Comparison of the early-term clinical results of capitate forage procedure and radial shortening osteotomy in Stage 3A Kienböck's disease

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The lunate collapse was first emphasized in cadaveric studies by Peste[1] and the X-ray changes on lunate were considered lunatomalacia by Robert Kienböck.[2] While its radiological incidence has been reported ranging from 0.27 to 1.9%,[3,4] it is 0.0066% in the largest series in the literature without any significant difference in age, sex, ethnicity, comorbidities, smoking status, and excessive alcohol use.[5] Many factors such as a history of recurrent microtrauma, arterial or venous-induced intrinsic insufficiency, hypercoagulability, corticosteroid use, decreased radial inclination, and negative ulnar variance have been blamed in the etiology.[4] The classification which is still widely used for staging, guiding treatment, and comparing outcomes was introduced by Stahl and modified by Lichtman based on magnetic resonance imaging (MRI).[6]

ABSTRACT

Objectives: This study aims to evaluate the efficacy of an alternative method by comparing an old established method with a new less invasive method in the surgical treatment of Stage 3A Kienböck's disease.

Patients and methods: Between January 2014 and July 2018, a total of 35 patients (28 males, 7 females; mean age: 22.8±3.3 years; range, 17 to 29 years) who underwent surgery due to Kienböck's disease were retrospectively analyzed. The patients were divided into two groups according to the procedure applied as the capitate forage procedure (CFP) group (Group 1, n=16) and the radial shortening osteotomy (RSO) group (Group 2, n=19). Patients with a minimum follow-up period of 18 months were examined according to the MAYO wrist scores pre- and postoperatively.

Results: The postoperative MAYO scores were statistically significantly higher in both groups (CFP, p=0.001; RSO, p=0.000). However, the osteotomy group showed statistically significantly higher results than the forage group in terms of not only postoperative scores, but also pre- and postoperative score difference (p=0.004).

Conclusion: Our study results confirm that both CFP and RSO are effective in the treatment of Stage 3A Kienböck's disease. However, RSO should be the first choice in Stage 3A patients with high success rates. Supported by long-term follow-up results, CFP may be considered a minimally invasive alternative only in selected patients who avoid major surgery or expect a rapid return to work.

Keywords: Capitate forage, Kienböck's disease, lunate avascular necrosis, lunatomalacia, os lunatum, radial shortening osteotomy, ulnar variance.

The main goal of treatment is pain relief and preservation of grip strength and range of motion (ROM).[7] There is no consensus on the optimal treatment of the disease. Surgical interventions show several differences according to the severity of the condition, stage, and surgeon's attitude. There are three different surgical treatment options for Kienböck's disease: *(i)* surgeries which reduce the loading to lunate bone biomechanically, *(ii)* revascularization

procedures, and *(iii)* salvage procedures.[8] Radial shortening osteotomy (RSO) is the procedure that is frequently preferred and published with good results, particularly in patients with negative ulnar variance.[9,10] It is preferred for core decompression and joint-leveling effects that provide appropriate load transmission and increased blood supply to the carpal bones by mimicking an acute fracture and helping to heal.[11] On the other hand, the capitate forage procedure (CFP) is a novel and easier technique which is applied by drilling capitates bone via Kirschner wires (K-wires) for its possible decompressive and blood flow increasing effect. Minimally strength and grip decrease and preserved ROM suggest that the treatment is well tolerated by patients.[12]

Radial shortening osteotomy is a conventional and proven technique that is assumed to both optimize joint biomechanics and increase blood flow from the osteotomy line to the wrist. The CFP is a novel application with a minimally invasive nature that is assumed to reduce carpal pressure and increase blood supply as a result of drilling into the capitate bone. In the present study, we aimed to evaluate the efficacy of an alternative method by comparing an old established method with a new less invasive method in the surgical treatment of Stage 3A Kienböck's disease.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Beylikdüzü State Hospital, Department of Orthopedics and Traumatology between January 2014 and July 2018. Direct radiographic imaging was performed and MRI was planned for the patients who applied with complaints of wrist pain, grip strain, and limitation of wrist movements. Conservative treatment was applied to all patients who were found to have lunate avascular necrosis and were diagnosed with Kienböck's disease. Non-steroidal anti-inflammatory drugs, wrist splints, and lifestyle changes to protect the wrist from repetitive trauma were recommended to all patients. Surgical treatment was recommended for the patients whose symptoms persisted for at least eight weeks despite adherence to given recommendations. Finally, a total of 35 patients (28 males, 7 females; mean age: 22.8±3.3 years; range, 17 to 29 years) who underwent surgery due to Kienböck's disease were included. Inclusion criteria were as follows: Stage 3A Kienböck's disease diagnosed with both X-ray and MRI, treated with RSO or CFP, having a minimum of 18 months of follow-up. Exclusion criteria were as follows: Kienböck's disease treated with a combined or alternative method and performing salvage procedures, disease stages except for 3A according to Lichtman/Stahl classification, accompanying ipsilateral carpal instabilities, and/or scaphoid lesions, insufficient follow-up period, ipsilateral upper extremity injuries, and positive ulnar variance. The arthroscopic staging was not performed during surgery. The patients were divided into two groups according to the procedure applied as the CFP group (Group 1, n=16) and the RSO group (Group 2, n=19) (Table 1 and Table 2).

According to the revised MAYO hand and wrist score subscales pain level, functional status, ROM, and grip strength were measured for each patient pre- and postoperatively (minimum 18 months of follow-up, at the last outpatient clinic control) and compared statistically. Wrist motion measurements were performed with a goniometry, and grip strength was measured with a Jamar dynamometer (Sammons Preston, Bolingbrook, Illinois, USA). Pain and functional status were evaluated according to verbal categorical level. They were also questioned to determine their pain level on a scale of 0 to 20 and their function as severe to no disabilities. No postoperative patient satisfaction questionnaire was applied.

Surgical technique

Capitate Forage Procedure: In the first group of patients, general anesthesia and/or upper extremity nerve block was performed. Following site cleaning and wrapping procedures, the lunate was kept in the center after the dorsal mini-incision under the control of fluoroscopy, on the radiolucent hand table. The central area of the capitate which is not covered by cartilage was reached by blunt dissection and extensor tendons were protected. Then, the forage procedure was applied from the center of the capitate to the periphery through the 1.5 mm K-wire drilling four to five times and soft tissues were repaired (Figure 1). The patients who underwent regional anesthesia were discharged on the same day and those who underwent general anesthesia were discharged the next day. No postoperative splint or movement restriction was applied.

Radial Shortening Osteotomy: After a similar preoperative preparation and under the pneumatic tourniquet, the second group of the patients was approached with a 5 to 7-cm volar incision. Maximum 2 to 3-mm radial shortening performed to avoid damaging wrist biomechanics, distal anatomical radius plate, and locking screws was performed after an anatomical reduction under the fluoroscopy. In the RSO group, neither inclination was changed

TABLE I
Patient distribution, demographic characteristics, and ROM in Group 1

Patient no	Age/Sex	Follow-up (month)	Side	Pain	Functional status	Grip strength (%)	Preoperative ROM	Postoperative ROM	Preoperative the modified Mayo wrist score	Postoperative the modified Mayo wrist score
1	24/M	21	Left	None	Returned to regular employment	100	45	110	30	90
2	19/M	20	Right	None	Restricted employment	100	55	>120	40	95
3	29/M	18	Left	None	Returned to regular employment	100	45	110	35	90
4	22/M	18	Right	None	Returned to regular employment	100	50	110	45	90
5	21/M	19	Right	None	Returned to regular employment	100	65	115	45	90
6	20/M	20	Left	None	Restricted employment	100	55	>120	40	95
7	18/F	21	Right	None	Returned to regular employment	100	60	105	40	90
8	17/M	36	Left	None	Restricted employment	100	70	>120	50	95
9	23/M	34	Right	Mild occasional	Restricted employment	100	50	100	55	80
10	21/F	26	Right	Mild occasional	Restricted employment	100	55	90	50	80
11	22/M	30	Left	None	Restricted employment	75-100	50	80	40	70
12	24/M	18	Left	Mild occasional	Restricted employment	75-100	45	80	40	65
13	25/M	24	Left	Mild occasional	Restricted employment	75-100	50	70	45	65
14	22/F	19	Right	Mild occasional	Able to work, but unemployment	25-50	50	50	50	45
15	22/M	18	Right	Moderate, tolerable	Able to work, but unemployment	25-50	40	45	35	40
16	21/M	18	Right	Moderate, tolerable	Able to work, but unemployment	25-50	60	40	45	40

ROM: Range of motion.

TABLE II
Patient distribution, demographic characteristics, and ROM in Group 2

Patient no	Age/Sex	Follow-up (month)	Side	Pain	Functional status	Grip strength (%)	Preoperative ROM	Postoperative ROM	Preoperative the modified Mayo wrist score	Postoperative the modified Mayo wrist score
1	20/M	18	Right	None	Restricted employment	100	45	>120	45	95
2	29/M	26	Right	None	Returned to regular employment	100	45	>120	35	100
3	22/F	38	Left	None	Returned to regular employment	100	50	105	40	90
4	19/M	30	Left	Mild occasional	Returned to regular employment	100	40	>120	30	95
5	27/M	19	Right	None	Returned to regular employment	100	60	>120	55	100
6	21/M	18	Right	None	Restricted employment	100	45	>120	50	95
7	24/M	42	Right	Mild occasional	Returned to regular employment	100	40	>120	35	95
8	26/M	36	Left	None	Returned to regular employment	100	45	110	35	90
9	28/F	24	Right	Mild occasional	Returned to regular employment	100	50	>120	40	95
10	22/M	18	Right	None	Returned to regular employment	100	45	110	45	90
11	19/M	19	Right	Mild occasional	Returned to regular employment	100	50	>120	55	95
12	26/M	20	Right	None	Returned to regular employment	100	50	110	50	90
13	23/F	19	Right	None	Returned to regular employment	100	60	>120	50	100
14	29/M	20	Right	Mild occasional	Returned to regular employment	100	50	100	40	85
15	24/M	18	Left	Mild occasional	Returned to regular employment	100	40	95	35	85
16	21/M	18	Right	Mild occasional	Returned to regular employment	100	45	100	35	85
17	19/M	19	Left	None	Returned to regular employment	100	45	90	35	90
18	27/F	25	Right	None	Returned to regular employment	100	55	100	40	90
19	25/M	24	Left	Mild occasional	Returned to regular employment	100	60	>120	40	95

ROM: Range of motion.
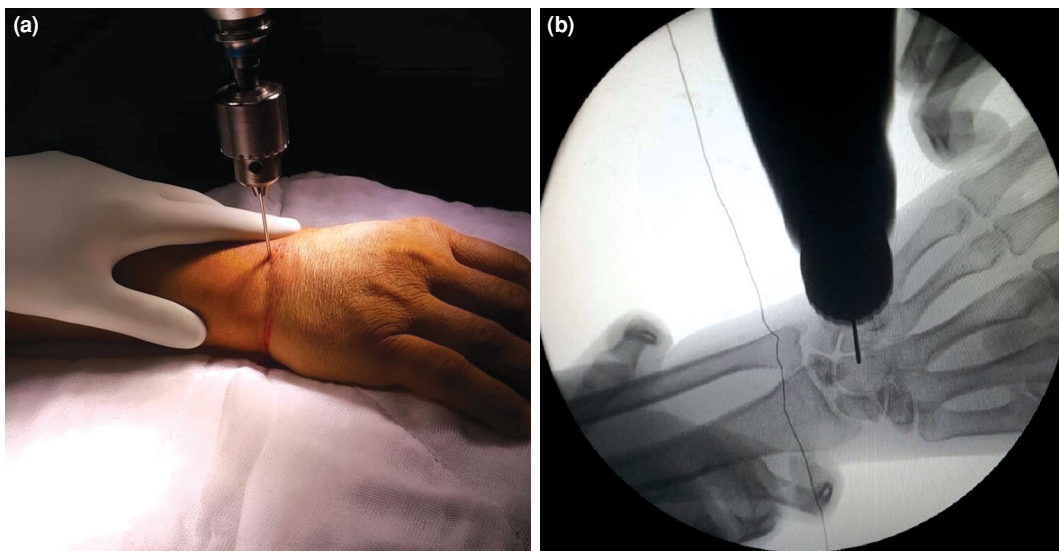
FIGURE 1. Capitate forage procedure. **(a)** Intraoperative positioning, **(b)** Fluoroscopy image.

nor wedge osteotomy performed during surgery. A mini-vacuum drain was placed under the fascia and soft tissues were repaired. All patients applied the same plate screw system (Turktıpsan A.Ş, Ankara, Türkiye) and the drain was removed the day after surgery (Figure 2). A volar short arm splint was applied for two weeks. All patients were discharged on the second postoperative day.

At the first follow-up in the second postoperative week, the sutures were removed in all patients and the splints of the RSO group patients were terminated. Finger movements were encouraged from the first day, and wrist movements were completely allowed after splint removal. Active employees in the CFP group were allowed to continue their work after the second-week control and the active employees in the RSO group after the sixth-week control. The patients were called for routine follow-up at 6, 12, 18, and 24 months and evaluated using direct radiography. The MRI was requested for the patients who continued their control after 24 months (Figure 3).

Statistical analysis

According to the calculation of the post-hoc sample size, the power of the study was found slightly over 80% with an alpha value of 0.05. The standard effect
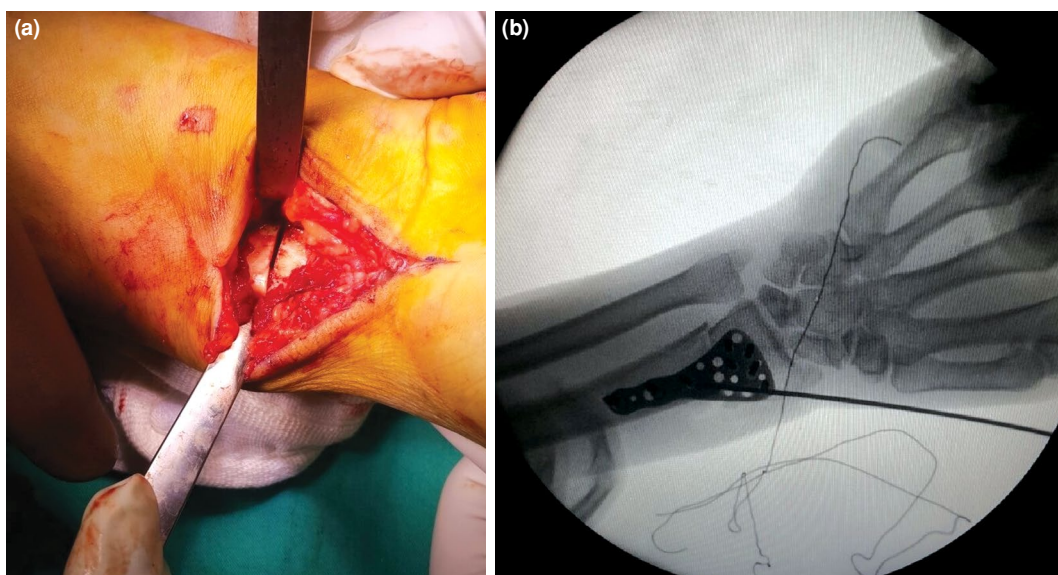
FIGURE 2. Radial shortening osteotomy. **(a)** Intraoperative positioning, **(b)** Fluoroscopy image.

size for quantitative data was set at 1.13% and the power of the study was 89%.

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. The distribution of variables was measured using the Kolmogorov-Smirnov test. The Mann-Whitney U test was used for quantitative independent data. The Wilcoxon test was used to analyze dependent quantitative data. The chi-square test was used in the analysis of independent qualitative data. A *p* value of <0.05 was considered statistically significant.

RESULTS

A total of 22 right and 13 left sides of 35 patients were operated. The mean follow-up was 23.2±6.8

(range, 18 to 42) months. No statistically significant difference was observed between the groups in terms of age, sex, and follow-up (p>0.05). Preoperative MAYO scores in Group 1 and Group 2 were not statistically significantly different (p>0.05) (Table 3a).

The postoperative MAYO scores in both groups showed a statistically significant difference compared to the preoperative scores (p<0.05), indicating that both procedures were effective treatment modalities for Stage 3A Kienböck's patients who were quite similar baseline characteristics. However, while comparing postoperative MAYO scores, Group 2 was found to be statistically significantly higher than Group 1 (p<0.05) (Table 3b). In addition, the radial shortening group showed statistically significantly higher results than the capitate forage group in terms of both postoperative MAYO scores and pre- and postoperative MAYO score difference (p<0.05).
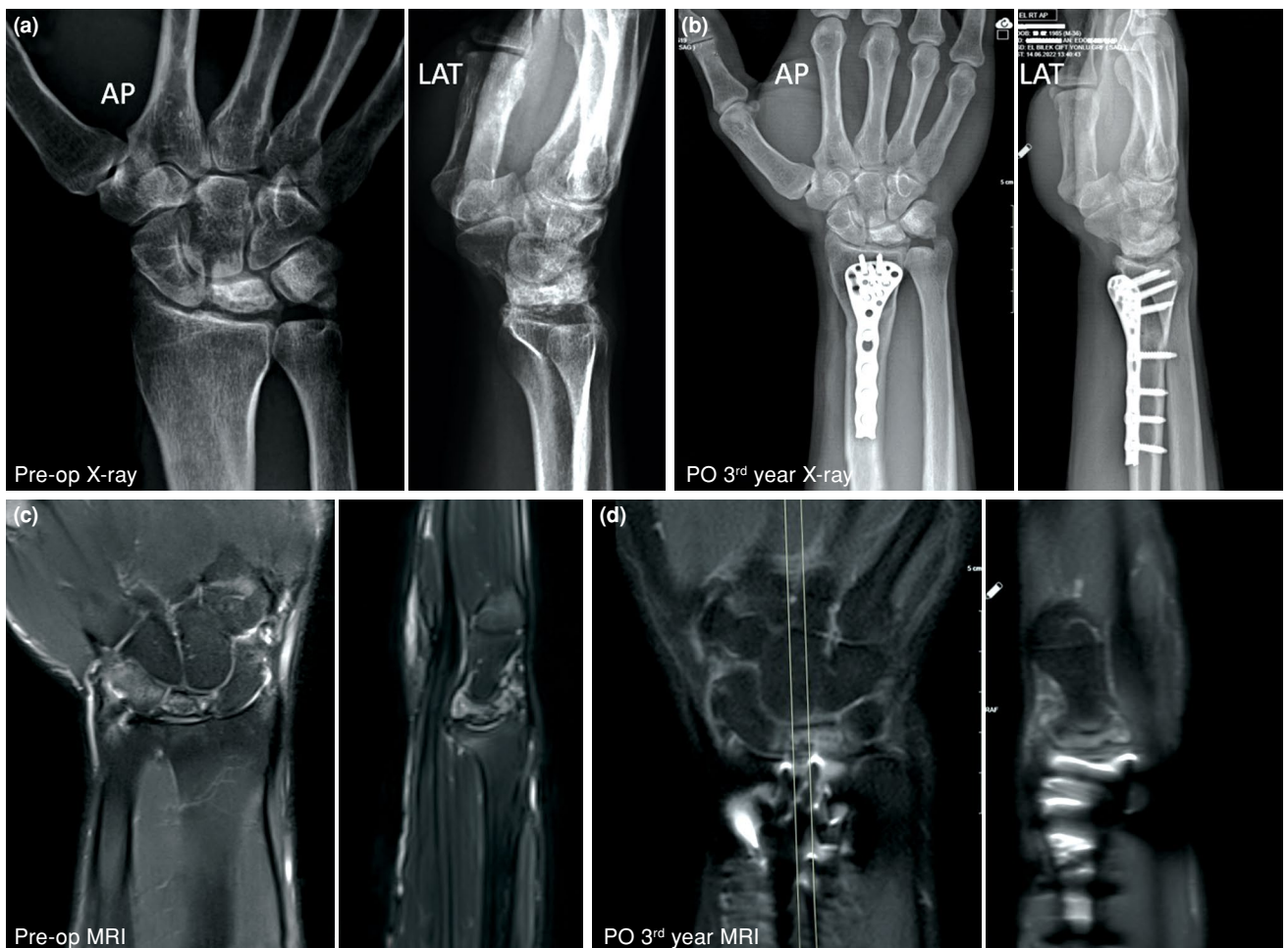
FIGURE 3. Radial shortening osteotomy, follow-up images. **(a)** Preoperative AP and lateral radiographs. **(b)** Postoperative third year AP, and lateral radiographs. **(c)** Preoperative coronal and sagittal MRI views. **(d)** Postoperative third year coronal and sagittal MRI views.
AP: Anteroposterior; MRI: Magnetic resonance imaging.

TABLE IIIA
Patients' characteristics

Variables	CFP group			RSO group			Total			p
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	
Age (year)			21.9±2.9			23.7±3.4			22.9±3.3	0.133[a]
Sex										0.909[a]
Male	13	81.3		15	78.9		28	80		
Female	3	18.8		4	21.1		7	20		
Follow-up (month)			22.5±5.9			23.7±7.5			23.2±6.8	0.781[a]
Side										0.545[a]
Right	9	56.3		13	68.4		22	62.9		
Left	7	43.8		6	31.6		13	37.1		

CFP: Capitate Forage Procedure; RSO: Radial Shortening Osteotomy; n: Number of participants; SD: Standard deviation; a: Mann-Whitney U test; p<0.05.

TABLE IIIB
Comparison of the functional results of the groups according to the MAYO score between and within the groups

	Within the modified Mayo wrist score			Between modified Mayo wrist score	
	Preoperative	Postoperative			
	Mean±SD	Mean±SD	p		p
Capitate forage procedure	42.8±6.6	76.3±19.9	**0.001[b]**	Preoperative	0.502[a]
Radial shortening osteotomy	41.6±7.5	92.6±4.8	**0.000[b]**	Postoperative	**0.004[a]**

SD: Standard deviation; a: Mann-Whitney U test, p<0.05; b: Wilcoxon Signed Ranks Test, p<0.05.

No complications were observed in the CFP group in the postoperative period, and all patients were able to return to work in the second week. Although we did not experience major complications in the osteotomy group, there was moderate complex regional pain syndrome in two patients which healed spontaneously at 12 weeks. Most of the patients were able to return to work after six weeks. However, there was no statistically significant difference in the return to work due to the heterogeneous groups formed by those working in physical and desk jobs, students, and non-employees. Both groups of the patients were relatively young and healthy, and there was no significant difference in terms of smoking.

Since follow-up MRI imaging could not be performed in all patients, the disease progression was evaluated based on direct radiographs. In the direct radiological imaging of Patients 12 and 13 with poor clinical results in the CFP group, the collapse of the carpal bones was observed, while in the Patient 14, degenerative changes were also observed around the lunate in addition to carpal collapse. These radiological changes were interpreted as Patients 12 and 13 regressed to Lichtman Stage 3B and Patient 14 to Stage 4. While no major radiological changes were observed in the other patients in the CFP group, the patient's complaints clinically regressed regardless of the radiological status. Carpal collapse and degenerative changes were not observed in any of the patients in the follow-up imaging of the RSO group, and it was thought that the patients did not progress to Lichtman Stages 3B, and 4. A moderate improvement in lunate collapse and signs of lunate sclerosis was observed in some of the patients, indicating that some patients might turn into Lichtman Stage 2 at further follow-ups. Satisfactory clinical improvements were observed in all RSO patients.

DISCUSSION

The lunate is located in the middle of the proximal carpal row and acts like a keystone for wrist biomechanics. Lunatomalacia may lead to progressive pain and dysfunction of the wrist joint. Unknown etiology and natural history lead to a wide range of different array of surgical interventions, which make it difficult to compare. In a study evaluating the attitude in the treatment of Kienböck's disease among hand surgeons, almost half of the participants preferred RSO in the

treatment of Stage 3A disease.[13] However, when the stage of the disease was 3B, most of the participants preferred salvage procedures and, for the treatment of Stage 2, the preferences differed and varied significantly. Although there are studies in the literature comparing different techniques, only the original article presented a successful method as a new technique for CFP. In our study, we investigated the effectiveness and positive or negative aspects of the method by comparing it with RSO, a widely adopted technique that is used frequently in daily practice. We performed RSO and CFP to Stage 3A patients and achieved statistically significant good results with a high patient satisfaction.

Two main reasons that stand out in the etiopathogenesis of the disease are vascular insufficiency and negative ulnar variant.[14] Currently, there are limited studies in the literature comparing Kienböck's disease treatment options. In our study, we focused on those two main reasons shown in the etiopathogenesis, and the results of RSO as joint-leveling procedure and CFP as decompression procedure were compared in the present study. Our study results highlight that although both RSO and CFP are successful methods in the treatment of Stage 3A Kienböck's disease, RSO is significantly superior. As a conventional and reliable method, RSO is a widely adopted technique with both an increase in blood supply and a joint-leveling effect. Also, CFP should be considered as an alternative that has a minimally invasive and easy-to-perform nature and the possible advantage of the rapid return to work.

The CFP was defined by Bekler et al.,[12] and it was presented as easy to reach, closer to the lunate, and safer to perform. Besides, they emphasized osteotomy procedures such as radial shortening work as a process that increases the blood flow of lunate. Therefore, they recommended performing osteotomies, not on the forearm, but on the capitate bone. There was a statistically significant improvement in patients who underwent CFP. The CFP is a decompressive method that can be preferred by orthopedic surgeons in terms of a short learning curve, easy to perform, less invasive nature, and rapid return to daily life. On the other hand, one of the most important limitations of Bekler et al.'s[12] study is that the study consists of a series of only nine patients. Since there was a statistically significant difference between the two groups in terms of surgical times, tourniquet application, and soft tissue damage due to surgery, blood supply, and healing response were expected to be different.

Although studies on CFP are limited in the literature, there are many decompression procedures

defined directly to the lunate and carpal bones or the distal metaphysis of the radius.[15] Furthermore, performing capitate osteotomy and capitate shortening procedures can make a similar impact to CPF and heal the disease by both could increasing blood flow and reducing compressive forces.[16-18] Some studies attempt to increase blood supply through the carpal bones, as well as through the radius and ulna metaphysis. Both Illarramendi et al.[11] and De Carli et al.[19] reported radius metaphyseal core decompression as a successful and reliable method for long-term follow-up. Similar to CFP, distal metaphyseal core decompression not only protects the wrist biomechanical, but also increases blood flow to lunate. Similar to the aforementioned studies, Blanco and Blanco[20] reported an improvement in wrist pain and movements in 10-year follow-up results of radial osteotomy applied to Kienböck patients regardless of ulnar variance. In addition, Patients 14, 15, and 16, who comprised approximately 18% of the CFP group, showed poor clinical outcomes. We closely monitor these patients' clinical progression and mid/long-term follow-up. Probably, we can investigate the wrist biomechanics of such patients in whom CFP fails in more detail and obtain predictive data about the patients who may fail.

In a very similar study to ours, Afshar et al.[18] reported reasonable results in both groups which compared the radial and capitate shortening osteotomy techniques in Stage 3A patients. According to this study, all patients in the RSO group complained of the presence of implants in their forearms. This situation can be considered one of the possible advantages of CFP.

Several techniques have been described for vascular bone grafting in the literature. The harvested sides (volar/dorsal), vessels (ulnar/radial), and bones (radius/ulna) vary according to the technique and the preferences of the defining clinicians.[21,22] Chevrollier et al.[23] reported that isolated capitate osteotomy results were better than combined capitate/hamate osteotomy, and also vascular bone grafting had no impact on outcomes. The study supports CFP in terms of both showing the positive effect of capitate osteotomy by increasing blood supply and the negative effects of secondary procedures on the resulting impairment of carpal row biomechanics. Similarly, Rabarin et al.[24] recommended using a simple and reliable method of capitate shortening, rather than performing RSO, particularly in ulnar neutral and ulnar positive patients, to avoid ulnar impaction and distal radial ulnar joint (DRUJ)

instability. In addition to being an effective method, CFP is a cost-effective surgical option, as it can be performed under regional anesthesia without the use of implants and does not require hospitalization, and does not cause labor loss.

There are many studies in the literature examining the relationship between Kienböck's disease and ulnar variance and anatomical risk factors.[25] The effect of ulnar variance on Kienböck's disease is a highly controversial issue. While some authors found a significant relationship between negative ulnar variance and disease,[26] some did not.[25] Moreover, Nakamura et al.[25] diagnosed Kienböck's disease in patients with positive ulnar variance. The vascular structure of the lunate bone has been a source of curiosity. In a cadaveric study, Gelberman et al.[14] described multiple patterns of vascularity, with the lunate receiving nutrient vessels from both a palmar and dorsal capsular plexus. Despite its unclear effect on the etiopathogenesis of negative ulnar variance, van Leeuwen et al.[27] reported it as the only prognostic factor associated with lunate collapse. The significant advantage of RSO over CFP may be due to its ability to prevent lunate collapse. Again, the factor which reveals this difference is that RSO is both a joint-leveling action and also a revascularization effect owing to the osteotomy.[27]

The RSO is a technique which is frequently used by orthopedic surgeons, and it has been reported that studies and knowledge are high with favorable results.[28] Radial and ulnar osteotomies may damage the front arm biomechanics while benefiting the recovery of Kienböck's disease. After osteotomies, bone union difficulty and DRUJ dysfunctions can be encountered.[12] Nakamura et al.[25] reported that radial shortening can be used in all stages of Kienböck's disease, but ulnar side wrist pain and DRUJ instability may occur in the shortening over 4 mm. While performing RSO, both Nakamura et al.[25] and Fontaine[29] suggested that the amount of shortening must not exceed 4 mm due to the risk of painful ulnocarpal impingement and DRUJ instability. In our study, we avoided excessive radial shortening and, thus, neither DRUJ instability or impingement nor nonunion occurred in our patients. Although we did not experience major complications after RSO, we observed complex regional pain syndrome in two of our RSO patients which healed spontaneously within 12 weeks.

Currently, wrist arthroscopy is used independently of the surgical procedure to be performed, in the staging of the disease and the detection of additional injuries, and also takes its place in the treatment both as a definitive treatment modality and by assisting the interventions.[30]

Due to the retrospective nature of our study, all our patients who complied with the inclusion criteria who underwent surgery due to Kienböck's disease were included. All procedures were performed by a single surgeon who has a minimum 10-year hand surgery experience. Randomization was not performed due to the retrospective nature of the study. Those who met the inclusion criteria among the patients who had consecutive RSO in the previous periods and those who recently received CFP consecutively were included in the study. The sample size of our study mostly consisted of young patients with no trauma history. The low mean age of the sample group can be attributed to the predominance of young men working in the industrial zone established in a region close to our hospital. Before surgery was recommended, wrist splints, immobilization, and anti-inflammatory medications were applied to all patients. Nevertheless, the strengths of our study are that both of our patient groups are relatively homogeneous, all of them are Stage 3A disease according to the Lichtman classification, and have a minimum of 18 months of follow-up. On the other hand, the retrospective nature of our study, the lack of randomization in preferred surgery for the patient, the absence of a non-operative control group, and the comparison of only two surgical procedures with a small sample size can be counted as the weaknesses of our study. However, our study provides only early period results, and considering the studies in the literature that offer 5 to 10 years of follow-up, long-term follow-up is needed to evaluate the progression of the disease and, particularly, the results of the CFO technique.

The surgeon's preference and habits, accurate assessment, realistic patient expectations, and detailed evaluation of current experience with Kienböck's disease treatment play a critical role in determining the optimum outcome for the patient. Although CFP is an effective method in patients with Stage 3A, RSO is probably more effective with both unloading and joint-leveling action and increasing blood supply. The CFP may be a suitable surgical option, particularly for early-stage patients who are unwilling to undergo major surgery, and particularly for patients who appear neutral or positive ulnar variance.

In conclusion, the results of the RSO are significantly higher, despite the aforementioned

advantages of CFP. With these advantages, it is necessary to examine the long-term results for CFP to be preferred in suitable patients. We believe that future studies need to be more focused on etiopathogenesis. Finally, RSO is a conventional and established procedure that has both biomechanical and increasing blood supply effects to treat lunatomalacia.

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