a potential reconstructive option for small- to intermediate-sized defects of the head and neck. Its robust regenerative bone potential, highly versatile nature, minimal DSM, low complication rate, ease of harvest, and simultaneous two-team approach offer an attractive and reliable reconstructive option. The free MFC flap would make an excellent addition to the armamentarium of microvascular head and neck reconstruction.

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## DISCLOSURES

*Shaun D. Mendenhall is an educational consultant for PolyNovo, which is unrelated to this study. All the other authors have no financial interests to declare in relation to the content of this article.*

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