New Surgical Approach to Advanced Kienböck Disease: Lunate Replacement With Pedicled Vascularized Scaphoid Graft and Radioscaphoidal Partial Arthrodesis

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Abstract: Reconstructive procedures such as proximal row carpectomy or partial arthrodesis have been commonly proposed for advanced Kienböck disease (Lichtmann IIIB to IV). The purpose of this study is to evaluate an alternative surgical technique to advanced Kienböck disease: lunate excision and replacement with pedicled vascularized scaphoid graft and partial radioscaphoidal arthrodesis. The main advantage of the proposed intervention is to preserve mobility while not jeopardizing prime clinical outcomes such as pain. By replacing the devitalized lunate we aim at maintaining midcarpal range of motion, and preventing disease progression with carpal collapse and osteoarthritis of the wrist. Between 2002 and 2008, 13 patients of mean age 41 years (range, 25 to 57 y) were operated using this technique. The surgical act included 3 key steps. First, we excised the lunate, then, filled the generated gap with the rotated scaphoid, using it as a pedicled vascularized autograft. Finally, we performed a partial radioscaphoid arthrodesis. At the final follow-up, none of the intervened patients had pain at rest, and 6 patients could perform nonrestricted daily activities. The average postoperative range of motion in flexion/extension was 70 degrees (range, 55 to 90 degrees), 44% (range, 38% to 54%) of what could be achieved by the contralateral arm, and only 16% (range, 14% to 19%) or 25 degrees (range, 18 to 30 degrees) less than the preoperative range of motion of the same wrist. Grip strength improved by more than 30% (range, 24% to 36%). At an average follow-up of 4 years after surgery, 12 of 13 patients had no radiographic evidence of osteoarthritis or collapse of subchondral bone at the level of the new scaphocapitate joint. At follow-up evaluation, the average DASH score was 14 points (range, 6 to 20). The patients experienced a significant improvement in their functional abilities, achieving good results compared with the conventional techniques. The absence of carpal collapse and good functional results are encouraging.

Key Words: Kienböck disease, vascularized transfers, carpal scaphoid

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Avascular necrosis of the lunate bone, also termed Kienböck disease (KD), was first described by Robert Kienbock, a radiologist from Austria, in 1910. The precise etiology of this lunate avascular necrosis, has been a source of controversy ever since. No single factor has been solely implicated, and the pathogenesis seems to emanate from a combination of predisposing or risk factors and a triggering element.[1]

The goals of surgical procedures in KD are to avoid progression of the disease and pain relief, trying to maintain wrist function and wrist kinematics as normal as possible. Since KD was first described, several treatment options with specific sets of advantages and disadvantages have been described to treat advanced stages of KD. The goals of surgical procedures in KD are to preserve wrist function, maintain normal wrist kinematics, and pain relief, when possible. Surgical approach is either a reconstructive or salvage procedure. The treatment of advanced stages, however, remains a challenge in hand surgery, because carpal alignment is disrupted and the revascularization capacity of the collapsed lunate is scarce. Reconstruction in these cases is often not possible, and the only options left are salvage procedures such as proximal row carpectomy,[2] intercarpal arthrodesis,[3] total wrist arthroplasty, or total wrist fusion.

The purpose of our study is to describe a new approach to advanced KD, namely, the replacement of the lunate with a pedicled vascularized carpal scaphoid graft, and radioscaphoidal partial arthrodesis. This grafting would take advantage of a congruent morphologic adaptation of the articular surface between the scaphoid and the capitate. On the basis of specimen observation, we have found that scaphocapitate joint is almost spherical in most of the cases. Our thought was that, if we transpose the scaphoid proximally and ulnarly, the congruence would be maintained. Mostly in those cases in which the head of the capitate had a pure spherical shape. In the anatomy laboratory, we found that rotating the scaphoid was associated to a more stable construct than compared with just an ulnar translation. The exact place to locate the scaphoid once translated is determined by the creation of the most stable and congruent new scaphocapitate joint.

Also, this vascularized osteochondral transfer would improve the local biological environment and thereby promote revascularization. In summary, the proposed technique offers a conservative alternative to the treatment advanced KD by creating a new articulation between scaphoid and capitate and preserving the midcarpal joint mobility and bone stock.

Patients were properly informed about the surgical act, its rationale, and its possible complications. They consented accordingly. To perform the study, we do not require approval by the Institutional Review Board or Ethics Board, as this study is a retrospective compilation of results obtained by a surgical technique.

INDICATIONS AND CONTRAINDICATIONS

This vascularized transfer is indicated for KD stage IIIB and IV (Lichtman classification). Previous surgery with exposure of the extensor retinaculum is a relative contraindication for this

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procedure due to the potential damage to the dorsal radius blood supply. Other contraindications include patients with previous fracture of the scaphoid or capitate, Preiser disease and patients with osteoarthritic changes in the midcarpal joint. Patient age and smoking were not considered contraindications.

PATIENTS

Between 2002 and 2008, 13 patients of mean age of 41 years (range, 25 to 57 y) were operated by a single surgeon using this technique. Of these patients 5 were men and 8 were women. The right wrist was involved in 9 patients (dominant site in 8 of these) and the left hand was treated in 4 (dominant site in 1) patients. All patients presented radiologic stages IIIB and IV (stage IIIB: 3 patients; stage IV: 10 patients) based on the Lichtman classification. Mean follow-up was 48 months (36 to 65 mo). The articular midcarpal surface of the scaphoid and capitate was preserved in all cases.

Patients were evaluated using the DASH questionnaire. Pain, satisfaction level, range of motion (ROM), and grip strength were also recorded. The patients were asked about their resumption of professional and recreational activities. Profession was divided into 3 groups, based on the manual requirements. Four patients were heavy manual worker (laborer, butcher, carpenter…); 5 patients were regular manual worker (driver, cook…); and the remaining 4 patients had low manual requirements (clerk…). These measurements were done by a single reviewer, who was not the main surgeon.

Pain intensity was scored as painless, pain with activity of daily living, or constant pain. The ROM of the wrist measured with a goniometer in degrees of flexion, degrees of extension, degrees of ulnar deflection, and degrees of radial deflection both before and after the vascularized scaphoid transposition. Grip strength was evaluated using a Jamar dynamometer (Sammons Preston Inc., Bollingbrook, IL). These measurements were done by a single reviewer, who was not the main surgeon. Functional condition was divided into (a) able to work, but unemployed; (b) resumption of usual employment; (c) resumption of usual employment with limitations; and (d) unable to work.

X-rays were performed to check for reduction in carpal height (central), sclerotic changes, fragmentation of the lunate and scaphoid, and to stage KD according to Lichtman classification. Carpal alignment was determined using the following parameters before surgery and at follow-up evaluation: Youm carpal height index[4] (length of third metacarpal/carpal height) and Nattrass index[5] (carpal height/length of capitate). The following features were analyzed on preoperative and follow-up x-rays to evaluate the grade osteoarthritis: radiographic evidence of arthritis at the scaphostyloid, scaphoradial, scapho-trapezium-trapezoid, lunocapitate, radiolunate, and lunotriquetral joints and wrist arthritis grade (grade 1: slight narrowing of the joint space of 1 joint; grade 2: moderate narrowing or involvement of >1 joint; grade 3: osteophytes, subchondral sclerosis, cysts; grade 4: arthritis including the midcarpal joint).

Magnetic resonance imaging (MRI) studies with gadolinium were performed on the coronal, sagittal, and axial planes with a Magneton Impact (Signa, General Electric Medical Systems, Wilwaukee, WI). Postoperative MRI multiplanar findings were evaluated and the signal intensity of the scaphoid was recorded. These MRI findings were compared with those performed 6 months after surgery, and imaging quality was not affected by the osteosynthesis titanium material.

All radiographic assessments and measurements were performed by a single investigator, blinded to the clinical results.

SURGICAL TECHNIQUE

The technique consists of a 3-staged surgical act: excision of the necrosed lunate, its substitution by the scaphoid vascularized pedicled osteochondral autograft, and finally a partial radioscaphoid arthrodesis.

Before the incision, the arm was elevated and exsanguinated from the wrist down to enable visualization of the vessels. The surgery was performed under brachial anesthesia

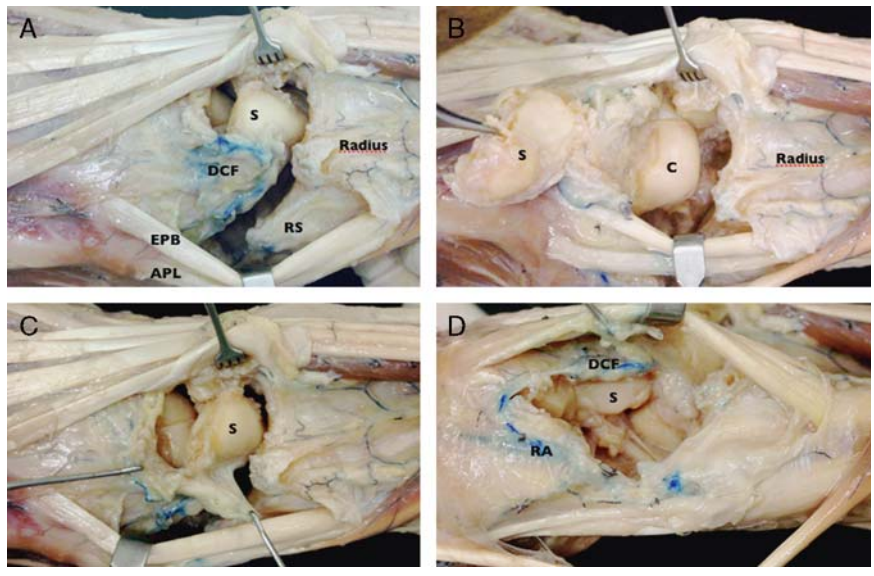

FIGURE 1. A–D, The dorsal capsular flap with the scaphoid in a fresh cadaver dissection. The relative technical ease of harvest, the reliable nutrient vessel blood supply, the long pedicle length, and the single exposure for both harvest and insetting have all made the use of this technique attractive. APL indicates abductor pollicis longus; C, capitate; DCF, dorsal capsular flap; EPB, extensor pollicis brevis; RS, radial styloid; RA, radial artery; S, scaphoid.

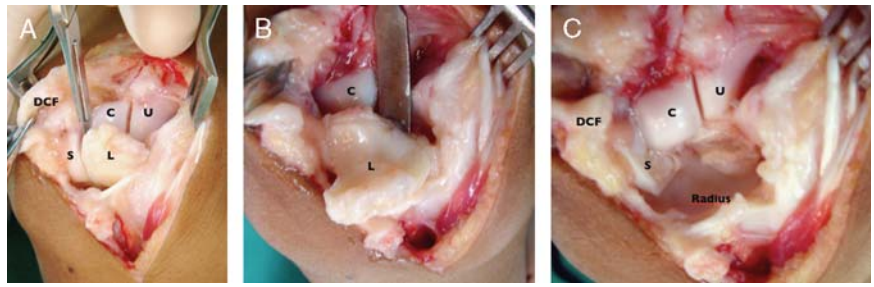

FIGURE 2. A, Through a dorsal wrist approach is performed the section of the scapho-lunate ligaments. B, Enucleation of the lunate. C, The space created in the proximal carpal row. C indicates capitate; DCF, dorsal capsular flap; L, lunate; S, scaphoid; U, unciform.

block. A dorsal wrist approach was developed through a zigzag incision. Sharp dissection is carried down to the retinaculum. The procedure involved identification and preservation of the sensory branch of the radial and ulnar nerves and the dorsal veins. The distal third of the extensor retinaculum is then elevated as a radial based flap from the fifth to the second compartment, and the extensor digitorum communis and extensor carpi radialis brevis tendons are separated. This allows for proper exposure of the dorsal capsule. We drew the dorsal capsular flap distal base as to include the maximum number of nutrient vessels from the dorsal intercarpal arch (Fig. 1). Once the graft was marked, a dorsal ligament sparing capsulotomy was made to expose the joint (Fig. 2). The scapho-lunate and triquetrum-lunate ligaments were sectioned (Fig. 2A). For the careful removal of the necrotic lunate it is important to respect the palmar arcuate ligament complex. The most complex surgical act is the dorsal scaphoid enucleation (Fig. 2B). It is difficult to section the palmar ligaments that attach the scaphoid with the capitate, triquetrum, and radial styloid, preserving the volar radiocapitate ligament (Fig. 2C).

We proceeded to the medial translation and rotation of the scaphoid (Figs. 3A, B). A fine rongeur is used to denude radiolunate articular facet down to bleeding cancellous bone (Figs. 4A, B). The scaphoid would then occupy its new place in the wrist, in the space created after excision of the lunate. As a result, the lunate articular surface of the scaphoid would be placed dorsally and on the palmar side we would have the trapezoidal articular surface of the scaphoid.

Temporary fixation is performed with 2 Kirschner wires. The correct axial scaphoid alignment is adjusted using the Kirschner wires as a joystick. It is necessary to properly align the carved spherical surfaces of the scaphoid and the radial epiphysis as to obtain a congruent arthrodesis surface, which would allow us to place circular (Spider) plate (Spider Limited Wrist Arthrodesis System; Kinetikos Medical, San Diego, CA). The plate-specific rasp is centered on the arthrodesis area, and reaming proceeds by hand until the rasp is seated below the dorsal lip of the radius. A small curette is used to remove any debris from the radiocarpal articulation. A regular-size Spider plate is placed such that 2 screws can be placed into the scaphoid and 3 screws can be placed into the radius. A 1.5-mm drill is used, followed by the placement of either 2.4-mm screws or, in the case of radius, 2.8-mm screws (Figs. 5A, B). Intraoperative fluoroscopy is used to confirm carpal alignment, plate position, and screw lengths. Capsule closure is then performed as to cover the implant and protect the extensor tendons' glide. Finally, we repaired the extensor retinaculum and the skin is closed.

REHABILITATION

Postoperatively, a long arm splint is left for 2 weeks, and would be then substituted by a long arm cast for another 2 weeks. At the fourth week postoperatively, the cast is removed and the patient is started on a course of supervised therapy of gentle wrist flexion and extension exercises. The strengthening exercises must begin gradually from 8 to 10 weeks, as symptoms permit, and is carried on for several years to ensure vascularization of the scaphoid.

RESULTS AND COMPLICATIONS

At follow-up evaluation, 4 patients were free of pain and 6 had pain during heavy manual labor. Pain during daily activity was reported by 2 patients and only 1 experienced pain at rest.

Subjective assessment of surgical outcome was rated by patients as "excellent" in 4 cases, "better" in 6, "no change" in 2, and "worse" in 1. Four patients resumed full labour, whereas 2 more patients resumed work with some limitations, and 6

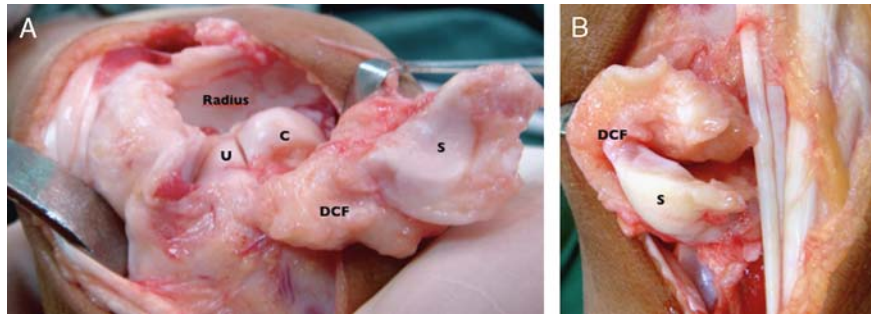

FIGURE 3. A, Dorsal rotation of the scaphoid through its dorsal capsular flap. B, Medial translation of the scaphoid. The scaphoid is placed in its new position in the proximal carpal row. C indicates capitate; DCF, dorsal capsular flap; S, scaphoid; U, unciform.

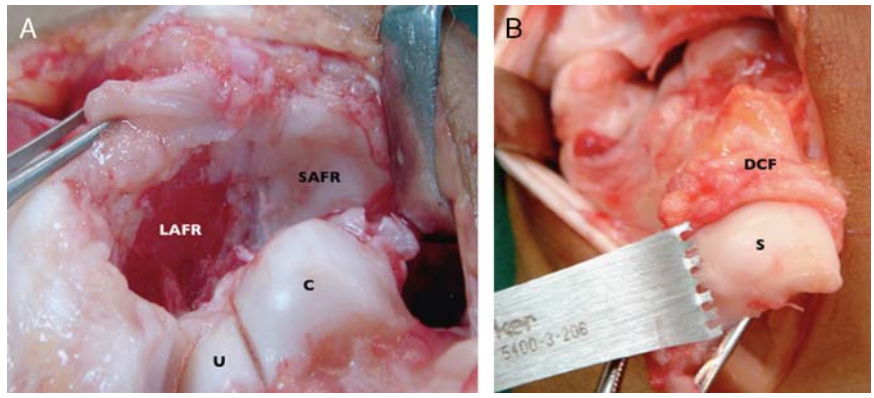

FIGURE 4. A, Denude lunate articular facet of the radius. B, Denude convex articular facet of the scaphoid. Hypothetically, scaphoid vascularization is not only ensured by the recurrent capsular vessels alone but also include vascular invasion from radial epiphysis, allowed by the radioscaphoid fixation. C indicates capitate; DCF, dorsal capsular flap; LAFR, lunate articular facet of the radius; S, scaphoid; SAFR, scaphoid articular facet of the radius; U, unciform.

judged they were fully functional but were unemployed. A single patient stated he was unable to work.

The results of the average preoperative/postoperative ROM are summarized in Table 1 (Figs. 6A–E).

Average preoperative grip strength was 22 kg (range, 13 to 32 kg) and climbed up to 36 kg (range, 24 to 47 kg) postoperatively. Grip strength improved by an average of 38% (Table 2, 3).

At follow-up evaluation, the average DASH score (possible range, 100 to 0) was 14 points (range, 6 to 20).

Radiologic Assessment of the Carpus

Direct postoperative anteroposterior and lateral x-ray proved a correct scaphoid positioning and a congruent scaphoradial arthrodesis (Figs. 7A, B; Figs. 8A, B). The capitate was consequently well aligned. At follow-up evaluation, all transposed scaphoids appeared with normal trabecular structure, and all scaphoradial arthrodesis were consolidated. We had no cases of scaphoid fragmentation. The average preoperative Youm 0.42 (range, 0.39 to 0.46) and Nattrass 1.32 (range, 1.20 to 1.39) index scores proved a carpal collapse before the surgery and a good recovery at follow-up evaluation (Youm 0.52: range, 0.50 to 0.54; Nattrass 1.54: range, 1.49 to 1.60). Postoperative MRI study showed no scaphoid necrosis.

Osteoarthritis

At an average follow-up of 4 years after surgery, 12 of 13 (92%) patients had no radiologic evidence of osteoarthritis. One patient with prior mild osteoarthritis (grade II) developed osteoarthritis of the wrist (grade IV). This patient was subsequently submitted to a total wrist arthrodesis.

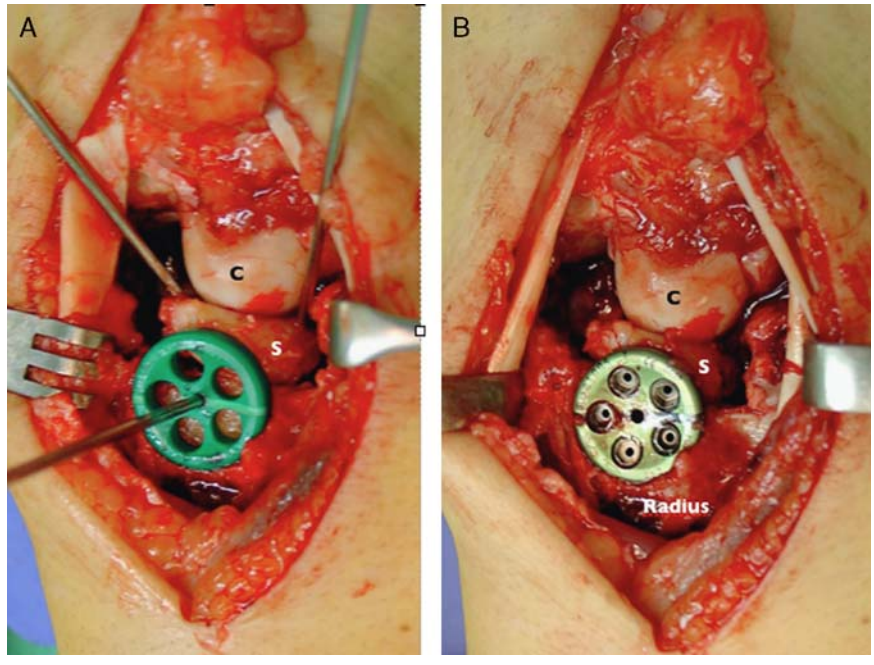

FIGURE 5. A and B, The partial radioscaphoid arthrodesis by the circular (Spider) plate. C indicates capitate; S, scaphoid.

TABLE 1. Results ROM Preoperative Versus ROM Postoperative

	Preoperative			Postoperative			Difference Pre-Postoperative	
	ROM of Affected Wrist (deg.)	ROM of Opposite Wrist (deg.)	Percentage Between ROM of Affected Wrist and ROM of Opposite Wrist (%)	ROM of Affected Wrist (deg.)	ROM of Opposite Wrist (deg.)	Percentage Between ROM of Affected Wrist and ROM of Opposite Wrist (%)	ROM Preoperative-ROM Postoperative (deg.)	Percentage of ROM Preoperative-Percentage of ROM Postoperative (%)
Flexion	50	90	55	30	90	33	−20	−22
Extension	45	70	65	40	90	57	−5	−8
Radial deviation	18	25	72	16	25	64	−2	−8
Ulnar deviation	45	65	69	45	65	69	0	0
Forearm pronation	85	90	94	82	90	91	−3	−3
Forearm supination	87	90	97	84	90	93	−3	−3

ROM indicates range of motion.

In 3 patients, hardware was removed after arthrodesis consolidation because of chronic and nonresolving tenosynovitis.

DISCUSSION

Since KD was first described 100 years ago, several treatment options were advanced to treat advanced stages with collapsed lunate or even osteoarthritis of the carpus.

The correction of carpal malalignment is the main treatment goal and is thought to prevent osteoarthritis of the wrist. Reconstruction of carpal alignment can be achieved either by adequate substitution of the lunate or by revascularization procedures. In contrast, some salvage techniques have also been described for this purpose. These include proximal row carpectomy, intercarpal arthrodesis, and total wrist fusion.

FIGURE 6. Range of movement of the wrist after the surgical procedure. A, Radial deviation; B, neutral; C, ulnar deviation; D, extension; E, flexion.

TABLE 2. Partial Intercarpal Arthrodesis

References	Follow-up	Stage Lichtman	n	ROM (deg.)	Grip Strength (%)	DASH
Allieu et al[6]	40 mo	III	11	—	66	—
Meier et al[7]	4 y	II/III/IV	59	67	—	28
Van den Dungen et al[8]	13 y	II/III	11	74	58	17
Watson et al[9]	51 mo	II/III	28	100	82	—
Nakamura et al[10]	42 mo	III	13	76	77	—
Yasuda et al[11]	53 mo	IIIB	10	93	—	—
Mir et al[12]	29 mo	IIIB/IV	13	70	80	14

Comparison of the results of our series of cases against the results of other published series treated by partial intercarpal arthrodesis.
ROM indicates range of motion.

Lunate replacement arthroplasty models have not offered acceptable results for several reasons. Lunate silicone implants have been shown to be deleterious to the wrist because of silicone synovitis[17–19] and inability to stabilize the carpus. Our experience with those implants is not so satisfactory, as they could develop significant chondral lesions in the radius and capitate, triggering early degenerative joint disease. In addition, because of the difficulty of reconstructing the ligamentous attachments, the implant may sublux or even dislocate into the carpal tunnel.[17]

With improved understanding of the dorsal blood supply of the distal radius and advances in surgical techniques, the use of pedicled vascularized bone grafts have been increasingly popular in KD. In contrast, revascularization procedures cannot be used in advanced stages of KD, because their success is linked to the presence of an intact cartilage shell (without fracture or fragmentation) and to the absence of any evidence of carpal arthrosis.[20]

Levelling procedure had been advocated as alternative therapeutic approach for advanced stages of KD. The effect of radial shortening or ulnar lengthening in ulnar-minus variance is limited, because these procedures do not correct the carpus alignment. According to widely varying results,[21–24] the value of a levelling procedure for advanced stages of KD in ulnar-minus variance remains controversial. In situations of neutral or positive ulnar variance the treatment options are more controversial, and unloading procedures are not indicated.[10] Other authors have recommended a lateral closing-wedge osteotomy of the distal radius in such cases.[12]

Other surgical options such as Saffar's procedure[25] were described for advanced stages of KD (stages IIIA to IV), with a fixed and narrow radiocapitate distance being its limitation (DASH 22, 57% ROM, 79% grip power).

In general, a partial intercarpal arthrodesis such as scapho-trapezium-trapezoid[26,27] or scaphocapitate arthrodesis[3,26] offer a possible resort in late-stage KD. The goals of these intercarpal fusions are to preserve carpal height, maintain the scaphoid in its proper position, prevent degenerative arthritis, and to relatively unload the lunate when preserved.[28–30] Those salvage procedures have a DASH score between 19 and 31 points, and the ROM is reduced at an average between 52% and 63%, whereas the grip power is 64% to 71% that of the opposite side.[30–32] Others authors use a modified Graner's procedure consisting of the progressive capitate lengthening after excision of the lunate to restore carpal height.[33]

When the articular surfaces of the capitate and radius are preserved, proximal row carpectomy might be a valid optional salvage procedure in advanced cases. It has shown good long-term results. However, it changes carpal biomechanics dramatically and is considered to be the last resort before total fusion or total alloarthroplasty. In published series, this procedure has a DASH score of 12 to 22 points, and the ROM is reduced by 35% to 58%, whereas the grip power is 62% to 92% that of the opposite side.[2,13–17]

This treatment option permits the transfer of a vascularized pedicled osteochondral autograft to achieve congruent morphologic adaptation of the articular surface between the scaphoid and the capitate. In addition, one of the major

TABLE 3. Proximal Row Carpectomy

References	Follow-up	Stage Lichtman	n	ROM (deg.)	Grip Strength (%)	DASH
Croog and Stern[13]	23 mo	III/IV	21	105	78	12
Lumdsen et al[14]	15 y	III	17	88	92	
De Smet et al[15]	67 mo	III/IV	21	76	63	22
Nakamura et al[10]	80 mo	III/IV	7	64	62	
Begley and Engber[16]	3 y	III	14	—	72	
Mir et al[12]	29 mo	IIIB/IV	13	70	80	14

Comparison of the results of our series of cases against the results of other published series treated by proximal row carpectomy.
ROM indicates range of motion.

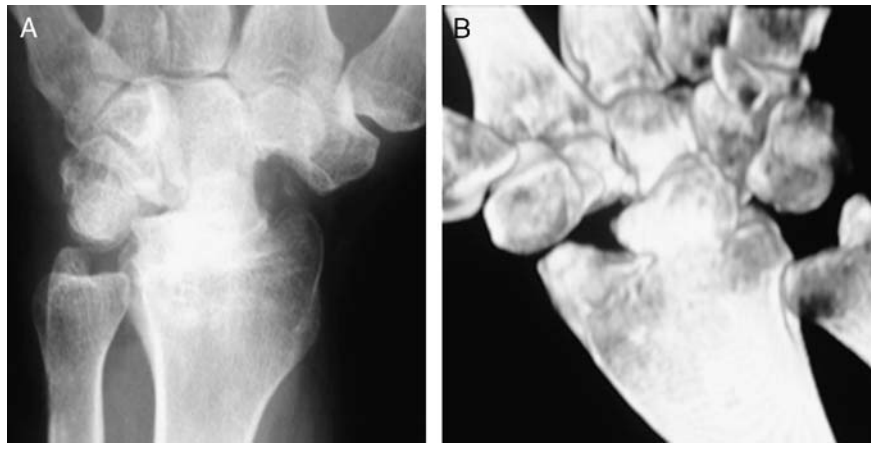

FIGURE 7. The consolidation of radioscaphoid partial arthrodesis. A, Anteroposterior image of an x-ray. B, A reconstruction of a computed tomography. The consolidation of radioscaphoid partial arthrodesis.

advantages of vascularized pedicled bone graft is that its function is relatively independent of that of the host bed. They are implanted with their own functional blood supply. The graft-host union occurs much more rapidly and without substantial bone resorption or substitution of necrotic bone, all seen with nonvascularized grafts. This lack of resorption and revascularization result in the vascularized grafts providing superior structural strength during the first 6 weeks after implantation. Better vascularization of the grafted scaphoid may be reflected in 2 aspects. First at the level of the arthrodesis, through a faster consolidation. Being vascularized could also imply preservation or noncollapse of subchondral bone at the level of the new scaphocapitate joint. We obtained adequate bone healing in all radioscaphoid arthrodesis performed, and the vascularized bone graft was viable in all patients. In fact, in our proposed technique, the arthrodesis was thought as to add intrinsic stability to the rotated scaphoid, after it was stripped and deprived of its ligamentous unions during the transfer. Furthermore, the bone graft would restore the height of the proximal carpal row (as in a partial arthrodesis), reproducing the physiological biomechanics of a midcarpal joint.

We acknowledge the limitations of our study. This is a retrospective study, with a limited number of patients and a short follow-up. Therefore, the exact long-term therapeutic effects of vascularized scaphoid transposition need to be checked carefully through a study with longer follow-up. Furthermore, it could be even better to plan a prospective comparison of different techniques indicated in same stages of KD.

Finally, the described technique is an alternative surgical technique to advanced KD. A new articulation between the scaphoid and the capitate was created, preserving the midcarpal joint mobility (dart throwing motion) and the carpal bone stock. This new joint has excellent joint congruency, which eventually slows progression of the midcarpal joint disease. Thus, we believe that the proposed technique offers an edge over other salvage procedures such as proximal row carpectomy or the 4 corner arthrodesis, extending the indication to a specific group of patients. This would encompass patients with degenerative radiocarpal joint disease (stabilized with the partial arthrodesis after the vascularized transfer) but maintaining a rather unaffected middle carpal joint. In addition, this procedure would not impede subsequent surgery if need arises, and this in better conditions, through bone preservation.

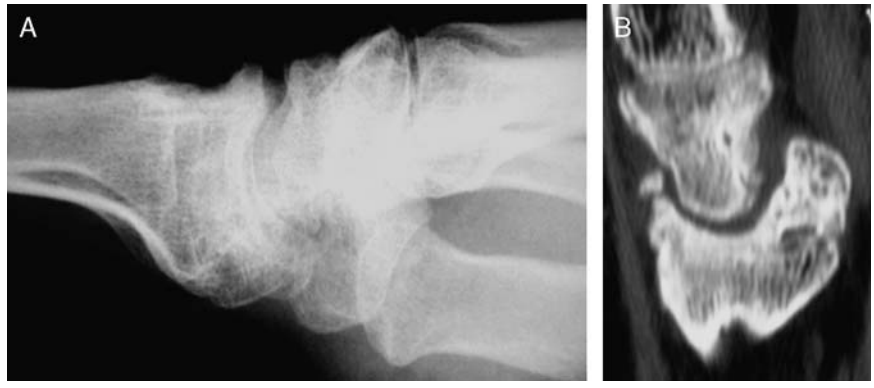

FIGURE 8. The consolidation of radioscaphoid partial arthrodesis. A, Lateral image of an x-ray. B, A sagittal section of a computed tomography.

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