Surgery Article

AMERICAN ASSOCIATION FOR HAND SURGERY

HAND
2024, Vol. 19(6) 895–903

DOI: 10.1177/15589447231151430
journals.sagepub.com/home/HAN

The Medial Femoral Trochlea Osteochondral Flap for Scaphoid Reconstruction: A Systematic Review

Brahman Sivakumar[1,2,3,7,8], Richard Lawson[1], and David J. Graham[2,4,5,6]

Abstract

Background: The medial femoral trochlea flap has been used to resurface scaphoids with recalcitrant proximal pole fractures or avascular necrosis, providing vascularized osteochondral tissue with similar morphological characteristics. This article aims to review the contemporary literature on its use for scaphoid reconstruction. **Methods:** A systematic review of Embase, PubMed, Cochrane Central Register of Controlled Trials, and MEDLINE assessed the use of medial femoral trochlea flaps in scaphoids. **Results:** Eight studies were included, with 76 patients at a mean age of 26 years. Forty-three patients underwent clinical review, and 10 patients underwent radiographic evaluation, at a mean 23.3 months of follow-up. Flaps were generally performed for proximal pole fractures, avascular necrosis, nonunion, or failure of prior fixation; 94.4% of the flaps united. No marked change in sagittal plane motion was noted; reductions were seen in axial and coronal plane motion. The Disabilities of the Arm, Shoulder, and Hand scores improved from a mean of 25.2 to 11.5. Radiographic markers also improved. A total of 12.3% of patients had unplanned return to theater. Three patients required early revision for vascular thrombosis, and 1 patient suffered a volar carpal dislocation. Three patients underwent salvage procedures for ongoing pain. **Conclusions:** Although technically demanding, promising early-term to medium-term results are noted with the use of medial femoral trochlea flaps in the scaphoid.

Keywords: medial femoral trochlear, MFT, osteochondral free flap, scaphoid nonunion

Introduction

Reconstruction of focal chondral defects poses a complex clinical problem and is often treated ultimately via arthrodesis or arthroplasty. Cartilaginous resurfacing offers an alternative therapeutic option, particularly in young or highly functional patients in whom arthroplasty or arthrodesis may not provide satisfactory outcomes. Traditional resurfacing procedures, such as abrasion arthroplasty or microfracture, result in the formation of fibrocartilage, with often limited improvement due to inherent biomechanical differences when compared with native hyaline cartilage.[1] Nonvascularized osteochondral autografting has been used to replace articular surfaces with healthy hyaline cartilage in both large and small joints. Donor sites have been as disparate as the non-weight-bearing portion of the distal femur, the distal articular surface of the hamate, and the osteochondral interface of the rib; recipients include the knee, ankle, distal radioulnar, and proximal interphalangeal joints.[1-4]

However, perfusion and nutrition of these grafts are dependent on vascular ingrowth from surrounding bone and synovial diffusion. There is growing appreciation for the importance of subchondral blood supply in chondrocyte nutrition, with a porcine study demonstrating superior cartilage

[1]Royal North Shore Hospital, St Leonards, NSW, Australia
[2]Australian Research Collaboration on Hands (ARCH), Mudgeeraba, QLD, Australia
[3]The University of Sydney, Camperdown, NSW, Australia
[4]Gold Coast University Hospital, Southport, QLD, Australia
[5]Griffith University School of Medicine and Dentistry, Southport, QLD, Australia
[6]Queensland Children's Hospital, South Brisbane, Australia
[7]Hornsby Ku-ring-gai Hospital, Hornsy, NSW, Australia
[8]Nepean Hospital, Kingswood, NSW, Australiaa

Corresponding Author:
David J. Graham, Australian Research Collaboration on Hands (ARCH), Suite 4/75 Railway Street, Mudgeeraba, QLD 4213, Australia.
Email: davegraham80@gmail.com

quality and survival in osteochondral vascularized flaps when compared with nonvascularized grafts in an intrasynovial environment isolated from surrounding bony vascular ingrowth.[5] Hence, the use of osteochondral flaps has gained acceptance, particularly when considering resurfacing procedures in the carpus, where a paucity of intrinsic vascular supply and small recipient beds may limit vascular ingrowth.

The medial femoral trochlea (MFT) osteochondral flap was first described in 2008 and is of particular use in the reconstruction of recalcitrant proximal pole scaphoid nonunions or avascular degenerative lunates due to its morphologic similarities.[6,7] This article aims to review the literature on MFT reconstruction of the scaphoid and report on outcomes, providing a narrative overview and reporting on outcomes.

Methods

This literature review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines. In March 2021, an electronic search was conducted using the Ovid MEDLINE, PubMed, Embase, and Cochrane Central Register of Controlled Trials databases. To achieve maximal search strategy penetration, various combinations of the terms "medial femoral trochlea," "scaphoid," "non-union," "carpus," and "flap" were used as key words or Medical Subject Headings terms, or via wildcard inquires. After the exclusion of duplicates, title and abstract screening was performed to assess relevance. Potentially relevant articles then underwent full-text screening, with the references reviewed to capture additional studies of interest.

All studies that were published in English and reported clinical outcomes following the use of osteochondral flaps harvested from the MFT for scaphoid reconstruction were eligible for inclusion. Studies published in alternate languages; those reporting on flaps without a chondral component (ie, the medial femoral condyle [MFC] osseous flap); and those not detailing clinical outcomes were excluded. The quality of included studies was graded using the Oxford Centre for Evidence-Based Medicine (OCEBM) levels of evidence.[8] Data were extracted from the text, tables, and figures of included articles, and simple statistical analysis was performed where possible. Owing to the niche nature of the procedure under review, multiple reports have been published from the same cohorts. Thus, reports which could not be confidently deemed unique were excluded, and data with the longest follow-up were included for analysis. Primary authors of included studies were contacted for clarification of data if required.

Results

The literature search yielded 41 articles, with 28 remaining after exclusion of duplicates (Figure 1). A further article was excluded as it was not published in English, leaving 27 studies for full-text appraisal. Twelve studies reported on clinical outcomes following MFT reconstruction of the scaphoid. Four articles reproduced previously published data, leaving 8 studies with a cohort of 76 patients from 7 different centers for inclusion (Table 1). All studies were adjudged level 4 using the OCEBM classification. Due to heterogeneous outcomes reporting between studies, appropriate cohort sizes are reported per variable.

The cohort consisted of 67 men and 9 women, with a mean age of 26 years (17-47; n = 72). Forty-three patients were able to be reviewed clinically, with a mean of 23.3 months at final follow-up (12-36; n = 42); a further 10 patients were assessed via radiographs alone. In all, 42% of patients were smokers (n = 19).

The mean interval between initial injury and MFT reconstruction was 45.2 months (6-96; n = 20). The etiology in all patients bar one was a scaphoid fracture with avascular necrosis, nonunion, or failure of prior fixation, with resultant inadequate proximal bone stock or quality to permit other fixation methods. The remaining patient had Preiser's disease. Fifty-six of the 72 patients had prior operative intervention, with a mean of 0.93 previous operations (0-3). In total, 58% (39 of 67) of these operations involved internal fixation with no augmentation, 21% (14 of 67) utilized nonvascularized bone graft, and 19% (13 of 67) employed a local pedicled osseous flap. One patient underwent excision of the proximal pole of the scaphoid.

All patients underwent resurfacing of the proximal pole of the scaphoid except for one, who had intercalary resurfacing of the radioscaphoid articulation (following a scaphoid waist fracture nonunion with segmental loss of the articular surface). Fixation during MFT reconstruction was achieved using Kirschner wires (K-wires), miniplates, compression screws, or a combination. Four of the 72 patients received skin paddles for flap monitoring. 94.4% (68 of 72) of the MFT osteochondral flaps went on to unite, at a mean of 11.6 weeks (7-22; n = 54). Eleven patients underwent planned removal of K-wires, screws, or the skin paddle.

There was no marked change in sagittal plane motion, with mean preoperative flexion and extension of 42.7° and 46.8° (n = 39) and postoperative values of 40.8° and 42.2° (n = 40), respectively. Similarly, there was a slight reduction in coronal plane motion after reconstruction, with mean preoperative radial and ulnar deviation of 15.0° and 34.4° (n = 8), diminishing to 10.9° and 27.8° (n = 22) postoperatively. A more marked reduction was noted in axial motion—mean postoperative pronation and supination were 69.3° and 70.4° (n = 22), down from preoperative measurements of 80.0° and 83.6° (n = 7), respectively. Only 5 patients had grip strength recorded prior to reconstruction, with a mean of 27.2 kg; in comparison, measurements across 33 patients after MFT noted an average grip strength of 36.1 kg (Table 2).

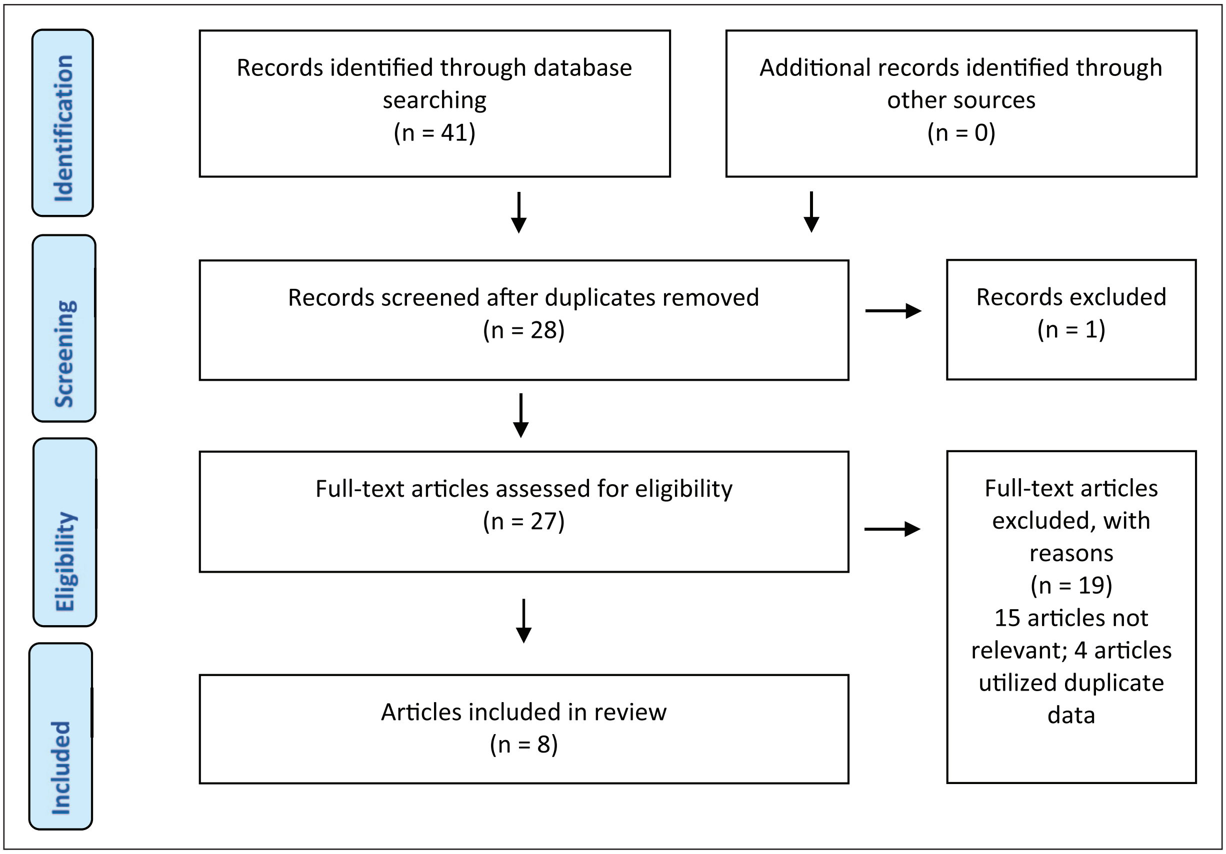

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis flow diagram of systematic review.

Table 1. Summary of Demographics in Included Studies.

Author	Y	LOE	n (MFTs)	Etiology	Mean time from injury to procedure, mo	n (f/u)	Mean f/u, mo	Mean age, y	Sex (M/F)
Burger et al[9]	2013	IV	14	Proximal pole nonunion	48.6 (14-46)	14	14.0	28.9	12/2
Tremp et al[10]	2016	IV	1	Proximal pole AVN	6.0	1	36.0	20.0	0/1
Freniere et al[11]	2019	IV	1	Fracture with AVN	12.0	1	12.0	31.0	1/0
Aribert et al[12]	2019	IV	2	Proximal pole nonunion	NR	2	14.0	28.0	2/0
Pet et al[13]	2020	IV	41	Fracture with AVN	NR	11 clinical/10 radiographic	28.8 clinical/24.0 radiographic	24.1	35/6
Crepaldi et al[14]	2020	IV	1	Waist fracture with intercalary defect	NR	1	36.0	24.0	1/0
Alolabi et al[15]	2020	IV	4	3 proximal pole nonunion; 1 Preiser disease	NR	4	20.5	25.5	4/0
Keating et al[16]	2021	IV	12	Proximal pole scaphoid fracture	50.0	8	34.0	31.0	12/0

Note. LOE = level of evidence; MFT = medial femoral trochlea; f/u = follow-up; AVN = avascular necrosis; NR = not recorded.

The Disabilities of the Arm, Shoulder, and Hand (DASH) score dropped from a preoperative mean of 25.2 (n = 12) to a postoperative value of 11.5 (n = 36). Only 3 patients completed a preoperative Visual Analog Score (VAS) for pain, with an average score of 5 out of 10 (3.5-8). This improved to a postoperative VAS of 1.6 (0-6; n = 10). Final Patient-Rated Wrist Evaluation score was 18.7 (n = 30). A single study commented on resolution of pain, with complete resolution in 10 patients from a cohort of 14.

When considering radiographic markers, mean scapholunate angle decreased from 57.2° to 53.0° (n = 22), and mean radiolunate angle increased from −1.9° to 4.9° (n = 28).

Table 2. Summary of Preoperative and Postoperative Clinical Results.

Author	Y	Complications	Preoperative F/E, °	Preoperative RD/UD, deg	Preoperative P/S, deg	Postoperative F/E, deg	Postoperative RD/UD, deg	Postoperative P/S, deg
Burger et al[9]	2013	1 nonunion = revision surgery	43.0/46.0	NR	NR	44.0/46.0	NR	NR
Tremp et al[10]	2016	Nil	20.0/60.0	20.0/50	NR	NR	NR	NR
Freniere et al[11]	2019	Severe pain at 12 mo = S4CF	NR	NR	NR	50.0/35.0	NR	NR
Aribert et al[12]	2019	2 early reoperations = vessel thrombosis	68.0/68.0	17.4/45.0	90.0/90.0	50.0/50.0	20.0/27.0	90.0/90.0
Pet et al[13]	2020	1 wound dehiscence; 1 early reoperation = thrombosis; 1 hardware migration = removal; 1 patellofemoral pain = arthroscopic debridement; 1 nonunion	46.5/47.1	NR	NR	43.8/43.6	10.4/27.9	61.4/62.7
Crepaldi et al[14]	2020	Bony resorption on final radiographs	20.0/10.0	0.0/30.0	NR	30.0/20.0	10.0/30.0	NR
Alolabi et al[15]	2020	1 nonunion = S4CF	NR	NR	NR	NR	NR	NR
Keating et al[16]	2021	1 volar dislocation = revision; 1 wrist pain = S4CF	35.5/45.5	17.0/31.0	76.0/81.0	31.0/34.0	9.5/27.5	75.0/85.0

Note. F = flexion; E = extension; RD = radial deviation; UD = ulnar deviation; P = pronation; S = supination; NR = not recorded; S4CF = scaphoidectomy and 4-corner fusion.

Only 1 study measured radioscaphoid angles, with little change (45.9° preoperatively to 46° post-reconstruction; n = 8); similarly, little difference was reported in carpal height ratio (0.49-0.50; n = 20). Features of asymptomatic radioscaphoid osteoarthritis were noted on routine radiographic follow-up in 9 of 47 patients, with 2 of these also demonstrating midcarpal changes.

Nine patients required an unplanned return to theater (12.3%; n = 73). There were 4 early reoperations, with 3 anastomotic revisions after thrombosis (2 arterial and 1 venous). The remaining patient was found to have a volar radiocarpal dislocation on routine postoperative radiographs following proximal pole reconstruction via a volar approach, with revision within 2 weeks of the index operation. There was one episode of late hardware migration requiring removal. Despite MFT reconstruction, 3 patients complained of ongoing intractable wrist pain and dysfunction, requiring salvage in the form of scaphoidectomy and 4-corner fusion. A single patient complained of persistent patellofemoral pain, which was treated with arthroscopic debridement of the harvest site and retropatellar area. Four of the 76 patients were reported to have a nonunion, with 1 patient undergoing revision surgery with nonvascularized bone grafting; the remainder had not undergone any further operations at the final follow-up.

Discussion

Recalcitrant carpal bone nonunions pose a therapeutic conundrum, particularly in the settings of juxta-articular fractures or avascular nonunion with limited bone stock following prior failed fixation, or articular surface involvement with fragmentation. Although arthroplasty or arthrodesis offers salvage options, an osteochondral reconstruction may be beneficial, allowing resurfacing with hyaline cartilage and healthy underlying bone. Nonvascularized graft has been used to resurface small osteochondral lesions in convex joint surfaces around the body but requires a stable rim to offer the peripheral support and large adjacent cancellous surface necessary for integration.[7] Osteochondral autograft with an independent vascular supply offers an attractive alternative in peripheral lesions or small bones without adequate supporting bone stock.

Malinin and Ouellette[17] demonstrated the importance of subchondral perfusion for maintenance of osteochondral grafts in a baboon model. They harvested numerous dowel grafts from the femoral trochlea and lined half of the harvest sites with methylmethacrylate cement to prevent vascular ingrowth, before reinserting all the grafts. Although both groups showed survival of cartilage at 1 and 3 years after surgery on gross, histological, and electromicroscopic evaluation, the grafts that had been denied a subchondral vascular supply displayed clear degenerative changes. Malinin and Ouellette[17] concluded that although synovial diffusion was sufficient to maintain cartilage nutrition, an adequate subchondral perfusion was vital in preventing long-term degeneration.

Higgins et al[5] built on this to show that vascularized osteochondral flaps demonstrate superior cartilage survival and quality in an intrasynovial environment when compared with nonvascularized grafts. Adjacent osteochondral segments were harvested (either with a pedicle to maintain an autonomous blood supply, or without) and reinserted into defects that were lined with cement in the MFT of pigs. Histological analysis 6 months later revealed a smooth hyaline cartilaginous surface with chondrocytes organized in a columnar fashion in the vascularized segments; however, the nonvascularized grafts showed decreased cartilage development with poorer matrix, reduced collagen synthesis, and abnormal chondrocytes.[5] He hypothesized that the additional difficulty and operative time required in providing a pedicled vascular supply to autologous osteochondral transplant may result in histologically and clinically superior results when compared with nonvascularized grafts. This has been clinically supported in the setting of free toe joint transfers, where greater preservation of joint space has been noted in vascularized transfers when compared with nonvascularized transfers.[18]

The MFT provides convex osteochondral tissue that can be used to resurface carpal bones with complex articular fractures or avascular necrosis. Cadaveric modeling has shown this region experiences the lowest contact pressures in the patellofemoral joint with quadriceps loading, rendering it potentially the most favorable harvest site in the distal femur.[19] The MFT may also display similar dimensions to the carpal bones. Computed tomography (CT) in an unmatched cohort of nonpathological wrists and knees revealed a mean axial radius of curvature (ROC) of the MFT of 7.98 mm, comparable to the sagittal ROC of the scaphoid (7.97 mm), lunate (9.92 mm), and capitate (6.65 mm).[7] Similarly, the sagittal ROC of the MFT (25.56 mm) corresponded to the coronal ROC of the proximal carpal row (26.99 mm). However, a more detailed analysis via CT of 12 matched cadaveric femurs and scaphoids indicated greater anatomical variation, with the MFT surface nearly flat in some donors and markedly convex in others.[20] Although the mean ROC for the cohort was not significantly different between the radioulnar axis of the proximal pole of the scaphoid (17.1 mm) and the craniocaudal axis of the MFT (23.6 mm), individual specimens did show greater variability, with up to 99% difference noted. A significant difference was noted for mean ROC between the mediolateral axis of the MFT and the corresponding dorsovolar aspect of the proximal pole of the scaphoid, at 53.5 and 11.7 mm, respectively.[20] The authors concluded that the promising early reported clinical results from carpal resurfacing via MFT flaps may be due to the vascularized nature of the osteochondral transfer and that recreation of native scaphoid anatomy may be of lesser importance.

Histological analyses of cartilage biopsies in patients undergoing repeat surgery after MFT transplant have confirmed the viability of transferred chondrocytes. Zimmerman et al[21] reported finding uniformly organized and evenly spaced viable chondrocytes with unremarkable surrounding fibrocartilaginous stroma in a patient who underwent resurfacing of the lunate for Kienbock disease. Similarly, Freniere et al[11] noted histologically normal cartilage 1 year after MFT flap resurfacing of a scaphoid proximal pole, despite the patient requiring a scaphoidectomy and midcarpal arthrodesis to treat pain that may have been caused by radioscaphoid impingement.

The MFT flap has been used to replace a range of articular surfaces, including the scaphoid, lunate, and the talus.[10,13] The majority of the literature involves scaphoid reconstruction following either fracture with proximal pole fragmentation or avascular necrosis. The harvested osteochondral segment is approximately 2 cm × 1 cm × 1 cm, with the longest dimension measuring from proximal to distal and used to recreate the greater curvature of the scaphoid.[22] Resurfacing can be performed via either dorsal or volar approaches, although the dorsal route is preferred due to ease of access to the proximal pole and recipient vessels, preservation of supporting volar ligaments, and stable fixation of the MFT flap to the distal scaphoid.[14,15,22] Osteotomy of the native scaphoid is performed to allow generous resection of diseased bone while preserving a thin osteochondral sliver to permit midcarpal articulation with the capitate and maintain the distal attachments of the scapholunate ligament.[23,24] Cadaveric studies suggest that expansion of the dimensions of the MFT flap ("overstuffing") when compared with the native proximal pole may aid in preventing carpal malalignment and correcting established dorsal intercalated segmental instability.[25] After obtaining a snug reduction with the native distal scaphoid, the flap is secured with a more longitudinal screw than in conventional fracture fixation, to achieve perpendicular compression across the osteotomy and avoid prior screw tracks.[22]

This review assesses outcomes following scaphoid resurfacing via MFT flaps. It finds a pooled union rate of 94.4% at a mean of 11.6 weeks, similar to that reported by Kazmers et al[26] in his review of all flaps from the medial genicular arterial system (97.8%, at an average of 13.9 weeks). The slight discrepancy in union may be accounted for by the larger cohort and higher proportion of smokers (42% compared with 36%) in our study. Range of motion decreased in all planes after reconstruction; thus, careful preoperative patient counseling is key. Despite this, there was a substantial improvement in all patient-reported outcome measures. In particular, the DASH score dropped from 25.2 to 11.5 (greater than the reported minimally important clinical difference of 10), and the VAS improved from 5 to 1.6.[27] These improvements are preserved in the medium term—Pet provided the longest available follow-up when he reported maintained clinical and radiographic outcomes at a mean of 4.1 years after reconstruction in a subgroup of 10 patients from a cohort which has been otherwise included in this review.[23]

The risk of major complications (excluding nonunion) in this review was 10.9%. This risk was similar to the pooled rate determined by Kazmers (10.3%); however, when stratified by extremity, Kazmers et al[26] found a lower rate of complications during upper limb applications (6.2%, compared with 17.1% for the lower extremity). A single catastrophic early failure was noted following proximal pole reconstruction via a volar approach—the authors attributed the radiocarpal dislocation to the significant soft tissue dissection required for exposure, with subsequent loss of palmar capsuloligamentous support (which cannot be repaired due to passage of the pedicle), as well as an insufficiently sized osteochondral graft.[16]

An understanding of donor site morbidity is crucial, particularly when harvest is from an uninvolved limb in often young and athletic patients. Giladi et al[28] performed a systematic review of donor site morbidity of all osseous flaps from the distal femur in 2017, standardizing outcomes into 3 categories—good, with no postoperative complications or delays in recovery; fair, with delays in recovery (greater than 3 months until pain free), persistent mild scar discomfort, or donor paresthesia; and poor, with persistent knee pain, functional limitation, or requiring a procedural intervention to treat a complication. He found reports on 50 patients undergoing free MFT flap surgery, with data on 48 of these presented in a manner permitting analysis. Thirty-four patients (71%) reported good donor site outcomes; 10 patients (21%) had fair results; and 4 patients (8%) had poor outcomes at a mean follow-up of 26.4 months.[28] It must be noted that the majority of these patients were derived from a single series, with Windhofer et al[29] reporting on 45 patients from 2 centers undergoing an MFT flap at a mean of 27-month follow-up. He found stable tibiofemoral and patellofemoral articulations with symmetrical range of motion in all patients. The International Knee Documentation Committee score was used to evaluate general knee function, with a mean score of 96 (0 representing maximal and 100 representing no disability). The Western Ontario and McMaster Universities Osteoarthritis Index assessed degeneration and was reported at 6% (with 0% indicating no disability and 100% indicating complete incapacity). Magnetic resonance imaging and radiographs were performed in 35 patients and demonstrated no degenerative change or bone edema on the patella, with normal alignment. The site of harvest also appeared completely resurfaced with fibrocartilage. Despite this, 9% of patients (4 of 45) reported some degree of continuous knee discomfort throughout the day (a mean of 2 out of 10) and 22% (10 of 45) complained of intermittent knee discomfort. Giladi et al[28] commented that although most of the literature regarding distal femoral osseous harvest involved the MFC flap, patients undergoing MFT harvest were more likely to experience long-term knee pain or dysfunction.

Although not the primary focus of this review, 4 articles contained some description of knee pain after MFT harvest, with 8 patients of a cohort of 22 reporting minor discomfort and a further 2 describing significant pain at the final follow-up.[13-16] One patient required knee arthroscopy and debridement of the harvest site. In his long-term follow-up of a subset of 10 patients at 49 months after MFT harvest, Pet et al[23] reported a mean Knee Injury and Osteoarthritis Outcome Score of 91 (0 indicating no function and 100 indicating ideal capacity), with lower scores in the sports and recreation domain (80) when compared with the activities of daily living (95). This domain-specific information is useful when assessing the appropriateness of MFT reconstruction in a particular patient.

Other complications of osseous distal femoral flaps include saphenous nerve injury, hematoma or seroma formation, and femoral fracture. The frequency of temporary saphenous nerve dysfunction (either sensitivity or paraesthesia) has been reported as high as 50%—thus, detailed preoperative counsel and careful intraoperative nerve identification and protection are key.[30] Half of all secondary procedures following distal femoral osseous flaps are due to fluid collections, and the application of bone wax to the cancellous harvest site and utilization of a drain may minimize this risk.[28] Femoral fracture following MFT harvest has not been previously reported in the literature and is unlikely due to the small harvest size when compared with the potential scale of MFC flaps. Fractures have been reported after large MFC harvest, with biomechanical studies revealing no changes in axial stability regardless of size, but a greater tendency toward torsional failure when exceeding 7 cm in length.[31-35] Given the relative recency of the use of MFT reconstructive flaps, the literature is limited by a lack of long-term data regarding donor site morbidity, and extended follow-up is required to elucidate chronic sequalae.

The use of osteo-costochondral rib graft is an alternate technique allowing autologous resurfacing of the proximal scaphoid. Although not replacing like-for-like, the graft aims to act as a biological spacer, restoring scaphoid length and dimensions, and preventing carpal collapse. Biopsy on patients undergoing reoperation for presumed radial styloid impingement after rib grafting demonstrated variable survival of surface and deeper chondrocytes, with changes in the articulating surface suggestive of adaptive metaplasia in the chondral portion of the graft.[4] Three studies[36-38] in the literature have reported on a total of 65 patients undergoing this procedure, 62 of whom were available for clinical follow-up up to a mean of 5 years. Most patients experienced improvements in pain and function, with no conversions to salvage procedures. However, similar to MFT reconstruction, long-term outcomes are lacking, and an extended duration of follow-up will be beneficial.

This study has several weaknesses. All included studies are case reports or series, with meta-analysis precluded due to absence of comparative studies. Heterogeneous outcomes report limited pooled analysis. For summary purposes, this study averaged DASH scores, but it should be noted that the scores are nonlinear. However, this study provides a systematic review of the literature regarding outcomes following MFT resurfacing of the scaphoid. It finds promising early-term to medium-term clinical and radiological outcomes. Although technically demanding, similarities to scaphoid morphology and the presence of hyaline articular cartilage confer the potential of long-term preservation of function and carpal biomechanics. This needs to be offset against the pooled complication rate of 10.9%, which may diminish once learning curves are overcome. Further prospective, long-term, and comparative studies to alternative resurfacing and salvage procedures will be beneficial.

Author Contributions

B.S. was involved in performing the review and write-up of the article. D.J.G. was involved in writing the article and editing and reviewing of the articles to be included. R.L. was involved in write-up and editing the article.

Ethical Approval

Not required.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

No informed consent was required for this study.

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.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Brahman Sivakumar https://orcid.org/0000-0003-0890-2132
David J. Graham https://orcid.org/0000-0003-3421-822X

References

1. Hangody L, Dobos J, Balo E, et al. Clinical experiences with autologous osteochondral mosaicplasty in an athletic

population: a 17-year prospective multicenter study. *Am J Sports Med*. 2010;38(6):1125-1133.
2. Gudas R, Stankevicius E, Monastyreckiene E, et al. Osteochondral autologous transplantation versus microfracture for the treatment of articular cartilage defects in the knee joint in athletes. *Knee Surg Sports Traumatol Arthrosc*. 2006;14(9):834-842.
3. Faulkner S, Graham DJ, Hile M, et al. Hemi-hamate arthroplasty for base of middle phalangeal fracture: a systematic review [published online ahead of print June 8, 2021]. *HAND [N.Y.]*. doi: 10.1177/15589447211014623.
4. Sandow MJ. Proximal scaphoid costo-osteochondral replacement arthroplasty. *J Hand Surg Br*. 1998;23(2):201-208.
5. Higgins JP, Borumandi F, Burger HK, et al. Nonvascularized cartilage grafts versus vascularized cartilage flaps: comparison of cartilage quality 6 months after transfer. *J Hand Surg Am*. 2018;43(2):188.e1-188.e8.
6. Kalicke T, Burger H, Muller EJ. A new vascularized cartilage-bone-graft for scaphoid nonunion with avascular necrosis of the proximal pole. Description of a new type of surgical procedure. *Unfallchirurg*. 2008;111(3):201-205. (In German)
7. Hugon S, Koninckx A, Barbier O. Vascularized osteochondral graft from the medial femoral trochlea: anatomical study and clinical perspectives. *Surg Radiol Anat*. 2010;32(9):817-825.
8. Howick J, Chalmers I, Glasziou P, et al. The 2011 Oxford CEBM levels of evidence [Introductory document]. Oxford Centre for Evidence-Based Medicine. https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence.
9. Burger HK, Windhofer C, Gaggl AJ, et al. Vascularized medial femoral trochlea osteocartilaginous flap reconstruction of proximal pole scaphoid nonunions. *J Hand Surg Am*. 2013;38(4):690-700.
10. Tremp M, Haumer A, Wettstein R, et al. The medial femoral trochlea flap with a monitor skin island: report of two cases. *Microsurgery*. 2016;37(5):431-435.
11. Freniere BB, Giladi AM, Iorio ML. Vascularized osteochondral grafts: histologic evaluation of chondrocyte viability with viable hyaline nonfibrous cartilage. *J Hand Microsurg*. 2019;11(Suppl 1):S26-S30.
12. Aribert M, Corcella D, Bouyer M. Free composite medial femoral trochlea osteochondral cutaneous flap for wrist scaphoid and lunate cartilage lesions: advantages of a skin paddle. *Hand Surg Rehabil*. 2019;38(4):262-267.
13. Pet MA, Assi PE, Yousaf IS, et al. Outcomes of the medial trochlea osteochondral free flap for proximal scaphoid reconstruction. *J Hand Surg Am*. 2020;45(4):317-326.e3.
14. Crepaldi BE, Keating C, Ek ET, et al. Medial femoral trochlea graft for scaphoid waist nonunion: a case report and review of the literature. *J Wrist Surg*. 2020;9(3):186-189.
15. Alolabi N, Lovy AJ, Shin AY, et al. Medial femoral trochlea flap reconstruction: clinical outcomes and perspectives. *J Plast Reconstr Aesthet Surg*. 2021;74:1991-1998.
16. Keating C, McCombe D, Powell CA, et al. Reconstruction of the proximal scaphoid with a medial femoral trochlea osteochondral graft: minimum 2-year results. *J Hand Surg Am*. 2021;46(3):248e1-248.e9.
17. Malinin T, Ouellette EA. Articular cartilage nutrition is mediated by subchondral bone: a long-term autograft study in baboons. *Osteoarthritis Cartilage*. 2000;8(6):483-491.
18. Tsubokawa N, Yoshizu T, Maki Y. Long-term results of free vascularized second toe joint transfers to finger proximal interphalangeal joints. *J Hand Surg Am*. 2003;28(3):443-447.
19. Garretson RBIII, Katolik LI, Verma N, et al. Contact pressure at osteochondral donor sites in the patellofemoral joint. *Am J Sports Med*. 2004;32(4):967-974.
20. Hill JR, Heckmann N, McKnight B, et al. Medial femoral trochlea osteochondral graft: a quantitative anatomic comparison to the proximal pole of the scaphoid. *J Wrist Surg*. 2020;9(4):283-288.
21. Zimmerman RM, Allen EA, Higgins JP. Chondrocyte viability 3.5 years following a vascularized medial femoral trochlea osteocartilaginous free flap. *JBJS Case Connect*. 2016;6(4):e90.
22. Higgins JP, Burger HK. Medial femoral trochlea osteochondral flap: applications for scaphoid and lunate reconstruction. *Clin Plastic Surg*. 2020;47:491-499.
23. Pet MA, Higgins JP. Long-term outcomes of vascularized trochlear flaps for scaphoid proximal pole reconstruction. *Hand Clin*. 2019;35(3):345-352.
24. Higgins JP, Burger HK. Proximal scaphoid arthroplasty using the medial femoral trochlea flap. *J Wrist Surg*. 2013;2(3):228-233.
25. Capito AE, Higgins JP. Scaphoid overstuffing: the effects of the dimensions of scaphoid reconstruction on scapholunate alignment. *J Hand Surg Am*. 2013;38(12):2419-2425.
26. Kazmers NH, Thibaudeau S, Steinberger Z, et al. Upper and lower extremity reconstructive applications utilizing free flaps from the medial genicular arterial system: a systematic review. *Microsurgery*. 2018;38(3):328-343.
27. Gummesson C, Atroshi I, Ekdahl C. The disabilities of the arm, shoulder and hand [DASH] outcome questionnaire: longitudinal construct validity and measuring self-rate health change after surgery. *BMC Musculoskeletal Disord*. 2003;4:11.
28. Giladi AM, Rinkinen JR, Higgins JP, et al. Donor-site morbidity of vascularized bone flaps from the distal femur: a systematic review. *Plast Reconstr Surg*. 2018;142(3):363e-372e.
29. Windhofer C, Wong VW, Larcher L, et al. Knee donor site morbidity following harvest of medial femoral trochlea osteochondral flaps for carpal reconstruction. *J Hand Surg Am*. 2016;41(5):610-614.
30. Rodriguez-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 Surg*. 2011;64(4):515-527.
31. Son JH, Giladi AM, Higgins JP. Iatrogenic femur fracture following medial femoral condyle flap harvest eventually requiring total knee arthroplasty in one patient. *J Hand Surg Eur Vol*. 2019;44(3):320-321.
32. Haines M, Baba M, Stewart D. Iatrogenic femur fracture following medial femoral condyle flap harvest. *J Hand Surg Am*. 2020;45(9):885e1-885.e3.
33. Katz RD, Parks BG, Higgins JP. The axial stability of the femur after harvest of the medial femoral condyle corticocancellous flap: a biomechanical study of composite femur models. *Microsurgery*. 2012;32(3):213-218.

34. Endara MR, Brown BJ, Shuck J, et al. Torsional stability of the femur after harvest of the medial femoral condyle corticocancellous flap. *J Reconstr Microsurg*. 2015;31(5):364-368.
35. 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 bonegraft. *J Clin Orthop Trauma*. 2014;5(1):6-17.
36. Sandow MJ. Costo-osteochondral grafts in the wrist. *Tech Hand Up Extrem Surg*. 2001;5(3):165-172.
37. Veitch S, Blake SM, David H. Proximal scaphoid rib graft arthroplasty. *J Bone Joint Surg Br*. 2007;89(2):196-201.
38. Yao J, Read B, Hentz V. The fragmented proximal pole scaphoid nonunion treated with rib autograft: case series and review of the literature. *J Hand Surg Am*. 2013;38(11):2188-2192.