Vascularized Bone Graft to the Lunate Combined With Temporary Scaphocapitate Fixation for Treatment of Stage III Kienböck Disease: A Report of the Results, a Minimum of 2 Years After Surgery

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Purpose To report the outcomes of patients with stage III Kienböck disease treated by vascularized bone graft (VBG) followed by temporary scaphocapitate (SC) fixation, a minimum of 2 years after surgery.

Methods Twenty-six patients (mean age, 35 years) with stage III Kienböck disease (16 with stage IIIA and 10 with stage IIIB), treated with VBG followed by SC fixation for 4 months, were retrospectively followed for at least 2 years (range, 24−121 months; mean, 61.8 months). The preoperative and postoperative assessments included range of motion (ROM) of the wrist, grip strength (GS), wrist pain, the modified Mayo wrist score (MMWS), carpal height ratio (CHR), Ståhl index (STI), and radioscaphoid angle (RSA). The outcomes of each assessment of the stages IIIA and IIIB groups at the final examination were compared with those before surgery.

Results In both stages IIIA and IIIB groups, GS increased after surgery. Decrease of CHR and STI was associated with the increase of RSA in the stage IIIA group after surgery, while RSA decreased, although neither CHR nor STI significantly increased in the stage IIIB patients. No patient demonstrated deterioration of the wrist pain after surgery. Twenty-one of 26 patients had an improved MMWS grade at the final follow-up.

Conclusions Vascularized bone graft combined with SC fixation for 4 months provided greater GS, pain relief, and functional improvement compared with before surgery in both stages IIIA and IIIB groups. *(J Hand Surg Am. 2018;43(8):773.e1-e7. Copyright © 2018 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Kienböck disease, lunate collapse, scaphocapitate fixation, vascularized bone graft, ulnar variance.

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THERE ARE 3 SURGICAL STRATEGIES for the treatment of Kienböck disease: unloading, revascularization, and salvage of the lunate. Unloading procedures include shortening or wedge osteotomy of the radius,[1,2] lengthening of the ulna,[3] capitate shortening,[4] and partial arthrodeses such as the scaphotrapezio-trapezoidal[5,6] or scaphocapitate (SC) arthrodesis.[7] Previous cadaveric studies have demonstrated that

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unloading procedures decrease the biomechanical stress load on the lunate.[8,9] However, excessive radial shortening or ulnar lengthening is sometimes followed by ulnar wrist pain.[10] Partial wrist arthrodesis restricts wrist motion. Revascularization procedures include transplantation of a vascular pedicle[6,11] or vascularized bone[12–14] to the lunate. Salvage procedures include removal of the necrotic lunate with or without tendon interposition[6,15] or a prosthetic device.[16,17] These are often indicated when the disease is associated with arthritic changes of the radiocarpal and intercarpal joints (Lichtman stage IV disease).

Treating stage III Kienböck disease is challenging. Several authors have noted that the biomechanical properties of the lunate[18] and surgical outcomes can differ between stage IIIA and stage IIIB disease.[6,19,20] These authors have recommended intercarpal arthrodesis,[20] or unloading combined with revascularization procedures to treat stage IIIB disease.[6,19,21] However, it remains unclear whether unloading procedures should be combined with revascularization procedures in stage III disease. If unloading the lunate is necessary, it is unclear if this should be permanent or temporary and, if temporary, for how long. It also remains unclear which types of unloading procedure is the most favorable to combine with revascularization procedures in stage III disease.

We treat stage III Kienböck disease—both stages IIIA and IIIB—using transplantation to the lunate of a vascularized bone graft (VBG) harvested from the distal dorsal radius[12–14] followed by temporary fixation of the SC joint for 4 months using 2 1.5-mm K-wires. The goal of temporary SC fixation is to reduce the biomechanical load on the lunate until it recovers the structural strength needed to bear the stress load on the lunate with VBG transplantation. The purpose of this study was to report the outcomes of VBG with temporary SC fixation in patients with stages III A and III B Kienböck disease, a minimum of 2 years after surgery.

MATERIALS AND METHODS

The inclusion criteria for this study were as follows. All patients had stage III Kienböck disease in 1 wrist, were aged 15 to 70 years, and were still active in their daily lives. Patients with negative ulnar variance greater than 2 mm were not included because they were treated using a radial shortening osteotomy, with or without VBG.[19,21] The patients were followed up for at least 2 years after surgery. None of the patients had another pathological condition in either upper limb outside of Kienböck disease. None of the patients had any severe systemic diseases, osteoporosis, poorly controlled diabetes mellitus, or other diseases necessitating systemic treatment with steroids or anticoagulation agents.

Lunate bones showing collapse with a radioscaphoid angle (RSA) of 60° or less on plain x-ray films were defined as stage IIIA, and those with an RSA angle greater than 60° were defined as stage IIIB.[20] In this study, because our surgery included procedures involving both the intercarpal and the radiocarpal joints, SC fixation and the reduction of the osteocartilaginous fractures of the lunate by VBG transplantation, osteoarthritic changes often occurred in the perilunate joints after surgery, regardless of progression of the disease stage. Thus, stage IV Kienböck disease was defined as stage IIIB Kienböck disease with degenerative osteoarthritic changes around the lunate on plain x-ray films, either grade III or grade IV in the Kellgren-Laurence classification (joints with moderate or large osteophytes, definite or marked joint space narrowing, some or severe subchondral sclerosis, and possible or definite deformity).

The physical examination included range of motion (ROM) and grip strength (GS) of both wrists. The ROM of the affected wrist was expressed as a percentage of that of the contralateral wrist. The GS of the affected hand was expressed as a percentage of that of the hand before the disease involvement, which was estimated by the GS of the opposite healthy hand. According to a previous paper, most right-handed people are 10% stronger in the dominant hand and most left-handed people have similar GS in both hands.[22] The right GS was thus adjusted to be 10% greater than the left GS in the right-handed patients. In the left-handed patients, the GS of the affected hand was expressed as a percentage of that of the opposite hand.

The radiological examinations included measurement of the carpal height ratio (CHR), Ståhl index (STI), and RSA,[20] and were performed using plain x-ray films of the affected wrists. We also assessed the function and pain of the affected hands using the modified Mayo wrist score (MMWS) and visual analog scale (VAS) score of the wrist pain before and after surgery. In the MMWS, scores 90 to 100 points were graded as excellent, 80 to 89 points as good, 65 to 79 as fair, and 0 to 64 points as poor. Regarding the VAS, scores of 40 to 100 were graded as severe, 25 to 39 as moderate, 10 to 24 as mild, 1 to 9 as minimal, and 0 as none. The data were collected from the medical records before surgery and at final follow-up and assessed retrospectively by 1 of the authors (S.O.), who did not perform the surgery in these patients. The Committee for Medical Ethics of our university approved this study.

Surgery

One senior author (R.K.) performed all operative procedures. All VBGs were harvested from the distal dorsal radius. The VBGs were supplied by the fourth and fifth extensor compartmental arteries (ECAs) as described by Sheetz et al[12] in 23 of 26 patients. In the other 3 patients, the VBGs were supplied by retrograde blood flow from the fourth ECA because of hypoplasia of the fifth ECA. After harvesting, each VBG was trimmed to about 5 × 8 × 12 mm. The necrotic tissue was removed from the lunate through entry via the dorsal surface of the bone using a curette or surgical bur, leaving a shell of cartilage or subchondral bone. The VBG was transplanted into the bone cavity created by removal of the necrotic tissue. When the collapse of the lunate was severe, especially in stage IIIB disease, the radiolunate and lunocapitate articular surfaces, including the underlying subchondral bone, were elevated proximally and distally, respectively, using a periosteal elevator to enlarge the bone cavity in order to accommodate the VBG. Cancellous bone was taken from the donor site of the VBG and packed into any remaining space between the VBG and the wall of the bone cavity in the lunate. After transplantation of the VBG and cancellous bone, 2 1.5-mm K-wires were inserted between the scaphoid and the capitate. This was done while traction was applied to the thumb and by pushing the scaphoid tubercle dorsally to place the scaphoid into a position of maximal extension. The tips of the wires were buried beneath the skin. The wrist was immobilized with a short-arm cast for 1 month followed by a short-arm orthosis for an additional 3 months. The K-wires for the SC fixation were removed 4 months after surgery and the patients were encouraged to move the wrist in their daily life within the limits of tolerable wrist pain. Patients were permitted to engage in contact sports activities and manual labor approximately 6 months after surgery, if they felt little or no pain in the wrist. Six patients required a formal hand therapy program.

Statistical analysis

Paired *t* tests were used to compare the results of ROM, GS, CHR, STI, and RSA before surgery with those at the final examination, respectively, in each group. Significance was set at *P* less than .05.

RESULTS

We performed VBG transplantation plus SC fixation on 38 wrists of 37 patients with stage III Kienböck disease from 2004 to 2012. Six patients withdrew from the study before the 2-year follow-up. One patient in whom both wrists were affected by Kienböck disease was not included in the study. One patient who underwent arthroscopic triangular fibrocartilage complex repair, 2 patients who had surgery for a distal radius fracture of the contralateral wrist within 2 years after the VBG transplantation plus SC fixation, and 1 patient who had ipsilateral painful carpometacarpal arthritis were removed from the study. Twenty-six patients (19 men and 7 women) met the inclusion criteria for this study: 16 with stage IIIA disease and 10 with stage IIIB disease. The ulnar variance of these patients ranged from −2 mm to +2 mm. The groups were similar for age at surgery, follow-up periods, sex, hand dominance, smoking status, and ulnar variance (Table 1).

TABLE 1. Demographic Data

	Stage IIIA	Stage IIIB
Number of patients	16	10
Age (y)*	35.9 ± 15.1	32.8 ± 13.1
Follow-up period (mo)*	64.9 ± 26.8	56.7 ± 33.4
Gender male/female	11/5	8/2
Dominant/nondominant hand	8/8	6/4
Smoker/nonsmoker	7/9	4/6
Ulnar variance positive/null/negative	6/9/1	1/7/2

*Age and follow-up period: mean ± SD.

Table 2 demonstrates the results of each assessment before surgery and at the final examination. The ROM of the wrist at the final examination was similar to the preoperative value in each group. The GS increased after surgery in both stages IIIA and IIIB groups. All patients exhibited stronger GS at the final follow-up compared with that before surgery, except 1 patient in the stage IIIA group. Three patients in the stage IIIA group and 4 in the stage IIIB group exhibited an increased STI after surgery. The decrease of CHR and STI was accompanied by an increase in RSA after surgery in the stage IIIA group; however, although neither CHR nor STI increased, RSA decreased in the stage IIIB group (Fig. 1).

With respect to pain, 7 of 26 reported mild pain, 16 moderate pain, and 3 had severe pain before surgery, whereas 11 had no pain, 9 reported minimal pain, 5 mild pain, and 1 severe pain, at the final examination. The VAS grade decreased in all patients except 3 (2 and 1 in the stages IIIA and IIIB groups, respectively) whose grades were

TABLE 2. Physical and Radiological Assessment Data*

	Preoperative	Final Follow-Up
Stage IIIA		
ROM of the wrist (%)†	71.3 ± 17.2 (62.2–80.5)	79.2 ± 10.7 (73.5–84.9)
GS (%)‡	59.3 ± 22.5 (47.4–71.3)	87.7 ± 9.1 (82.9–92.6)
CHR	0.52 ± 0.04 (0.50–0.54)	0.49 ± 0.05 (0.47–0.52)
STI	0.44 ± 0.05 (0.42–0.47)	0.40 ± 0.07 (0.37–0.44)
RSA (°)	47.1 ± 6.5 (43.6–50.6)	51.6 ± 10.0 (46.3–57.0)
Stage IIIB		
Arc of the wrist (%)	66.1 ± 19.3 (52.3–79.9)	65.2 ± 16.1 (53.7–76.7)
GS (%)‡	59.5 ± 12.2 (50.8–68.2)	83.9 ± 13.2 (74.4–93.4)
CHR	0.50 ± 0.04 (0.47–0.53)	0.49 ± 0.04 (0.46–0.52)
STI	0.34 ± 0.08 (0.28–0.40)	0.31 ± 0.06 (0.26–0.35)
RSA (°)	65.6 ± 4.7 (62.2–69.0)	56.7 ± 4.9 (53.2–60.2)

*Mean value ± SD. Values in parentheses are mean 95% confidence intervals.
†ROM of the affected wrist is expressed as a percentage of that of the opposite wrist.
‡GS of the affected hand is expressed as a percentage of the value estimated by that of the opposite hand.

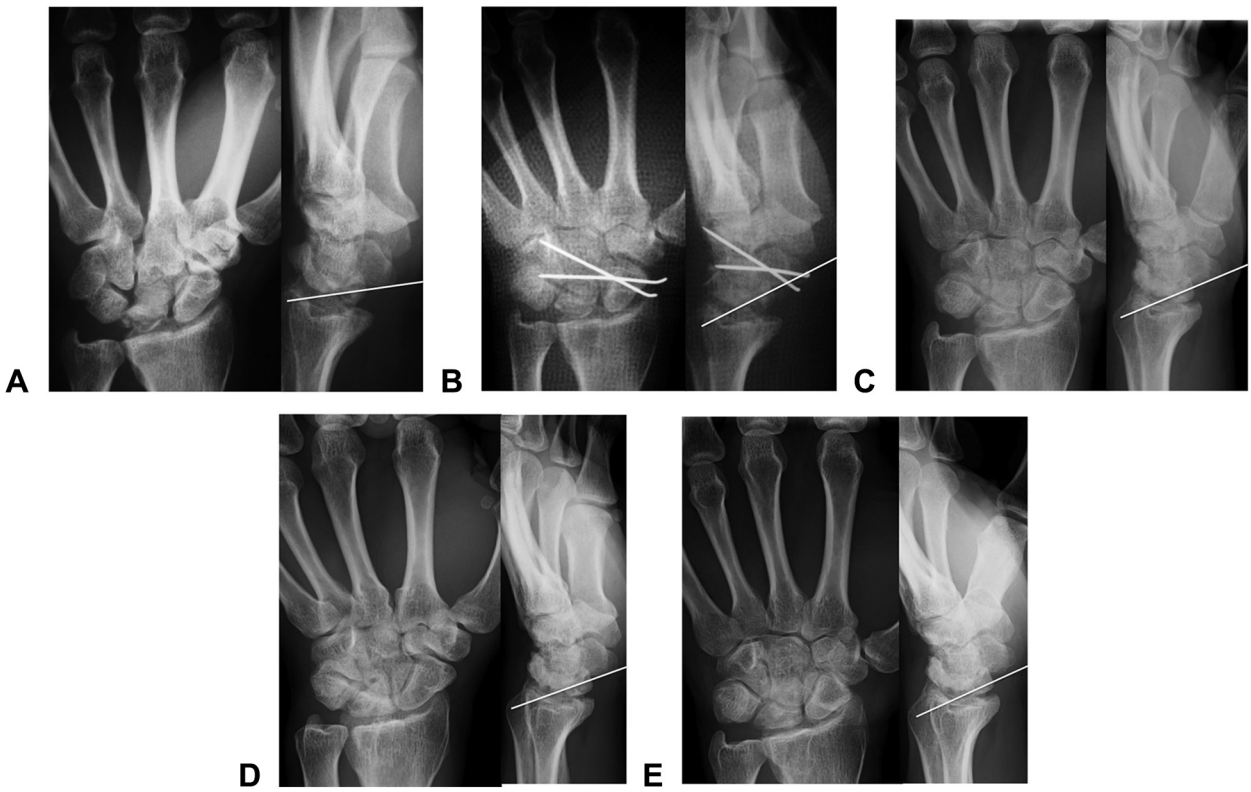

FIGURE 1: Left wrist plain x-ray films of a right-handed 32-year-old carpenter with stage IIIB disease **A** just before surgery, **B** just after surgery, **C** at 5 months after surgery, **D** at 2 years after surgery, and **E** at the final follow-up 5 years after surgery. The STI increased from 0.33 before surgery to 0.35 just after surgery, after which it gradually decreased to 0.33 at 6 months after surgery, 0.31 at 2 years after surgery, and 0.31 at 5 years after surgery. The RSA decreased from 72° before surgery, to 56° just after surgery, and finally to 58° at 5 years after surgery. Scores on the VAS grade for wrist pain improved from the moderate pain before surgery to the weak pain at 5 years after surgery, and GS increased from 61% of that adjusted by the right GS before surgery to 97% at 5 years after surgery. The contour of the transplanted VBG became obscure at 5 months, indicating that the VBG might have incorporated with the lunate bone. White lines represent the lateral axis lines of the scaphoid bones, which were measured by the method described by Goldfarb et al.[20]

TABLE 3. Changes of VAS and MMWS After Surgery

Case	Age (y)	Sex	Stage	VAS Before Surgery*	VAS at Final Follow-Up*	MMWS Before Surgery†	MMWS at Final Follow-Up†
1	50	F	IIIA	Mild	Mild‡	Poor	Good
2	32	M	IIIA	Moderate	None	Poor	Excellent
3	66	F	IIIA	Moderate	Minimal	Poor	Fair
4	36	M	IIIA	Severe	Minimal	Poor	Fair
5	47	M	IIIA	Mild	Minimal	Fair	Fair
6	27	F	IIIA	Moderate	None	Poor	Excellent
7	45	M	IIIA	Severe	None	Fair	Fair‡
8	54	F	IIIA	Moderate	Mild	Poor	Poor
9	32	M	IIIA	Moderate	None	Poor	Good
10	24	M	IIIA	Moderate	None	Poor	Good
11	18	M	IIIA	Moderate	None	Poor	Good
12	20	F	IIIA	Moderate	None	Poor	Fair
13	52	M	IIIA	Severe	Severe‡	Poor	Poor‡
14	17	M	IIIA	Mild	Minimal	Fair	Good
15	37	M	IIIA	Moderate	Mild	Poor	Fair
16	17	M	IIIA	Mild	None	Fair	Good
17	40	M	IIIB	Moderate	Mild	Poor	Good
18	47	M	IIIB	Mild	Mild‡	Fair	Poor§
19	21	M	IIIB	Mild	Minimal	Fair	Poor§
20	32	F	IIIB	Moderate	Minimal	Poor	Good
21	23	M	IIIB	Moderate	None	Poor	Fair
22	59	F	IIIB	Moderate	Minimal	Poor	Fair
23	24	M	IIIB	Moderate	None	Poor	Good
24	16	M	IIIB	Mild	None	Poor	Good
25	32	M	IIIB	Moderate	Minimal	Poor	Fair
26	34	M	IIIB	Moderate	Minimal	Poor	Fair

*VAS: severe, > 40; moderate, 25–39; mild, 10–24; minimal, 0–9; none, 0.
†MMWS: excellent, 90–100; good, 80–89; fair, 65–79; poor, < 65.
‡No change after surgery.
§Deterioration after surgery.

unchanged and did not increase after surgery (Table 3).

Regarding MMWS grade, 6 were in the fair and the remaining 20 in the poor category before surgery, whereas 2 were in the excellent, 10 each in the good and fair, and 4 in the poor category at the final examination. The MMWS grades increased after surgery in 20 patients of 26, were unchanged in 4 (all in the stage IIIA group), and decreased in 2 (both in the stage IIIB group) (Table 3).

Complications

Two patients developed a superficial infection around the K-wires used for SC fixation. One underwent replacement of a K-wire and the other patient's infection subsided after administration of oral antibiotics. No other patients required additional surgery during the follow-up periods.

DISCUSSION

In the stage IIIA group, CHR and STI decreased and RSA increased after surgery; however, RSA decreased and was not associated with increase of STI and CHR in the stage IIIB group. When RSA decreases, the scaphoid rotates dorsally. The RSA decrease is usually associated with the increase of STI. In the present study, after removal of the necrotic bone, the subchondral bone of the lunate was elevated proximally and distally to accommodate the VBG in stage IIIB patients. This surgical maneuver

was followed by extensive disruption of the scapholunate and lunotriquetral articular surfaces of the lunate, which had already degenerated and were partially broken. Inflammation followed by fibrous tissue formation at the sites of the articular disruption might have led to increased stiffness of the scapholunate and lunotriquetral ligaments. We speculate that the ligament stiffness occurring with the scaphoid in a maximally extended position might have limited the scaphoid motion and prevented the palmar rotation of the scaphoid in the stage IIIB group.

We transplanted VBGs of nearly the same size as the lunate regardless of the extent of collapse. In advanced Kienböck disease, compared with the normal lunate, the collapsed lunate is longer in the sagittal plane and shorter in the coronal plane. Transplantation of a large VBG to the lunate increases the coronal length and creates a large lunate bone with longer coronal and sagittal lengths. In our previous study, we found that a large lunate bone created by transplantation of a large VBG combined with capitate shortening markedly affected wrist motion.[21]

Several previous papers have reported that the mean time for bone union of scaphoid nonunion with avascular necrosis of the proximal bone fragment, using VBGs, was greater than 3 months.[23–26] In our study, the contour of the VBGs became obscure in the lunate on plain x-ray in most patients around 3 to -4 months after surgery, indicating that the VBGs might have incorporated within the lunate. We thus immobilized and unloaded the wrists for 4 months after surgery. However, there were 7 patients whose STI increased after surgery. We speculate that SC fixation for 4 months was not long enough to prevent lunate collapse. To increase STI after the VBG transplantation, permanent lunate decompression or arthrodesis of the carpal bones might be necessary in both stages IIIA and IIIB, although previous authors have reported that permanent decompression of the lunate was needed only in stage IIIB disease.[6,19] Despite the decrease of STI, the mean RSA was within the normal range in both stages IIIA and IIIB groups at the final follow-up. Moreover, GS increased, wrist pain was relieved, and MMWS improved in most of our patients. A VBG transplantation followed by a 4-month SC fixation might be an acceptable option for treatment of both stages IIIA and IIIB Kienböck diseases.

This study has several limitations. First, we did not assess the change in vascularity of the lunate after VBG transplantation. We performed postoperative magnetic resonance imaging studies in 6 patients 5 years after surgery and found that the T1- and T2-weighted signal intensities remained low in some parts of the lunate in these patients. These results suggest that the entire lunate was not ossified by the VBG and that some parts of the lunate retained necrotic or fibrotic tissue. We did not assess the influence of ulnar variance on the results in this study because the range of variance was limited to within ± 2 mm. In addition, several recent studies have reported finding no relationship between ulnar variance and the occurrence of Kienböck disease.[27,28] The reduced wrist pain after VBG transplantation to the lunate might be more related to the transection of the posterior interosseous nerve during the process of harvesting the VBG[29] and reduction of synovitis around the collapsed lunate rather than VBG transplantation to the lunate.

In conclusion, increased grip strength and pain relief in the affected wrist were obtained in the majority of patients in both stages IIIA and IIIB groups after VBG transplantation to the lunate followed by a 4-month SC fixation. Although the mean values of ROM and STI were greater in the stage IIIA group than in the stage IIIB group (Table 2), both groups achieved satisfactory clinical outcomes after surgery.

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