



Scaphoidectomy and 4-corner arthrodesis with headless compression screws: results, complications and their treatment

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Scaphoidectomy and 4-corner arthrodesis is a common salvage surgery for degenerative wrist pathology. The purpose of this study was to evaluate the results of this procedure performed with headless compression screws, with a special focus on postoperative complications and their treatment. We assessed 36 wrists in 31 patients that were treated between 2009 and 2017. Mean follow-up was 5.2 years (range 2.9- 9.4). Pain was expressed on a Visual Analog Scale. The Quick Disabilities of the Arm, Shoulder and hand (qDASH) questionnaire and Michigan Hand Outcome Questionnaire (MHOQ) were used to assess patient functionality and satisfaction. Range of motion and grip strength of both wrists were measured. Radiographs of the operated wrist were evaluated. Mean pain score was 1.5 ± 2.3 with 19% of patients being completely free of pain also during activity. Mean qDASH was 44 ± 20 and mean MHOQ was 10 ± 5 . Mean flexion-extension arc of the operated wrist was 69° and 61% of the contralateral wrist. Mean grip strength was 35kg and 89% of the opposite wrist. Non-union was observed in two patients. Two patients required hardware removal and in three patients a pisiformectomy was performed. Conversion to total wrist arthrodesis was needed in one patient. We observed postoperative complications in 28% of our patients. Most complications can successfully be treated with additional surgery. The presence of

pisotriquetral arthritis should be assessed before surgery and treated with pisiform excision.

Keywords : Scaphoidectomy ; arthrodesis ; fusion ; screw ; outcome ; complications.

INTRODUCTION

Excision of the scaphoid combined with “4-corner” arthrodesis of the capitate, lunate, triquetrum and hamate was first described by Watson et al. in 1984 (1). Indications for this procedure include painful scapholunate advanced collapse (SLAC), scaphoid nonunion advanced collapse (SNAC), midcarpal arthritis and avascular necrosis of the scaphoid or the capitate. Good to excellent long-term results can be expected (2,3). Different fixation methods have been described to stabilize the midcarpal joint like staples, K-wires, and plate and screws (3). Two decades ago, Krakauer et al. (4) and Tomaino et

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Ethical Review committee. An institutional review board approval for this study and a written informed consent of each included patient was obtained (Eudract B371201942661).

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al. (5) introduced the use of headless compression screws (HCS) for this indication (6). This technique seems to be most favorable, because this hardware is not prominent and the bony compression that is provided by the screws is beneficial for bone healing (7). Nevertheless, postoperative complications have been reported (6,8-11).

The goal of this study was to evaluate the outcome and complications after scaphoidectomy and 4-corner arthrodesis with headless compression screws with a follow-up of at least 2 years, and how these complications can be managed or prevented.

MATERIALS AND METHODS

An Institutional Review Board (IRB) approval for this study and a written informed consent of each included patient was obtained (Eudract B371201942661).

We performed 54 scaphoidectomy and 4-corner arthrodesis procedures in our institution from November 2009 until October 2017. All surgeries were performed by a single surgeon (JD) with a level 3 expertise for this surgery according to Tang and Giddins (12). For this retrospective follow-up study, we were able to recruit 36 operated wrists in 31 patients. Five patients underwent the procedure bilaterally. Three patients died and 15 could not be reached or were not able to participate. The chart file of each included patient was reviewed to collect data on patient demographics, surgical indication, operative procedure and postoperative complications. Patients were invited for a follow-up consultation, at which time we measured flexion-extension and radial-ulnar deviation of both wrists using a goniometer. Grip strength was measured bilaterally with a Jamar dynamometer in the second position. Postoperative pain, at rest and during activity, was expressed on a 10-point Visual Analog Scale (VAS; 0 = no pain; 10 = worst pain). The Dutch version of the Quick Disabilities of the Arm, Shoulder, and Hand Questionnaire (qDASH) was used to evaluate overall functionality of the operated extremity. Patient satisfaction was evaluated by the Dutch version of the Michigan Hand Outcome Questionnaire (MHOQ) part 6 for both hands. Anteroposterior and lateral radiographs of the wrist

were judged for union, hardware complications, radiolunate arthritis and possible other findings. Of all measurements, mean and standard deviation were calculated. For the MHOQ part 6, a sign test and signed-rank test were performed to determine if the difference between the operated and non-operated hand was statistically significant. These tests do not require normality of the patient specific differences between the operated and non-operated wrist.

There were 24 males and 7 females. 5 patients underwent the procedure bilaterally, but not simultaneously. Mean age was 62 years (range 44-82). 11 patients smoked (30.6%). 24 of the 36 procedures concerned the dominant wrist (67%). Mean follow-up time was 5.2 years (range 2.9-9.3). Surgical indications included SNAC wrist grade II (n=2), SNAC wrist grade III (n=9), SLAC wrist grade II (n=8), SLAC wrist grade III (n=9), midcarpal arthritis (n=7), Preiser's disease (n=1).

The surgical technique was based on Ozyurekoglu et al. (8) with the only adaptation that we routinely performed a neurectomy of the posterior interosseus nerve. Bone fixation was performed with Mini Acutrak 2 screws (Acumed LLC, Hillsboro, OR, USA). In 9 cases, a bicolumnar fixation method with one triquetrum-hamate screw according to Ozyurekoglu was used. In the other 27 cases, there was a diagonal screw fixation of the triquetrum, hamate and capitate as described by Draeger et al. (9) In 7 cases, capitolunate fixation was performed with two screws instead of one because bone quality was evaluated as suboptimal. In all cases, the dorsal intercalated segment instability (DISI) was corrected. A total of 15 concomitant procedures were performed in 14 patients: radial styloidectomy (n=2), carpal tunnel release (n=8), in situ release of the ulnar nerve at the elbow (n=2), ulnar shortening osteotomy (n=1), Burton-Pellegrini procedure (n=1) and pisiformectomy (n=1). Postoperatively, the wrist was immobilized in a short-arm cast for 4 weeks, followed by automobilization and a removable splint for another 4 weeks. Strengthening exercises and progressive mobilization under supervision of a certified physiotherapist started 8 weeks after surgery.

RESULTS

Postoperative range of motion of the wrist and grip strength are shown in Table I. Flexion averaged 34° (range 15-56°) and extension 34° (range 10-60°). The mean flexion-extension arc was 61% of the contralateral wrist. Mean radial deviation was 15° (range 4-25°) and mean ulnar deviation was 24° (range 5-44°). The mean arc of radial-ulnar wrist motion was 54% of the contralateral side. Average grip strength of the operated hand was 35 kg (range 12-80 kg), which corresponded to 89% of the grip strength of the contralateral side. For comparison with the contralateral side, only patients with unilateral surgery were included.

Residual wrist pain and the result of the functionality and satisfaction questionnaires are shown in Table I. 18 patients were pain free at rest (50%) and 7 of them did not experience pain during activity (19%). 30 patients completed the MHOQ for their control and operated wrist. The difference between both was calculated. Statistical analysis showed a significant negative difference in 16 patients (53%), meaning that patient satisfaction of the operated wrist was lower than the non-operated wrist. In 9 patients (30%), satisfaction of both wrists was the same. A minority of the patients (17%) was more satisfied of their operated wrist than their control wrist.

Successful bone healing was achieved in 34 patients (94%). Small calcifications in the scaphoid

resection space were present in 25 cases (69%). Degenerative changes at the radiolunate joint were observed in one patient (3%) and at level of the distal radial ulnar joint in 7 cases (19%).

We observed postoperative complications in 10 (28%) of our patients (Table II). 7 patients (19%) were reoperated and all complications, except for 2, were considered solved at final follow-up.

DISCUSSION

Scaphoidectomy with 4-corner arthrodesis is a motion-sparing, limited wrist arthrodesis that has been studied extensively. Pain relief is typically excellent. 40-60% of normal wrist motion is maintained and 75-80% of normal grip strength can be expected (2). The results in our study confirm this. With an average grip strength of 89% of the contralateral site, our results score even higher than the values mentioned in literature.

Midcarpal wrist fusion decreases function of the operated upper extremity as demonstrated by high qDASH scores. It is unclear why the qDASH scores in our series score higher than the DASH scores in comparable series (8,9). The qDASH score is not specific enough to examine this. Results can be obscured by concomitant elbow or shoulder pathology. The MHOQ score more specifically evaluates patient satisfaction of hand and wrist function. Since previous reports all use different questionnaires it is difficult to compare the results.

Table I. — Postoperative outcome after scaphoidectomy and 4-corner arthrodesis with headless compression screws. Comparison of the current study with results in the literature

	N	Mean follow-up (years)	Mean flexion-extension arc (°)	Mean radio-ulnar deviation arc (°)	Grip strength (kg)	VAS pain	Mean DASH score
Current study	36	5.2	68	39	35	Rest: 1.5 ± 2.3 Activity: 3.4 ± 2.9	qDASH 44
Draeger et al. (2014)	11	3.3	88	/	32	1.8 ± 2.4	DASH 17
Ozyurekoglu et al. (2012)	33	0.7	71	35	29	0.6 ± 1	DASH 13
Richards et al. (2011)	19	/	10-20 in 3 patients 30-60 in 16 patients	/	/	/	/

Table II. — Postoperative complications after scaphoidectomy and 4-corner arthrodesis with headless compression screws

	N	Mean follow-up (years)	Nonunion (N)	Hardware problems (N)	Conversion to total wrist fusion (N)	Other complications (N)
Current study	36	5.2	2 (6%)	3 (8%)	1 (3%)	1 pisiform instability 1 dysesthesia dorsal ulnar nerve 1 scar hypersensitivity 1 ulnar impaction syndrome
Richards et al. (2011)	19	/	1 (5%)	3 (16%)	0 (0%)	1 ulnar styloid impaction syndrome 1 wrist stiffness
Ozyurekoglul et al. (2012)	33	0.7	2 (6%)	2 (6%)	1 (3%)	/
Draeger et al. (2014)	11	3.3	0 (0%)	1 (9%)	0 (0%)	/
Iordache et al. (2016)	27	1.0	3 (11%)	4 (15%)	1 (4%)	1 dysesthesia dorsal ulnar nerve 1 dysesthesia superficial radial nerve
Mamede et al. (2018)	15	2.1	1 (7%)	/	0 (0%)	1 complex regional pain syndrome



Figure 1. — Nonunion. A. Nonunion between lunate and capitate with screw fracture. B. Revision surgery was performed with removal of the broken screw, interposition of distal radial bone graft and K-wire fixation. C. CT-scan two months after surgery demonstrates successful bone healing.

Scaphoidectomy with 4-corner arthrodesis is a technically demanding procedure. Complication rate depends on the fixation method (13). Secondary operation rate in our study was found to be 19%, far below the one observed by Williams et al. with different fixation techniques (34,4%) (14).

The advantages of HCS are that they can be positioned perpendicular to the fusion site and that they provide compression, two factors that promote bone healing (7). In the literature, non-union rates after HCS fixation varies between 0-11% (6,8-10).

Treatment options for this complication have not been well described. We observed two patients that did not achieve primary healing of the midcarpal arthrodesis. The first patient had proximal migration, fracture and penetration of the capitulate screw into the radiocarpal joint. This patient underwent revision surgery for screw removal and revision arthrodesis of the midcarpal joint with interposition of cancellous bone graft from the distal radius and fixation with 3 K-wires (Figure 1). Finally, successful bone healing with good clinical and



Figure 2. — *Avascular necrosis of the lunate.* Nonunion between lunate and capitate with radiographic signs of avascular necrosis of the lunate (bone sclerosis, interosseous cysts). A. AP view B. Lateral view.

radiographic outcome was obtained. The second patient had nonunion of the capitulunate articulation combined with avascular necrosis of the lunate (Figure 2). This was associated with a pain score of 3 in rest and 5 during activity. The patient did not find this debilitating enough to warrant secondary surgery.

Hardware problems are typically reported with fixation techniques that require dorsal hardware, with incidences of up to 31% (15). HCS can be buried inside the bone. This reduces the chance of hardware irritation. Hardware problems with HCS including loosening, screw fracture, intra-articular screw penetration and local irritation, range between 6-16% (Table II). We observed one patient with secondary migration of the capitulunate screw into the radiocarpal joint at 4 months after surgery. Both screws were removed with uncomplicated further healing and good clinical results. In another patient, diffuse wrist pain continued after his surgery for avascular necrosis of the scaphoid. Postoperative radiographs showed adequate bone healing and no signs of implant related problems. Screw removal did not improve his complaints.

Excision of the pisiform bone was performed in three patients. In one patient, the pisiform was excised simultaneously with the 4-corner fusion because of preoperatively symptomatic pisotriquetral arthritis. In the other two patients, a pisiformectomy was performed respectively three

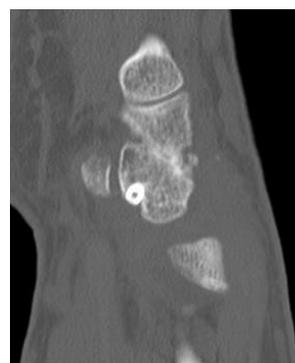


Figure 3. — *Pisotriquetral screw penetration.* Postoperative development of pain at the pisotriquetral joint. Sagittal computed tomography images show marginal intra-articular penetration of the screw.



Figure 4. — *Painful instability of the pisiform.* Plain radiographs one month (A) and six months after surgery (B) show progressive proximal migration of the pisiform relative to the triquetrum.

and seven months after the initial surgery. In the first patient, pisotriquetral pain was caused by intra-articular penetration of the ulnar-sided screw (Figure 3). The second patient postoperatively developed a painful instability of the pisiform with clunking of the pisotriquetral joint during wrist motion (Figure 4). Both patients were symptom free after removal of the pisiform bone. The development of PT joint pathology after scaphoidectomy and 4-corner arthrodesis has been reported anecdotally (3,16,17). First, the cartilage of the PT joint can be damaged by the initial trauma that caused the SNAC or SLAC wrist deformity. A scaphoid fracture or scapholunate ligament tear is typically caused by a fall on the outstretched hand. This typically requires impact on the palm of the hand, including the pisiform bone.

Second, improper screw placement can damage the PT articular surfaces. Trail et al. reported 2 cases of pisiform excision that was indicated for incorrect screw placement after dorsal circular plate fixation (3). Third, PT joint contact pressure increases with wrist extension and DISI rotational deformity of the carpus (16,18). Longstanding DISI deformity increases so the likelihood of PT osteoarthritis. Clinical examination of patients that are planned for scaphoidectomy and 4-corner fusion should therefore include PT shock and compression tests. If any tenderness is revealed, concomitant pisiformectomy should be performed. Alternatively, the PT joint can be decompressed by removing the triquetrum and performing a lunate-capitate-triquetrum arthrodesis instead of a 4-corner fusion (19). PT osteoarthritis can also be confirmed with x-ray examination. The joint can radiographically be visualized with a 30° supinated view of the wrist in neutral position (16). This view should also be used during surgery to confirm correct screw placement.

One patient developed incapacitating wrist pain five years after surgery, possibly after a low impact trauma. Computed tomography showed densification and fracture of the lunate, suggesting avascular necrosis (Figure 5). She became completely pain free after total wrist fusion.

An incidence of secondary radiolunate arthritis of 66,6% has been reported with a follow-up of 15 years (20). With our minimum 2-year follow-up, we only observed this in 3%. This needs further investigation as there are no series that use HCS screws with longer follow-up yet. Capitulate fixation with HCS placed in a retrograde manner has the theoretical advantage of sparing the proximal lunate articular surface. The previously reported conversion rates to total wrist arthrodesis varies between 2.4 and 29%, depending on the fixation technique that is used (8). HCS fixation scores remarkably lower with a conversion rate of only 0-4% (Table II).

One patient had temporary sensory dorsal ulnar nerve impairment. This nerve is specifically at risk when a HCS is inserted through a separate incision just distal to the ulnar styloid process. Sensation completely recovered one year postoperatively. Another patient experienced persistent hyper-



Figure 5. — Posttraumatic lunate avascular necrosis. Densification and fracture of the lunate five years after surgery, probably caused by avascular necrosis.

sensitivity around the scar on the dorsal side of the wrist. Ulna shortening osteotomy was performed in one patient, 4 years after her initial surgery, due to ulnocarpal impingement.

The present study evaluates a patient group of one technique of scaphoidectomy and 4-corner fusion performed by a single surgeon. Limitations are the retrospective design and the lack of preoperative measurements. The results of this study support the use of HCS for bone fixation and can help in decision making for complication management after 4-corner arthrodesis.

CONCLUSION

Scaphoidectomy and 4-corner arthrodesis with headless compression screws can provide good pain relief with functional residual wrist motion and strength. We observed postoperative complications in 28% of our patients. Most complications can successfully be treated with additional surgery.

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