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Examining the Efficacy of Arthroscopic Scaphocapitate Arthrodesis for Advanced Kienbock's Disease: Clinical and Radiological Outcomes

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Background: Altering wrist biomechanics, Kienbock's disease leads to progressive carpal collapse that results in early arthritis and degenerative changes. By shifting the loading axis toward the radioscaphoid joint, scaphocapitate arthrodesis (SCA) has been reported as a salvage procedure effective in treating symptomatic patients with advanced Kienbock's disease. In this study, we aimed to evaluate the clinical and radiological outcomes of arthroscopic SCA in symptomatic patients with advanced stages of Kienbock's disease.

Methods: Between March 2010 and February 2021, we included 15 patients with symptomatic stage IIIA (n=2) and stage IIIB (n=13) Kienbock's disease who were followed up for a minimum of 24 months after arthroscopic SCA with or without lunate excision. The lunate was excised in 6 patients and retained in 9. Visual analog scale (VAS) pain score, grip strength, range of motion (ROM), active flexion-extension arc, and modified Mayo wrist score (MMWS) were measured preoperatively and at each follow-up examination after surgery. Operation-related complications and radiographic changes were also assessed.

Results: There were 13 women and 2 men, with a mean age of 57.6 years (range, 21–74 years) at the time of undergoing arthroscopic SCA. Follow-up ranged from 24 to 116 months, with an average of 56.9 ± 32.3 months. Bony union was achieved in all patients. At preoperative examination, wrist ROM (67%) and grip strength (48%) significantly decreased, compared to the contralateral wrist. At the final follow-up, there were significant improvements in VAS, grip strength, and MMWS, whereas the active wrist ROM showed no significant change. Radioscaphoid angle recovered after surgery, while radiographic carpal collapse and ulnar translation of the carpus occurred. In subgroup analysis according to excision of the lunate, there were no significant differences in VAS, MMWS, grip strength, or total ROM. However, increased ulnar translation and decreased radial deviation were noted in the lunate excision group.

Conclusions: Arthroscopic SCA achieved significant improvements in pain and wrist function in patients with advanced Kienbock's disease without any complications. Excision of the lunate when performing arthroscopic SCA seemed to induce progressive carpal ulnar translation, with no apparent clinical benefits over retaining it.

Keywords: *Osteonecrosis, Lunate bone, Arthroscope, Arthrodesis*

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Kienbock's disease is a rare disease characterized by avascular necrosis of the lunate due to various causes. Although the natural progress of the disease is unclear, the progression of avascular necrosis of the lunate results in the mechanical collapse thereof.[1] Lunate collapse increases pressure on the adjacent carpal bones and disrupts the arrangement of the carpal row, leading to wrist arthritis and permanent restriction of wrist function.

Lichtman classification is commonly used to describe stages of Kienbock's disease based on radiographic findings (stage I: normal radiograph, stage II: density change and lytic and sclerotic changes in the lunate, stage IIIa: lunate collapse with a radioscaphoid [RS] angle of less than 60°, stage IIIb: lunate collapse with an RS angle of greater than 60°, and stage IV: degenerative changes around the lunate).[2] In the early stages (stages II and IIIa), joint leveling procedures, such as radial shortening or capitate shortening, that reduce pressure on the lunate and increase blood flow to alleviate necrosis of the lunate or direct revascularization procedures are recommended. If recovery of the lunate seems difficult due to the progression of necrosis in the late stages (stages IIIb and IV), either limited carpal arthrodesis that bypasses the force applied to the lunate through arthrodesis of the carpal bones around the lunate or proximal row carpectomy is used.[2-4] Limited carpal arthrodesis includes scaphotrapeziotrapezoid arthrodesis, scaphocapitate arthrodesis (SCA), and capitohamate arthrodesis, and relatively good clinical results have been reported for both limited carpal arthrodesis and proximal row carpectomy.[5]

The wrist arthroscope has conventionally been used to observe the inside of joints while treating ligament damage, fractures, or nonunion of the carpal bones. However, with the development of surgical devices and techniques, outstanding results have been reported for surgical treatment using an arthroscopic portal only.[6-8] The carpal bones have relatively little soft-tissue attachment, making them vulnerable to disrupting their blood supply during surgery. An arthroscopic approach, which involves making small incisions and using specialized instruments to access the joint, can help preserve the integrity of the surrounding soft-tissue attachments and the blood supply to the carpal bones, potentially leading to better healing outcomes.

In this study, we aimed to evaluate the outcomes of arthroscopic SCA in terms of successful bone union rates, clinical symptoms and functional status, radiographic changes, and any complications. We also sought to determine whether lunate excision impacts these outcomes.

METHODS

The Institutional Review Board of Yonsei University Health System, Severance Hospital approved this study (IRB No. 4-2022-0973) and waived the requirement for informed consent. Between March 2010 and February 2021, surgical treatment was performed on 42 patients diagnosed with Kienbock's disease. Of these patients, those with advanced-stage Kienbock's disease who had undergone arthroscopic SCA with a minimum of 24 months of follow-up were included in the study. The surgery was performed by a single arthroscopic hand surgeon (YRC). We excluded patients who underwent open surgeries, such as proximal row carpectomy (4 cases), scaphocapitate fusion (5 cases), or radial shortening osteotomy (14 cases), as well as those with missing data or x-rays (4 cases). A total of 15 patients were included in the final analysis. Initially, we performed arthroscopic SCA for Kienbock's disease concurrently with lunate excision. However, a study found that the presence or absence of the lunate did not significantly affect clinical outcomes in cases of limited carpal fusion for Kienbock's disease.[9] As a result, we switched to a lunate-preserving approach in later surgeries after 2015: the lunate was excised in 6 patients and retained in 9.

Surgical Technique

Under general anesthesia, patients were placed in the supine position, with the affected upper extremity supported on a hand table and draped. A pneumatic tourniquet was then applied. The patient's arm was then suspended in an Arc Wrist Tower (Acumed); traps were put on the index, middle, and ring fingers and then a 10-pound weight was hung. The ulnar midcarpal portal was created, and a 1.9-mm arthroscope was inserted through the portal. Then, a scaphotrapezial or radial midcarpal portal was made for the working portal. Only midcarpal portals were used for arthroscopic SC fusion. The evaluation of lunate cartilage status was not conducted during the arthroscopic procedures. Through the working portal, the articular cartilage of the scaphocapitate interface was removed until the bleeding cancellous bone was exposed. The scaphoid was reduced to a radioscaphoid angle (RSA) of 30° to 60° and provisionally maintained with 2 Kirschner-wires under mini C-arm (Fluoroscan InSight; Hologic Inc.) (Fig. 1A and B). For bone grafting, cancellous bone was harvested from the iliac crest using a Michele trephine through a small incision (Fig. 2A-C). A small rongeur was engaged to break the harvested bone into small chips placed within the sheath of a 3.5-mm burr (Fig. 2D). Next, the bone-packed sheath was introduced through the scaphotra-

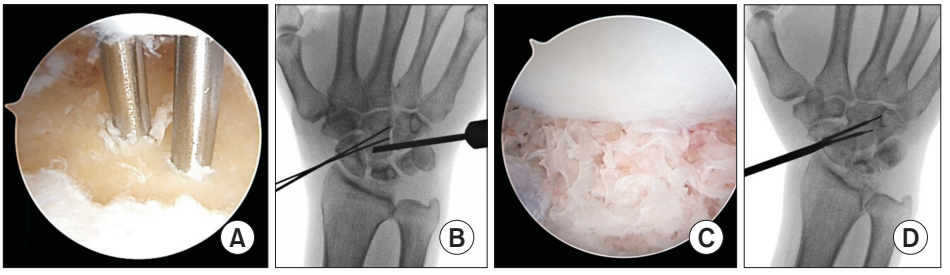

Fig. 1. (A, B) The articular cartilage of the scaphocapitate interface was removed. The scaphoid was reduced and provisionally maintained with 2 Kirschner wires. (C) Harvest bone was packed in the gap of the scaphoid and capitate. (D) Final fixation was achieved with 2 headless compression screws.

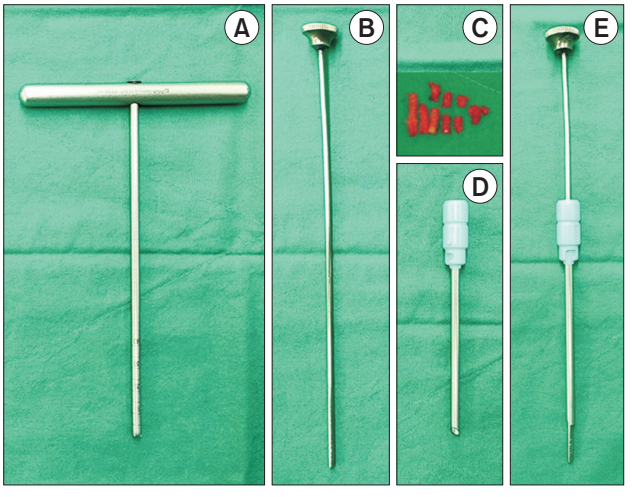

Fig. 2. (A) Trocar of the Michele trephine. (B) Stylet of the Michele trephine. (C) Harvested auto iliac crest bone. (D) A 3.5-mm burr sheath. (E) Using the trephine stylet, auto iliac bone was packed into the 3.5-burr sheath, and subsequently, bone was inserted into the scaphocapitate joint.

pezial, trapezoidal, or midcarpal radial portal into the gap between the scaphoid and the capitate under direct arthroscopic vision, emanating from the midcarpal ulnar portal (Fig. 1C). The gap was filled with cancellous bone using a stylet of the Michele trephine to empty the sheath (Fig. 2E). While performing bone grafting under the arthroscope, the supplied water was blocked, and a probe or a periosteal elevator was used to pack the defect with grafted bone. Two headless compression screws provided final fixation (Fig. 1D). In the first 6 patients, subtotal lunate excision, leaving the volar cortex of the lunate with preservation of the volar radiocarpal ligaments to maintain carpal stability, was performed together using a motorized burr and a shaver through the mid carpal portals. After closing the portals, a sterile dressing was applied. For 2 months, the wrist was immobilized in a short-arm, volarly based, plaster wrist orthosis, and finger exercises were performed. After another 2 months, a computed tomography scan was taken to confirm union, and the patients began wrist joint exercises.

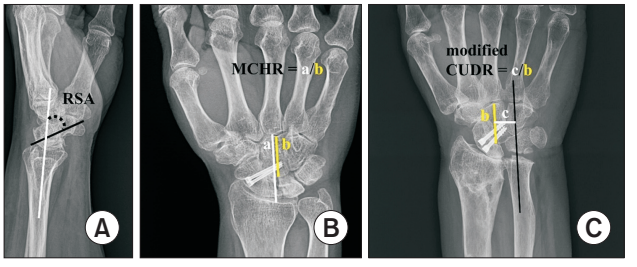

Fig. 3. (A) Radioscaphoid angle (RSA) was defined as the angle between the axes of the radius and scaphoid. (B) Modified capitate height ratio (MCHR) was determined by the ratio of a (base of the third metacarpal to the distal articular surface of the radius) to b (longitudinal length of the capitate). (C) Modified carpal-ulnar distance ratio (CUDR) was defined by the ratio of c (the distance between the center of the capitate head and the ulna's longitudinal axis) to b (the longitudinal length of the capitate).

Outcome Evaluation

Clinical results were assessed using visual analog scale (VAS) pain score, grip strength, range of motion (ROM), active flexion-extension arc, and modified Mayo wrist score (MMWS). Radiological outcomes included modified capitate height ratio (MCHR), modified carpal-ulnar distance ratio (CUDR), and RSA; these were measured preoperatively and at each follow-up visit after surgery (Fig. 3A). MCHR was determined by the ratio of the distance from the base of the third metacarpal to the distal articular surface of the radius to the longitudinal length of the capitate (Fig. 3B).[10] Decreasing MCHR values indicated reduced carpal height. CUDR was defined by the ratio of the distance between the center of the capitate head and the ulna's longitudinal axis to the longitudinal length of the capitate (Fig. 3C).[9] Decreased modified CUDR values reflected increased ulnar translation. Operation-related complications were also assessed.

Statistical Analysis

The Wilcoxon signed-ranked test was applied to compare pre- and postoperative groups. The Wilcoxon rank sum test was applied for the comparison of subgroups. We used IBM SPSS version 26.0 (IBM Corp.).

Table 1. Preoperative and Postoperative ROM and Grip Strength

Variable	Preoperative		Postoperative		*p*-value
	Mean ± SD	Proportion to contralateral wrist (%)	Mean ± SD	Proportion to contralateral wrist (%)	
Flexion (°)	33.00 ± 14.61	58	30.67 ± 14.25	53	0.453
Extension (°)	39.00 ± 17.03	72	46.67 ± 16.55	86	0.018*
Radial deviation (°)	13.00 ± 5.92	67	12.33 ± 3.20	64	0.720
Ulnar deviation (°)	25.33 ± 13.02	75	31.67 ± 7.72	94	0.118
Flexion-extension arc (°)	72.00 ± 25.55	65	77.33 ± 24.99	69	0.360
Full ROM (°)	110.33 ± 39.48	67	121.33 ± 30.50	74	0.130
Grip strength (kg)	25.20 ± 14.38	49	35.47 ± 15.36	69	0.007*

ROM: range of motion, SD: standard deviation.
*Statistically significant, $p \leq 0.05$.

Table 2. Radiographic Outcome Measures

Variable	Preoperative	Postoperative	*p*-value
MCHR	1.52 ± 0.07	1.48 ± 0.13	0.036*
Modified CUDR	0.90 ± 0.16	0.80 ± 0.20	0.001*
RSA	60.27 ± 5.90	44.21 ± 3.09	0.001*

Values are presented as mean ± standard deviation.
MCHR: modified capitate height ratio, CUDR: carpal-ulnar distance ratio, RSA: radioscaphoid angle.
*Statistically significant, $p \leq 0.05$.

Table 3. Subgroup Analysis of ROM, Grip Strength, and Clinical and Radiological Results

Variable	Lunate excision group	Lunate retain group	*p*-value
Flexion (°)	26.67 ± 11.69	33.33 ± 15.81	0.456
Extension (°)	40.83 ± 17.15	50.56 ± 15.9	0.328
Radial deviation (°)	10.00 ± 3.16	13.89 ± 2.20	0.036*
Ulnar deviation (°)	30.83 ± 10.21	32.22 ± 6.18	0.776
Flexion-extension arc (°)	67.50 ± 23.18	83.89 ± 25.22	0.224
Full ROM (°)	108.33 ± 31.57	130.00 ± 28.17	0.181
Grip strength (kg)	32.33 ± 17.25	37.56 ± 14.65	0.607
MMWS	62.50 ± 17.82	67.22 ± 16.03	0.607
VAS pain score	2.17 ± 1.33	3.56 ± 3.32	0.607
MCHR	1.42 ± 0.17	1.52 ± 0.09	0.272
Modified CUDR	0.67 ± 0.14	0.88 ± 0.19	0.050*
Operation time (min)	141.5 ± 21.11	109.00 ± 42.38	0.145

Values are presented as mean ± standard deviation.
ROM: range of motion, MMWS: modified Mayo wrist score, VAS: visual analog scale, MCHR: modified capitate height ratio, CUDR: carpal-ulnar distance ratio.
*Statistically significant, $p \leq 0.05$.

RESULTS

There were 13 women and 2 men, with a mean age of 57.6 years (range, 21–74 years) at the time of undergoing arthroscopic SCA. Follow-up ranged from 24 to 116 months, with an average of 56.9 ± 32.3 months. VAS decreased from 7.47 ± 1.41 to 3.00 ± 2.73 ($p = 0.001$), and MMWS increased from 39.67 ± 21.00 to 65.33 ± 16.31 ($p = 0.001$). ROM increased from 67% to 74% of that of the contralateral wrist ($p = 0.130$), and grip strength increased from 49% to 67% of that of the contralateral wrist ($p = 0.007$) (Table 1). MCHR decreased from 1.52 to 1.48 ($p = 0.036$), and modified CUDR decreased from 0.90 to 0.80 ($p = 0.001$). Modified CUDR decreased by 11.1%, and MCHR decreased by 2.6%. RSA recovered after surgery from 60.27 to 44.21 ($p = 0.001$) (Table 2). Based on subgroup analysis, there were no significant differences in clinical outcomes, such as VAS, MMWS, grip strength, and total ROM, between the lunate excised and retained groups. However, decreased radial deviation and increased ulnar translation were noted in the lunate excision group (Table 3, Fig. 4). Bony union was achieved in all patients, and no additional surgery was needed. Additional procedures were performed as follows: Wafer operation (4 cases), debridement of the triangular fibrocartilage complex (TFCC;

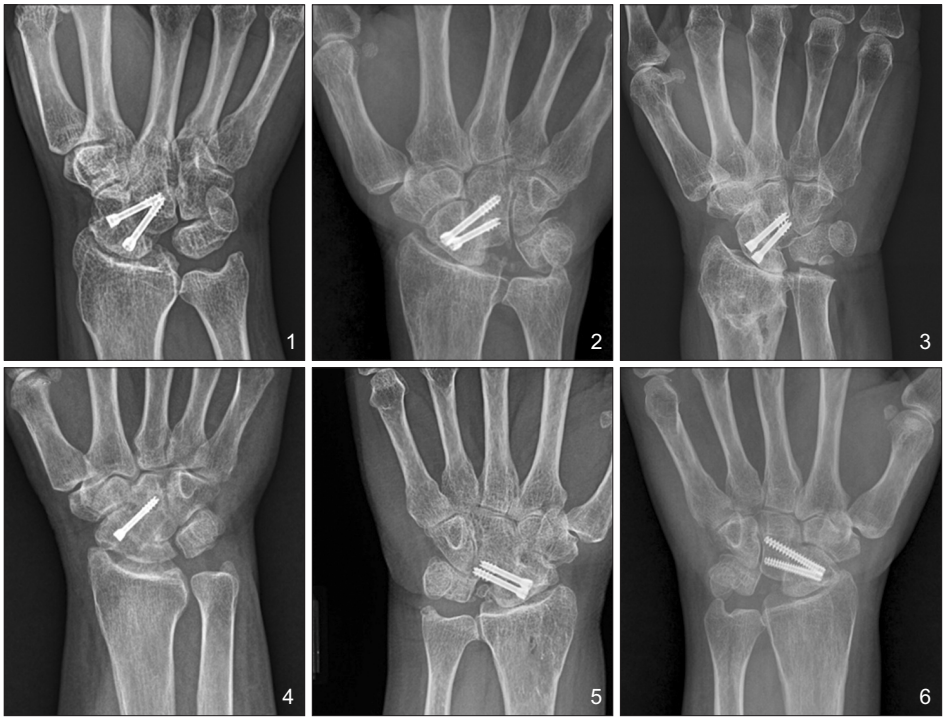

Fig. 4. In the final postoperative images of the lunate excision group, ulnar translation of the scaphoid beyond the scapholunate ridge was observed in cases 2, 3, 4, and 5.

1 case), TFCC foveal repair and ulnar shortening osteotomy (1 case), TFCC peripheral repair (1 case), and ulnar shortening osteotomy (1 case).

DISCUSSION

Based on the results of this study, we suggest that arthroscopic SCA leads to significant improvements in clinical outcomes, such as reduced pain (VAS) and improved wrist function (MMWS, grip strength) among patients with advanced Kienbock's disease. Following surgery, RSA was restored and all 15 patients achieved bony union. Modified CUDR and MCHR slightly decreased after arthroscopic SCA. Subgroup analysis indicated that ulnar translation was more severe in the lunate excision group. This suggests that lunate excision may have a negative effect on radiocarpal stability. To obtain good clinical results with SCA, it may be necessary to reduce a rotated scaphoid to its normal range and then fix it with sufficient force.[11] In this study, there were no cases where arthroscopic surgery was changed to open surgery.

Despite good clinical results being reported for a variety of limited carpal arthrodesis techniques, there are several reasons why we chose arthroscopic SCA. One is that the scaphocapitate joint is easily accessible through the mid carpal portal. Another is that the surgical method is simple because only 1 joint needs to be fused. Lastly, researchers have consistently reported that successful results can be achieved after arthroscopic surgery for scaphoid nonunion.

There were no cases of nonunion among our patients. Nonunion has been reported in about 0 to 23% of patients treated with open SCA and in 0 to 10% with arthroscopic SCA.[12-17] The low incidence of nonunion with arthroscopic surgery may be related to the preservation of the surrounding soft-tissue attachments and the blood supply to the carpal bones, potentially leading to better healing outcomes, with a less invasive procedure. Moreover, the arthroscopic procedure holds many advantages in terms of cosmetic aspects, pain, and recovery of ROM after surgery because the scope of the incision is small and the wrist joint capsule is not damaged.[18]

We have performed SCA that maintains the lunate since 2015. When comparing patients in whom the lunate was removed or maintained before or after 2015, respectively, we noted that VAS and MMWS were significantly improved in both cases. Rhee et al.[9] also argued that there was no correlation between radiological changes, such as a decrease in carpal height or an increase in ulnar translation, and short-term clinical results after SCA, as was the case in this study. However, ulnar translation increased in the lunate excision group, and radial deviation decreased slightly when compared to the lunate retained group. We suspect that when the lunate is removed, the extrinsic ligament attached to the lunate is damaged, leading to increased stress on the radioscaphocapitate ligament

and then to progression of ulnar translation. As a result, impingement occurs, and radial deviation is relatively decreased. Nevertheless, improvement in clinical outcomes was achieved regardless of where lunate excision and ulnar translation progressed when lunate excision was performed. Hence, considering the need for the additional surgical time of lunate excision, it is thought that maintaining the lunate in the treatment of Kienbock's disease with SCA is preferable.

In accordance with the report by Kawai et al.,[19] good long-term results were obtained only with lunate resection for Kienbock's disease, and Shimizu et al.[20] performed arthroscopic lunate resection while preserving the dorsal and volar cortex of the lunate in 15 cases of low-demanding patients under the age of 65 years to minimize damage to the dorsal intercarpal and dorsal radiocarpal ligaments attached to 99% of the lunate.[19] As a result, disruption of the carpal row could not be prevented, but excellent clinical results were obtained in 13 cases of long-term results with more than 2 years.[20] It would seem contradictory that good clinical results are observed in both cases in which only the lunate is removed or SCA is performed while maintaining the lunate. However, the SCA itself diverts the compressive force from the capitate to the lunate, transferring it to the scaphoid, thereby relieving the pressure on the lunate and facilitating improvements in symptoms as much as removal of the lunate. Therefore, considering that pain improves even if the lunate is not removed, pain from progressive Kienbock's disease is thought to be due to disruption of the lunate or carpal row by compressive forces rather than due to necrosis of the lunate itself.

Limited carpal arthrodesis, a palliative treatment, improves muscular strength by improving pain after surgery and enables patients to lead their daily life. Despite improved disabilities of the arm, shoulder, and hand (DASH) scores, it is accompanied by a restriction of the movement of the joints due to the arthrodesis. Research indicates that ROM is most limited with scaphotrapezio-trapezoid arthrodesis; however, with SCA, wrist ROM is limited to about 1/3.[21] In the case of capitohamate arthrodesis with lunate excision, it has been reported that ROM is maintained with limited arthrodesis of the distal row; thus, it is thought that an arthroscopic study will be required in the future.[22,23] In this study, most patients did not recover to ROM on the unaffected side before surgery, but they showed clinical improvements in terms of pain reduction, grip strength, and DASH and MMWS scores. However, the greater the restriction on ROM, the greater the loading applied to the adjacent joint, suggesting that long-term follow-up will be required.

This study has a few limitations that warrant consideration. It is difficult to generalize the results of this study because the number of patients included in the study is small, despite the long study period. In particular, we subdivided a limited number of cases in the arthroscopic SCA surgery group into even smaller subgroups based on lunate excision and preservation, and conducted subgroup analysis using non-parametric statistical methods. Therefore, caution is necessary when interpreting the results. There also was no controlled comparison with open SCA. However, due to the rarity of Kienbock's disease, most studies on limited wrist arthrodesis have been conducted on a small number of patients. This study is meaningful in that it is the first to show that SCA using an arthroscope can produce satisfactory results like open SCA.

In this study, arthroscopic SCA achieved significant improvement in pain and wrist function in patients with advanced Kienbock's disease. Excision of the lunate did not provide clinical benefits over retaining it when conducting arthroscopic SCA.

CONFLICT OF INTEREST

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

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