Original Article
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Comparison of Long-term Outcomes between Nonoperative Treatment and Vascularized Bone Graft for Kienböck Disease: A Systematic Review and Single-Arm Meta-Analysis

Jin Yeop Park, MD, Jae Kwang Kim, MD, Young Ho Shin, MD

Department of Orthopaedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

Background: This systematic literature review compared long-term outcomes between nonoperative treatment and vascularized bone graft (VBG) in patients with Kienböck disease.

Methods: We systematically reviewed studies on nonoperative treatment and VBG for Kienböck disease with a mean follow-up of ≥ 5 years. A systematic search was conducted in the Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, and Embase databases to select relevant articles. Data on patient demographics, treatment details, and outcomes were extracted.

Results: Twelve studies (6 for nonoperative treatment and 6 for VBG) were included. The proportion of wrists showing worsening Lichtman stages after treatment was 40.2% (95% confidence interval [CI], 25.7–56.6) and 17.0% (95% CI, 10.2%–26.9%) in the nonoperative treatment group and VBG group, respectively. No change in the stage was observed in 52.4% (95% CI, 25.5%–78.0%) and 77.8% (95% CI, 66.7%–86.0%) of the wrists in the nonoperative treatment group and VBG group, respectively. The proportion of wrists without pain at the final follow-up was 29.2% (95% CI, 16.6%–46.1%) and 35.9% (95% CI, 22.6%–52.0%) in the nonoperative treatment group and VBG group, respectively. The proportion of wrists with more than a moderate degree was 30.4% (95% CI, 22.7%–39.4%) and 12.9% (95% CI, 5.5%–27.4%) in the nonoperative treatment group and VBG group, respectively. The 95% CIs of the mean wrist range of motion and mean grip strength ratio of the affected side to the contralateral side substantially overlapped in the two groups.

Conclusions: The VBG group showed greater improvement in the radiographic stage and wrist pain than did the nonoperative treatment group after treatment, but meaningful differences in parameters were not observed. Further well-designed studies are needed to confirm the superiority of VBG to nonoperative treatment regarding radiographic and clinical outcomes.

Keywords: *Avascular necrosis, Bone graft, Kienbock disease, Lunate, Vascularized*

Various operative treatments for Kienböck disease are available according to patient characteristics, symptom severity, radiographic stage of the disease, and surgeon's judgment.[1,2] The goals of operative treatments are pain relief, functional improvement, and disease progression prevention.[3,4] In general, radial osteotomy and revascularization procedures are performed to promote the recovery of the diseased lunate in the early stages.[5,6] Salvage procedures, such as limited carpal fusion or proximal row carpectomy, are required in the advanced stages of the disease to maintain carpal stability and prevent carpal collapse.[7]

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Correspondence to: Young Ho Shin, MD
Department of Orthopaedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Korea
Tel: +82-2-3010-1838, Fax: +82-2-2045-4542
E-mail: 123sinyh@gmail.com

Vascularized bone graft (VBG) is a strategy to facilitate revascularization to the avascular necrotic lunate. While the indications for a VBG have been established as Lichtman stages I, II, and IIIA, the precise indications remain unclear.[7] Since Hori et al.[8] successfully introduced revascularization to the necrotic bone, several anatomical sites have been reported as available VBG donor sites for patients with Kienböck disease: VBGs from the distal radius[2,5,6] or metacarpal[2,9] were available from the dorsal aspect of the wrist; vascularized[10] or pronator quadratus pedicled bone grafts[11] from the distal radius; and vascularized pisiform transfer[12] from the volar aspect of the wrist. The distal femur[13] and iliac bone[14] were also available as donor sites for free VBGs. Despite the increase in available donor sites and surgically favorable clinical outcomes, most previous studies were retrospective case series without comparison. The impact and efficacy of VBG on Kienböck disease compared with those of nonoperative treatments, therefore, remain unclear.

Since the prevalence of Kienböck disease is too low for large-scale comparative or prospective studies,[4] a systematic review is a pragmatic option to assess the superiority of VBG to nonoperative treatments. Thus, in the present study, we performed a systematic literature review comparing the long-term outcomes of nonoperative treatment and VBG in patients with Kienböck disease.

METHODS

Ethical approval was not sought for the present study because it was a systematic review of retrospective studies.

Search Strategy

We performed a systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[15] A literature search was conducted in April 2020 using the Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, and Embase databases to identify articles published between 1980 and April 2020 (Table 1). The references of the identified articles and reviews were also checked for relevance.

Eligibility Criteria

Studies were included if they met the following criteria: (1) reports of clinical or radiographic outcomes of VBG or nonoperative treatments, including studies in which no clinical intervention was conducted; (2) a mean follow-up period of ≥ 5 years after each treatment; and (3) publication in English. For multiple papers reporting on the same patient cohort, the paper with the highest number of participants was included.

Study Selection

The identified records were saved using EndNote (X9; Clarivate) and a crude exclusion of duplicates was performed. Two authors (JYP and YHS) independently screened the titles and abstracts of the studies that met the inclusion criteria. The full manuscript text was analyzed when the abstract was unavailable. Disagreements regarding the title and abstract screening were resolved by including the article for completeness. A consensus among the reviewers resolved disagreements when the full text of an article was analyzed.

Data Extraction

We extracted data on the authors, year of publication, study design, level of evidence, sample size, patient characteristics (i.e., sex, age, and involved site), and treatment details. Radiographic stages and clinical outcomes, including pain, range of motion (ROM) of the wrist, and grip strength, were documented. Data were classified into two groups: the VBG group, which included patients who received one form of VBG, and the nonoperative treatment group, which included patients who underwent nonoperative treatment or no treatment at all.

Table 1. Search Strategy

Database	Search condition
CENTRAL	((MeSH descriptor: [Osteonecrosis] explode all trees and MeSH descriptor: [Lunate Bone] explode all trees) or (Osteonecrosis*:ab,ti,kw and Lunate*:ab,ti,kw) or Kienböck*:ab,ti,kw or Kienböeck*:ab,ti,kw or Kienbock*:ab,ti,kw or Kienboeck*:ab,ti,kw or lunatomalacia*:ab,ti,kw) with Publication Year from 1980 to 2020, in Trials
PubMed	(("Osteonecrosis"[Mesh] AND "Lunate Bone"[Mesh]) OR (Osteonecros*[TW] AND Lunate*[TW]) OR Kienböck*[TW] OR Kienböeck*[TW] OR Kienbock*[TW] OR Kienboeck*[TW] OR lunatomalacia*[TW]) AND English[Lang] AND ("1980/01/01"[pdat]:"2020/12/31"[pdat])
Embase	('Kienboeck disease'/exp OR (('bone necrosis'/exp OR Osteonecros*:ab,ti,kw) AND ('lunate bone'/exp OR Lunate*:ab,ti,kw)) OR Kienböck*:ab,ti,kw OR Kienböeck*:ab,ti,kw OR Kienbock*:ab,ti,kw OR Kienboeck*:ab,ti,kw OR lunatomalacia*:ab,ti,kw) AND [english]/lim AND [1980-2020]/py

Statistical Analysis

Comparative studies on the treatment of Kienböck disease were limited, so each treatment was assessed using a single-arm meta-analysis only. Pretreatment status and treatment outcomes were evaluated by descriptive analysis or percentages and estimated using 95% confidence intervals (CIs) in both groups. We did not calculate the *p*-values; however, we used non-overlapping CIs to indicate a meaningful difference. Heterogeneity among individual studies was assessed using Cochran's Q test and I^2 test.[16)] If the *p*-value was less than 0.05 or the I^2 was more than 50%, suggesting heterogeneity between the studies, the random effects model was selected to aggregate individual outcomes. If the *p*-value was more than or equal to 0.05 and the I^2 was less than or equal to 50%, suggesting that data from individual studies favor homogeneity, the fixed effects model was adopted. The values for the individual studies were weighted according to the number of enrolled wrists. A chi-square test was used to compare loss to follow-up between the groups.

RESULTS

Study Characteristics

The initial search yielded 1,730 relevant studies in the Central (n = 14), PubMed (n = 775), and Embase (n = 941) databases. Eventually, 12 retrospective studies remained after removing duplicate studies and screening the titles, abstracts, and full texts of the potential studies, which comprised 7 case series and 5 comparative studies (Fig. 1). Six studies included a total of 218 patients who received nonoperative treatment or no treatment; the other six studies included a total of 127 patients who received one of several forms of VBG. Among them, 132 wrists of 125 patients (57.3% of 218 patients) in the nonoperative treatment group and 95 wrists of 95 patients (74.8% of 127 patients) in the VBG group were assessed at the final follow-up. The follow-up rate was significantly higher in the VBG group than in the nonoperative treatment group ($p = 0.001$).

Several patients from 4 studies in the nonoperative treatment group showed bilateral involvement, but each article did not explain how cases with bilateral involvement were handled. Therefore, we ignored the bilaterality and assessed each wrist of such patients separately. The pooled mean follow-up period was longer in the nonoperative treatment group (16.2 years; 95% CI, 11.8–20.5; $I^2 = 95.8\%$; heterogeneity: $p < 0.001$) than in the VBG group (8.4 years; 95% CI, 6.0–10.8; $I^2 = 96.3\%$; heterogeneity: $p < 0.001$). The pooled mean age of the enrolled patients was 37.0 years (95% CI, 30.5–43.6; $I^2 = 91.3\%$; heterogeneity: $p < 0.001$) in the nonoperative treatment group and 33.5 years (95% CI, 27.6–39.4; $I^2 = 85.9\%$; heterogeneity: $p < 0.001$) in the VBG group. The study characteristics are described in detail in Tables 2 and 3.[2,5,6,9,12,14,17-22)]

Treatment Details

In the nonoperative treatment group, 1 study did not provide any clinical intervention,[17)] 4 studies provided primarily nonoperative treatments,[18-21)] and 1 study provided both.[22)] Immobilization using a splint or cast was the most commonly used nonoperative treatment. The immobiliza-

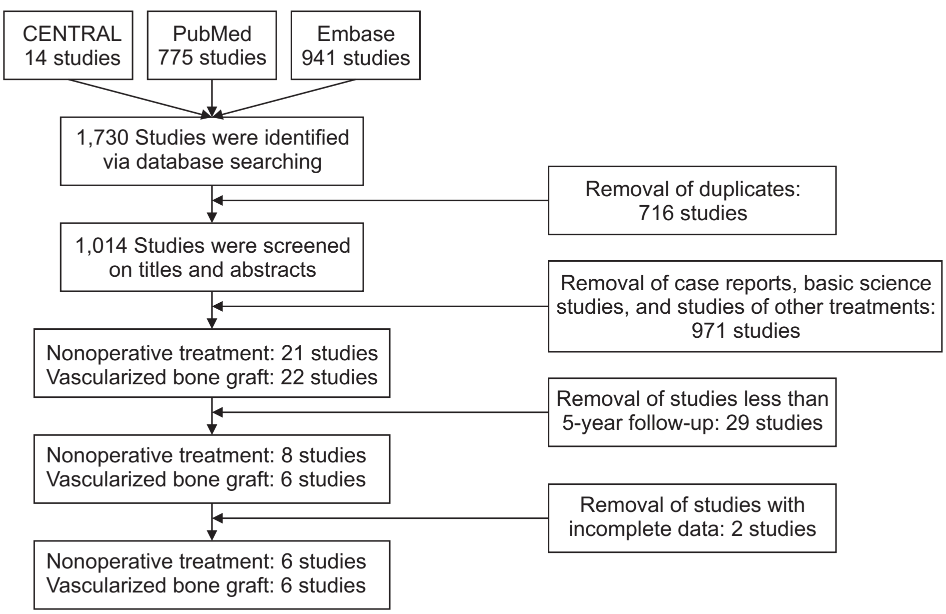

Fig. 1. Flowchart of the article search process.

Table 2. Characteristics of the Included Studies

Study	Study design	Level of evidence	No. of cases (patients)	Case treatment (range)	Mean age (yr)	Mean FU time (yr)	Note
Nonoperative treatment group							
Evans et al. (1986)[19]	Retrospective comparative	III	16 (14)	Splint: 11 (6 mo–20 yr); cast: 3 (6 wk–3 mo); strapping: 1; nothing: 1	32.3	21.4	
Kristensen et al. (1986)[22]	Retrospective comparative	III	26 (24)	Nothing: 26	34.2	18.2	
			23 (22)	Cast: 23 (2–24 wk)	27.2	23	
Fujisawa et al. (1996)[20]	Case series	IV	17 (17)	Splint: 12 (1–13 mo); analgesics: 5	30.7	15.6	Twenty of 67 patients were followed up for more than 10 years. Three patients with bilateral lesions were excluded.
Delaere et al. (1998)[21]	Retrospective comparative	III	22 (21)	Splint at night during period of pain	42	5.4	
Van den Dungen et al. (2006)[18]	Retrospective comparative	III	19 (19)	Splint at night during period of pain	50.1	12.3	Nineteen of 59 patients were followed up.
Viljakka et al. (2016)[17]	Case series	IV	9 (8)	Nothing: 8; splint: 1	42.9	18.1	Three of the eight patients were advised to undergo surgery, but no treatment was administered due to relatively mild symptoms
Vascularzied bone graft group							
Daecke et al. (2005)[12]	Case series	IV	23 (23)	Vascularized pisiform transposition	27.2	12.5	Twenty-three of 29 patients were followed up. Eleven of 23 patients underwent radial shortening osteotomy due to ulnar minus variance
Arora et al. (2008)[14]	Case series	IV	18 (18)	Free VBG from iliac crest	30	12.7	Eighteen of 40 patients were followed up.
Afshar et al. (2013)[5]	Case series	IV	7 (7)	4+5 ECA	22.5	6.5	
Fujiwara et al. (2013)[9]	Case series	IV	10 (10)	1,2 ICSRA: 2; 2,3 ICSRA: 2; 2nd MCA: 1; 3rd MCA: 5	43.2	12.3	Eighteen patients who had VBG or VBG + radial-shortening osteotomy were analyzed. Other data were analyzed from the 10 patients who had VBG only, except for the follow-up period.
Nakagawa et al. (2016)[2]	Retrospective comparative	III	12 (12)	1,2 ICSRA	33	5.8	
			8 (8)	4+5 ECA	38	5.8	
			8 (8)	2nd MCA	32	5.8	
Ye et al. (2020)[6]	Case series	IV	9 (9)	4+5 ECA	47.4	5.8	

FU: follow-up, VBG: vascularized bone graft, ECA: extensor compartmental artery, ICSRA: intercompartmental supraretinacular artery, MCA: metacarpal artery.

Table 3. Clinical and Radiologic Results of the Included Studies

Study	No. of cases (patients)	Initial stage (I : II : IIIA : IIIB : IV : uk)	FU stage (I : II : IIIA : IIIB : IV : uk)	Changes in stage (improved : worsen : unchanged : uk)	FU pain (no : mild : moderate : severe)	FU grip strength ratio (%)	FU flexion + extension of wrist (°)	Note
Nonoperative treatment group								
Evans et al. (1986)[19]	16 (14)	0 : 3 : 6 (IIIA+IIIB) : 3 : 4	0 : 3 : 4 (IIIA+IIIB) : 9 : 0	0 : 3 : 9 : 4	7 : 6 : 3 : 0	72.3	68.4	
Kristensen et al. (1986)[22]	26 (24)				8 : 12 : 6 : 0			
	23 (22)				7 : 12 : 4 : 0			
Fujisawa et al. (1996)[20]	17 (17)	3 : 3 : 8 (IIIA+IIIB) : 3 : 0	0 : 5 : 5 (IIIA+IIIB) : 7 : 0	4 : 8 : 5 : 0	9 : 2 : 6 : 0	79.9	103.5	
Delaere et al. (1998)[21]	22 (21)				2 : 11 : 4 : 5	64	97	
Van den Dungen et al. (2006)[18]	19 (19)	1 : 7 : 8 (III) : 3 : 0	1 : 2 : 8 (III) : 8 : 0	0 : 10 : 9 : 0	0 : 11 : 7 : 1	100	91.7	Used another classification system similar to the Lichtman staging system; no separate stages IIIA and IIIB
Viljakka et al. (2016)[17]	9 (8)	0 : 0 : 7 : 2 : 0 : 0	0 : 0 : 5 : 0 : 4 : 0	0 : 4 : 5 : 0		93	91	
Vascularized bone graft group								
Daecke et al. (2005)[12]	23 (23)	0 : 13 : 6 : 1 : 0 : 3	2 : 9 : 3 : 3 : 3 : 3	3 : 6 : 11 : 3	8 : 12 : 0 : 3	83.6	113	
Arora et al. (2008)[14]	18 (18)	0 : 0 : 15 : 3 : 0 : 0	0 : 0 : 14 : 2 : 2 : 0	0 : 2 : 16 : 0			92.1	
Afshar et al. (2013)[5]	7 (7)	0 : 3 : 4 : 0 : 0 : 0	0 : 4 : 3 : 0 : 0 : 0	1 : 0 : 6 : 0	3 : 3 : 1 : 0	95		
Fujiwara et al. (2013)[9]	10 (10)	0 : 10 : 0 : 0 : 0 : 0	0 : 0 : 8 : 2 : 0 : 0	0 : 2 : 8 : 0		88.5		
Nakagawa et al. (2016)[2]	12 (12)	0 : 2 : 4 : 6 : 0 : 0	0 : 1 : 4 : 7 : 0 : 0	0 : 1 : 11 : 0		91	72	
	8 (8)	0 : 6 : 2 : 0 : 0 : 0	0 : 5 : 3 : 0 : 0 : 0	0 : 1 : 7 : 0		82	77	
	8 (8)	0 : 0 : 4 : 4 : 0 : 0	0 : 0 : 3 : 5 : 0 : 0	0 : 1 : 7 : 0		91	70	
Ye et al. (2020)[6]	9 (9)	0 : 2 : 7 : 0 : 0 : 0	0 : 2 : 7 : 0 : 0 : 0	0 : 0 : 9 : 0	3 : 5 : 1 : 0	89	80	

FU: follow-up, uk: unknown.

tion period of individual patients was reported in 3 of the 5 studies (49 wrists), with a mean immobilization period of 8.6 months (range, 0.5–72 months), except for 1 extreme case with an immobilization period of 20 years. In 2 studies, a splint was applied during periods of pain. In the VBG group, 1 study applied free VBG harvested from the iliac crest,[14)] and vascularized pisiform transposition was performed in another study.[12)] The remaining 4 studies applied a VBG from the distal radius or metacarpal, while the 4 or 5 extensor compartmental artery pedicled bone graft was most commonly used.[2,5,6,9)] One study by Daecke et al.[12)] analyzed 11 of the 23 total patients who underwent radial shortening osteotomy simultaneously with VBG.

Radiographic Stage

Nine of the 12 studies reported changes in Lichtman stage pre- and post-treatment (3 in the nonoperative treatment group and 6 in the VBG group).[2,5,6,9,12,14,17,19,20)] As 2 studies in the nonoperative treatment group did not separate Lichtman stages IIIA and IIIB,[19,20)] we compared the proportions of wrists with Lichtman stage III or higher between the two groups. The pooled proportion of wrists with Lichtman stage III or higher was 71.9% (95% CI, 54.5%–84.6%; I^2 = 16.6%, heterogeneity: p = 0.302) and 73.2% (95% CI, 47.5%–89.2%; I^2 = 69.3%; heterogeneity: p = 0.002) before treatment in the nonoperative treatment group and VBG group, respectively (Fig. 2). The pooled proportion of wrists that showed worsening of the Lichtman stage after treatment was 40.2% (95% CI, 25.7%–

Study	Initial lichtman stage stage III, IV (%)	Lower limits	Upper limits	Relative weights
Nonoperative treatment group				
Evans, 1986	75.0	44.8	91.7	34.1
Fujisawa, 1996	64.7	40.4	83.2	58.8
Viljakka, 2016	95.0	52.5	99.7	7.2
Subtotal	**71.9**	**54.5**	**84.6**	
VBG group				
Daecke, 2005	35.0	17.7	57.4	36.6
Arora, 2008	97.4	69.0	99.8	3.9
Afshar, 2013	57.1	23.0	85.6	13.8
Fujiwara, 2013	95.5	55.2	99.7	3.8
Nakagawa, 2016*	83.3	52.3	95.8	13.4
Nakagawa, 2016†	25.0	6.3	62.3	12.1
Nakagawa, 2016‡	94.4	49.5	99.7	3.8
Ye, 2020	77.8	42.1	94.4	12.5
Subtotal	**73.2**	**47.5**	**89.2**	

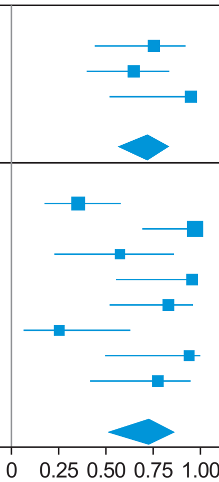

Fig. 2. The pooled pretreatment proportion of wrists with Lichtman stage III or higher in the nonoperative treatment and vascularized bone graft (VBG) groups. Nakagawa et al.[2)] have reported the outcomes of three different treatments: *1, 2 supraretinacular intercompartmental artery pedicled bone graft, †4, 5 extensor compartmental artery pedicled bone graft, and ‡second dorsal metacarpal artery pedicled bone graft.

Study	Aggravation of the lichtman stage (%)	Lower limits	Upper limits	Relative weights
Nonoperative treatment group				
Evans, 1986	25.0	8.3	55.2	34.1
Fujisawa, 1996	47.1	22.5	69.7	58.8
Viljakka, 2016	44.4	17.7	74.9	7.2
Subtotal	**40.2**	**25.7**	**56.6**	
VBG group				
Daecke, 2005	30.0	14.1	52.7	36.6
Arora, 2008	11.1	2.8	35.2	3.9
Afshar, 2013	6.3	0.4	53.9	13.8
Fujiwara, 2013	20.0	5.0	54.1	3.8
Nakagawa, 2016*	8.3	1.2	41.3	13.4
Nakagawa, 2016†	12.5	1.7	53.7	12.1
Nakagawa, 2016‡	12.5	1.7	53.7	3.8
Ye, 2020	5.0	0.3	47.5	12.5
Subtotal	**17.0**	**10.2**	**26.9**	

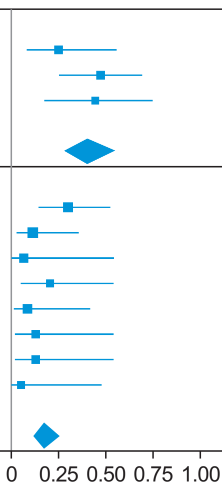

Fig. 3. The pooled proportion of wrists that showed worsening of the Lichtman stage in the nonoperative treatment and vascularized bone graft (VBG) groups. Nakagawa et al.[2)] have reported the outcomes of three treatments: *1, 2 supraretinacular intercompartmental artery pedicled bone graft, †4, 5 extensor compartmental artery pedicled bone graft, and ‡second dorsal metacarpal artery pedicled bone graft.

56.6%; I^2 = 0.0%; heterogeneity: p = 0.471) and 17.0% (95% CI, 10.2%–26.9%; I^2 = 0.0%; heterogeneity: p = 0.649) in the nonoperative treatment group and VBG group, respectively (Fig. 3). In addition, the pooled proportion of wrists that did not show any change in the Lichtman stage was 52.4% (95% CI, 25.5%–78.0%; I^2 = 63.8%; heterogeneity: p = 0.063) and 77.8% (95% CI, 66.7%–86.0%; I^2 = 32.5%, heterogeneity: p = 0.168) in the nonoperative treatment group and VBG group, respectively (Fig. 4).

Wrist Pain

Eight of the 12 studies reported the level of wrist pain after treatment (5 in the nonoperative treatment group and 3 in the VBG group).[5,6,12,18-22] To describe the pain level, most studies used a nominal scale (e.g., no/mild/moderate/severe),[6,12,18-22] except for 1 study that used a visual analog scale (VAS).[5] We reclassified the pain level of each patient using 4 categories: no = no pain/VAS grade 0; mild = pain while performing heavy work/VAS grade 1–3; moderate = pain while performing light work/VAS grade 4–7; and severe = pain while performing daily activities/VAS grade 8–10.[4] The pooled proportions of wrists without pain after treatment were 29.2% (95% CI, 16.6%–46.1%; I^2 = 60.7%; heterogeneity: p = 0.026) and 35.9% (95% CI, 22.6%–52.0%; I^2 = 0.0%; heterogeneity: p = 0.912) in the nonoperative treatment group and VBG group, respectively (Fig. 5). In addition, the pooled proportion of wrists with more than a moderate degree pain was 30.4% (95% CI, 22.7%–39.4%; I^2 = 15.6%; heterogeneity: p = 0.313) and 12.9% (95% CI, 5.5%–27.4%; I^2 = 0.0%, heterogeneity: p = 0.981) in the nonoperative treatment group and VBG group, respectively (Fig. 6).

Study	No change of the lichtman stage (%)	Lower limits	Upper limits	Relative weights
Nonoperative treatment group				
Evans, 1986	75.0	44.8	91.7	34.1
Fujisawa, 1996	29.4	12.8	54.2	58.8
Viljakka, 2016	55.6	25.1	82.3	7.2
Subtotal	**52.4**	**25.5**	**78.0**	
VBG group				
Daecke, 2005	55.0	33.6	74.7	36.6
Arora, 2008	88.9	64.8	97.2	3.9
Afshar, 2013	85.7	41.9	98.0	13.8
Fujiwara, 2013	80.0	45.9	95.0	3.8
Nakagawa, 2016*	91.7	58.7	98.8	13.4
Nakagawa, 2016†	87.5	46.3	98.3	12.1
Nakagawa, 2016‡	87.5	46.3	98.3	3.8
Ye, 2020	95.0	52.5	99.7	12.5
Subtotal	**77.8**	**66.7**	**86.0**	

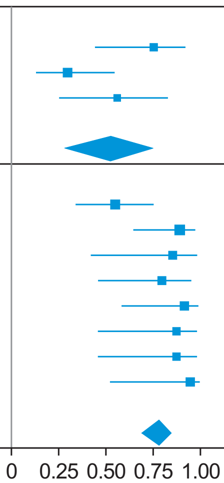

Fig. 4. The pooled proportion of wrists that did not show any change in the Lichtman stage in the nonoperative treatment and vascularized bone graft (VBG) groups. Nakagawa et al.[2] have reported the outcomes of three treatments: *1, 2 supraretinacular intercompartmental artery pedicled bone graft, †4, 5 extensor compartmental artery pedicled bone graft, and ‡second dorsal metacarpal artery pedicled bone graft.

Study	No pain at final follow-up (%)	Lower limits	Upper limits	Relative weights
Nonoperative treatment group				
Evans, 1986	43.8	22.5	67.6	18.9
Kristensen, 1986*	30.8	16.2	50.5	26.5
Kristensen, 1986†	30.4	15.3	51.5	23.3
Fujisawa, 1996	52.9	30.3	74.5	20.3
O.Delaere, 1998	9.1	2.3	30.0	8.7
Van den Dungen, 2006	2.5	0.2	29.8	2.3
Subtotal	**29.2**	**16.6**	**46.1**	
VBG group				
Daecke, 2005	33.8	18.4	55.7	58.4
Afshar, 2013	42.9	14.4	77.0	19.2
Ye, 2020	33.3	11.1	66.7	22.4
Subtotal	**35.9**	**22.6**	**52.0**	

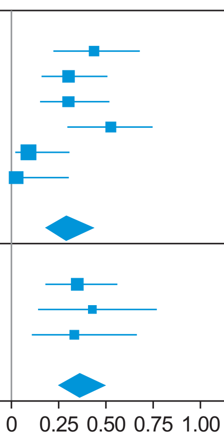

Fig. 5. The pooled proportion of wrists without pain at the final follow-up in the nonoperative treatment and vascularized bone graft (VBG) groups. Kristensen et al.[22] have reported the outcomes of two treatments: *no treatment and †conservative treatment.

Study	More than moderate degree pain at final follow-up (%)	Lower limits	Upper limits	Relative weights
Nonoperative treatment group				
Evans, 1986	18.8	6.2	44.7	10.1
Kristensen, 1986*	23.1	10.8	42.8	19.1
Kristensen, 1986†	17.4	6.7	38.2	13.7
Fujisawa, 1996	35.3	16.8	59.6	16.1
O.Delaere, 1998	40.9	22.8	61.8	22.0
Van den Dungen, 2006	24.1	22.6	64.4	19.2
Subtotal	**30.4**	**22.7**	**39.4**	
VBG group				
Daecke, 2005	13.0	4.3	33.5	59.9
Afshar, 2013	14.3	2.0	58.1	19.7
Ye, 2020	11.1	1.5	50.0	22.4
Subtotal	**12.9**	**5.5**	**27.4**	

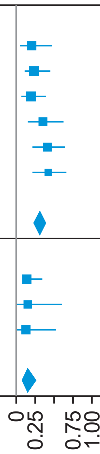

Fig. 6. The pooled proportion of wrists that had more than a moderate degree of pain at the final follow-up in the nonoperative treatment and vascularized bone graft (VBG) groups. Kristensen et al.[22] have reported the outcomes of two treatments: *no treatment and †conservative treatment.

ROM and Grip Strength

More than half of the studies provided wrist ROM in the sagittal plane only after treatment; therefore, we compared the sum of the volar flexion (VF) and dorsiflexion (DF) of the wrist joint (VF + DF) between the two groups. Nine of the 12 studies provided VF + DF after treatment (5 studies in the nonoperative treatment group and 4 studies in the VBG group).[2,6,12,14,17-21] The pooled mean VF + DF values were 90.8° (95% CI, 79.7°–101.9°; $I^2 = 73.6\%$; heterogeneity: $p = 0.004$) and 83.2° (95% CI, 73.6°–92.6°; $I^2 = 88.7\%$; heterogeneity: $p < 0.001$) in the nonoperative treatment group and VBG group, respectively.

The grip strength of the involved hand was reported as raw data or as the ratio compared to that of the contralateral side after treatment. We compared the mean grip strength ratio between the two groups. Ten of the 12 studies reported the mean grip strength ratio after treatment (5 in the nonoperative treatment group and 5 in the VBG group).[2,5,6,9,12,17-21] The pooled mean grip strength ratios were 81.0% (95% CI, 66.8%–95.3%; $I^2 = 91.4$; heterogeneity: $p < 0.001$) and 90.8% (95% CI, 88.8%–92.9%; $I^2 = 37.5$; heterogeneity: $p = 0.142$) in the nonoperative treatment group and VBG group, respectively.

DISCUSSION

To the best of our knowledge, this study was novel in evaluating the efficacy of VBG in treating Kienböck disease. Fewer wrists in the VBG group showed worsening Lichtman stages, and a greater proportion of the wrists did not show any change in stage compared to that in the nonoperative treatment group. In addition, the VBG group had fewer patients who had more than a moderate degree of pain than did the nonoperative treatment group. These parameters of the VBG group showed a tendency of improvement compared to those of the nonoperative treatment group, but the overlapping 95% CIs suggested limited evidence due to the small number of enrolled patients. Regardless of treatment options, ROM and grip strength were substantially reduced compared with the normal range.

After VBG, only 17.0% of the wrists showed worsening of the Lichtman stage, and 77.8% did not show any change, compared with 40.2% and 52.4% of the wrists after nonoperative treatment, respectively. In a previous study, 34.7% of wrists showed worsening of the Lichtman stage, and 62.5% of the wrists did not show any change after radial osteotomy.[4] Although direct comparison is impossible given the difference in study design and follow-up period, VBG showed the tendency of better radiographic outcomes than did nonoperative treatment or radial osteotomy. Thus, we believe that although VBG could not restore an already distorted lunate, it could halt or delay the progression of lunate collapse or carpal malalignment.

Distorted lunate anatomy produces symptoms in Kienböck disease. A fractured lunate cannot stand the mechanical forces from adjacent carpal bones, and a dissociated scapholunate relationship leads to the development of abnormal joint reaction forces. The abnormal loading to the carpal bones irritates the adjacent tissues of the lunate and causes synovitis and pain.[23] We expected that VBG would improve pain by healing the fractured lunate and enhancing its mechanical role as an intercalated bone. In addition, radiocarpal joint synovectomy, which should be performed for surgical exposure of the diseased lunate, would be a source of pain relief.[24] In this systematic review, the proportion of wrists with more than a moderate degree of pain was lower in the VBG group than in the nonoperative treatment group (12.9% vs. 30.4%), but the proportion of wrists without pain was similar between the two groups (35.9% vs. 29.2%). VBG appeared to reduce pain in patients with severe pain, but the number of collected studies and the number of enrolled patients in each study were not sufficient to demonstrate the efficacy of VBG in reducing pain in patients with Kienböck disease.

Open arthrotomy is inevitable in VBG, so the reduced wrist ROM after VBG was a concern for several clinicians.[25] However, the VBG group showed no meaningful difference in wrist VF and DF compared with the nonoperative treatment group in this study. Before treating Kienböck disease, a considerable patients have limited mobility compared with the normal value. Therefore, we can infer that the additional intra-articular procedure did not significantly affect the ROM of the wrist joint. Since conservative treatment of Kienböck disease primarily involves joint immobilization using a splint or cast for long periods, limited ROM would be observed in the nonoperative treatment group.

Our study has several limitations. First, the included studies predominantly described the outcomes of a single treatment, instead of comparing nonoperative treatment and VBG. Therefore, the background and patient cohort varied across studies, and single-arm meta-analysis was a realistic option. Second, the treatment methods applied in the nonoperative treatment and VBG groups varied. The nonoperative treatment methods included regimens ranging from no treatment to immobilization with various periods, while in the VBG group, various methods from various donor sites were used. This difference could be an unreported confounding factor for the treatment outcomes. Third, because of the limited data from enrolled studies, we pooled the original data with groups and presented our data mostly as a portion of specific status, and not as the absolute value and range. Finally, a substantial proportion of patients was lost to follow-up and excluded, resulting in a risk of biased results if the patients who dropped out did so because of worse outcomes.

In conclusion, the VBG group showed greater improvement than the nonoperative treatment group after treatment for Kienböck disease in terms of radiographic stage and wrist pain. However, the overlapping 95% CI across all parameters suggests that there was no meaningful difference. Regardless of treatment options, ROM and grip strength were substantially reduced compared with the normal range. Considering the medical cost and risk of donor site morbidity, VBG would not be a superior treatment compared to nonoperative treatment. Further well-designed, large-scale, long-term follow-up studies are needed to demonstrate the superiority of VBG over nonoperative treatments in terms of radiographic and clinical outcomes in Kienböck disease.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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ORCID

Jin Yeop Park https://orcid.org/0000-0002-2156-4214
Jae Kwang Kim https://orcid.org/0000-0001-5104-4634
Young Ho Shin https://orcid.org/0000-0002-9388-9720

REFERENCES

1. Danoff JR, Cuellar DO, Jane O, Strauch RJ. The management of kienbock disease: a survey of the ASSH membership. J Wrist Surg. 2015;4(1):43-8.
2. Nakagawa M, Omokawa S, Kira T, Kawamura K, Tanaka Y. Vascularized bone grafts from the dorsal wrist for the treatment of Kienbock disease. J Wrist Surg. 2016;5(2):98-104.
3. Beredjiklian PK. Kienbock's disease. J Hand Surg Am. 2009;34(1):167-75.
4. Shin YH, Kim JK, Han M, Lee TK, Yoon JO. Comparison of long-term outcomes of radial osteotomy and nonoperative treatment for Kienbock disease: a systematic review. J Bone Joint Surg Am. 2018;100(14):1231-40.
5. Afshar A, Eivaziatashbeik K. Long-term clinical and radiological outcomes of radial shortening osteotomy and vascularized bone graft in Kienbock disease. J Hand Surg Am. 2013;38(2):289-96.

6. Ye X, Feng JT, Yin HW, Qiu YQ, Shen YD, Xu WD. Use of 4+5 extensor compartmental vascularized bone graft and K-wire fixation for treating stage II-IIIA Kienbock;s disease. Hand Surg Rehabil. 2020;39(3):207-13.

7. Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH, Cohen MS. Green's operative hand surgery. 7th ed. Philadelphia: Elsevier; 2017.

8. Hori Y, Tamai S, Okuda H, Sakamoto H, Takita T, Masuhara K. Blood vessel transplantation to bone. J Hand Surg Am. 1979;4(1):23-33.

9. Fujiwara H, Oda R, Morisaki S, Ikoma K, Kubo T. Long-term results of vascularized bone graft for stage III Kienbock disease. J Hand Surg Am. 2013;38(5):904-8.

10. Mathoulin C, Wahegaonkar AL. Revascularization of the lunate by a volar vascularized bone graft and an osteotomy of the radius in treatment of the Kienbock's disease. Microsurgery. 2009;29(5):373-8.

11. Shin YH, Yoon JO, Ryu JJ, Lee TK, Choi SW, Kim JK. Pronator quadratus pedicled bone graft in the treatment of Kienböck disease: follow-up 2 to 12 years. J Hand Surg Eur Vol. 2020;45(4):396-402.

12. Daecke W, Lorenz S, Wieloch P, Jung M, Martini AK. Vascularized os pisiform for reinforcement of the lunate in Kienbock's disease: an average of 12 years of follow-up study. J Hand Surg Am. 2005;30(5):915-22.

13. Burger HK, Windhofer C, Gaggl AJ, Higgins JP. Vascularized medial femoral trochlea osteochondral flap reconstruction of advanced Kienbock disease. J Hand Surg Am. 2014; 39(7):1313-22.

14. Arora R, Lutz M, Deml C, Krappinger D, Zimmermann R, Gabl M. Long-term subjective and radiological outcome after reconstruction of Kienbock's disease stage 3 treated by a free vascularized iliac bone graft. J Hand Surg Am. 2008; 33(2):175-81.

15. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009; 6(7):e1000097.

16. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557-60.

17. Viljakka T, Tallroth K, Vastamaki M. Long-term natural outcome (7-26 years) of Lichtman stage III Kienbock's lunatomalacia. Scand J Surg. 2016;105(2):125-32.

18. Van den Dungen S, Dury M, Foucher G, Marin Braun F, Lorea P. Conservative treatment versus scaphotrapeziotrapezoid arthrodesis for Kienbock's disease: a retrospective study. Chir Main. 2006;25(3-4):141-5.

19. Evans G, Burke FD, Barton NJ. A comparison of conservative treatment and silicone replacement arthroplasty in Kienbock's disease. J Hand Surg Br. 1986;11(1):98-102.

20. Fujisawa K, Hirata H, Tomita Y, Higuchi Y, Morita A, Matsumoto M. Long-term follow up of patients with conservatively treated Kienböck's disease. J Orthop Sci. 1996;1(3): 182-6.

21. Delaere O, Dury M, Molderez A, Foucher G. Conservative versus operative treatment for Kienbock's disease: a retrospective study. J Hand Surg Br. 1998;23(1):33-6.

22. Kristensen SS, Thomassen E, Christensen F. Kienbock's disease: late results by non-surgical treatment: a follow-up study. J Hand Surg Br. 1986;11(3):422-5.

23. Bain GI, MacLean SB, Yeo CJ, Perilli E, Lichtman DM. The etiology and pathogenesis of Kienbock disease. J Wrist Surg. 2016;5(4):248-54.

24. Bochud RC, Buchler U. Kienbock's disease, early stage 3: height reconstruction and core revascularization of the lunate. J Hand Surg Br. 1994;19(4):466-78.

25. Shin YH, Kim J, Gong HS, Rhee SH, Cho MJ, Baek GH. Clinical outcome of lateral wedge osteotomy of the radius in advanced stages of Kienbock's disease. Clin Orthop Surg. 2017;9(3):355-62.