SCIENTIFIC ARTICLE

Arthroscopic Partial Capitate Resection for Type Ia Avascular Necrosis: A Short-Term Outcome Analysis

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Purpose To examine short-term clinical results of arthroscopic partial resection for type Ia avascular necrosis of the capitate.

Methods Patients who underwent arthroscopic treatment for type 1a avascular necrosis of the capitate with at least 1-year follow-up were identified through a retrospective chart review. The necrotic capitate head was arthroscopically resected with removal of the lunate facet and preservation of the scaphoid and hamate facets. Wrist range of motion, grip strength, and radiographic parameters—carpal height ratio, radioscaphoid angle, and radiolunate angle—were determined before surgery and at the latest follow-up. Patients completed a visual analog scale for pain; Disabilities of the Arm, Shoulder, and Hand measure; and the Patient-Rated Wrist Evaluation score before surgery and at the latest follow-up.

Results Five patients (1 male, 4 females) with a mean age of 34 years (range, 16–49 years) and a mean follow-up duration of 20 months (range, 12–36 months) were identified during the chart review. All were type Ia (Milliez classification). Arthroscopy revealed fibrillation or softening with cartilage detachment at the lunate facet of the capitate head and an intact articular surface at the scaphoid and hamate facet. At the latest follow-up, the mean wrist flexion-extension was 123° (vs 81° before surgery) and grip strength was 74% (vs 37% before surgery). The visual analog scale score for pain; the Disabilities of the Arm, Shoulder, and Hand score; and the Patient-Rated Wrist Evaluation score before surgery showed a significant improvement following treatment. Radiographic parameters did not significantly change at the final follow-up, although the proximal carpal row trended toward flexion.

Conclusions Arthroscopic partial resection of the capitate head was an acceptable treatment for type Ia avascular necrosis of the capitate. It provided adequate pain relief and improved the range of wrist motion and grip strength during short-term follow-up. *(J Hand Surg Am. 2015;40(12):2393–2400. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Capitate, necrosis, carpal bone, arthroscopy, partial resection.

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AVASCULAR NECROSIS OF THE CAPITATE is rare and of unknown etiology. Retrograde blood flow and poor intraosseous vascular anastomosis make the proximal pole prone to impaired blood flow, leading to avascular necrosis.[1] Several predisposing factors have been reported, including trauma,[2–8] hypermobility of the wrist,[9] steroid use,[10,11] systemic lupus erythematosus,[12] and gout.[13] Repetitive minor trauma may also be a cause in cases in which no other definitive etiological factor can be detected.[14–20]

The choice of surgical procedure depends on the pathological condition of the necrotic capitate, but therapeutic guidelines have not been established. Thirty-eight cases have been reported in the English literature, with treatment using surgical techniques, including intercarpal arthrodesis (22 cases),[4,5,8,9,10,16,21–29] proximal pole resection (4 cases) with or without drilling of the capitate,[19,20,30] prosthetic arthroplasty (4 cases),[4,17,24,31] vascularized or conventional bone grafting (5 cases),[2,15,32–34] posterior interosseous nerve resection (2 cases),[35,36] and arthroplasty (1 case).[37]

Wrist arthroscopy has evolved from being a predominantly diagnostic tool to a valuable adjunctive procedure for treatment of various wrist disorders.[38] Several authors have reported arthroscopic management for avascular necrosis of other carpal bones.[39,40] Here we investigated short-term clinical outcomes of 5 patients who underwent arthroscopic partial resection for type Ia avascular necrosis of the capitate.

MATERIALS AND METHODS

Patient demographics

From 2011 to 2014, we treated 5 patients (1 male, 4 females) with idiopathic avascular necrosis of the capitate using arthroscopic partial resection. Their ages at the time of surgery ranged from 16 to 49 years (mean, 34 years). In 4 of 5 patients, the dominant hand was affected; in 1 posttraumatic case, the nondominant hand was affected. None of the patients had a history of major trauma or inflammatory disease. All patients had undergone conservative treatment including nonsteroidal anti-inflammatory drugs, orthosis fabrication, and corticosteroid injection at other hospitals, and all had pain in the dorsal aspect of the wrist during rest and activities of daily living. The mean interval from the initial onset to diagnosis was 18 months (range, 12–36 months).

Avascular necrosis was diagnosed using magnetic resonance imaging (MRI) in all patients. Capitate necrosis was radiologically evaluated using the Milliez classification.[24] As per the classification, necrosis is defined as types Ia, Ib, Ic, II, or III based on the sclerotic or fragmentation pattern and extent of the necrotic lesion (Table 1). All patients had cystic changes and collapse at the proximal pole of the capitate and were categorized as type Ia. The indication for surgery was collapse or subchondral bone fracture of the capitate on plain radiographs, no revascularization on MRI, and failure to respond to conservative measures (Table 2).

TABLE 1. Milliez Classification

Type	Radiographic Appearance
I	Sclerotic change and fragmentation are apparent in the proximal part of the capitate.
Ia	Lunocapitate joint is involved.
Ib	Both lunocapitate and scaphocapitate joints are involved.
Ic	Scaphocapitate joint is involved.
II	Sclerotic change and fragmentation are apparent in the distal part of the capitate.
III	Sclerotic change and fragmentation are apparent in the entire capitate.

Pre- and postoperative evaluations

At the initial evaluation and latest follow-up, the operating surgeons determined functional outcomes based on the range of wrist extension and flexion and grip strength (compared with those of the unaffected side) and the results of the Disabilities of the Arm, Shoulder, and Hand (DASH) score and Patient-Rated Wrist Evaluation (PRWE) score. Subjective pain was rated on a visual analog scale (VAS). Radiographs were obtained in a standard manner with 90° shoulder abduction, neutral forearm rotation, and neutral wrist position. Changes in the carpal height ratio (CHR), radioscaphoid angle (RSA), and radiolunate angle (RLA) were evaluated. MRI scans were examined before surgery and at the final follow-up for all patients. Informed consent was obtained from each patient, and the appropriate institutional review board approval was obtained prior to case review.

Statistical analysis

Pre- and postoperative differences in functional and radiographic evaluations were compared by the Mann-Whitney U test. Significance was set at $P < .05$.

Surgical technique

Three surgeons (S.O., F.D., and H.M.) performed the operations under general anesthesia with tourniquet control. A 1.9-mm 30° arthroscope was placed in the 3-4 portal, and surgical instruments were passed through the 4-5 portal. A radiocarpal portal was first used to assess the articular surfaces of the radiocarpal joint, volar

TABLE 2. Patients' Demographics

Case	Age (y)	Sex	Affected Side/ Dominant Side	Etiology	Complaints (mo)*	Follow-up (mo)
1	45	F	L/R	Trauma	12	24
2	49	M	R/R	Idiopathic	36	18
3	25	F	R/R	Corticosteroids and chemotherapy	19	30
4	37	F	R/R	Idiopathic	12	12
5	16	M	R/R	Idiopathic	12	14

*The interval from the initial onset to diagnosis.

carpal ligaments, scapholunate interosseous ligament (SLIL), lunotriquetral interosseous ligament, and triangular fibrocartilaginous complex. Next, the midcarpal portal was used to assess the integrity of SLIL and LTIL and to inspect for cartilage detachment or loose bodies in the midcarpal joint (Fig. 1). The radial midcarpal portal was used as a viewing portal, and the ulnar midcarpal portal was used as a working portal. The capitate head was excised by forming a "reversed U-shaped" plane with preservation of the scaphoid and hamate facets (Fig. 2). The radial edge of the resection matched the SLIL, which divides the capitate head into the scaphoid and lunate facets. The ulnar edge of the resection fit the hamate facet. The distal resection was in a convex and concave shape, with the distal edge located approximately 5 mm from the articular surface of the capitate head. A 3.0-mm bur was applied in a back-and-forth motion to resect 5 mm of the capitate head via the ulnar midcarpal portal. The bur diameter was used to gauge the amount of bony resection. The depth was also checked using a portable fluoroscopy unit. The wrist was extended and flexed during the resection to confirm that there was no mechanical impingement (Fig. 1). After the tourniquet was removed, bleeding from the resected capitate edge was observed.

Postoperative care

After surgery, the wrist was immobilized in a short-arm cast for 3 weeks. Patients were then started on physical and occupational therapy for wrist mobilization. Active wrist motion was started with no limitation, and passive wrist motion was started 4 weeks after surgery. Strengthening exercises were instituted 2 weeks later. An orthosis was applied for up to 3 months after surgery for patient comfort.

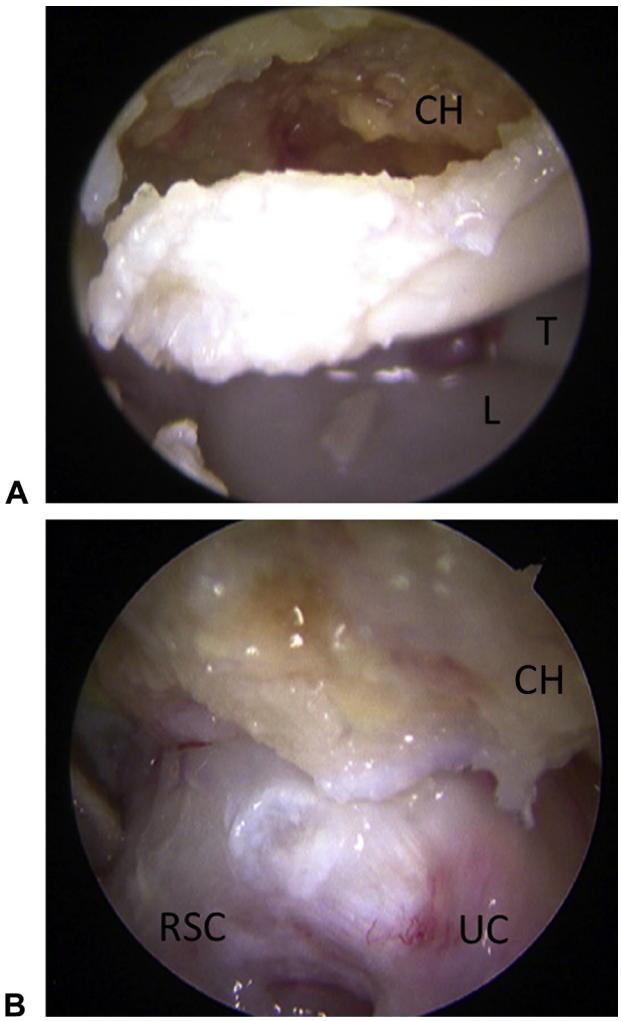

FIGURE 1: View from the dorsal radial midcarpal portal in the right hand (case 3). **A** Cartilage detachment of the capitate head (CH). L, lunate; T, triquetrum. **B** The CH following arthroplastic partial resection. RSC, radioscaphocapitate ligament; UC, ulnocapitate ligament.

RESULTS

Arthroscopic findings

There was marked synovitis in the midcarpal joint in all patients. Chondromalacia and partial detachment of articular cartilage were observed at the lunate facet of the proximal pole of the capitate in 2 of 5 patients (cases 1 and 4). Cartilage fissuring and subchondral bone fracture occurred in 3 patients. One patient had

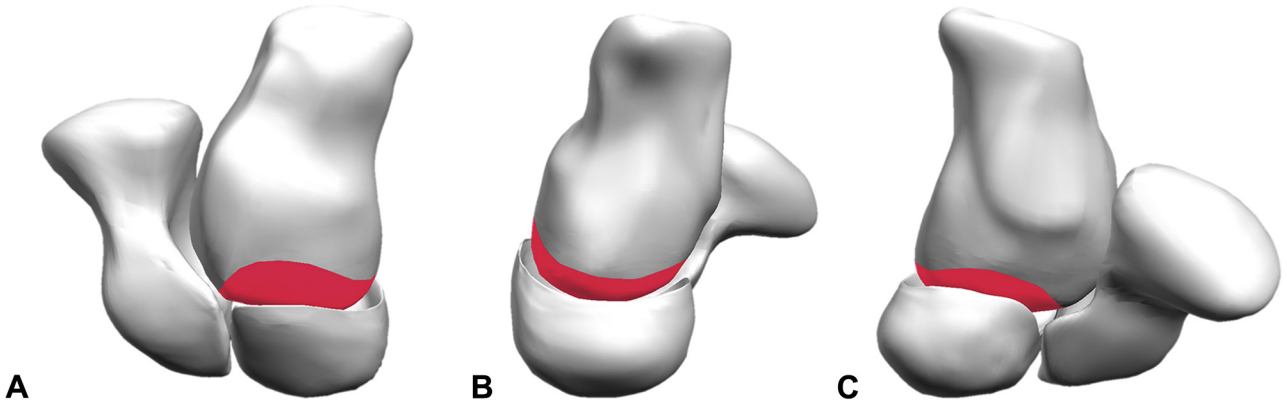

FIGURE 2: A three-dimensional diagram depicts the surgical technique. **A** Dorsal view; **B** Ulnar view; and **C** Volar view.

eburnation and a chondral defect at the lunate facet of the capitate head (case 2), 1 had an unstable articular cartilage flap at the lunate facet of the capitate head (case 3), and 1 had a loose osteochondral body in the midcarpal joint (case 5). All had a normal articular surface in the midcarpal joint except for the lunate facet of the capitate head. One patient (case 1) had an incidental finding of SLIL laxity (Geissler stage II), but the ligament was not repaired or reconstructed because this finding did not correlate with the patient's symptoms (Table 3).

TABLE 3. Arthroscopic Diagnosis

Case	Conditions of Articular Cartilage in Capitate Head	Additional Findings
1	Chondromalacia and partially detached in the lunate facet	SLIL G II; LTIL G I
2	Eburnation and a chondral defect in the lunate facet	SLIL G I; LTIL G I
3	Detached and formed unstable flap in the lunate facet	SLIL G I; LTIL G I
4	Chondromalacia and partially detached in the lunate facet	SLIL G I; LTIL G I
5	Detached and formed a free body in the lunate facet	SLIL G I; LTIL G I

G, Geissler classification; LTIL, lunotriquetral interosseous ligament.

Functional outcomes

The mean follow-up period was 20 months (range, 12–36 months). At the latest follow-up, the mean flexion-extension had significantly improved from 81° before surgery to 123° ($P < .05$), and grip strength on the affected side compared with that on the unaffected side had significantly increased from 37% to 74% ($P < .05$). There were significant improvements in the mean VAS from 6.8 to 1.1 ($P < .05$), the mean DASH score from 40 to 12 ($P < .05$), and the mean PRWE score from 59 to 19 ($P < .05$). All patients had noteworthy pain relief and recovery of activities of daily living (Table 4).

Radiographic findings

On initial examination, all patients had cystic changes and collapse at the proximal pole of the capitate (Fig. 3). At the final follow-up, wrist radiography indicated no sclerotic changes of the capitate or progressive osteoarthritic changes in the midcarpal joint (Fig. 3). The mean CHRs at the initial examination and latest follow-up were 0.52 and 0.50, respectively. The CHR decreased insignificantly in all patients ($P = .68$). The mean RSAs at the initial examination and latest follow-up were 64° and 68°, respectively, and the mean RLAs were −2° and −5°, respectively. RLA was determined by dorsal angulation as plus and by volar angulation as minus. Neither RSA nor RLA significantly changed after surgery ($P = .68$ and .10, respectively) (Table 5).

MRI findings

Preoperative T1-weighted images showed focal low-signal intensity in the proximal part of the capitate in 3 patients and diffuse low-signal intensity in the entire capitate in 2 patients. Fat-suppressed T2-weighted images showed focal low-signal intensity in the proximal part of the capitate in all cases, heterogeneous high-signal intensity in locations other than the proximal capitate head in 4 patients, and intermediate signal intensity in 1 patient. The signal intensity improved to nearly normal on T1- and T2-weighted MRI scans of all patients at the final follow-up (Fig. 4).

TABLE 4. Clinical Findings

	ROM (E-F arc)		GP (%)		VAS Pain (0–10)		DASH (0–100)		PRWE (0–100)	
Case	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	105	125	17	50	10	3	67	24	88	38
2	40	135	18	68	5.5	0	43	13	77	29
3	85	95	38	75	6	0	43	4	54	3
4	85	90	24	76	5	1.6	34	8	67	19
5	90	170	90	102	7.5	1	13	12	9	5
Average	81	123*	37	74*	6.8	1.1*	40	12*	59	19*

E-F, extension-flexion; GP, grip power; Post, postoperative; Pre, preoperative; ROM, range of motion.
*$P < .05$ vs mean preoperative value.

DISCUSSION

Wrist arthroscopy is important for evaluating articular cartilage, unrecognized chondral defects, or osteochondral fragments in the capitate head. We used only arthroscopic partial resection for type Ia avascular necrosis of the capitate. Arthroscopy revealed fibrillation or softening with cartilage detachment at the ulnar aspect (lunate facet) of the capitate head and almost intact articular surface at the radial aspect (healthy scaphoid facet) in all patients. The outcomes based on DASH, PRWE, and VAS pain scores showed significant improvements with maintenance of wrist flexion-extension after surgery. These functional outcomes suggest a beneficial effect of arthroscopic partial resection on type 1a avascular necrosis of the capitate for at least a year.

Milliez et al[24] assumed that the mechanism underlying carpal collapse is associated with the progression of capitate necrosis. As the disease progresses, the capitate eventually fragments and collapses with loss of carpal height and the development of scaphoid flexion. When the necrosis involves the scaphocapitate joint, the capitate and hamate translate laterally because of the loss of support from the capitate's proximal pole. Peters et al[30] suggested that this translation may further flex the scaphoid with the development of dorsal intercalated segmental instability deformity if the SLIL attenuates. In the current study, postoperative radiographic parameters showed no significant changes of carpal malalignment at an average follow-up of 20 months. We preserved the scaphoid and hamate facets and resected only the lunate facet to reduce subsequent overloading to the scaphotrapezial-trapezoid and triquetrohamate joints. We considered that preservation of the scaphoid facet helped to prevent further carpal collapse. Although we know of no long-term effects of arthroscopic resection compared with the natural course of capitate necrosis, the current procedure decompressed the necrotic capitate and eliminated joint incongruity between the lunate and the capitate. Restoring joint congruity at the midcarpal joint may have a beneficial effect to alter wrist biomechanics, resulting in a slow progression of the long-term degeneration of the carpus.

In a biomechanical study involving partial capitate resection, Kataoka et al[41] observed a significant 39% increase in the mean pressure in the radioscaphoid joint after partial capitate resection, but no change in the mean pressure was observed in the ulnocarpal joint. Although the current procedure did not result in significant carpal malalignment, increased pressure at the radioscaphoid, scaphotrapezial-trapezoid, and triquetrohamate joints may cause overloading and future osteoarthritis. Obtaining informed consent of the patients is recommended considering the possibility of further surgery, such as intercarpal arthrodesis.

Arthroscopic observation of the intrinsic wrist ligaments is required when evaluating capitate necrosis. Scapholunate interosseous ligament impairment also causes flexion of the scaphoid, resulting in dorsal intercalated segment instability deformity. Although 1 of the current patients (case 1) showed grade II incongruity between the scaphoid and the lunate, no severe ligament damage was observed. If a patient has complete tear of the intercarpal ligaments, an additional procedure, such as ligament reconstruction, may be needed for the prevention of carpal malalignment.

The choice of surgical procedure depends on the extent of damage to the capitate head. Intercarpal arthrodesis is the most common procedure for avascular necrosis of the capitate and provides good pain relief. Peters et al[30] reviewed 22 cases with capitate necrosis treated using intercarpal arthrodesis and found that the average range of the flexion-extension arc in the wrist joint changed from 95° to 78° at the final follow-up.

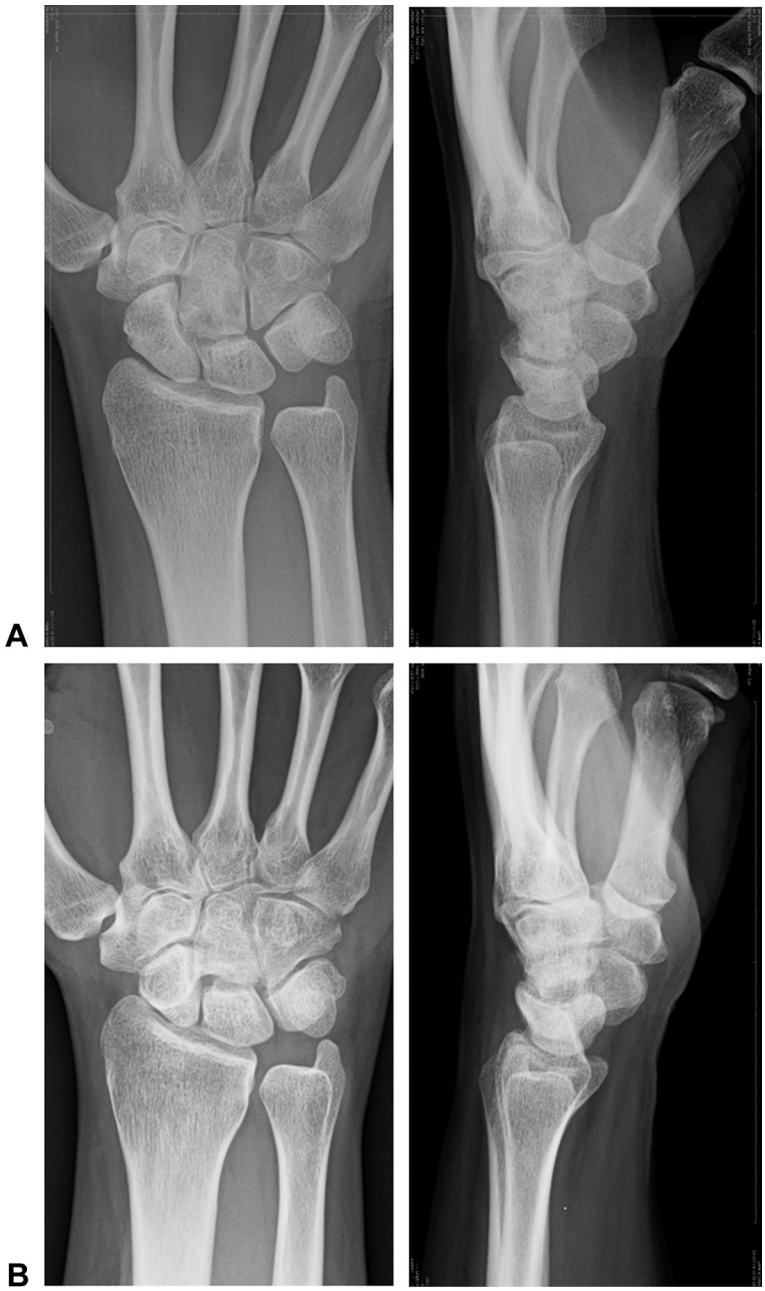

FIGURE 3: Radiographic findings (case 3). **A** Initial radiographs demonstrate cystic changes and collapse at the capitate head. **B** Neither sclerotic change of the capitate nor progressive osteoarthritic change was apparent at the final follow-up.

Among these cases, 3 were type Ia (14%) in the Milliez classification and most (14 of 22; 64%) were type Ib or III, with involvement of a larger area of the capitate compared with the patients in our series. For patients with higher levels of involvement of the capitate, such as type Ib or III, radical resection, including the scaphoid facet, may be required. In cases in which it is impractical to preserve the scaphoid facet, intercarpal arthrodesis may be required as primary surgery for preventing carpal collapse. In such cases, the surgeon can convert to arthroscopic intercarpal arthrodesis or to other open procedures after arthroscopically evaluating the capitate.

Milliez et al[24] also proposed a radiological classification for avascular necrosis of the capitate based on the portion of the bone involved. However, this classification was not based on MRI findings, and there is no standard MRI-based staging for necrosis. In normal bone, T1-weighted images show high-signal intensity, whereas T2-weighted images show intermediate signal intensity. In the advanced stages of complete osteonecrosis, both T1- and T2-weighted images show low-signal intensity in the entire capitate. Schmitt et al[42] suggested that reduced bone marrow signal in T1- and increased signal in

TABLE 5. Radiographic Findings

	CHR		RSA		RLA*	
Case	Pre	Post	Pre	Post	Pre	Post
1	0.56	0.52	65	75	10	5
2	0.51	0.49	65	65	−5	−5
3	0.53	0.52	50	55	10	0
4	0.51	0.48	65	70	−10	−10
5	0.46	0.46	75	75	−15	−15
Average	0.52	0.50	64	68	−2	−5

CHR, carpal height ratio; Post, postoperative; Pre, preoperative; RLA, radiolunate angle; RSA, radioscaphoid angle.
*RLA was determined by dorsal angulation as plus and by volar angulation as minus.

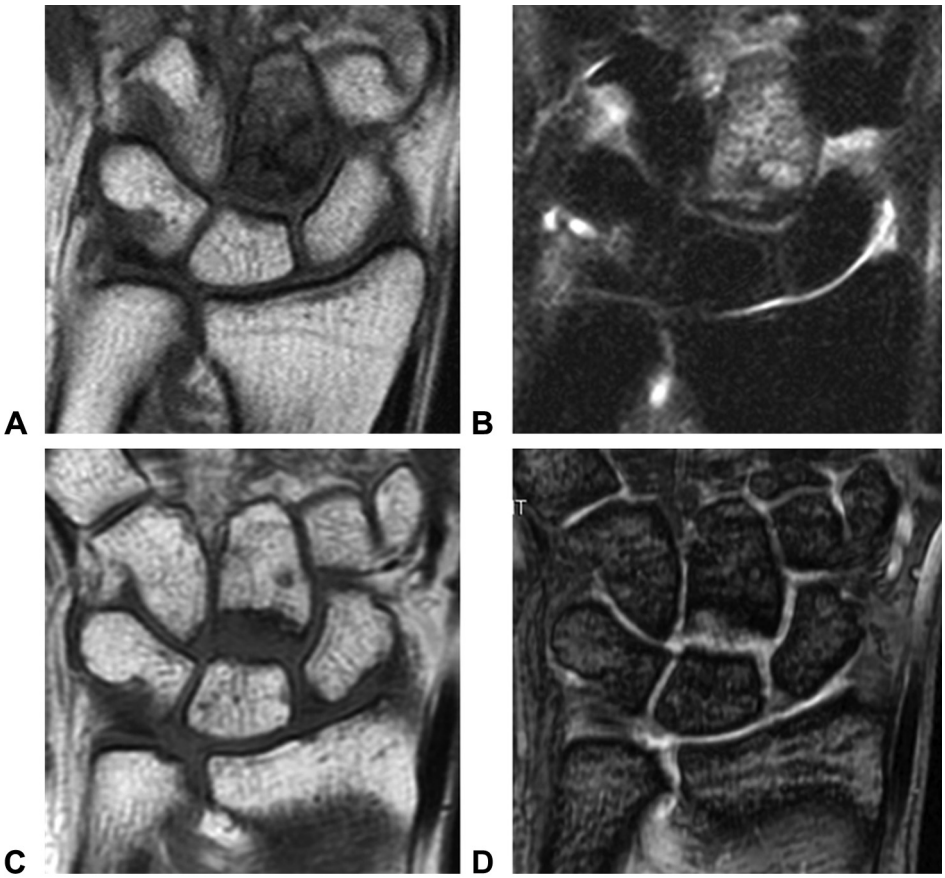

FIGURE 4: MRI (case 1). **A** Preoperative T1-weighted and **B** fat-suppressed T2-weighted images. **C** T1-weighted and **D** T2 star-weighted MRI at the final follow-up showed improvement based on the close-to-normal intensity of the capitate.

T2-weighted images were indicative of bone marrow edema. In the present series, we considered that the capitate head was necrotic when the proximal capitate head showed low-signal intensity in T1- and T2-weighted images. The body of the capitate was interpreted as having bone marrow edema when the remaining distal capitate showed low-signal intensity in T1- and heterogeneous high-signal intensity in T2-weighed images. Bleeding from the resected margin of the capitate suggested bone marrow edema of the distal capitate rather than complete necrosis. Furthermore, on postoperative T1-weighted images, the low-intensity area of the capitate at the distal aspect changed to a heterogeneous intermediate- to high-intensity area. Eventually, this signal reached normal intensity. These findings suggest that a treatment algorithm based on staging with MRI evaluation is needed to determine the optimal surgical treatment.

The main limitations of this study were the use of a retrospective case series and a short follow-up period. In addition, the number of patients was limited, and there was no comparative treatment. Within these limitations, arthroscopic partial resection provided adequate pain relief and improved wrist range of motion and grip strength with minimal disability in treatment of type Ia avascular necrosis of the capitate.

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