Vascularized Bone Flaps for the Treatment of Kienböck Disease

Matthew M. Florczynski, FRCSC, MD, MS[a], Kevin C. Chung, MD, MS[a,b,*]

KEYWORDS

• Free osteochondral flap • Kienböck disease • Lunate revascularization • Pedicled bone flap

KEY POINTS

- The vascular anatomy of the carpus can be conceptualized as a communicating series of longitudinal supplying vessels and transverse arches in forming a redundant blood supply to the bone.
- Compared to nonvascularized grafts, the use of vascularized bone flaps to treat osteonecrosis results in more rapid regeneration of bone and improved cartilage quality when osteochondral flaps are used.
- Pedicled 4,5 extracompartmental artery and metacarpal base flaps are preferred treatments for lunate osteonecrosis with preserved articular cartilage.
- Free osseocartilaginous flaps are indicated when osteonecrosis has occurred and the proximal lunate articular surface has been compromised.

INTRODUCTION

Over a century after Robert Kienböck coined the term lunatomalacia to describe radiographic changes from lunate osteonecrosis, the disorder with his namesake remains one of the great dilemmas in hand surgery.[1] Kienböck disease is a rare condition with an estimated prevalence ranging from less than 0.01% to 0.27%.[2,3] Its etiology is likely multifactorial, resulting from the interplay of vascular, mechanical, metabolic, and genetic factors.[4–6] Although historically there was debate about the natural history of Kienböck disease, studies have demonstrated a predictable relationship between the passage of time and progression of disease.[7–9] Radiographic changes and fragmentation of the lunate can occur within 6 months of the onset of symptoms, and though conventional treatments may improve symptoms, they do not alter the natural progression of disease.[10,11] Of the many surgical treatments available, only lunate revascularization has the potential to reverse the pathologic changes in Kienböck disease. With the advent of new techniques, indications for lunate revascularization are expanding and offer a promising solution for patients with previously unreconstructible lunate degeneration.

VASCULAR ANATOMY OF THE CARPUS

Osteonecrosis of the lunate has been linked to impaired vascularity in attempts to explain the pathophysiology of Kienböck disease. Early theories posited that a compression fracture results in disruption of the intraosseous blood supply

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[a] Section of Plastic Surgery, Department of Surgery, University of Michigan Medical School, Ann Arbor, MI, USA; [b] Comprehensive Hand Center Michigan Medicine, 2130 Taubman Center, SPC 5340, 1500 E. Medical Center Drive, Ann Arbor, MI 48109-5340, USA
* Corresponding author. Comprehensive Hand Center Michigan Medicine, 2130 Taubman Center, SPC 5340, 1500 E. Medical Center Drive, Ann Arbor, MI 48109-5340.
E-mail address: kecchung@umich.edu

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and subsequent osteonecrosis.[12,13] It was later postulated that lunate offloading procedures protect the lunate from fracture and osteonecrosis.[14] It is now clear that not all cases of Kienböck disease are precipitated by lunate fracture. Subsequent theories focused on natural variations in the arterial supply to the lunate and predisposition of particular vascular patterns to osteonecrosis.[15,16] Others suggested that increased intraosseous pressure impairs venous outflow and results in lunate osteonecrosis.[17,18] Although these hypotheses are reasonable, they have not been substantiated clinically.[4,19] Nevertheless, they have improved our understanding of the vascular anatomy of the lunate, which is central to the treatment of Kienböck disease.

Detailed knowledge of the vascular anatomy of the forearm and carpal bones is important for understanding lunate revascularization procedures. The radial, ulnar, and anterior interosseous artery (AIA), as well as lesser contributions from the deep palmar arch and recurrent branches of the ulnar artery, feed a series of dorsal and volar transverse arches that provide the extraosseous blood supply to the carpus.[15,20,21] A thorough analysis of the blood supply to the lunate was performed in a classic study by Gelberman and colleagues[15] Dorsally, 3 arches were found to contribute to the vascularity of the lunate. The dorsal radiocarpal arch was the most proximal and gave off nutrient vessels to the lunate and triquetrum. The dorsal intercarpal arch, traversing between the proximal and distal carpal rows, was the largest and most ubiquitous and supplied the distal carpal row, lunate, and triquetrum. The basal metacarpal arch was the most distal, smallest, and variably present. A similar pattern of volar arches was identified. The palmar radiocarpal and deep palmar arches were found to be present consistently, whereas the palmar intercarpal arch was only present in 53% of specimens and provided the smallest contribution. This system of longitudinal vessels communicating through transverse arches also supplies the distal radius, ulna, and metacarpal bones.[20,22] Taking advantage of this intricate structure, a variety of pedicled flaps can be designed to fit defects in the lunate.[23,24] The redundancy of this blood supply also facilitates safe anastomosis of free vascularized osteochondral flaps to recipient vessels.[21,25]

ROLE OF LUNATE REVASCULARIZATION IN THE TREATMENT OF KIENBÖCK DISEASE

Following the onset of osteonecrosis, a sequence of biologic events called “creeping substitution” is initiated, in which necrotic bone is resorbed and replaced by new bone.[26] This process is characterized by a relative predominance of osteoclast-mediated bone resorption compared with osteoblast-mediated bone formation.[4] As osteonecrosis progresses, the bone becomes vulnerable to subchondral fracture, precipitating irreversible degenerative changes. Nonvascularized bone grafts promote bone healing through this mechanism.[27] Contrastingly, vascularized bone flaps bypass the creeping substitution mechanism and are consolidated more rapidly with less resorption.[28,29]

Rationale for Vascularized Bone Flaps

The superiority of vascularized bone flaps over nonvascularized grafts has been demonstrated in animal models. Owing to similarities in the anatomy of the distal radius, canine models have been used to study osteonecrosis of the proximal pole of the scaphoid. Compared with nonvascularized grafts, reverse-flow vascularized pedicled flaps increased blood flow to the previously necrotic area and demonstrated higher levels of trabecular osteoblasts and osteoid on histologic analysis.[30,31] Hori and colleagues[32] demonstrated neovascularization and new bone formation after transplanting an isolated neurovascular bundle into the canine tibia. They subsequently described their successes with this technique in 9 cases of Kienböck disease; however, the purported salutary outcomes of vascular bundle implantation to the necrotic lunate have not been replicated.

The effects of free osseocartilaginous bone flaps on cartilage regeneration have also been studied. Articular cartilage is thought to rely primarily on synovial imbibition rather than intraosseous supply for blood flow. Higgins and colleagues[33] performed a study using pigs in which they implanted either nonvascularized or free vascularized osteochondral flaps into articular distal femur bone defects lined with methylmethacrylate cement to prevent communication between subchondral bone at the recipient site and the transplanted bone. After 6 months, the vascularized osteochondral flaps demonstrated superior cartilage surface quality and a greater percentage of viable chondrocytes. Although vascularized flaps formed new hyaline cartilage, the surface of nonvascularized grafts was composed of hyaline and fibrocartilage. Although treatments for Kienböck disease are generally meant to halt disease progression, vascularized bone flaps can potentially reverse changes caused by osteonecrosis and restore native functional anatomy.

Indications for Lunate Revascularization

With recent advances in revascularization techniques, salvage procedures should no longer be considered the only option for patients with advanced Kienböck disease. Vascularized pedicled bone flaps can be considered to replace necrotic subchondral bone any time the surrounding cartilage surface of the lunate is preserved. They can be used in conjunction with lunate unloading procedures to replace the existing bone loss and protect against future subchondral fractures due to radiocarpal contact. The indications for free vascularized osteochondral flaps are broader because they can be used to replace the degenerate proximal articular surface of the lunate in conjunction with an underlying bone defect. The use of pedicled and free vascularized bone flaps has been reported for Lichtman stages I through IIIC.[5] These techniques can also be used together with partial wrist fusions as an alternative to other salvage procedures.

EVALUATION OF OSTEONECROSIS OF THE LUNATE

As many patients with Kienböck disease are asymptomatic, the initial assessment must include a thorough clinical examination to rule out other causes of wrist symptoms. Patients typically present with unilateral progressive symptoms of insidious onset, characterized by dorsal, central wrist pain and swelling, and subtle decreases in wrist motion. Special attention should be paid to the duration of symptoms, as this has prognostic importance.[7–9] Standard wrist radiographs are the initial imaging modality of choice and the basis for the Lichtman classification.[34] Although radiographs are insensitive in early disease, lunate pathology may be detectable earlier than previously thought.[11] Osteonecrosis has a characteristic appearance with patchy densities and sclerosis, and making the diagnosis on radiographs may obviate the need for more costly advanced imaging.[35]

Role of Advanced Imaging Studies

Two advanced imaging modalities typically considered for preoperative evaluation of Kienböck disease are computed tomography (CT) and MRI. CT is useful in late disease for evaluating bone stock and subchondral fractures.[36] CT is also superior to other modalities for detecting specific lunate morphologies (ie, presence or absence of a medial hamate facet), which may have prognostic importance.[37] A recent study showed that the lunate width-to-height ratio measured on CT was a better predictor of carpal collapse than indices commonly measured on x-rays, such as ulnar variance and carpal height.[38] Careful preoperative evaluation of bony detail can be helpful in planning the site of bone graft harvest and estimating the amount of graft needed.

MRI is superior to other imaging modalities for the detection of early osteonecrosis.[35,39] T1-weighted images show a characteristic decrease in signal density thought to correspond to physiologic changes associated with creeping substitution. However, small areas of osteonecrosis may still be difficult to detect and T2-weighted images are often unremarkable. More importantly, the relevance of the MRI finding of avascularity to bone healing potential is not clearly defined.[40] Given these limitations, we recommend intraoperative evaluation of the carpal anatomy before proceeding with revascularization.

Role of Arthroscopy

Studies have called into question the reliability of radiographic classifications of Kienböck disease.[41,42] Imaging modalities fare particularly poorly in the assessment of articular cartilage of the carpus. Wrist arthroscopy has become the new standard for the assessment of articular surfaces of the lunate and the wrist.[43] Bain and Begg[44] developed an arthroscopic classification of Kienböck disease to guide surgical management based on the number of functional and nonfunctional articular surfaces surrounding the lunate. Functional articular surfaces were defined as smooth and glistening in appearance, whereas nonfunctional surfaces had degenerative changes such as synovitis, fraying, or fracture. They proposed a treatment algorithm based on these findings, and subsequent combined classifications and treatment algorithms based on similar principles have been developed.[45,46] Although arthroscopic classifications have their own shortcomings, the integrity of the lunate cartilage is central to determining the appropriate lunate revascularization procedure. Furthermore, arthroscopy can be used to assist or substitute certain open procedures, such as lunate decompression, limited wrist fusions, or proximal row carpectomy.[43]

TREATMENT OF KIENBÖCK DISEASE WITH LUNATE REVASCULARIZATION

The treatment of Kienböck disease with lunate revascularization can be divided into 2 categories of procedures. Vascularized bone flaps made up of corticocancellous bone can be used to reconstruct necrotic defects in the lunate, as long as an intact cartilage shell has been preserved.[47] These flaps are mostly pedicled, afforded by the redundant vascular anatomy of the carpus. Advantages of pedicled vascularized bone flaps include potential for rapid revascularization that bypasses the normal creeping substitution mechanism, using only one surgical incision with minimal donor site morbidity, and relative technical ease without need for microsurgery or articular reconstruction. The second category of lunate revascularization procedures requires reconstruction of subchondral and articular defects in the lunate using free osseocartilaginous flaps.

Pedicled Distal Radius Flaps

Use of a pedicled vascularized bone flap can be considered any time there is lunate bone loss with a preserved cartilage shell. Numerous pedicled vascularized bone flaps have been described based on the local anatomy of the hand and wrist.[22,23,47,48] The radial artery and AIA are the main feeding vessels to the dorsal distal radius and give off 4 main branches (**Fig. 1**). Each of these arteries is numbered based on its adjacent extensor tendon compartments, with the intracompartmental supraretinacular arteries (ICSRAs) traveling superficial to the extensor retinaculum and the extracompartmental arteries (ECAs) traveling deep along the floor of their extensor compartments. Owing to their radial location, flaps based on the 1,2 and 2,3 ICSRAs are commonly used in reconstruction of the proximal pole of the scaphoid. They can also be used in Kienböck disease, particularly the 2,3 ICSRA for its longer excursion.[49] Lunate revascularization with a pedicled pisiform flap has also been studied but is mostly of historical interest because of poor long-term outcomes.[50]

The 4,5 ECA flap has become a workhorse pedicled flap in Kienböck disease. It is often used in conjunction with a radial shortening osteotomy as a lunate unloading procedure in patients with ulnar negative wrists. The fourth ECA originates from the posterior division of the AIA, runs along the radial side of the floor of the fourth extensor compartment, and connects with the dorsal radiocarpal and intercarpal arches. The fifth ECA, which is the largest of the dorsal vessels, originates from the posterior division of the AIA and forms multiple anastomoses distally, including the fourth ECA. Although either the fourth or fifth ECAs can be used as pedicles on their own, incorporating both vessels increases the excursion of the pedicle considerably.[23]

One surgical technique we have done in patients with ulnar negative wrists and preserved lunate

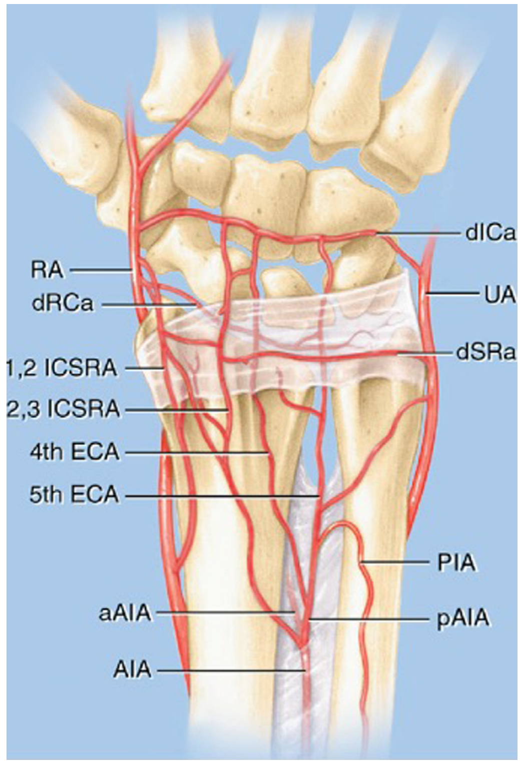

Fig. 1. Detailed anatomy of the dorsal distal radius demonstrating longitudinal feeding vessels (AIA, anterior interosseous artery; PIA, posterior interosseous artery; RA, radial artery; UA, ulnar artery) and communicating transverse arches (dICa, dorsal intercarpal arch; dRCa, dorsal radiocarpal arch; dSRa, dorsal supraretinacular arch). Four main vessel branches used for pedicled vascularized bone flaps are also shown (4th and 5th ECA, extracompartmental artery; 1,2 and 2,3 ICSRA, intracompartmental supraretinacular artery). aAIA and pAIA are anterior and posterior divisions of the anterior interosseous artery. (*From* Elhassan BT, Shin AY. Vascularized bone grafting for treatment of Kienböck disease. J Hand Surg Am. 2009;34(1):148; with permission)

articular cartilage is to use the 4,5 ECA flap in conjunction with a radial shortening osteotomy. Owing to the close proximity of the flap to the lunate, we do not typically inspect the lunate arthroscopically for this procedure. If arthroscopy is used, the 4,5 and ulnar midcarpal portals should be avoided because of the risk of injury to the fourth and fifth ECAs.[23] Instead, the 6U and 6R portals can be used as working portals, together with standard 3,4 and radial midcarpal viewing portals. Under a regional block with tourniquet control, we use a longitudinal midline incision made dorsally (**Fig. 2**A, B). Full-thickness skin flaps are elevated and a longitudinal or ligament-sparing arthrotomy is made over the carpus.[51] The lunate articular surface is inspected and the

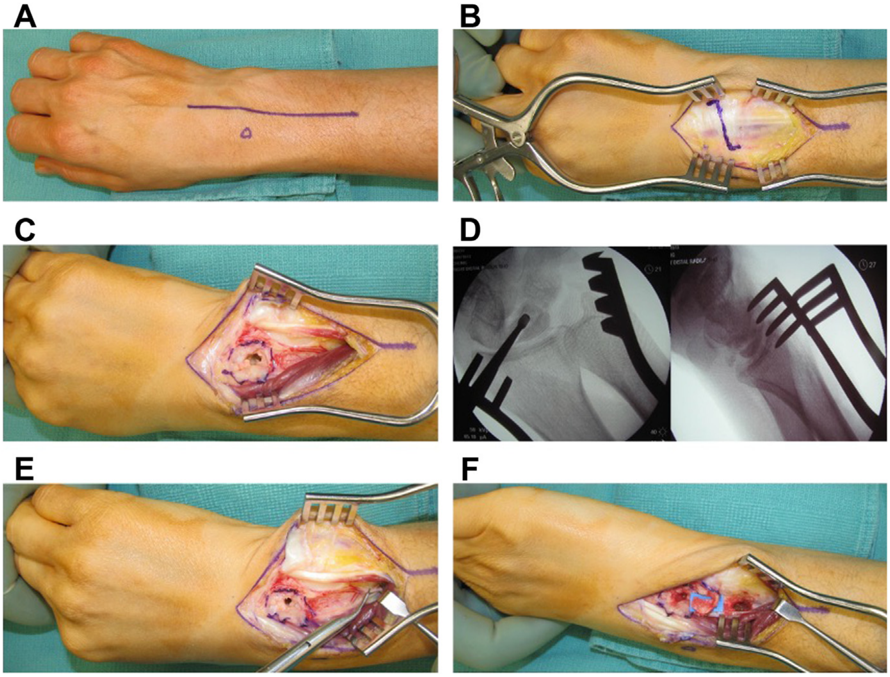

Fig. 2. Transfer of vascularized 4,5 extracompartmental artery bone flap to the lunate. (*A*) Dorsal skin incision. (*B*) Step-cut in extensor retinaculum during exposure of the dorsal wrist. (*C*) Exposure of the lunate (outlined) with core of necrotic bone removed. (*D*) Intraoperative fluoroscopic images of lunate. (*E*) Exposure and transection of posterior division of anterior interosseous artery with tenotomy scissors during flap harvest. (*F*) Pedicled flap harvest and transposition into lunate defect.

bone is probed for areas of necrosis. If the area of soft, necrotic bone is minimal, then a joint leveling procedure is performed without any further revascularization procedure. If there is necrotic bone, it is excised until a shell of cartilage and healthy cancellous bone remains (**Fig. 2**C, D). The articular shell can be gently expanded from the inside out if there is some collapse but preserved cartilage.

Once the size of the defect in the lunate has been measured, we proceed with the 4,5 ECA flap harvest (see **Fig. 2**B). The fifth ECA is identified on the floor of its extensor compartment while retracting the extensor digiti minimi tendon. The artery with its venae comitantes are traced proximally to their origin at the posterior division of the AIA. The fourth ECA branch is then identified and followed distally to its nutrient branches to the distal radius, usually 1-cm proximal to the articular surface (**Fig. 2**E). Osteotomes are then used to harvest a corticocancellous graft of the appropriate size. Once the bone flap has been elevated from the distal radius, the posterior branch of the AIA is ligated just proximal to where it divides into the fourth and fifth ECA. Retrograde arterial flow is obtained through the larger fifth ECA, with antegrade flow through the fourth ECA. The bone flap is mobilized and inset into the lunate defect (**Fig. 2**F). The flap is oriented in such a way that the cortical surface is dorsal and can serve as a strut.

Favorable outcomes have been reported using vascularized distal radius pedicled flaps in Lichtman stage II-IIIB disease. Moran and colleagues[52] followed 26 patients for a mean of 31 months and found that the 4,5 ECA flap provided reliable improvement in pain, patient-reported outcomes, and grip strength (from 50% to 89% of the unaffected side), with preserved range of motion. Radiographic outcomes were also favorable, as 77% of patients showed no further evidence of lunate collapse, and 71% of patients with follow-up MRIs showed evidence of revascularization. In a recent study, Hegazy and colleagues[53] evaluated 21 patients with Lichtman stage II disease and 24 patients with stage IIIA disease. For each group, roughly half of the patients underwent revascularization with a 4,5 ECA flap and lunate unloading with a capitate shortening osteotomy, whereas the other half underwent lunate unloading only. Although outcomes were equivalent for the 2 procedures in patients with stage II disease, patients with stage IIIA disease who underwent the combined treatment had significantly better range of motion, grip strength, and patient-reported

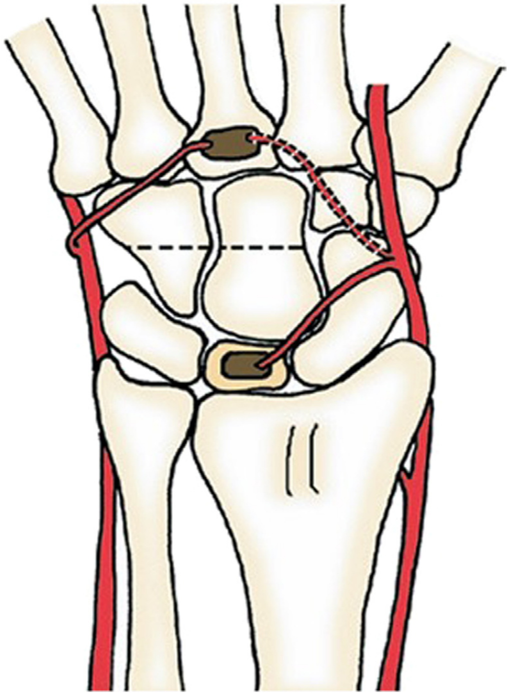

Fig. 3. Simplified schematic of third metacarpal base vascularized flap transfer. The pedicle is based on a dorsal metacarpal artery branch from the radial artery and the corticocancellous flap is set into the defect in the necrotic lunate. (*From* Waitayawinyu T, Chin SH, Luria S, Trumble TE. Capitate shortening osteotomy with vascularized bone grafting for the treatment of Kienböck disease in the ulnar positive wrist. J Hand Surg Am. 2008;33(8):1270; with permission).

outcomes. In these patients, the rate of failure for the combined procedure was 8%, compared with 28% when using the capitate-shortening osteotomy alone. Unfortunately, there remains a paucity of comparative outcomes in the literature to guide management.

Pedicled Proximal Metacarpal Flaps

Pedicled vascularized bone flaps from the metacarpal bases capitalize on the redundant circulation on the dorsum of the hand. The basal metacarpal arch gives off branches to the metacarpal bases via dorsal metacarpal arteries.[54,55] The arteries to the first and second metacarpal bases are more reliably present than branches to the ulnar metacarpals (**Fig. 3**). We use flaps based on the second or third dorsal metacarpal arteries in patients with ulnar positive wrists in conjunction with a capitate shortening osteotomy or capitohamate fusion for joint unloading (**Fig. 4**A). Because the bone harvest and the easier capitate shortening procedure are within the same wrist incision, this technique has become our preferred procedure in unloading the lunate and in revascularizing this bone.

Under a regional block with tourniquet control, we use a longitudinal midline incision made dorsally.[56] Extensor pollicis longus is transposed from the third extensor compartment and a capsulotomy is made between the second and fourth compartments. The lunate is inspected, debrided of necrotic bone, and contoured as described earlier. The size of the bone defect is measured. We typically perform a capitate shortening osteotomy before harvesting the bone graft (**Fig. 4**B). Often the capitate and hamate are strongly tethered and need to be shortened to maintain congruity between the proximal and distal carpal rows. The bone fragments can be fused using K-wires or a compression screw in the capitate. The corticocancellous graft from the base of the metacarpal is then harvested and inset (**Fig. 4**C). The second and third dorsal metacarpal artery pedicles have enough excursion from the basal metacarpal arch to be used as retrograde flow vascularized flaps to the lunate.

Waitayawinyu and colleagues[24] studied 14 patients with ulnar positive wrists and Lichtman stage II-IIIA disease who underwent concomitant capitate-shortening procedures and lunate revascularization with a pedicled flap from the third metacarpal base. With a follow-up of 26 to 65 months, they demonstrated significant improvements in grip strength and satisfaction scores, while wrist range of motion was maintained despite the partial fusion procedure. Thirteen patients returned to their previous occupation and 12 returned to their previous level of function. Studies have obtained similar findings with follow-up of 10 years or more, showing equivalent results to distal radius pedicled flaps.[49,57]

Free Femoral Trochlea Flaps

The most extensively studied osseocartilaginous transfer technique uses a free vascularized flap from the medial femoral trochlea (MFT).[58,59] Its advent has greatly expanded the indications for lunate revascularization by transplanting vascularized bone together with healthy articular cartilage. This technique is indicated for lunate bone loss together with disruption of its proximal articular surface, and can be used in conjunction with unloading procedures or partial wrist fusions. It offers a much needed alternative to wrist salvage for young patients with advanced Kienböck disease. For patients older than 50 years, a proximal row carpectomy is still our preferred option given the ease of bone removal and the relative longevity

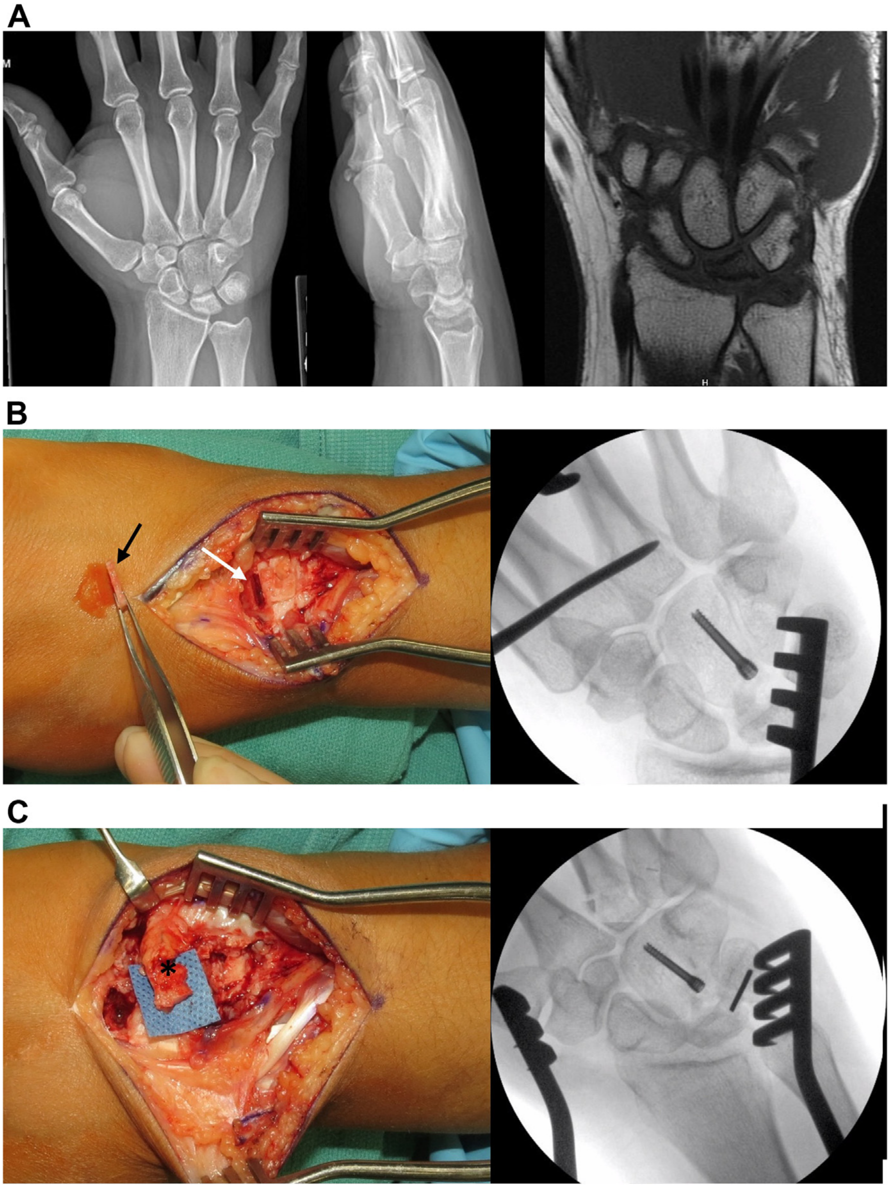

Fig. 4. Transfer of vascularized third metacarpal base flap into the lunate and capitate-shortening osteotomy. (*A*) Radiographs and MRI of a patient with Kienböck disease and an ulnar neutral wrist. (*B*) Intraoperative photograph of capitate osteotomy (*white arrow*) with removal of a wedge of bone (*black arrow*) and fluoroscopic image of fixation with a compression screw. (*C*) Intraoperative photograph of metacarpal flap harvest on its pedicle (*) and fluoroscopic image of fixation to the lunate with a Kirschner wire.

of this procedure. The main drawback of the free vascularized bone flap is that it is technically challenging, requiring consideration of the shape of the articular contour to be restored as well as microsurgical expertise. Donor site morbidity in harvesting a flap from the knee and the prolonged recovery process should be weighed carefully when considering the risks and benefits of surgery with the patient.[60–62] Salvage procedures such as proximal row carpectomy, wrist fusion, or total wrist arthroplasty may still be necessary at a later time if intractable pain occurs persists despite attempting to preserve the lunate.

The MFT flap requires an understanding of the local anatomy in the knee, which has been well described in the literature. The flap is based on branches of the dorsal geniculate artery (DGA) from the superficial femoral artery.[63] Notable branches from the DGA include the saphenous artery branch and dorsal cutaneous branch

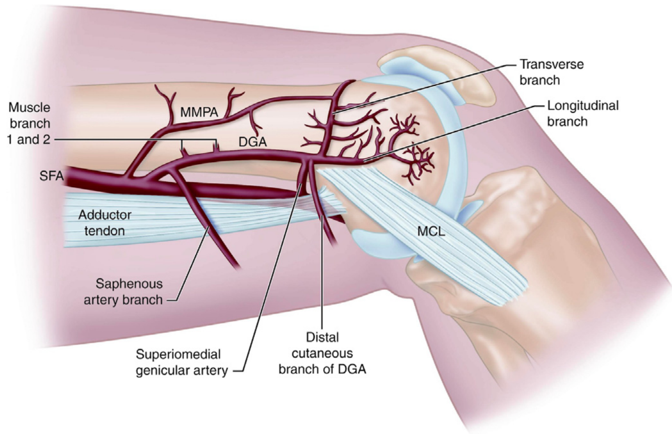

Fig. 5. Schematic of vascular anatomy of the medial femoral condyle. DGA, descending genicular artery; MCL, medial collateral ligament; MMPA, medial metaphyseal periosteal artery; SFA, superficial femoral artery. (*From* Iorio ML, Masden DL, Higgins JP. Cutaneous angiosome territory of the medial femoral condyle osteocutaneous flap. J Hand Surg Am. 2012;37(5):1034; with permission)

proximally, which can be used to elevate a skin paddle together with the osteochondral flap. Distally, the DGA gives off a transverse branch and a longitudinal branch that travel along the periosteum to the medial femoral condyle (**Fig. 5**). These have terminal branches that provide blood flow to the subchondral surface. Owing to the articular shape of the femoral condyle at the end points for these branches, the transverse branch is the pedicle of choice for osteochondral reconstruction of the lunate or scaphoid proximal pole, whereas the longitudinal branch is typically used when harvesting a vascularized bone flap without a chondral segment (ie, reconstruction of scaphoid waist nonunions).[58,64] The pedicle can be harvested as proximally as the origin of the DGA, resulting in a length of up to 8 cm.

When preparing to use the MFT flap for Kienböck disease, we perform an open or arthroscopic examination of the wrist to confirm the erosion of proximal lunate articular cartilage and subchondral bone loss. We also examine the lunocapitate articulation to ensure that these cartilage surfaces are preserved (**Fig. 7**A, B). During the procedure, 2 teams work simultaneously in the operating room. The patient is positioned supine under general anesthesia supplemented by regional blocks. The affected arm and ipsilateral leg are exsanguinated and tourniquets are inflated. A curving longitudinal incision is centered midway between the medial border of the patella and the medial epicondyle of the knee. The vastus medialis is elevated anteriorly in the subfascial plane. This brings the DGA into view, which is followed along the periosteum to the medial knee. The transverse branch is identified by its anteriorly directed path to the articular surface of the MFT (**Fig. 6**A).

At the same time, the second team exposes the lunate through a midline dorsal exposure, as discussed earlier. Subtotal resection of the necrotic lunate and proximal articular cartilage is performed. The size of the defect in the lunate is

A

B

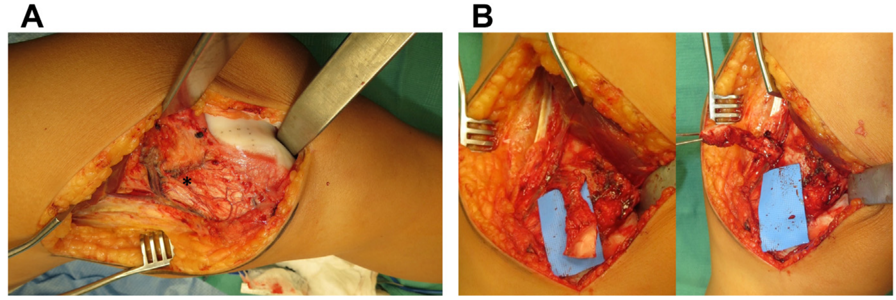

Fig. 6. Transfer of free vascularized medial femoral trochlea flap to the lunate. (*A*) Radiographs and MRI of a patient with Kienböck disease and disruption of the proximal lunate articulation. (*B*) Intraoperative photograph of preserved capitatolunate joint. (*C*) Detached radial artery branch to the first dorsal interosseous (*white arrow*) and adjacent lunate defect outlined. (*D*) Microscopic anastomosis of transverse branch of dorsal geniculate artery (*) and its 2 venae comitantes to the recipient vessels. (*E*) Intraoperative fluoroscopic image after inset of the flap into the lunate defect.

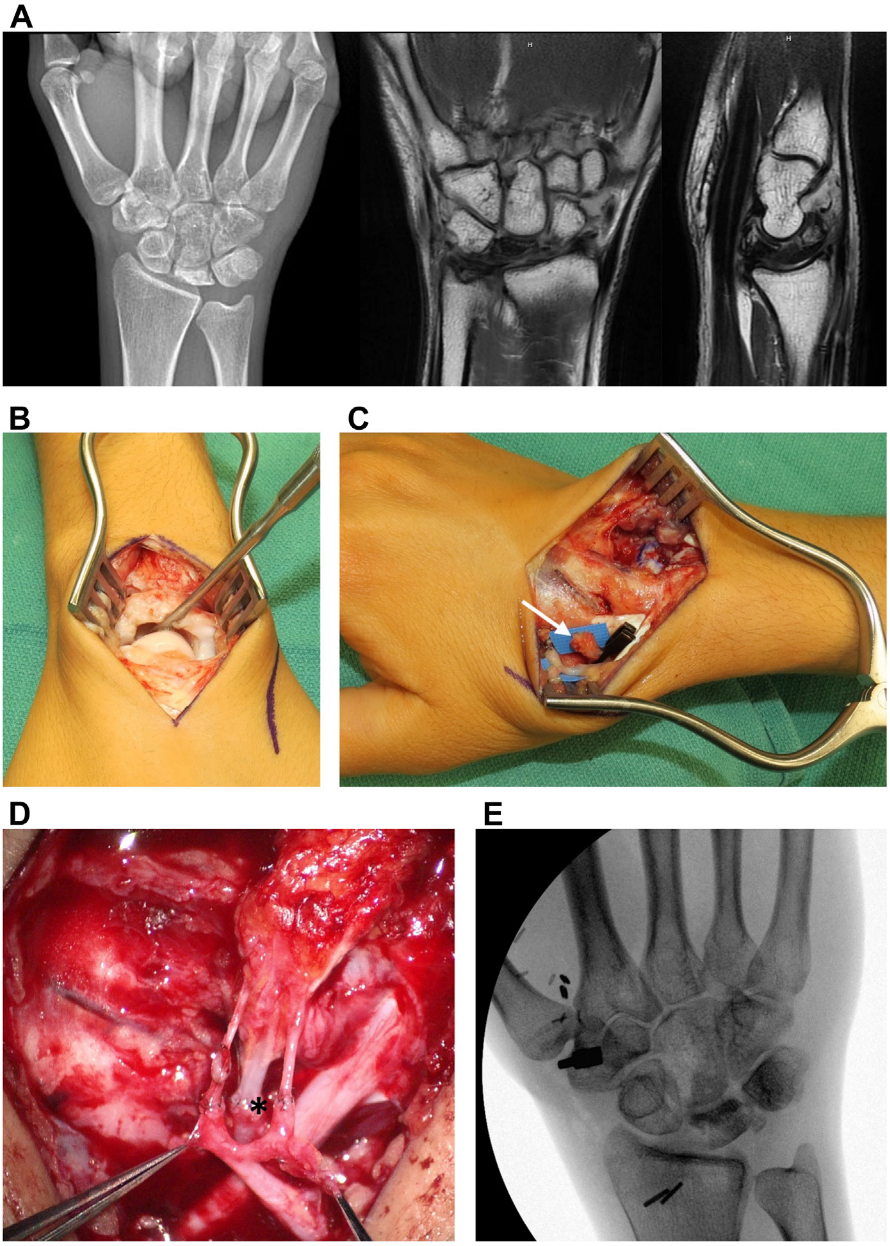

Fig. 7. Harvest of free vascularized medial femoral trochlea osseocartilaginous flap. (*A*) Photograph of the exposed medial femoral condyle, including the transverse branch (*) of the descending genicular artery and the outlined flap donor site. (*B*) Elevation of the osseocartilaginous flap on its pedicle.

measured in 3 dimensions and a marker is used to draw a templated flap onto the articular surface of the MFT. The osseocartilaginous flap and its pedicle, including the transverse arterial branch of the DGA and its 2 venae comitantes, are then harvested (Fig. 6B). We typically harvest as much of the DGA as possible in case additional length is needed. We inset the flap in the lunate defect and, under the microscope, perform an end-to-end arterial anastomosis with a terminal branch of the radial artery to the first dorsal interosseous muscle (Fig. 7C–E). We also perform anastomoses of the 2 venae comitantes to terminal branches of the cephalic vein. These vessels can all be accessed through the same dorsal incision used to expose the lunate. Finally, we use 1 or 2 screws to obtain fixation between the distal pole of the lunate and the MFT flap.

Several studies have demonstrated successful outcomes of lunate revascularization with the free

MFT flap. In a series of 16 patients with Lichtman stage II-IIIB disease followed for 12 to 34 months, Bürger and colleagues[58] showed radiographic healing and improved pain in all but 1 patient. Grip strength was improved to 85% of the contralateral side and range of motion was preserved. Lichtman stage remained stable in 10 patients, improved in 4, and worsened in 2. In a recent study, 23 patients with Lichtman stage IIIA-C Kienböck disease underwent lunate revascularization with a free osseocartilaginous flap harvested from the lateral femoral trochlea (LFT).[65] The pedicle of this flap is based on the superior lateral geniculate artery located under the iliotibial band.[66] Using this novel flap, Windhofer and colleagues[65] were able to closely match the contour of the articular defect in the lunate. At a mean follow-up of 34 months, 18 of 23 grafts were consolidated and patients demonstrated improved patient-reported outcomes with preserved range of motion, grip and pinch strength. Lichtman stage remained stable or improved in all but 2 patients. Although the specific indications for the LFT flap remain to be determined, the elucidation of alternative articular surfaces amenable to free flap harvest promises to revolutionize our approach to lunate revascularization in the future.

CLINICS CARE POINTS: KEY TECHNICAL PEARLS AND PITFALLS

- Always assess the bone quality and cartilage of the lunate before proceeding with a revascularization procedure, with either an open or arthroscopic technique.
- Evaluation of the ulnar variance can be helpful in deciding on the optimal pedicled bone flap based on the location of additional procedures for lunate unloading.
- Using a dorsal distal radius flap based on the fourth and fifth ECAs maximizes excursion compared with flaps based on the fourth ECA alone.
- The second metacarpal base has a larger and more consistent dorsal metacarpal artery than the third metacarpal base. However, the flap site with enough excursion to reach the lunate should be selected.
- The free MFT flap should be based on the transverse branch of the DGA. The articular site supplied by this branch closely approximates the contour of the proximal lunate articulation.

SUMMARY

Although the concept of lunate revascularization is not new, it has emerged as the promising next frontier in the treatment of Kienböck disease over the past decade. Of the many treatment options for this debilitating and still poorly understood disorder, revascularization procedures provide the most direct mechanism for reversing the pathologic process of osteonecrosis and restoring functional anatomy. Numerous pedicled bone flaps provide a reliable treatment for early disease and free vascularized flaps can be used in lieu of salvage operations for more advanced cases involving cartilage loss. The discovery of alternative free osseocartilaginous flap options may even further expand the indications for this technique in the future. Although recently developed techniques are promising, there is still a paucity of published research on their outcomes, and larger comparative studies are needed. Given the rarity of Kienböck disease, what is lacking in the literature to date is a prospective, collaborative, multicenter approach to determining the optimal surgical treatments for different stages of disease.

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