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Arthroscopy-assisted bone grafting for the treatment of SNAC stage I without radial styloidectomy

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Abstract

To report the clinical and radiological outcomes of arthroscopic bone grafting and percutaneous K-wire fixation without radial styloidectomy in patients with scaphoid nonunion advanced collapse (SNAC).

We retrospectively analyzed the records of 15 patients with SNAC who were treated with arthroscopic bone grafting and percutaneous K-wire fixation and subsequently followed up for a minimum of 1 year between November 2009 and March 2018. The clinical outcomes were evaluated by comparing the range of motion (ROM), grip strength, the modified Mayo Wrist Score, and visual analog scale (VAS) scores for pain, all of which were measured preoperatively and at the last follow-up. The radiologic outcomes were evaluated by comparing the scapholunate (SL) and radiolunate (RL) angles preoperatively and at the last follow-up.

All 15 cases of nonunion were resolved. The average radiologic union time was 9.7 ± 1.2 weeks. The average VAS score increased from 5.7 ± 2.3 (range, 2 – 10) preoperatively to 1.3 ± 1.3 (range, 0 – 3) at the last follow-up ($P < .05$). The average modified Mayo wrist score increased from 58.3 ± 14.0 preoperatively to 80.0 ± 9.2 at the last follow-up ($P < .05$). The mean ROM of the wrist improved, but there was no statistical significance. At the last follow-up, the mean flexion and radial deviation on the affected side were significantly decreased, and the mean extension on the affected side was significantly improved compared to the normal side ($P < .05$). The mean preoperative SL and RL angles were 66 ± 11.9° and 7.2 ± 6.8°, respectively, and were decreased to 50.4 ± 7.5° and 6.4 ± 5.2°, respectively, at the last follow-up. The mean SL angle was significantly corrected ($P = .01$).

Arthroscopic bone grafting and percutaneous Kerschner (K)-wire fixation without radial styloidectomy are considered to be very effective methods for correcting scaphoid deformities to treat SNAC stage I. However, caution may be needed during the surgery to prevent reductions in flexion and the radial deviation of the wrist.

Abbreviations: CT = computerized tomography, DISI = dorsal intercalated segment instability, ICCs = interclass correlation coefficients, K = Kirschner, LT = lunotriquetral, MCR = mid-carpal radial, MCU = mid-carpal ulna, PA = posteroanterior, RL = radiolunate, ROM = range of motion, SL = scapholunate, SNAC = scaphoid nonunion advanced collapse, STT = scaphotrapeziotrapezoidal, TFCC = triangular fibrocartilage complex, VAS = visual analog scale.

Keywords: arthroscopy, bone graft, K-wire, scaphoid nonunion advanced collapse

1. Introduction

In symptomatic scaphoid nonunion advanced collapse (SNAC), it is difficult to achieve satisfactory results with simple open reduction and internal fixation of the scaphoid. Therefore, several surgical procedures can be considered depending upon the SNAC stage.[1] Among them, in patients with stage I SNAC, a traditional scaphoid bone graft to stabilize the scaphoid and radial styloidectomy to remove arthritis impingement is an accepted surgical option.[2,3] Several options for scaphoid bone grafts are available, but it is important to remember that, regardless of the option, maintaining blood supply to the scaphoid, exposing healthy cancellous bone through the debridement of necrotic bone and connective tissue, fracture reduction, and bone grafts with stable internal fixation are essential.[4,5] Recently, successful percutaneous and less invasive methods using arthroscopy for scaphoid bone grafting have been reported.[6–8] In this study, arthroscopy was employed to perform bone grafting on the scaphoid.

Radial styloidectomy was first described for the treatment of scaphoid nonunion in 1948 by Barnard and Stubbins.[9] Since then, it has been an adjunct to other procedures for the treatment of arthritis localized to the radioscaphoid joint.[2,10–12] However, it was difficult to find previously published studies on radial styloidectomy as the primary, not an adjuvant, procedure, although the procedure has been performed for many years. In addition, even if performed carefully, radial styloidectomy has

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request

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the potential risk for carpal instability, which raises the question of whether this procedure is essential for treating stage I SNAC.

Therefore, we hypothesized that, if the scaphoid nonunion is properly reduced without an impact on the scaphoid and radial styloid process, progression to arthritis or pain will not occur. While performing arthroscopic bone grafting on the scaphoid nonunion, synovectomy and debridement on the radioscaphoid joint was thoroughly performed, but radial styloidectomy was not.

The purpose of this study was to report the clinical and radiological outcomes of arthroscopic-assisted bone grafting without radial styloidectomy in patients with SNAC stage I.

1.1. Consent

This study received approval from the Institutional Review Board at Jeonbuk National University Hospital (CUH 2020-05-040-002).

2. Material and Methods

This study was a retrospective case series with prospectively gathered data. Fifteen patients with SNAC stage I, who had been treated with arthroscopic bone grafting and percutaneous K-wire fixation from November 2009 to March 2018 were included in the study. All patients were available for functional outcome and radiologic examination assessments at a minimum of 1 year following surgery. The patients included 14 males and 1 female with an average age of 44 years (range, 28 – 61 years). The affected sides were the right wrist in 10 patients and the left wrist in 5 patients. A total of 12 mid-third and 3 proximal-third fractures were included. The time interval between the injury and the operation ranged from 12 months to 40 years (median time, 17 years; 6 patients unknown). The most common causes of the injuries were falls in 6 patients, sports injuries in 2 patients, a traffic accident in 1 patient, and unknown in 6 patients. The average follow-up period was 30 months (range, 12 – 72 months) (Table 1).

During arthroscopy, carpal ligament injuries were graded using the system described by Geissler et al,[13] and the lesions of the triangular fibrocartilage complex (TFCC) were classified according to the system described by Palmer.[14]

We identified a tenosynovial giant cell tumor around the TFCC and the mass was completely excised piece-by-piece with grasping forceps. Furthermore, as a closed rupture in the flexor pollicis longus tendon was present in the same patient, we concomitantly performed a fourth flexor digitorum sublimis tendon transfer.

Bone union was clinically assessed as the resolution of tenderness at the anatomical snuffbox on physical examination and radiologically with wrist posteroanterior (PA), lateral, and semipronated oblique views, and posteroanteriorly with ulnar deviation assessed as the disappearance of the fracture line with bony trabecular across the original fracture. However, if the assessment was ambiguous, the bone union was further evaluated using computerized tomography.

The patients were evaluated for ROM of the wrist using a hand-held goniometer, grip strength measured on a dynamometer, and a VAS for pain (0 = no pain, 10 = worst pain). Functional outcome was evaluated by comparing the modified Mayo wrist score and the VAS score, which were measured preoperatively and at the final follow-up.[15] For the radiologic assessment, the SL and RL angles were measured on radiographs obtained preoperatively and at the final follow-up according to the recommendation of Roh et al[16] Two hand surgeons individually measured the SL and RL angles. The data are expressed as the mean ± standard deviation. The SL and RL angles, which were measured preoperatively and at the final follow-up, were compared.

2.1. Surgical technique

Arthroscopic bone grafting was performed as described in previous studies.[7,8] The surgical instruments included a 1.9-mm video arthroscope (Linvatec, CONMED Linvatec, Utica, NY), 2.0- and 2.9-mm shavers, a 3.0-mm burr, and a radiofrequency probe. We also used 2 custom-made cannulas (3.8 and 3.0 mm) and 2 custom-made trocars (3.2 and 2.7 mm) for percutaneous bone grafting. We made 3/4 and 4/5 portals for the radiocarpal joint, mid-carpal radial (MCR), mid-carpal ulna, and 1 accessory portal for the mid-carpal joint. An accessory portal was located in the portion between the MCR and scaphotrapeziotrapezoidal (STT) portals.

We first inspected the radiocarpal joint. During arthroscopy, we found degenerative changes caused by impingement in the radial styloid process. However, sufficient arthroscopic debridement was performed including synovectomy to fully remove up to the joint capsule, but we did not perform a radial styloidectomy (Fig. 1). We then transferred the arthroscope to the mid-carpal joint and examined the status of the articular cartilage and the nonunion site. Both ends of the nonunion site were debrided and burred by the burr and shaver until a healthy-looking cancellous bone with punctate bleeding was seen. After completing the preparation for the bone graft, the scaphoid was reduced using an image intensifier. Subsequently, temporary retrograde pin fixation was performed on the distal anterior tubercle of the scaphoid using a 1.2-mm K-wire. To correct deformities in patients with humpback deformity and dorsal intercalated segment instability (DISI) deformity,

Table 1

Demography of the patients.

Patient no.	Age (yr)/sex	Site (R/L)	Intervals between injury and surgery (mo)	Causes of injury	Location of facture	Last follow-up (mo)
1	49/M	Rt.	360	Fall down	Waist	12
2	40/M	Lt.	Unknown	Unknown	Waist	13
3	43/M	Rt.	192	TA	Waist	15
4	28/M	Rt.	12	Sport	Waist	72
5	46/M	Lt.	Unknown	Unknown	Waist	49
6	51/M	Rt.	Unknown	Unknown	Waist	22
7	61/M	Rt.	480	Fall down	Proximal	14
8	48/M	Lt.	Unknown	Unknown	Waist	52
9	31/M	Rt.	120	Fall down	Waist	55
10	39/M	Rt.	Unknown	Sport	Waist	60
11	41/M	Lt.	240	Fall down	Waist	14
12	42/M	Rt.	12	Fall down	Waist	26
13	56/M	Lt.	72	Fall down	Proximal	28
14	60/M	Rt.	360	Sport	Waist	15
15	32/M	Rt.	Unknown	Unknown	Proximal	13

TA = traffic accident.

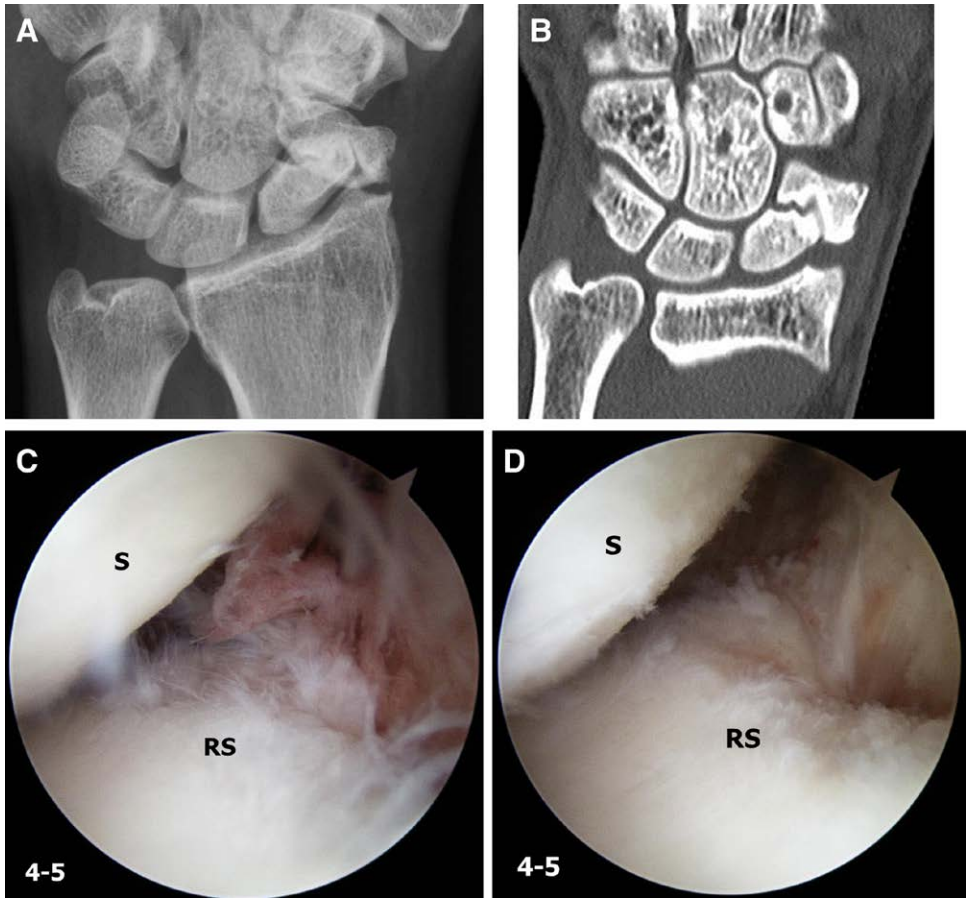

Figure 1. A 46-year-old male patient with nonunion of the left scaphoid fracture. Preoperative left wrist plain (A) and CT scan (B) scaphoid view showing nonunion at the waist of the scaphoid with degenerative changes around the radial styloid process due to radioscaphoid impingement. The radiocarpal arthroscopy image of the radial styloid process of the same patient's left wrist shows synovitis and degenerative changes (C) and after synovectomy and vaporization without styloidectomy (D). CT = computed tomography, RS = radial styloid process, S = scaphoid.

the RL joint was fixed with a K-wire after correcting the position of the lunate from the posterior flexion to neutral by flexing the carpal joint from the neutral position. Subsequently, we reduced the distal fragment to the proximal fragment by traction and manipulation with gentle passive ulnar deviation and hyper-supination and extension of the wrist with the dorsum of the hand on a rolled-up towel. Next, we percutaneously fixed the scaphoid with a 1.2-mm K-wire (Fig. 2). Subsequently, cancellous bone was harvested from the iliac crest for bone grafting. The harvested bone was cut into small pieces using scissors. Bone grafting was performed by placing a 3.8-mm cannula at the site of the nonunion through the MCR portal, placing the cancellous bone at the portal entrance, and pushing it in with a 3.2-mm trocar while continuously visualizing the site of the nonunion with an arthroscope inserted through the mid-carpal ulna portal (Fig. 3). The bone graft was fixed with fibrin glue (Greenplast Kit, Green Cross, Korea). Additional scaphoid fixation was performed via an image intensifier using 2 1.2-mm K-wires after removing all traction (Fig. 4).

Postoperatively, the wrist was immobilized with a below-elbow thumb spica splint. In the case of humpback deformity and DISI deformity, the wrist was immobilized with an above-elbow thumb spica splint for 2 weeks to protect the RL pinning, which was removed at 2 weeks, after which, we applied a below-elbow thumb spica cast for 8 weeks. Postoperatively, radiological images were obtained weekly after surgery until a union was achieved, and the K-wires were removed when the union was achieved (Fig. 5). Joint movement was allowed from the time of the K-wire removal, and continuous rehabilitation was performed. Excessive activity was limited until the preoperative ROM was regained.

Figure 2. Intraoperative photograph showing scaphoid reduction and temporary K-wire fixation.

2.2. Statistical analysis

The IBM SPSS version 20.0 (IBM Corp., Armonk, NY) program was used for the statistical analyses of all data. We used a paired samples test to compare the preoperative and last follow-up ROM, grip strength, modified Mayo wrist scores, VAS scores, and SL angle and RL changes. *P* values of <.05 were considered statistically significant. Interobserver reliability was tested using

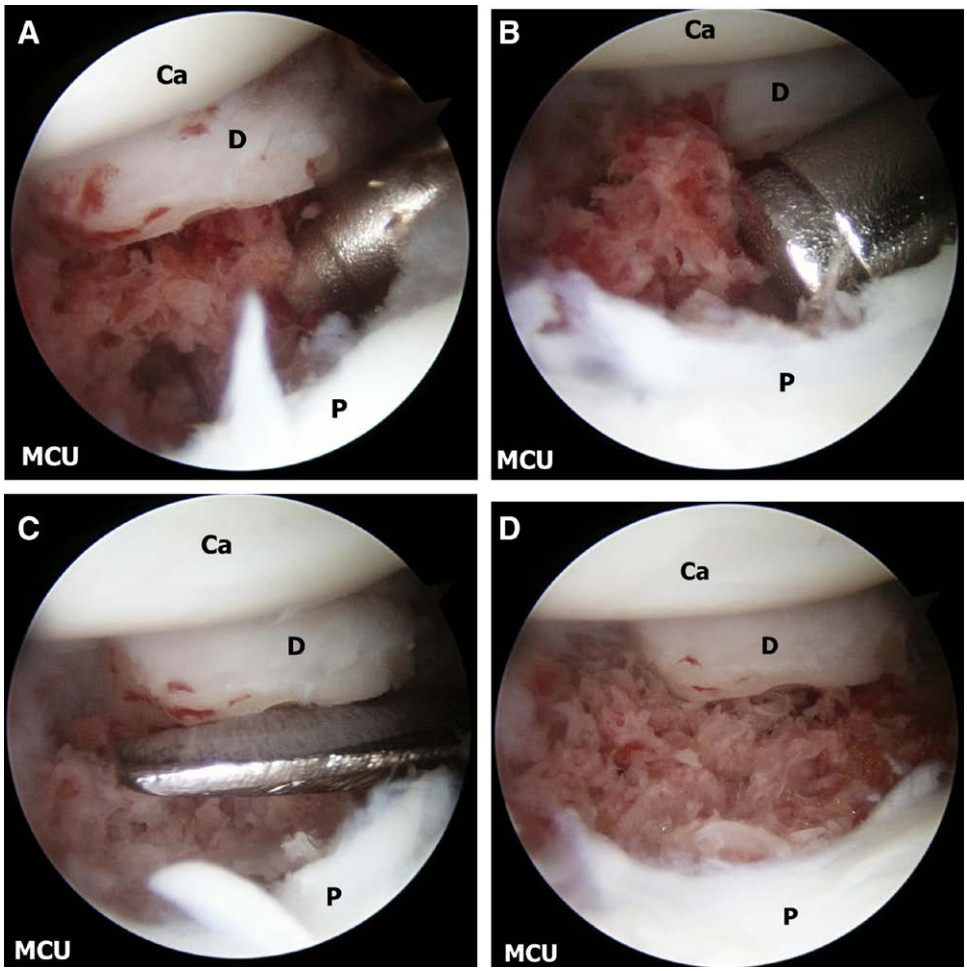

Figure 3. (A–D) The same patient's left wrist mid-carpal arthroscopy images of percutaneous autogenous iliac cancellous bone grafting at the nonunion site using a cannula and trocar. Ca = capitate, D = distal fragment, P = proximal fragment.

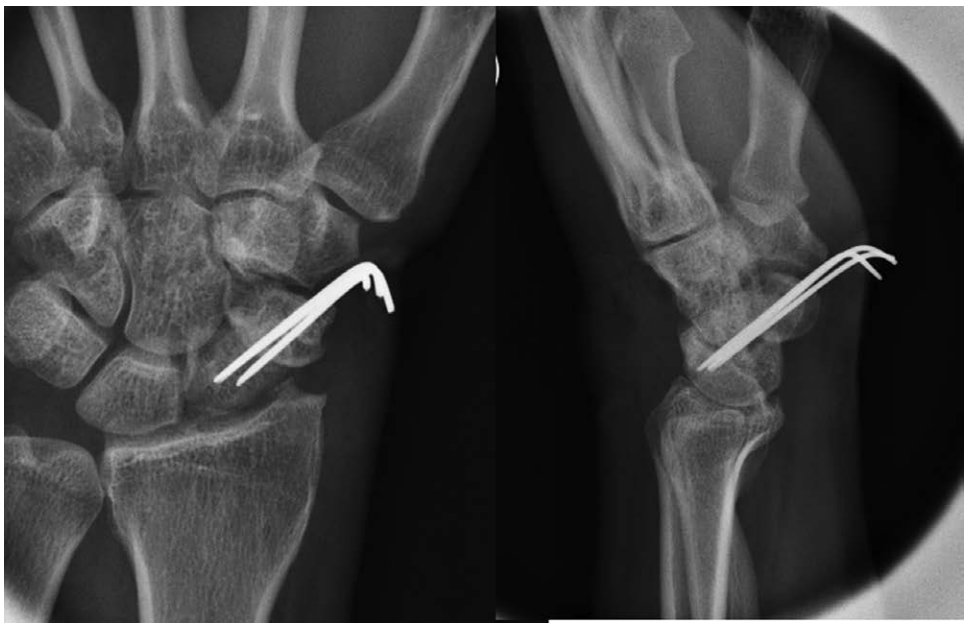

Figure 4. Immediate postoperative plain left wrist scaphoid radiograph shows internal fixation with K-wires and grafted bone at the nonunion site.

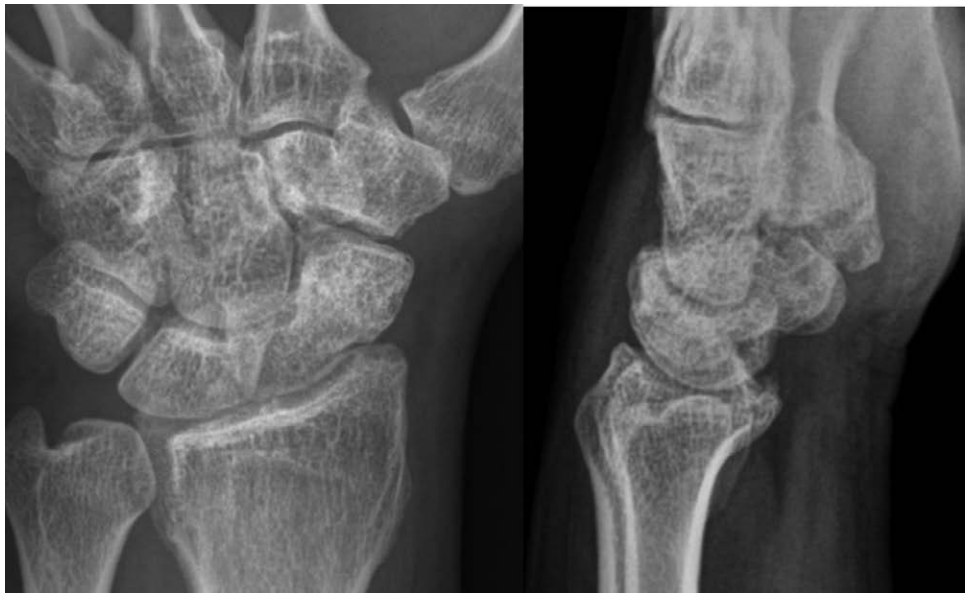

Figure 5. Postoperative 49-month follow-up plain left wrist scaphoid radiograph shows complete bony union.

interclass correlation coefficients (ICCs), as described by Shrout and Fleiss.[17] The interclass correlation coefficients were calculated in which 0–0.39 was poor; 0.40–0.74 was moderate; and 0.75–1.0 was excellent reliability and compared to the study subject criteria.

Statistical analyses were performed using the paired t-test.[18] A *P* value of <.05 was considered statically significant.

3. Results

We identified SL ligament injuries in 7 patients, and all were classified as grade II. We identified grade II lunotriquetral (LT) ligament injuries in 2 patients. We identified triangular fibrocartilage complex injuries (TFCC) in 3 patients, of which 2 were type 1A and 1 was type ID. We identified punctate bleeding at both ends of the nonunion site during arthroscopic debridement in all patients. The average operation time was 177 minutes (range, 88–270 minutes) (Table 2).

The scaphoid nonunion was united in all patients. The average radiologic union time was 9.7 ± 1.2 weeks (range, 8–13 weeks). The mean active ROM of the wrist improved to 85% ± 8.7% of that of the normal side compared to a preoperative active ROM of 80% ± 9.4% of the normal side, but there was no statistical difference (*P* = .232). However, a comparison of the flexion, extension, radial deviation, and ulnar deviation angles at the final follow-up showed that the mean flexion was 47° ± 9.1° on the affected side and 53.6°± 10.7° on the normal side (*P* = .001), and the mean extension was 59.2°± 6.7° on the affected side and 58° ± 13.2° on the normal side (*P* = .001). The affected side exhibited significantly better extension, but lower flexion than the normal side. The mean radial deviation was 11.6° ± 8° on the affected side and 13.1° ± 7° on the normal side (*P* = .004), and the mean ulnar deviation was 40° ± 6° on the affected side and 34° ± 7.6° on the normal side (*P* = .472). The affected side exhibited significantly less radial deviation than the normal side. The mean grip strength showed significant improvement from an average of 79.4% ± 20.9% of the normal side preoperatively to 88.6% ± 13.5% of the normal side at the final follow-up (*P* = .033). The average VAS score significantly decreased from 5.7 ± 2.3 (range, 2–10) preoperatively to 1.3 ± 1.3 (range, 0–3) at the final follow-up (*P* < .05). The average modified Mayo wrist score significantly improved from 58.3 ± 14 preoperatively to 80.0 ± 9.2 at the final follow-up (*P* < .05). For the radiologic outcomes, the mean SL angle showed significant improvement from an average of 66° ± 7.9° (ICCs = 0.881) preoperatively to 50.4° ± 7.5° (ICCs = 0.913) at the final follow-up (*P* = .001). However, the mean RL angle showed no significant difference from an average 7.2° ± 6.8° (ICCs = 0.845) preoperatively to 6.4°± 5.2° (ICCs = 0.915) at the final follow-up (*P* = .539) (Table 3). There were no complications such as infection, nerve injury, or tendon rupture (Table 3).

Table 2

Demography of the patients.

Patient no.	Associated lesions	Punctate bleeding+	Operation time (min)
1	SNAC stage I	D, P+	215
2	S-L, L-T II, SNAC stage I	D, P+	210
3	SNAC stage I	D+, P–	270
4	S-L II	D, P+	130
5	SNAC stage I	D, P+	225
6	S-L II, SNAC stage I	D, P+	200
7	S-L II, SNAC stage I	D, P+	120
8	SNAC stage I, TFC 1-A	D, P+	120
9	S-L, L-T II, SNAC stage I	D, P+	210
10	SNAC stage I	D, P+	120
11	SNAC stage I	D, P+	270
12	SNAC stage I	D, P+	144
13	SNAC stage I	D–, P+	88
14	S-L II, TFCC 1D, GCT, FPL rupture	D, P+	150
15	S-L II, TFCC 1A	D, P+	185

+D, P + = distal and proximal fragment bleeding, L-T = lunotriquetral ligament, P– = proximal fragment no bleeding, S-L = scapholunate ligament, SNAC = scaphoid nonunion advanced collapse, TFC = triangular fibrocartilage.

4. Discussion

Although the specific incidence of scaphoid fracture leading to scaphoid nonunion and subsequent arthritis is unknown, the natural history of untreated scaphoid nonunion is the progression to carpal collapse, resulting in wrist arthritis (SNAC).[2,19] Proximal scaphoid extension and distal fragment flexing after the scaphoid nonunion lead to scaphoid humpback deformity and DISI, which also, in turn, results in arthritis of the

Table 3

Demography of the patients.

Patient no.	SL* angle (degree) (pre/last f/u)	RL* angle (degree) (pre/last f/u)	Time to union (wks)	VAS* (pre/last f/u)	Grip strength* (% of normal side) (pre/last f/u)	ROM* (% of normal side) (pre/last f/u)	Last follow-up ROM* (normal/affected side) (F,E,RD,UD)
1	76/33.5	3/2.5	8	5/3	66/85	73/73	75,70,15,40/50,50,5,40
2	73.5/47.5	2.5/2.75	9	7.5/2.5	30/60	76/80	60,70,20,60/50,60,20,30
3	54.5/41.5	2/1	10	5/2.8	89/85	68/89	60,70,25,35/45,65,15,45
4	54/48	5/7.5	9	8/0	88/100	78/76.2	64,70,20,40/30,66,12,40
5	57/53	1.5/3	13	7.3/2.5	100/100	97/94	65,60,15,50/50,60,15,45
6	53/49	17.25/21	9	7/0	71/100	73/92	65,65,20,45/50,65,15,50
7	64.5/60	3.5/4	9	4/0	100/100	78/92	60,65,20,35/50,60,20,35
8	80/52	6/4	9	7/0	72/105	75/101	50,60,10,44/50,62,10,44
9	79.5/46	18/5	10	10/2	63/80	75/91	75,75,30,45/70,70,20,45
10	68/56.5	6.5/11	11	3/3	100/100	87/84	46,60,40,46/44,60,12,46
11	63/49	0/1.5	11	6/2	90/80	89/73.5	70,55,10,35/35,50,10,30
12	52/45.5	8/7.5	8.5	4/0	112.5/95	100/72.5	50,76,20,36/36,66,-10,40
13	78.5/57	12.5/9	10	2/2	61.1/64	86.6/85.2	50,62,10,40/46,50,5,36
14	85/54.5	21/11	9.5	8/0	80/90	79/83	54,66,20,34/50,55,5,34
15	52/63.5	1.5/5.5	10.2	2/1.5	68.4/85	71.9/91	50,60,26,50/50,50,20,50

E = extension, F = flexion, Pre/last f/u = preoperative/last follow-up, R-L = radiolunate ligament, RD = radial deviation, ROM = range of motion, S-L = scapholunate ligament, UD = ulna deviation.
S-L, Scapholunate ligament; R-L, Radiolunate ligment; Pre/last f/u: Preoperative/Last follow-up; ROM: Range of montion.

carpal joint. Accordingly, symptoms such as function or motion limitation and pain occur in the carpal joint.[1,2,20] In this study, the preoperative period of scaphoid nonunion ranged from 1 to 40 years, with an average of 17 years, but 6 patients did not accurately remember when their injury occurred. The preoperative SL angle ranged from 52° to 85° with an average of 66°. Nine patients presented angles of >60°.

SNAC is usually divided into 3 stages depending upon where arthritis occurs.[20] In the early stages of SNAC, osteoarthritis usually presents in the dorsal rim of the radius styloid process and distal scaphoid fragment. The symptomatic SNAC treatment options, regardless of the stage, include proximal row carpectomy, limited intercarpal arthrodesis, scaphoid excision and intercarpal arthrodesis, and total wrist arthroplasty.[1,2,21,22] However, Slade and Dodds[3] reported that SNAC stage I could be treated with open debridement, an interpositional corticocancellous bone graft or vascularized bone graft, internal fixation, and radial styloidectomy, and these procedures are accepted surgical options for the treatment of stage I SNAC. For bone grafting a scaphoid nonunion, the advantage of an open bone graft is that the bone fragment can be visualized during debridement, fracture reduction, and the correction of accompanying deformities. However, these methods can sometimes cause the unnecessary detachment of bone fragments and destruction of the fracture site, giving rise to additional issues.[5,23,24] Additionally, any type of open surgery has the drawbacks of pain, stiffness, and hypertrophic scars.[25] For these reasons, percutaneous and less invasive methods using arthroscopy for the treatment of scaphoid nonunion have recently been used.[9–11] Several authors have reported up to 96% union rates with these methods.[26,27] Regarding the reasons for this high bone union rate, arthroscopic-assisted percutaneous and minimally invasive procedures can avoid carpal ligament injury, because they do not require an open arthrotomy and can preserve as much of the tenuous blood supply of the scaphoid as possible.[6–8,27,28] Minimal disturbance of the vascularity of the scaphoid and the impacted cancellous bone graft can contribute to the high union rate and the relatively short time to bone union compared to open treatment.[8] We achieved bone union at an average of 9.7 weeks in all patients. Minimal disturbance of the ligament structures also allowed a more vigorous rehabilitation regimen to prevent stiffness and led to good clinical outcomes. We found an increased ROM at the final follow-up compared to the preoperative ROM, although arthritis was present. However, the increase was not statistically significant. Compared to the normal side, extension and ulnar deviation showed statistically significant improvements, whereas flexion and radial deviation showed statistically significant decreases. These results may have been affected by the carpal joint extension and ulnar deviation applied for fracture reduction and deformity correction during surgery. Thus, we considered it necessary to perform provisional K-wire fixation after reduction and deformity correction and determine whether the appropriate flexion and radial deviation angles were achieved during surgery. Another advantage of the arthroscopic-assisted procedure was that the accurate diagnosis and treatment of intraarticular pathology and cartilage were possible at the same time.[7,8] We diagnosed 7 patients with grade II SL instability and 2 with grade II LT instability and performed thermal shrinkage. Although we did not additionally analyze the effect of thermal shrinkage in these patients, all patients except for patient 4 (Tables 1–3) showed improvements in VAS scores, grip, and ROM. In 3 patients, we performed debridement due to TFCC injury. In 1 patient, a giant cell tumor was present and removed it. Even without magnetic resonance imaging at the final follow-up due to the patient's refusal, no particular finding was observed. Arthroscopic-assisted treatment of a scaphoid nonunion has many advantages, as described above. However, in most cases, arthroscopic surgery has been performed only when the selected scaphoid nonunion, namely the fracture, was well maintained, and there was no severe sclerosis or bone resorption at the nonunion site. Kim et al[27] argued that arthroscopic surgery was a contraindication when there was SNAC and that it also had limitations in obtaining normal carpal alignment. However, we achieved SL angle recovery in all 9 patients who preoperatively exhibited DISI based on their SL angles. We believe that this may have been because, after adequate arthroscopic debridement and removal of the interposed fibrous tissue and sclerotic avascular bone, flexion and pronation deformity could be corrected by a closed maneuver.

Radial styloidectomy has been a standard surgical method since it was first described in 1948,[29] and is often used as an adjunct to other procedures for the treatment of arthritis localized to the radioscaphoid joint. However, radial styloidectomy can be an extrinsic cause of carpal instability of the wrist, related to the degree of radial styloid excision. Therefore, how much excision of the styloid is necessary is still debated. In a cadaver study, Nakamura et al[30] recommended no >3 to 4 mm to avoid an increased risk of carpal

instability. Recently, arthroscopic radial styloidectomy has been introduced and reported to have advantages such as less invasiveness, less morbidity, and earlier motion.[12] Wong and Ho reported performing a styloidectomy of about 5 mm and arthroscopic bone grafting on 24 patients with SNAC stages I and II.[8] However, we could not find a previous article suggesting that radial styloidectomy was effective as the main treatment procedure, and not as an adjunct in the treatment of SNAC. Thus, we established a hypothesis that radial styloidectomy may not be required if no impingement occurs between the scaphoid and radial styloid process after the treatment of a scaphoid nonunion. For synovitis accompanied by radioscaphoid joint arthritis, we intended to perform a thorough arthroscopic synovectomy and debridement, which included the joint capsule.[31] In addition, we believe that it would be acceptable to perform a styloidectomy additionally when impingement occurs between the scaphoid and radial styloid process after the scaphoid bone union.[32] In this study, all patients had bone unions, and there was no additional impingement. As all patients showed improvements with respect to postoperative pain, we believe that it would lead to positive outcomes if scaphoid normal alignment and bone union were achieved without performing a radial styoidectomy, which has varying potential outcomes and expected risks related to surgery.

The limitations of this study were that it was a retrospective study with a small sample size of 15 patients, and the statistical significance might be small. Furthermore, as only outcomes before and after arthroscopic bone grafting were compared without directly comparing to the SNAC stage I patient group treated with open surgery, it was not possible to conclude what treatment option was better in this study. However, SNAC stage I was not a contraindication for an arthroscopic bone graft, and arthroscopic bone grafting and percutaneous K-wire fixation without a styloidectomy showed decreased flexion and radial deviation angles in the carpal joint functionally compared to the normal side. Nevertheless, this study has significance as it confirmed that this treatment option could achieve satisfactory outcomes, both clinically and radiologically.

5. Conclusion

We believe that arthroscopic bone grafting and percutaneous K-wire fixation without radial styloidectomy would be a very effective treatment option for treating patients with SNAC stage I. Nonetheless, caution should be applied during surgery to ensure that the flexion and radial deviation angles in the carpal joint do not decrease.

Author contributions

Conceptualization: Young Keun Lee.
Data curation: Young Keun Lee.
Formal analysis: Young Keun Lee. Young Ran Jung
Investigation: Young Keun Lee.
Methodology: Young Keun Lee.
Supervision: Young Keun Lee.
Validation: Young Keun Lee.
Visualization: Young Keun Lee.
Writing – original draft: Young Keun Lee, Young Rang Jung
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