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ORIGINAL STUDY

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Combined radial wedge and shortening osteotomy versus scaphocapitate arthrodesis in advanced Kienböck's disease

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Although various surgical techniques have been reported for the treatment of advanced Kienböck's disease (Lichtman stage IIIB and above), the appropriate operative treatment is still being debated. This study compared the clinical and radiological outcomes of combined radial wedge and shortening osteotomy (CRWSO) and scaphocapitate arthrodesis (SCA) in the treatment of advanced Kienböck's disease (above type IIIB) with a minimum of 3 years of follow-up. We analyzed the data from 16 and 13 patients who underwent CRWSO and SCA, respectively. The average follow-up period was 48.6±12.8 months. Clinical outcomes were evaluated using the flexion-extension arc, grip strength, Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH), and Visual Analogue Scale (VAS) for pain. The following radiological parameters were measured: ulnar variance (UV), carpal height ratio (CHR), radioscaphoid angle (RSA), and Stahl index (SI). Osteoarthritic changes in the radiocarpal and midcarpal joints were evaluated using computed tomography (CT).

Clinically, both groups showed significant improvements in the grip strength, DASH, and VAS at final follow-up. However, regarding the flexion-extension arc, the CRWSO group showed a significant improvement, while the SCA group did not. Radiologically, compared to the preoperative values, the CHR results improved at final follow-up in the CRWSO and SCA groups. There was no statistically significant difference in the degree of CHR correction between the 2 groups. By the final follow-up visit, none of the patients in either group had progressed from Lichtman stage IIIB to stage IV. Considering restoration of wrist joint range of motion, CRWSO may be a good alternative for limited carpal arthrodesis for advanced Kienböck's disease.

Keywords : Kienböck's disease; Lunate; osteotomy; arthrodesis.

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INTRODUCTION

Kienböck's disease is a disorder of the lunate bone resulting from a compromised vascular supply *(1)*. Although the etiology of this disease remains unclear, its progressive character is well understood.

Lichtman's radiological classification defines stage IIIB as decreased carpal height with fixed scaphoid rotation *(2)*. Stage IV is characterized by radiocarpal or midcarpal degenerative arthritis. The advanced stages of Kienböck's disease refer to those above IIIB with a decrease in the carpal height and fixed scaphoid rotation.

In the advanced stages, many authors advocate for the use of limited carpal arthrodesis (LCA), such as scaphotrapeziotrapezoid (STT) or scaphocapitate (SC) arthrodesis *(3,4)*. However, the use of these salvage procedures, which reduce the radiocarpal and midcarpal joints' range of motion (ROM), has not been readily agreed upon in young and active patients *(5)*. Rather, some studies have reported that radial osteotomy for advanced stage Kienböck's disease showed improvement of clinical and functional outcomes *(6-10)*.

To date, only a few published reports have directly compared the clinical and radiological outcomes of radial osteotomy and LCA for advanced Kienböck's disease *(11,12)*. Thus, there is still controversy around the optimal treatment for advanced Kienböck's disease.

Here, we used both combined radial wedge and shortening osteotomy (CRWSO) and scaphocapitate arthrodesis (SCA) for the treatment of advanced Kienböck's disease. CRWSO is an extra-articular decompression procedure that minimizes the stress load applied to the lunate bone. SCA is an intra-articular procedure that involves direct carpal alignment correction. It is a salvage procedure that is used to prevent the progression of degenerative osteoarthritis around the lunate bone. This study aimed to compare the clinical and radiological outcomes of CRWSO and SCA in the treatment of advanced Kienböck's disease.

MATERIALS AND METHODS

This retrospective study's protocol was approved by our hospital's institutional review board. The senior author performed CRWSO or SCA for advanced stage Kienböck's disease (Lichtman stages IIIB and IV) on 2 groups of patients between July 2013 and September 2017. Both CRWSO and SCA were offered to the patients, and selection was made after discussion regarding the advantages and disadvantages of both procedures. Patients who had complete postoperative follow-up records for a

Table I. — Demographic data of patients

Demographic Variables	CRWSO (n=16)	SCA (n=13)	p value
Age at operation (Year)	40.1 ± 11.9	49.5 ± 12.9	0.075
Sex			0.066
Male	7 (43.75%)	5 (38.46%)	
Female	9 (56.25%)	8 (61.54%)	
Follow-up period (Month)	47.1 ± 11.1	50.6 ± 13.2	0.539
Lichtman stage			0.330
IIIB	11 (68.75%)	7 (53.85%)	
IV	5 (31.25%)	6 (46.15%)	
Side involved			0.352
Right	7 (43.75%)	7 (53.85%)	
Left	9 (56.25%)	6 (46.15%)	

Values are presented as mean ± standard deviation or n (%). CRWSO = Combined Radial Wedge and Shortening Osteotomy; SCA = Scapho-Capitate Arthrodesis.

minimum of 3 years (range, 3-6 years) were included in this study. Patients with Lichtman stage IIIA or lower, a follow-up period shorter than 3 years, and without postoperative computed tomography (CT) scans were excluded.

Sixteen and 13 patients who underwent CRWSO and SCA, respectively, met the inclusion criteria. The patient's demographic data are summarized in Table I. In the CRWSO group, the average age at the time of the surgery and follow-up time were 40.1 years old and 47.1 months, respectively (range, 19-62 years and 36-74 months, respectively). The CRWSO group included 7 men and 9 women, and 11 and 5 Lichtman stages IIIB and IV patients, respectively. In the SCA group, the average age at the time of surgery and follow-up time were 49.5 years and 50.6 months, respectively (range, 26-64 years and 38-72 months, respectively). The SCA group comprised 5 men and 8 women. There were 7 and 6 Lichtman stages IIIB and IV patients, respectively.

When CRWSO was performed, regardless of the ulnar variance (UV), we planned for wedge angle correction to 10-15° and for radial shortening to 1-2 mm. Before surgery, we conducted provisional osteotomy to review the adequacy of the correction by the paper tracing method (Fig. 1A). We made a plastic template of the same shape as paper template obtained in provisional osteotomy. Intraoperatively, 2 guide pins were placed according to a preoperatively planned sterile, real-sized, plastic template and osteotomy was performed using an oscillating saw under fluoroscopic control (Fig. 1B). Then, the osteotomies were fixed using 2.4 mm locking compression plates (LDRS®, Synthes, Oberdorf, Switzerland). Bone grafting was not performed at the osteotomy site. Postoperatively, a

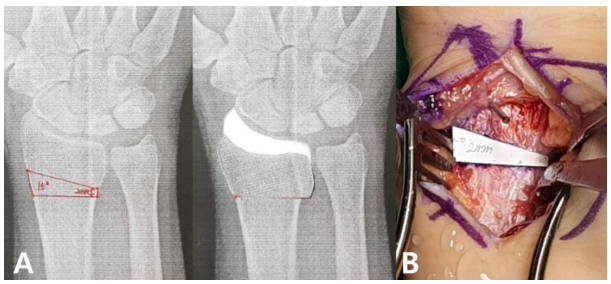

Figure 1. — (A) The degree of wedge angle and shortening were planned through provisional osteotomy using the paper tracing method. (B) Osteotomy was performed with reference to a sterile plastic template prepared preoperatively.

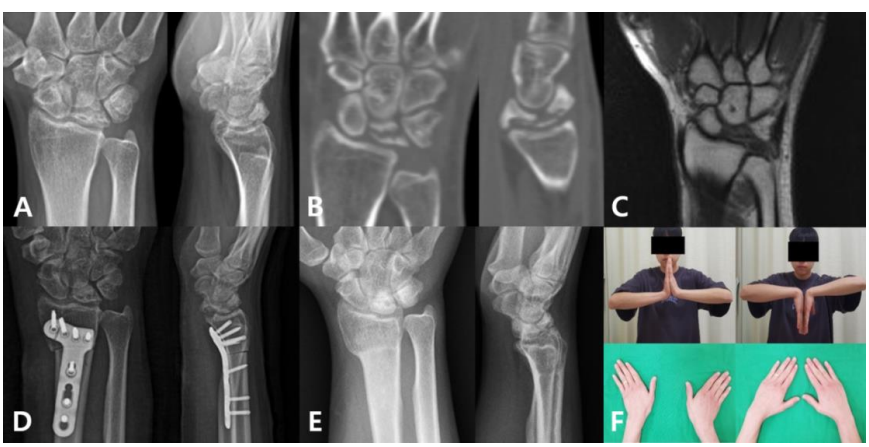

Figure 2. — (A) Preoperative posteroanterior and lateral radiograph of a 25-year-old woman with stage IIIB Kienböck's disease in the left wrist. (B) Preoperative computed tomography (CT) scan showing collapse and fragmentation of lunate bone. (C) Preoperative T1 weighted magnetic resonance imaging showing diffuse decreased signal intensity of the lunate bone. (D) A plain radiograph showing neutral ulnar variance immediately after combined radial wedge and shortening osteotomy. (E) At the 4-year follow-up after radial osteotomy, the plain radiographs and CT scans indicated no progressive lunate collapse or degenerative changes. (F) The patient showed a similar wrist joint range of motion compared to the contralateral side.

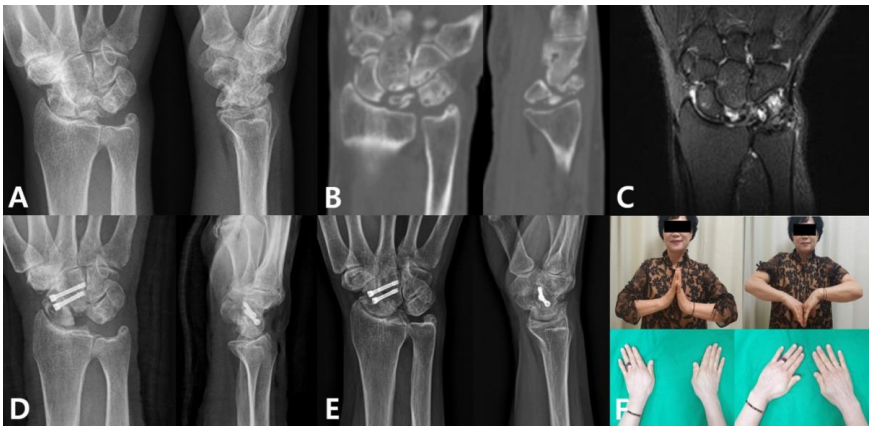

Figure 3. — (A) Preoperative posteroanterior and lateral radiograph of a 64-year-old woman with stage IV Kienböck's disease in the right wrist. (B) Preoperative computed tomography (CT) scans showing lunate fragmentation and degenerative arthritic changes of the adjacent carpal bones. (C) Preoperative T2 weighted magnetic resonance imaging showing mixed signal intensity of the lunate bone and radiocarpal degenerative arthritis. (D) Postoperative radiograph immediately after lunate excision and scaphocapitate (SC) arthrodesis. (E) At the 5-year follow-up visit, the plain radiograph indicated complete SC bone fusion and no further progression of the osteoarthritic changes. (F) The patient was satisfied with the symptom improvements; however, the range of motion was limited when compared to the contralateral side.

short arm splint was applied for the first 2 weeks; thereafter, passive ROM exercises were initiated by switching to a removable splint (Fig. 2).

When SCA was performed, collapsed lunate bones causing intra-articular impingement were excised in all patients. Then, the scaphocapitate articular cartilage was denuded with mini-rounger, and the scapholunate angle was adjusted to between 30°and 60°, SCA was performed using two 3.0 mm headless compression screws (3.0 HCS®, Synthes, Oberdorf, Switzerland). The scapholunate angle, screw orientation, and arthrodesis position were adjusted under fluoroscopy. Cancellous autograft bone taken from distal radius was grafted to the arthrodesis site. Postoperatively, after applying a short arm cast for 6 weeks, patients were switched to removable splints and began gradual passive ROM exercises (Fig. 3).

To evaluate the functional outcomes, the wrist joint flexion-extension arc angle, grip strength of both hands, and Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire (scale of 0-100, with higher scores indicating greater disability) and visual analogue scale (VAS) scores were assessed preoperatively and at each follow-up visit. The wrist flexion-extension arc was measured using a goniometer. With the elbow flexed at 90° and the forearm in a neutral position, the grip strength of both hands was measured using a hand dynamometer (B&L Engineering, Santa Ana, CA, United States).

Radiological alterations to the lunate and wrist joint were evaluated using the initial and follow-up plain radiographs. Lichtman stage progression and deteriorations in the osteoarthritic changes at the wrist joint were assessed using preoperative CT. Bone union after CRWSO and arthrodesis after SCA were checked through serial plain radiographs. In addition, radiological measurements, including the UV, carpal height ratio (CHR), radioscaphoid angle (RSA), and Stahl index (SI) were measured on the initial and follow-up radiographs. After at least 3 years follow-up, CT was used to investigate whether the Lichtman stage worsened and whether the arthritic change had progressed.

The Mann-Whitney *U* test or Fisher's exact test were used to compare the demographic characteristics, preoperative status, and final follow-up outcomes between the 2 groups. The Mann-

Whitney *U* and Fisher's exact tests were used to analyze numeric and nonnumeric data, respectively. The Wilcoxon signed-rank test was used to compare the preoperative and postoperative outcomes within each group. All statistical analyses were performed using SPSS version 25.0 for Windows. (IBM Corp., Armonk, NY, United States). A p-value <0.05 was considered statistically significant.

RESULTS

Table 1 describes the preoperative demographic data. The patient's age, sex, Lichtman stages IIIB and IV ratio, follow-up period, and side involved did no differ significantly between the 2 groups.

All clinical assessments, such as the flexion-extension arc, grip strength, and DASH and VAS scores were similar in the preoperative evaluations between the 2 groups (Table II). When comparing the preoperative and final follow-up data, both methods resulted in significant improvements in the grip strength, and DASH and VAS scores at final follow-up. However, regarding the flexion-extension arc, there was a significant improvement in the CRWSO group, but not the SCA group (p<0.001 and p=0.249, respectively).

When comparing the groups, there were no significant differences in the degree of correction by the final follow-up visit, grip strength, and DASH and VAS scores. The flexion-extension arc increased by 25.1°±10.2° and decreased by 9.9°±16.2° in the CRWSO and SCA groups, respectively, indicating a significant difference (p<0.01).

Table II. — Clinical outcomes

	CRWSO (n=16)	SCA (n=13)	p value
Flexion/Extension ROM (°)			
Preoperative	94.1 ± 8.0	90.8 ± 9.1	0.398
Final follow-up	119.2 ± 12.3	81.1 ± 11.2	<0.001
Correction*	25.1 ± 10.2	-9.9 ± 16.2	<0.001
p value	<0.001	0.249	
Grip strength†			
Preoperative	55.1 ± 7.8	52.6 ± 7.2	0.559
Final follow-up	86.5 ± 3.9	85.2 ± 5.4	0.075
Correction*	31.4 ± 8.8	32.5 ± 8.57	0.559
p value	<0.001	0.01	
DASH score			
Preoperative	38.8 ± 5.5	39.4 ± 5.0	0.650
Final follow-up	7.7 ± 3.5	7.6 ± 3.4	0.880
Correction*	31.0 ± 5.8	31.8 ± 6.3	0.559
p value	<0.001	<0.001	
VAS score			
Preoperative	6.4 ± 1.0	6.2 ± 0.8	0.548
Final follow-up	1.4 ± 0.9	1.5 ± 0.9	0.682
Correction*	5.0 ± 1.4	4.6 ± 1.1	0.329
p value	<0.001	<0.001	

Values are presented as mean ± standard deviation. * Difference between the preoperative and final follow-up values. † Percentage of the affected hand compared to the normal contralateral hand. CRWSO = Combined Radial Wedge and Shortening Osteotomy; SCA = Scapho-Capitate Arthrodesis; ROM = Range Of Motion; DASH = Disabilities of the Arm, Shoulder, and Hand Questionnaire; VAS = Visual Analogue Scale.

Table III. — Radiographic outcomes

	CRWSO (n=16)	SCA (n=13)	p value
Ulnar variance (mm)			
Preoperative	-0.79 ± 1.36	-0.33 ± 0.97	0.423
Final follow-up	0.82 ± 1.86	-0.58 ± 1.70	0.068
Correction*	1.61 ± 1.27	-0.25 ± 1.08	<0.001
p value	0.001	0.812	
Carpal height ratio			
Preoperative	0.49 ± 0.06	0.49 ± 0.05	0.914
Final follow-up	0.52 ± 0.05	0.50 ± 0.04	0.374
Correction*	0.03 ± 0.04	0.02 ± 0.02	0.068
p value	0.007	0.016	
Radioscaphoid Angle (°)			
Preoperative	63.1 ± 3.9	63.9 ± 6.8	0.983
Final follow-up	63.5 ± 4.6	54.7 ± 7.1	<0.001
Correction*	0.04 ± 3.19	-9.23 ± 11.53	0.009
p value	0.723	0.017	
Stahl Index			
Preoperative	0.37 ± 0.07	0.32±0.08	0.092
Final follow-up	0.41 ± 0.07		
Correction*	0.04 ± 0.11		
p value	0.301		
Osteoarthritis progression	0 / 16	2 / 13	0.513

Values are presented as mean ± standard deviation. * Difference between preoperative and final follow-up values. CRWSO = Combined Radial Wedge and Shortening Osteotomy; SCA = Scapho-Capitate Arthrodesis.

In the radiological evaluation (Table III), preoperatively, there were no significant differences between the 2 groups in indicators such as the UV, CHR, RSA, and SI. The UV was slightly negative in both groups preoperatively. At the final follow-up, the UV only increased significantly in the CRWSO group (p=0.001). There was a significant difference in the degree of UV correction between the 2 groups (p<0.001). Compared to the preoperative values, the CHR results improved at final follow-up in the CRWSO and SCA groups (p=0.007 and p=0.016, respectively). There was no statistically significant difference in the degree of CHR correction between the 2 groups (p=0.068). Compared to the preoperative value, only the SCA group's RSA had decreased significantly at final follow-up (p=0.017). The degree of RSA correction differed significantly between the 2 groups (p=0.009). The postoperative SI could not be analyzed because lunate excision was performed in the SCA group.

By the final follow-up, none of the patients in either group had progressed from Lichtman stage IIIB to stage IV. There were 2 Lichtman stage IV cases in the SCA group, indicating deterioration of the degenerative changes in the wrist. The progression of the degeneration was not prominent and was mainly confined to the radioscaphoid joint. In every patient, the osteotomy and arthrodesis sites in the CRWSO and SCA groups, respectively, attained bone union. There were no other surgical complications such as infection, neurovascular injury, or nonunion.

DISCUSSION

Although various surgical techniques have been reported for the treatment of advanced Kienböck's disease, the appropriate operative treatment is still being debated. Specifically, there is no consensus on the standard surgical treatment for Lichtman stage IIIB and above.

Radial closing wedge or shortening osteotomy have demonstrated good clinical outcomes; however, these kind of opeartions were unable to regain the shape of the collapsed lunate and carpal misalignment of advanced Kienböck's disease *(13,14)*. Condit et al. argued that, at stage IIIB or higher, scaphoid malrotation, carpal height loss, and lunate deformities could not be corrected, even with radial shortening osteotomies *(15)*. Therefore, the efficacy of radial osteotomy has been questioned as a treatment for disease above stage IIIB *(8,16)*. However, Watanabe et al. recently reported that a radial closing wedge may be a reasonable option for patients with stage IIIB disease *(17)*. Matsui et al. and Soejima et al. also presented notable outcomes of radial shortening osteotomy for advanced stages of Kienböck's disease *(7,10)*.

Contrastingly, LCA is based on radiocarpal articulation and carpal alignment preservation. The purpose of LCA is to preserve carpal height, to maintain the scaphoid in its proper position, to prevent degenerative arthritis *(18)*. Here, we performed SCA as a LCA procedure. This is because SCA has a wider contact area between the carpal bones that are fused and is technically easier than other LCAs such as STT arthrodesis. Luegmair reported significant pain reduction at a mean follow-up period of 8.75 years in 5 patients with stages IIIB and IV Kienböck's disease who were treated with SCA *(19)*. In 10 patients with stage III Kienböck's disease who underwent SCA, Sennwald et al. reported significant pain reduction in 90% of the patients with an average of 36 months of follow-up *(20)*. However, LCA, including SCA, has the disadvantage of postoperative ROM restriction. Additionally, these salvage procedures cannot prevent the progression of secondary osteoarthritis in the radiocarpal and midcarpal joints *(16,19,21)*.

Thus far, only 2 studies have directly compared the clinical and radiological outcomes of radial osteotomy and LCA for advanced Kienböck's disease (stage IIIB or higher). In these studies, both radial osteotomy and LCA had excellent clinical and radiological outcomes. Das Gupta et al. compared the treatment outcomes of 36 and 13 patients treated with radial shortening osteotomy and STT arthrodesis, respectively. They suggested that the patient's wish to restore full active ROM and negative UV are indications for radial osteotomy rather than LCA *(11)*. Tatebe et al. compared the outcomes of 28 cases of radial closing wedge osteotomy and 10 cases of STT or SC arthrodesis. They reported that the active flexion-extension arc increased by approximately 9.7° after radial closing wedge osteotomy and decreased by approximately 16.0° after STT or SCA *(12)*.

The difference between the 2 aforementioned comparative studies and our study is that we performed a combined radial wedge and shortening osteotomy. Here, the flexion-extension arc after CRWSO increased by 25.1° from the preoperative value. This was a significant improvement when compared to shortening osteotomy or closing wedge osteotomy alone. In radial osteotomies, ROM recovery occurs due to the effects of preserved midcarpal motion and midcarpal area decompression. We propose that this effect could be maximized by performing a combination of wedge and shortening osteotomy. This improvement in the postoperative ROM makes a significant difference in patient satisfaction.

Another study reported on the outcomes of a combined radial wedge and shortening osteotomy. Hong et al. performed a combined radial wedge and shortening osteotomy for non-negative UV patients only among Lichtman stages IIIA and IIIB patients, and found excellent results at a mean follow-up period of 22.3 months *(22)*. Here, a combined radial wedge and shortening osteotomy was performed in all patients with advanced Kienböck's disease, regardless of the degree of UV. Since we performed CRWSO in patients with neutral or positive UVs, there may be concerns about overcorrection *(9)*. We propose that by adjusting the shortening length to less than 2 mm, the risk of iatrogenic ulnar impaction

syndrome or distal radioulnar joint arthritis could be reduced. Additionally, we considered that by adjusting the wedge osteotomy angle to less than 15°, there were no occurrences of radioscaphoid degenerative change, limitation of forearm rotation, ulnar deviation, or radial deviation.

In terms of the radiological factors, CRWSO showed good results that were not inferior to SCA. Our study outcomes showed that CHR remained unchanged with no further collapse in both CRWSO group and SCA group. In the final follow-up, the degree of correction of the RSA showed a significant improvement in the SCA group than the CRWSO group. However, even in the CRWSO group, RSA was no longer increased compared to the preoperative value. This means that even though CRWSO did not restore scaphoid rotation as much as SCA, it prevented deterioration of scaphoid rotation during the follow-up period. On the CT scans performed 3-years postoperatively, there was no new radiocarpal or midcarpal arthritis, and no cases of worsened preexisting arthritis. We propose that CRWSO is an effective surgical intervention for the prevention of disease progression radiologically.

This study has several limitations. It is a retrospective study that has not been randomized. Hence, it has a potential for selection bias. However, since there were no statistically significant differences in age, sex, Lichtman stage, and follow-up period, it can be inferred that there is little difference between two groups preoperatively. The second limitation is the relatively short follow-up period and the small sample size. Therefore, a variety of long-term, prospective studies are needed.

CONCLUSION

Both CRWSO and SCA provided excellent clinical and radiological results in patients with advanced Kienböck's disease during midterm follow up. We suggest that CRWSO may be a good alternative to LCA for advanced Kienböck's disease, especially for patients who wish to preserve a wider wrist ROM.

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