Outcome of scaphocapitate arthrodesis for treatment of Kienböck's disease with and without lunate excision

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Background
Kienbock's disorder is a degenerative wrist disease that is largely defined by idiopathic lunate bone avascular necrosis. This research objective was to assess the Scaphocapitate arthrodesis (SCA) efficacy in terms of wrist motion improvement, pain relief, and radiographic alterations in comparison to SCA without lunate excision.
Methods
This observational prospective study was conducted on 20 patients with Kienbock's disease (stage IIIB), who attended Benha University Hospital Orthopedics Clinic or Shebin Teaching Hospital. All patients were allocated into two groups; group 1 (n=10) involved patients with lunate excision and group 2 (n=10) involved patients without lunate excision. All participants were assessed through clinical examination full history taking, and radiological assessment by plain radiography and confirmed by computed tomography to assess if there is arthritic changes or not and MRI.
Results
Regarding the functional outcome, the postoperative grip strength and modified mayo wrist score increased significantly in group 1 as regard to group 2 (P=0.001, 0.033). The pain outcome differed significantly among both groups (P=0.019), being better in group 1 compared with group 2. The satisfactory outcome significantly differed between both groups (P=0.001), group 1 showed superior satisfaction compared with group 2.
Conclusion
SCA with lunate excision showed superior radiological and functional outcomes, better pain relief, and a higher satisfaction rate in Kienbock's disease management.

Keywords:
Kienbock's disease, lunate excision, outcome, scapho-capitate arthrodesis

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Introduction

The disease of Kienbock is a degenerative wrist disorder that is largely defined by idiopathic the lunate bone avascular necrosis. It is claimed to have a prevalence of seven patients per 100 000 individuals, and the prognosis deteriorates as the patient ages. Even though the precise origin is uncertain, Kienbock's disorder is due to negative ulnar variance, stress syndrome, and lunate morphology [1]. Kienbock's illness can result in chronic wrist pain with substantial restrictions, similar to other carpal bone disorders. The genesis of this condition remains unclear, despite its diagnosis almost a century ago; nonetheless, mechanical, traumatic, and vascular causes have been implicated [2].

The therapy of this condition remains a topic of debate. Treatment options for the condition are determined by the Lichtman classification. Lunatic sclerosis is the component of Stage II. The capitatum's proximal migration following the lunate's collapse was designated as Stage III. Stage III was subdivided into IIIA, IIIB, and IIIC. Stage IIIB was defined as the absence of collapse of the lunate, flexion of the scaphoid bone, a scapholunate angle (SL) greater than 60°, and a reduction in carpal height (+) [3,4].

Most surgeons utilize conservative treatment for Kienbock's illness during the initial stages; however, palliative surgical procedures may be more suitable in the later stages [5]. Scaphocapitate arthrodesis (SCA) or Scaphotrapeziotrapezoid (STT) with lunate salvage are examples of limited wrist arthrodesis that may be prescribed for individuals having neutral ulnar variation or more advanced stages [6,7].

One of the objectives of SCA is to correct and/or retain scaphoid alignment and carpal height, as

well as to off-load the lunate (if saved). Functional mobility and sufficient grip strength are preserved over the long haul, but pain is greatly alleviated by SCA with lunate excision done in Kienbock's illness advanced stage [8]. Patients having radio scaphoid joint osteoarthritis are considered candidates for lunate excision arthroplasty, particularly those with stage III (particularly stage IIIB) and IV Kienbock's disease [9,10].

This study hypothesis was that SCA+ lunate excision in Kienbock's illness advanced stages with lunate collapse produces consistent and satisfactory outcomes throughout time. This research objective was to assess the SCA efficacy in terms of pain alleviation, wrist mobility improvement, and radiographic alterations in comparison to SCA without lunate excision.

Patients and methods

This observational prospective study was performed on 20 patients, aged 18–60 years old, with stage IIIB of Kienbock's disease regarding to Lichtman classification, without arthritic changes, and normal ulnar variance, who attended to Benha university hospital Orthopedics clinic or Shebin teaching hospital, during the period between January 1 to July 1, 2024. Parents provided formal informed consent. Each parent will be provided with a secret code number and an explanation of the study's objective.

Exclusion criteria included skeletally immature patients, patients with previous wrist surgery, with previous wrist joint disease, with arthritic changes and low demand patients.

All participants were allocated into two groups; group 1 (n=10) involved patients with lunate excision and group 2 (n=10) involved patients having no lunate excision.

All patients were assessed through taking full history (age and sex), clinical examination and history taking and radiological assessment by plain radiography (lateral and postero-anterior wrist radiographs) and was confirmed by CT to assess if there is arthritic changes or not and MRI.

Surgical technique

All patients underwent the procedure using an open dorsal approach. Partial wrist denervation was achieved by performing an ulnar and radial subcutaneous undermining and sectioning the branches of the superficial articular nerve that originate from the sensory branches of radial and ulnar nerves. Between the third and fourth extensor compartments, the extensor retinaculum was incised. The posterior interosseous nerve terminal branch was completely resected. Once the tendons of the extensor were retracted, the articular capsule was opened in a T-shape to execute an arthrotomy. The articular surfaces of the scaphoid and the radius were inspected to confirm the absence of degenerative alteration. The articular surfaces between the capitate and scaphoid were subsequently prepped utilizing a bone drill, and a lunate excision was then done. A 'joystick'sensation was experienced as a result of a Kirschner (K-) wire insertion into the bone to rectify scaphoid flexion. The scaphoid was repaired when the radio-scaphoid angle was less than 60.

A single surgeon administered the standard treatment strategy to all patients included in the trial. The deflated lunatum was removed by a longitudinal dorsal incision in the skin. Subsequently, the cartilage of scaphocapitate joint was excised using a mini-rounger, and the SL was lowered to normal values (30–60) utilizing an angular, stable circular plate. SCA was implemented. The image intensifier was utilized to regulate the SL and the arthrodesis position. To optimize the arthrodesis success, spongeous autografts were transplanted from the arthrodesis site to iliac wing. Prophylaxis was initiated 30 min before surgery with intravenous cefazolin sodium 3×1 g, which was maintained for 24 h following the procedure.

The immobilization of the wrist was done using a short arm brace that extended till the palmar crease postoperatively to facilitate the metacarpophalangeal joint free motion. The withdrawal of the brace was done after 4 weeks, and the participants were advised to initiate elbow and metacarpophalangeal joint motion. Subsequently, passive wrist joint exercises were initiated. Active and forceful motions of the wrist were allowed under the supervision of an expert physiotherapist after the 8th week.

Postoperative follow-up

The patients were monitored over a period of 6–12 months. Active motion of finger commenced instantly following surgery, and motion of the wrist joint was permitted 6 weeks postoperatively. The postoperative radiographs were gained following the operation immediately, and they were taken every 4 weeks until scaphocapitate fusion was completed. Subsequently, they were taken every 2 months throughout the period of follow-up.

Clinical evaluation

The normal contralateral side and the preoperative results were compared with the range motion of wrist

(radial ulnar deviation, extension, and flexion) assessed utilizing a goniometer. Radiographic evaluation:

The scaphocapitate angle, lunate height index 'method of Stahl,' carpal height index, and ulnar variance were measured using the conventional lateral and postero-anterior radiograph views for both preoperative and postoperative evaluation. The postoperative radiograph was obtained immediately following surgery and again every 4 weeks until SCA was reached. Subsequently, it was obtained every 2 months during the follow-up period.

Functional scores evaluation

The Modified Mayo Wrist Score was employed to conduct a functional evaluation (MMWS). The pain scale will be self-reported and rated by the questionnaire provided by the MMWS [11]. Therefore, 25 points are attributable to no pain, whereas 0 points are attributable to extreme agony. Utilizing a JAMAR hand dynamometer, grip strength was assessed (expressed as a percentage of healthy side strength) [12].

Statistical analysis

The statistical analysis was carried out utilizing SPSS v28 (IBM Inc., Armonk, NY, USA). Utilizing an unpaired Student's *t*-test, quantitative data were given as standard deviation and mean (SD) and compared among the two treatment groups. When applicable, analysis of qualitative variables was done using the χ^2 or Fisher's exact tests and provided as frequency and percentage (percent). In the event of two correlated samples, the paired sample *t*-test is a statistical method that is employed for the comparison of the two populations' means. Statistical significance was determined using a two-tailed *P* value of less than 0.05.

Results

Both groups exhibited a negligible difference in the baseline variables, which included age, sex, BMI, weight, height, smoking, and residence. Additionally, the clinical data regarding the side of injury and dominant wrist, and the operation time revealed insignificant differences among both groups Table 1.

In both groups, the radiological evaluation revealed that the postoperative wrist extension and flexion and ulnar deviation were higher significantly in comparison with the values preoperatively (P<0.05), while the radial deviation postoperatively was significantly decreased in comparison with deviation preoperatively (P<0.001, <0.001). The postoperative scapho-capitate angle and carpal height ratio in group 1 were significantly reduced compared with preoperative angle (P=0.008, 0.007), while in group 2 was insignificantly different compared with preoperative angle and carpal height ratio. The radio-scaphoid angle in both groups was insignificantly different compared with preoperative angle. When comparing both groups with each other's, the postoperative wrist extension and flexion were higher significantly in group 1 in comparison with group 2 (P=0.004, 0.038), the postoperative radial deviation, scapho-capitate angle, and carpal height ratio were significantly reduced in group 1 in comparison with group 2 (P<0.05). There was an insignificant variance among the two groups as regard to wrist extension and flexion, radial deviation, scaphocapitate angle, and carpal height ratio preoperatively. Additionally, pre- and postoperative ulnar deviation and radio-scaphoid angle showed no significant difference between the two groups Table 2.

According to the functional outcome, in both groups, the postoperative grip strength and MMWS showed significant elevation in comparison with the values preoperatively (P<0.05). The postoperative grip strength and MMWS revealed a significant increase in group 1 as regards to group 2 (P=0.001, 0.033), with no significant variance between both groups regarding the preoperative grip strength and MMWS. The pain outcome differed significantly between both groups (P=0.019), being better in group 1 in comparison with group 2 Table 3.

Table 4 reveals that the hospital stay and follow-up duration revealed significant variance among

Table 1 Baseline characteristics and clinical data of the studied groups

	Group 1 (N=10) [n (%)]	Group 2 (N=10) [n (%)]	P value
Age (years)	35.40±10.71	36.6±12.38	0.819
Sex			
Male	4 (40)	2 (20)	0.628
Female	6 (60)	8 (80)	
Weight (kg)	77.60±13.34	86.20±13.01	0.162
Height (m)	1.66±0.03	1.64±0.03	0.144
BMI (Kg/m^2)	28.07±4.58	32.15±5.12	0.077
Residence			
Urban	2 (20)	3 (30)	1.00
Rural	8 (80)	7 (70)	
Smoking	4 (40)	3 (30)	1.00
Side of injury			
Right wrist	5 (50)	3 (30)	0.650
Left wrist	5 (50)	7 (70)	
Dominant wrist			
Dominant wrist	6 (60)	5 (50)	1.00
Nondominant wrist	4 (40)	5 (50)	
Operation time (min)	59.0±13.36	60.4±10.5	0.797

Data presented as frequency (%) or mean±SD.
BMI, body mass index.

Table 2 Radiological data of the studied groups

	Group 1 (*n*=10)	Group 2 (*n*=10)	*P* value
Wrist extension			
Preoperative	40.20±4.08	42.30±4.35	0.280
Postoperative	59.60±3.92	53.30±4.69	0.004*
P value within group	<0.001*	<0.001*	
Wrist extension			
Preoperative	41.10±3.45	39.0±3.27	0.179
Postoperative	55.10±3.67	51.1±4.28	0.038*
P value within group	<0.001*	<0.001*	
Radial deviation			
Preoperative	24.3±2.45	24.1±2.08	0.846
Postoperative	14.8±2.2	17.0±1.49	0.017*
P value within group	<0.001*	<0.001*	
Ulnar deviation			
Preoperative	24.7±2.63	23.8±2.7	0.460
Postoperative	38.0±2.83	37.5±4.5	0.770
P value within group	<0.001*	<0.001*	
Radio-scaphoid angle (°)			
Preoperative	57.8±11.73	55.0±20.25	0.710
Postoperative	47.8±15.02	53.6±14.62	0.393
P value within group	0.114	0.861	
Scaphocapitate angle (°)			
Preoperative	67.2±17.67	66.0±14.96	0.872
Postoperative	48.5±8.68	62.7±7.29	0.001*
P value within group	0.008*	<0.001*	
Carpal height ratio			
Preoperative	0.47±0.06	0.48±0.06	0.672
Postoperative	0.41±0.02	0.45±0.04	0.005*
P value within group	0.007*	0.163	

Data presented as mean±SD.
*Statistically significant as *P* value less than 0.05.

Table 3 Evaluation of the functional outcome of the studied groups

	Group 1 (*n*=10)	Group 2 (*n*=10)	*P* value
Grip strength			
Preoperative	18.1±1.85	17.3±2.75	0.455
Postoperative	27.2±2.39	23.4±1.78	0.001*
P value within group	<0.001*	<0.001*	
MMWS			
Preoperative	6.1±3.51	5.5±2.51	0.665
Postoperative	17.3±4.24	13.6±2.8	0.033*
P value within group	<0.001*	<0.001*	
Pain, *n* (%)			
Good	8 (80)	2 (20)	0.019*
Fair	2 (20)	5 (5)	
Poor	0	3 (30%)	

Data presented as mean±SD or frequency (%).
MMWS, modified mayo wrist score.
*Statistically significant as *P* value less than 0.05.

the two groups. Regarding the complications incidence, wound infection absence, nonunion or other complications were observed. The study of preoperative and postoperative radiograms of all patients did not reveal any signs of radioscaphoid arthritis.

Table 4 Hospital stay, follow-up and complications of the studied groups

	Group 1 (*n*=10)	Group 2 (*n*=10)	*P* value
Hospital stay (days)	3.00±0.82	3.30±0.82	0.424
Follow-up (months)	8.2±1.87	8±1.94	0.817

Data presented as mean±SD.

Table 5 Satisfactory outcome of the studied groups

	Group 1 (*n*=10)	Group 2 (*n*=10)	*P* value
Satisfactory outcome			
Good	9 (90)	1 (10)	0.001*
Fair	1 (10)	6 (60)	
Poor	0	3 (30)	

Data presented as frequency (%).
*Statistically significant as *P* value less than 0.05.

The satisfactory outcome showed a significant difference among both groups (*P*=0.001), group 1 showed superior satisfaction compared with group 2 Table 5.

Discussion

There is still much mystery surrounding the cause of lunatum osteonecrosis, more specifically Lichtman grade IIIB Kienbock's disease. This form of the condition is characterized by increased loading on the lunatum following scaphoid flexion, which leads to rapid collapse and speeds up the disease's progression [13]. Stage III and IV advanced Kienbock's disease was effectively treated with excision of lunatum, limited carpal fusion wrist fusion, lunatum replacement, and proximal row carpectomy [14].

In the term of lunate bone collapse, a local debridement and synovectomy are feasible with the simple excision of the lunate, which is successful in the medium term [15]. Nevertheless, the capitate's proximal migration is further facilitated by excision, which then leads to carpal disarray. A variety of outcomes were achieved using the interposition of silicone, pyrocarbon, or tendon to fill unoccupied spaces [16,17].

The SCA method was defined as a technique that achieves consequences that are as effective as those of STT. In this method, the rates of nonunion are reduced by half. This approach was demonstrated to be successful in patients with nonunion low-rate treatment and can be implemented arthroscopically in conjunction with other methods. On the other hand, patients who had long-term follow-up frequently exhibited radiographic evidence of radioscaphoid arthritis [18].

This trial objective was to assess the SCA efficacy in terms of wrist motion improvement, pain relief, and radiographic alterations in comparison to SCA with lunate excision.

Numerous biomechanical investigations have demonstrated that SCA mitigates the forces that are applied to the lunate. In theory, SCA offers a load-bearing column that enables the transmission of forces from the hand to the distal radius without involving the lunate. Nevertheless, the scaphoid can be severely reduced in motion at the lunatocapitate joint and the radiolunate joint can experience greater shear stress, which can accelerate the development of degenerative changes. This can be achieved by locking the distal carpal row to the scaphoid [19,20].

SCA can lead to improved grip strength. Pisano *et al.* [21] found that the average grip strength had increased to 120% (mean, 29 kg) of the preoperative evaluation; nevertheless, this enhancement only caused the treated wrist to achieve 74% of the contralateral wrist's strength. accordingly, Sennwald and Ufenast [22] found that after an average of 36 months of follow-up, the affected wrist had 72% less grip strength than the untreated wrist.

Minamikawa *et al.* [23] investigated the motion of the wrist using cadaveric specimens in order to determine the ideal radioscaphoid angle, which is 30–57º, to allow for the most efficient wrist kinematics after SCA. Sennwald and Ufenast [22] found a trend toward improved mean radioscaphoid angles, which increased from 56 before surgery to 52 immediately after SCA. This trend was sustained at a mean follow-up of 51 months, with a mean of 51. In Rhee *et al.* [24] study, even in individuals with late stages of illness (IIIB/IV), they observed a substantial advancement in the radioscaphoid angle following surgery. Pisano *et al.* [21] observed no substantial decline in scaphoid alignment or carpal height during a mean follow-up of 23 months.

Watson *et al.* [25] reported that Lunate excision was anticipated to be necessary for 32% of patients within two years of STT arthrodesis with preserved lunate. These authors revealed that having a relatively intact lunate with osteochondral fractures can still be painful and may necessitate excision. This is supported by the fact that patients who had the lunate removed had an average pain level of 0.6 (0–1) at the final follow-up, whereas patients who had SC arthrodesis with preserved lunate had an average pain level of 1.4 (0–2).

Luegmair *et al.* [26] studied the SC treatment in the Kienbock's disease late stage and demonstrated the long-term therapeutic advantages of SC arthrodesis in the stage IIIB and IV Kienbock's illness treatment. Radiographic examination demonstrated that ulnar translation and carpal collapse had ceased over time. Nevertheless, patients who experienced a follow-up of over a decade frequently exhibited radiographic evidence of mild to moderate secondary radioscaphoid arthritis. They demonstrated that the clinical and radiologic outcomes of our series were not influenced by the removal of the lunate. Results were comparable for patients having stage IIIB and IV Kienbock's illness.

Charre *et al.* [8] conducted a retrospective evaluation of procedures and investigated 17 individuals' responses to SCA combined with lunate excision for the treatment of advanced Kienbock's sickness (18 wrists). Stage IIIA was reached by five, Stage IIIB by twelve, and Stage IV by one. It was shown that SCA with lunate excision, performed in the latter stages of Kienbock's disease, significantly reduces pain while preserving functional mobility and long-term adequate grip strength.

Özdemir *et al.* [27] found that Functioning results in individuals suffering Lichtman's stage IIIB Kienbock's disease before and after the excision of lunatum and SCA with an angular stable circular plate. Their research led them to the conclusion that angular stable circular plate fixation in conjunction with lunatum excision and SCA provides pain relief while still allowing for a satisfactory range of motion maintenance. The MMWS was used to classify five (55.6%) patients as excellent and four (44.4%) patients as fair.

The short sample size was a significant limitation of the present study. Patients who undergo SCA for Kienbock's illness should be advised of the possibility of prolonged discomfort and neighboring joint deterioration, which may necessitate additional treatments. The efficacy of this treatment might be demonstrated by comparative studies and multicentre trials, which could expand the number of patients.

Conclusion

Scaphocapitate arthrodesis with lunate excision showed superior radiological and functional outcomes, better pain relief and higher satisfaction rate in management of Kienbock's disease.

Acknowledgments

The manuscript has been read and approved by all the authors, the requirements for authorship have been met, and each author believes that the manuscript represents honest work.

Authors' contributions

OME conceived and supervised the study; ASAE was responsible for data collection. SMM analyzed and interpreted the data. All authors provided comments

on the manuscript at various stages of development. All authors read and approved the final manuscript.

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Nil.

Conflicts of interest
There are no conflicts of interest.

Abbreviation

BMI	Body mass index
CT	Computed tomography
LWA	Limited wrist arthrodesis
MMWS	Modified mayo wrist score
MRI	Magnetic resonance imaging
SCA	Scaphocapitate arthrodesis
SL	Scapholunate angle
STT	Scaphotrapeziotrapezoid.

References

1. Kariksiz M, Karakoyun O. Mid-term follow-up results of gradual capitate lengthening for the treatment of stage IIIA Kienbock's disease. J Orthop Surg (Hong Kong) 2023; 31:102–109.
2. Hwang JS, Shim BJ, Li Q, Kim J, Baek GH. The natural history of Kienböck's disease diagnosed at more than 50 years of age. Clin Orthop Surg 2022; 14:450–457.
3. Chojnowski K, Opiełka M, Piotrowicz M, Sobocki BK, Napora J, Dąbrowski F, *et al*. Recent advances in assessment and treatment in Kienböck's disease. J Clin Med 2022; 11:34–39.
4. Bae JY, Shin YH, Choi SW, Moon SH, Park HS, Kim JK. A novel classification of Kienbock's disease based on magnetic resonance imaging. Int Orthop 2023; 47:2023–2030.
5. Bhardwaj P, Varadharajan V, Godora N, Sabapathy SR. Kienbock's disease: Treatment options - a search for the apt! J Hand Surg Asian Pac Vol 2021; 26:142–151.
6. Goyal N, Singh V, Barik S, Behera S. Limited carpal fusion in Kienböck's disease: Early results following scaphocapitate arthrodesis. J Wrist Surg 2020; 9:404–410.
7. Adler JA, Conti Mica M, Cahill C. Wrist salvage procedures for the treatment of Kienbock's disease. Hand Clin 2022; 38:447–459.
8. Charre A, Delclaux S, Apredoai C, Ayel J-E, Rongieres M, Mansat P. Results of scaphocapitate arthrodesis with lunate excision in advanced Kienböck disease at 10.7-year mean follow-up. J Hand Surg Eur Vol 2018; 43:362–368.
9. Iwasaki N. Surgical Treatments: Lunate Excision. Introduction to Kienböck's Disease: Basic Science, Diagnosis and Treatment: Springer; 2023. p. 111–6.
10. Hayakawa K, Suzuki T, Furuhata R, Kimura H, Matsumura N, Iwamoto T, *et al*. Artificial lunate arthroplasty for Kienböck disease with multiple extensor tendon ruptures: A case report. JBJS Case Connect 2023; 13:23–29.
11. Knie C, van Schoonhoven J. Long-term results after total wrist fusion. Arch Orthop Trauma Surg 2023; 143:6469–6475.
12. Lupton-Smith A, Fourie K, Mazinyo A, Mokone M, Nxaba S, Morrow B. Measurement of hand grip strength: A cross-sectional study of two dynamometry devices. S Afr J Physiother 2022; 78:1768.
13. Rioux-Forker D, Shin AY. Osteonecrosis of the lunate: Kienböck disease. J Am Acad Orthop Surg 2020; 28:570–584.
14. Wang PQ, Matache BA, Grewal R, Suh N. Treatment of stages IIIA and IIIB in Kienbock's disease: A systematic review. J Wrist Surg 2020; 9:535–548.
15. Lichtman DM, Pientka WF 2nd, MacLean S, Bain G. Precision medicine for Kienböck disease in the 21st century. J Hand Surg Am 2022; 47:677–684.
16. van der Heijden B, van Laarhoven C. Pyrocarbon disc interposition arthroplasty (pyrodisk) for the treatment of carpometacarpal thumb joint osteoarthritis. JBJS Essent Surg Tech 2022; 12:e21.00034.
17. Tanwin Y, Maes-Clavier C, Lestienne V, Gaisne E, Loubersac T, Kerjean Y, *et al*. Medium-term outcomes for amandys implant: A 5-year minimum follow-up of 63 cases. J Wrist Surg 2022; 11:6–15.
18. Bouri F, Hantouly AT, Alzobi O, Toubasi AA, Kayali H, Fuad M, *et al*. Clinical and radiological outcomes of scaphocapitate fusion in Kienböck disease: A systematic review and meta-analysis. J Hand Surg Glob Online 2023; 5:435–444.
19. Shams A, Samy MA, Mesregah MK, Abosalem AA. Scapho-luno-capitate fusion with proximal lunate articular surface preservation for management of grade IIIA Kienböck's disease: a prospective case series. J Orthop Traumatol 2023; 24:23.
20. Seradge H, Parker W, Seradge C, Steppe C, McKenzie A. Dynadesis for treatment of dynamic scaphoid instability with 20-year results. J Wrist Surg 2023; 12:73–80.
21. Pisano SM, Peimer CA, Wheeler DR, Sherwin F. Scaphocapitate intercarpal arthrodesis. J Hand Surg Am 1991; 16:328–333.
22. Sennwald GR, Ufenast H. Scaphocapitate arthrodesis for the treatment of Kienböck's disease. J Hand Surg Am 1995; 20:506–510.
23. Minamikawa Y, Peimer CA, Yamaguchi T, Medige J, Sherwin FS. Ideal scaphoid angle for intercarpal arthrodesis. J Hand Surg Am 1992; 17:370–375.
24. Rhee PC, Lin IC, Moran SL, Bishop AT, Shin AY. Scaphocapitate arthrodesis for Kienböck disease. J Hand Surg Am 2015; 40:745–751.
25. Watson HK, Monacelli DM, Milford RS, Ashmead DI. Treatment of Kienböck's disease with scaphotrapezio-trapezoid arthrodesis. J Hand Surg Am 1996; 21:9–15.
26. Luegmair M, Saffar P. Scaphocapitate arthrodesis for treatment of late stage Kienbock disease. J Hand Surg Eur Vol 2014; 39:416–422.
27. Özdemir G, Akgül T, Çiçekli Ö, Yılmaz B, Atbinici H, Yücel F. Lunatum excision and scaphocapitate arthrodesis in Kienböck's disease. J Orthop Surg (Hong Kong) 2017; 25:230–245.