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Reconstruction of scaphoid non-union and total scaphoid avascular necrosis in a pediatric patient: a case report

Oded Ben-Amotz · Christine Ho · Douglas M. Sammer

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Abstract
Background The medial femoral condyle vascularized bone graft has grown in popularity for treating recalcitrant fracture non-unions and has become particularly useful in treating scaphoid non-union with avascular necrosis of the proximal pole. The medial femoral condyle is an excellent source of dense, well-vascularized bone and results in minimal donor site morbidity.
Methods We describe an unusual case of chronic scaphoid non-union and total scaphoid avascular necrosis in a skeletally immature patient. Scaphoid reconstruction was performed with a vascularized medial femoral condyle graft, with successful graft incorporation, and restoration of pain-free wrist motion.
Conclusions Technical considerations for harvest of the medial femoral condyle bone graft in the skeletally immature patient are discussed.

Introduction

The vascularized medial femoral condyle (MFC) bone graft was initially described by Hertel and Masquelte as a pedicled flap based on the branches of the descending genicular artery [18]. Sakai et al. [37] subsequently advanced the concept of a free vascularized MFC graft. The free vascularized MFC graft can be harvested in two different ways, depending on the requirements of the recipient site. It can be harvested as a thin, pliable flap of corticoperiosteal tissue that can be wrapped around non-union sites in long bones [1, 4, 5, 8, 13, 16, 26, 33]. Alternatively, it can be harvested as a structural corticocancellous graft and interposed in non-union sites or in small segmental osseous defects [7, 15, 21, 23, 28, 29, 32, 38]. Because of its versatility, relatively straight-forward harvest, and minimal donor site morbidity [1, 34], it has become an established treatment option for recalcitrant non-unions.

The scaphoid is the most commonly fractured carpal bone and is prone to non-union and avascular necrosis (AVN), particularly when the fracture involves the proximal pole [2, 3, 6, 9, 11, 17, 30, 31, 36, 40]. Only a few cases of distal pole AVN or total scaphoid AVN have been reported [10, 20, 27, 39]. We present a case of chronic scaphoid non-union with total scaphoid AVN in a skeletally immature patient, treated successfully with a free vascularized MFC graft.

O. Ben-Amotz · D. M. Sammer (✉)
Department of Plastic Surgery, University of Texas Southwestern Medical Center at Dallas, 1801 Inwood Rd., Dallas, TX 75390, USA
e-mail: Douglas.Sammer@UTSouthwestern.edu

C. Ho
Department of Orthopedic Surgery, Texas Scottish Rite Hospital for Children-Children's Medical Center of Dallas, University of Texas Southwestern Medical Center, Dallas, TX, USA

Case Report

History

A 17-year-old, right-hand-dominant healthy male sustained a left wrist injury at 11 years of age. The patient did not present for medical treatment until 6 years after his initial injury. At that initial clinic visit, he complained of wrist stiffness, as well as constant, persistent pain that occurred with wrist flexion, limiting his ability to perform manual tasks and participate in sports. Plain radiographs confirmed scaphoid non-union with cystic changes and sclerosis in both poles consistent with avascular necrosis (Fig. 1). Computed tomography (CT) scan demonstrated severe humpback deformity and scaphoid collapse. Pre-operative magnetic resonance imaging (MRI) demonstrated near-complete avascular necrosis of the scaphoid, involving the proximal and distal poles (Fig. 2).

Fig. 1 PA and lateral radiographs demonstrating scaphoid non-union and humpback deformity

Operation

A two-team approach was used. Under tourniquet control, a volar approach to the scaphoid was performed, and the non-union site was visualized. The wrist was flexed, bringing the extended lunate into neutral alignment with the radius, and then, a temporary radio-lunate transfixing 0.062-in. Kirschner wire was placed to hold the lunate and proximal pole of the scaphoid in reduction. The wrist was brought back into neutral flexion-extension, opening the non-union site. The non-union was debrided with an oscillating saw. Both poles appeared necrotic and sclerotic, and there was no punctate bleeding from the distal or proximal pole. A curette was used to debride as much necrotic bone as possible, leaving only as much bone intact as required for fixation. The residual segmental defect measured 1.5 cm in length. Next, the radial artery and venae comitantes were dissected in the distal forearm.

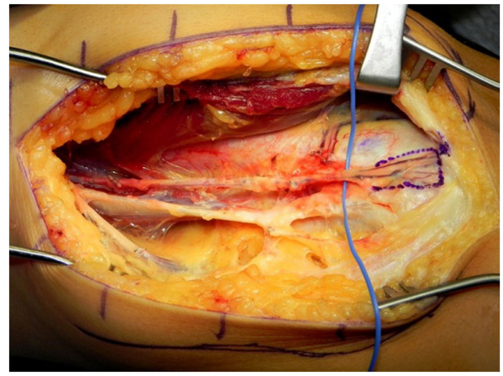

Fig. 3 The usual circular vascular pattern was identified within the periosteum, with the largest concentration of nutrient vessels typically present in the distal and posterior quadrants

Simultaneously, the vascularized MFC bone graft was harvested from the ipsilateral lower limb. Under tourniquet control, a longitudinal incision was made in the distal third of the medial thigh, in-line with the femur, and extending over the MFC. The fascia overlying the vastus medialis was divided, and the plane between the vastus medialis and adductor magnus was developed. The descending genicular artery and venae comitantes were identified. The vessels were dissected proximally to the adductor hiatus, and distally to the MFC. The saphenous branch and muscle branches were ligated and divided. At the MFC, the usual circular vascular pattern was identified within the periosteum, with the largest concentration of vessels appearing in the distal-posterior quadrant (Fig. 3). A 1.5 cm×1.0 cm bone graft was marked out in this region, and the periosteum was sharply divided along three margins of the graft, leaving periosteum intact on the side where the pedicle entered the graft. Care was taken to design the graft proximal to the distal femoral physis. Using an osteotome and a sagittal saw, the bone graft was elevated and mobilized, with dimensions of 1.5 cm×1.0 cm×1.0 cm. The graft bled readily while attached only to its pedicle

Fig. 2 Pre-operative coronal T1 and coronal post-contrast T1 magnetic resonance imaging (MRI), demonstrating complete avascular necrosis of the scaphoid, involving the proximal and distal poles

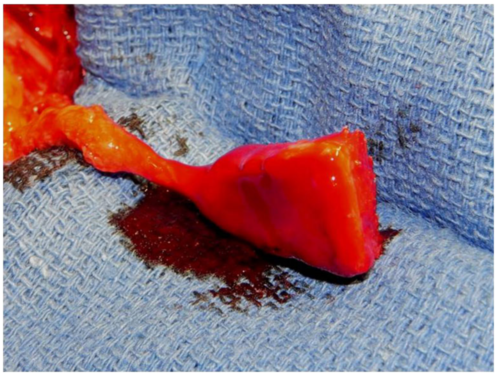

Fig. 4 The graft bled readily after harvest, prior to division of its pedicle

(Fig. 4). The pedicle was then divided, and the graft transferred to the recipient site at the wrist.

After minor contouring of the bone graft, it was placed into the prepared scaphoid non-union site, with the periosteum and pedicle facing volarly. A guidewire was advanced retrograde across the scaphoid, and its position was confirmed with fluoroscopy. A second temporary derotational guidewire was also placed eccentrically in the scaphoid to prevent rotation during insertion of the screw. After drilling over the guidewire with a cannulated drill, a 2.4-mm-diameter cannulated headless compression screw (DePuy Synthes, West Chester, PA) was then advanced retrograde, transfixing the distal pole, intercalated graft, and proximal pole with good compression. Fluoroscopy was used to evaluate scaphoid reduction, graft position, and screw position and length. Next, an end-to-end anastomosis of one of the recipient and donor venae comitantes was performed. The remaining recipient and donor venae comitantes were ligated. The descending genicular artery was anastomosed end-to-side to the radial artery. All anastomoses were performed under the operating microscope and hand-sewn using 9-0 and 10-0 nylon sutures. After clamp and tourniquet release, there was good flow across both anastomoses, with periosteal bleeding at the bone graft.

Post-operative Course

Post-operatively, the patient's scaphoid reconstruction was protected with a thumb spica cast until complete union had occurred. At 2 ½months, the graft had fully incorporated and united both distally and proximally on plain radiographs. At 8 months, the patient had returned to full activity, with complete resolution of pain. His wrist had 70° of active wrist flexion (passive wrist flexion to 90°), 70° of wrist-extension, 90° of pronation, 90° of supination, 40° of ulnar deviation, and 30° of radial deviation. The scaphoid remained fully healed on radiographs with good incorporation of the graft (Fig. 5).

Discussion

Due to its limited retrograde blood supply, the scaphoid is prone to fracture non-union. Reported non-union rates range from 5 to 50 % of scaphoid fractures [2, 6, 9, 17, 30, 31, 36, 40]. Proximal pole AVN complicates 13 to 50 % of scaphoid fractures, depending upon fracture location, with an increased incidence when the fracture is located in the proximal pole [3, 11, 17, 40]. Fracture non-union with secondary AVN is a challenging problem that requires the transfer of vascularized bone for the best chance of achieving successful union. The free vascularized MFC bone graft has become a popular choice due to its reliable anatomy, ease of dissection, and minimal donor site morbidity. It is particularly useful in the presence of humpback deformity, because a large quantity of dense, vascularized structural bone can be harvested [12, 14, 22, 25].

In this case, both the proximal and distal poles had developed AVN. Although AVN is typically isolated to the proximal pole when it occurs after a scaphoid fracture, there are

Fig. 5 Lateral and ulnar deviation radiographs obtained at 8 months post-operatively demonstrating the fully incorporated bone graft

three reports in the literature that describe AVN of the distal scaphoid pole [10, 27, 39]. In addition, there is a single report of scaphoid AVN involving both the proximal and distal poles [20], as was the case in our patient. In this scenario, a reasonable option would be to perform a salvage operation such as scaphoid excision and four-corner arthrodesis. However, given the patient's young age, it was felt that an effort to reconstruct the scaphoid was warranted.

Elevating a vascularized MFC bone graft in a skeletally immature patient introduces a unique technical consideration. It is important to design the bone graft so that its harvest does not damage the distal femoral physis. The nutrient vessels of the MFC graft are consistently supplied by the descending genicular artery in 89 % of patients, and by the superomedial genicular artery, which is found in 100 % of patients. Both vessels typically feed the circular vasculature within the periosteum on the medial side of the femoral condyle. The nutrient vessels arise from this vasculature and perforate the cortex to supply the bone of the condyle. The nutrient vessels are the greatest in number in the posterior distal quadrant of the condyle [19, 24, 35, 41, 42]. Although this quadrant is typically the best location for designing the bone graft due to the number and density of nutrient vessels, the surgeon should adjust the donor site as needed in order to avoid physeal injury. If the location of the physis is not clear, intraoperative fluoroscopy can be used to confirm its location.

In summary, this case represents a rare instance of complete scaphoid AVN in the setting of chronic fracture non-union. It illustrates the utility of the vascularized MFC bone graft in reconstructing avascular non-unions and emphasizes the technical points associated with performing the vascularized MFC bone graft in skeletally immature patients.

Conflict of Interest Oded Ben-Amotz declares that he has no conflict of interest.

Christine Ho declares that she has no conflict of interest.

Douglas Michael Sammer declares that he has no conflict of interest.

Statement of Human and Animal Rights All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 [1]. Informed consent was obtained from all patients for being included in the study.

Statement of Informed Consent Written informed consent was obtained from the subject of the case report.

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