Chapter 7
Scaphoid Nonunion: Surgical Fixation Without Bone Graft

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Case Presentation

A 21-year-old right-hand dominant elite hockey player presented to our clinic with a known left scaphoid fracture. He sustained this injury 7 months ago while playing hockey. He was able to continue playing, albeit with wrist pain. He presented to the emergency room after the game and was diagnosed with a wrist sprain as no fractures were identified on initial radiographs. His pain gradually resolved over the course of 4 weeks and he returned to play the remaining 5 months of the season. He denies reinjuring the wrist, but noted a recurrence of symptoms when he started off-season training.

He complained of radial-sided wrist pain, exacerbated by activities causing loading of the wrist, particularly when bench press weightlifting. Another X-ray was performed, and an established scaphoid waist nonunion was identified. He was then immobilized

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J. Yao (ed.), *Scaphoid Fractures and Nonunions*,
DOI 10.1007/978-3-319-18977-2_7

in a short-arm thumb spica cast and referred to our hand and upper limb center.

Physical Assessment

The wrist appeared normal, with no swelling or deformity noted on examination. He had pain with palpation in the anatomic snuffbox. He had normal range of motion of the digits and elbow. Flexion and extension of the affected wrist were 49° and 37°, respectively, compared to 79° and 59° on the unaffected side. The distal radioulnar joint was stable. Pronation and supination of the affected wrist were 80° and 82°, respectively, compared to 77° and 83° on the unaffected wrist. The hand had normal sensation within all nerve distributions. The Watson-shift test was negative, and the remainder of the hand and wrist examination was within normal limits.

Diagnostic Studies

Scaphoid X-ray views of the left wrist demonstrated evidence of a nonunited scaphoid waist fracture (Fig. 7.1a, b, c). Minimal sclerotic changes were evident adjacent to the fracture site. There were mild cystic changes and no humpback deformity. There was no evidence of a dorsal intercalated segmental instability (DISI) deformity or degenerative changes (i.e., scaphoid non-union advanced collapse (SNAC) wrist). A CT scan was performed to better delineate the fracture [1, 2]. CT was used because it more reliably identifies fracture displacement and angulation, especially when used in conjunction with X-ray imaging [1, 2]. Figure 7.2a and b is representative coronal and sagittal cuts of the scaphoid. The CT scan demonstrated mild cystic changes adjacent to the fracture, confirming that there was minimal sclerosis along the fracture line and no underlying humpback deformity

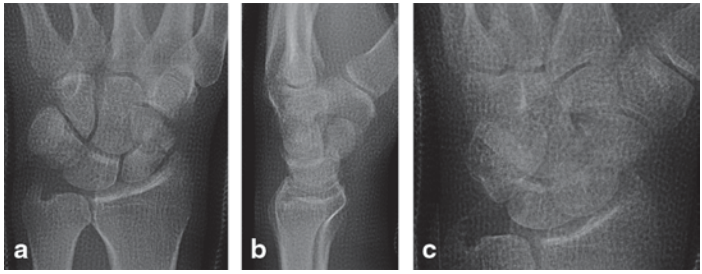

Fig. 7.1 Scaphoid views of the left wrist. **a** PA view demonstrating cystic changes at fracture site. **b** Lateral view demonstrating maintenance of normal alignment, with no humpback or angular deformity. **c** Oblique view featuring minimal displacement of the fracture. (Published with kind permission of © Christopher Doherty and Ruby Grewal, 2015. All rights reserved)

or displacement. An MRI was performed to rule out avascular necrosis of the proximal pole [3]. Figure 7.3 is a coronal cut of a T1-weighted MRI demonstrating scaphoid nonunion with no evidence of avascular necrosis of the proximal pole of the scaphoid.

Diagnosis

This patient was diagnosed with a scaphoid nonunion. As with many nonunions, it most likely occurred as a result of a missed scaphoid fracture, which we suspect occurred as a result of his injury 7 months ago. The chronicity of his injury (> 6 months) allowed us to classify it as a nonunion rather than a delayed union [4].

Radiographic findings (X-ray and CT) that supported this diagnosis included evidence of a fracture at the waist of the scaphoid without evidence of callus formation or bone bridging the fracture gap, mild sclerosis, and cystic formation [5]. Avascular necrosis (AVN) was ruled out based on the MRI.

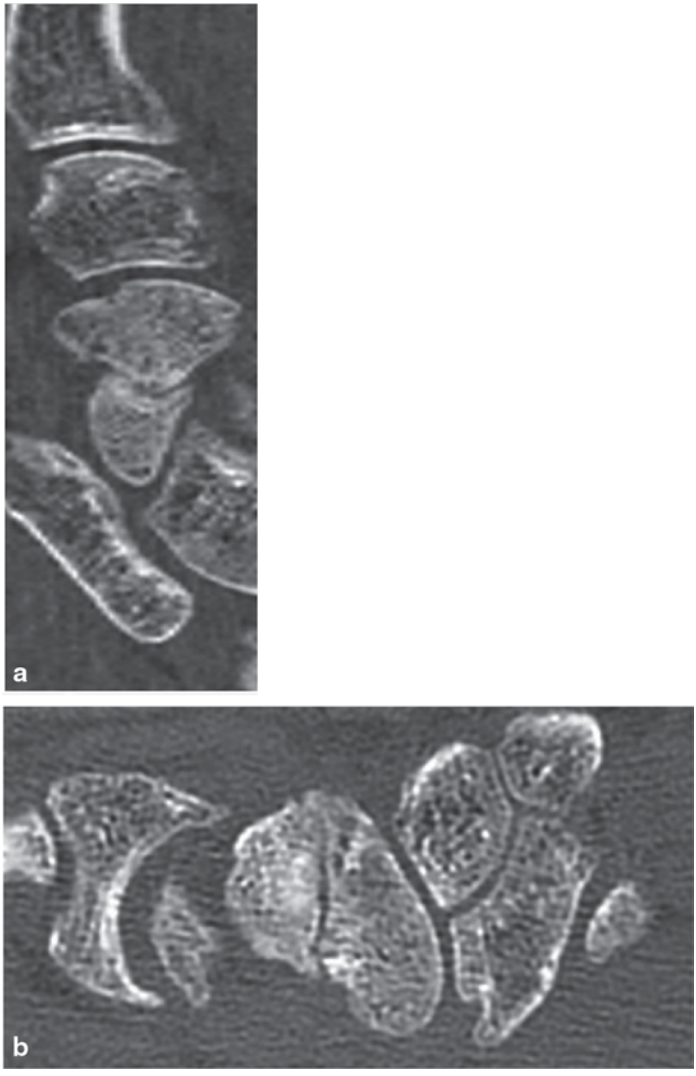

Fig. 7.2 Computed tomography of the left scaphoid. **a** Coronal cut demonstrating minimal sclerosis and mild cystic changes. **b** Sagittal view showing no humpback deformity and alignment of the fracture fragments. (Published with kind permission of © Christopher Doherty and Ruby Grewal, 2015. All rights reserved)

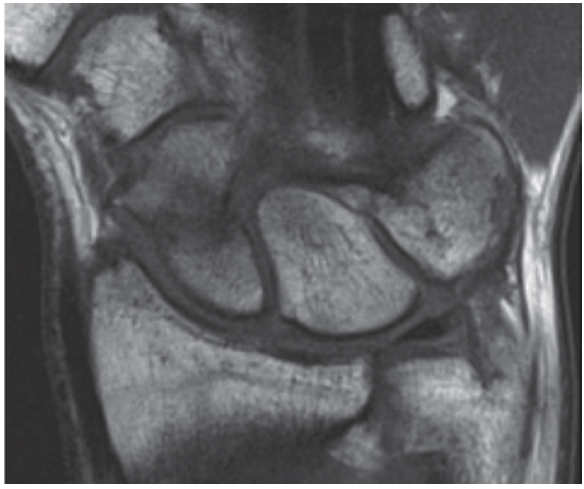

Fig. 7.3 T1-weighted MRI demonstrating scaphoid nonunion with no evidence of avascular necrosis of the proximal pole of the scaphoid. (Published with kind permission of © Christopher Doherty and Ruby Grewal, 2015. All rights reserved)

Management Options

The treatment goals for scaphoid nonunions are to achieve bony healing, correct any underlying carpal deformities, and prevent future arthritis. While it may be reasonable to offer a trial of immobilization in cases of delayed union, once patients are greater than 6 months from the initial injury, operative intervention provides a more predictable outcome. Surgical options for scaphoid nonunions include internal fixation (using an open, percutaneous, or arthroscopic approach) with or without bone grafting. The decision to perform internal fixation without the use of bone graft cannot be definitively made until the nonunion has been adequately evaluated. Evaluation includes careful assessment of the preoperative imaging and direct assessment of the scaphoid intraoperatively. Preoperatively, radiographic features that may suggest that a bone graft is not necessary include minimal sclerosis at the nonunion site (less than 1 mm), minimal cyst forma-

Fig. 7.4 Intraoperative evaluation demonstrating an intact cartilaginous cap. (Published with kind permission of © Christopher Doherty and Ruby Grewal, 2015. All rights reserved)

tion, no collapse or change in the architecture of the scaphoid, and normal vascularity of the proximal fragment [6]. If these criteria are not met, bone grafting will likely be required. The intraoperative evaluation of the scaphoid nonunion is a critical step, which helps to confirm whether bone grafting is required, as preoperative imaging may not always correlate with intraoperative findings [7]. Intraoperative evaluation of the nonunion can be performed open or arthroscopically [7, 8]. Intraoperative features that are compatible with fixation without bone grafting include an intact cartilaginous cap, evidence of only a faint nonunion fracture line in the waist of the scaphoid, no humpback deformity, minimal differential movement between proximal and distal fragments, and minimal sclerosis or resorption at the edges of each fracture fragment [8]. For example, Fig. 7.4a and b demonstrates an intact cartilaginous cap upon intraoperative inspection with radiographic evidence of a fracture in the waist of the scaphoid. Internal fixation without bone graft is generally reserved for non-to-minimally displaced fractures, within approximately 6 months of injury, that fit the abovementioned criteria [7–9]. Fixation should be rigid and in our experience this is best achieved with a headless compression screw, following the same

technique as with an acute scaphoid fracture. Other methods of fixation (i.e., K-wire fixation) are not recommended as compression at the nonunion site is a key component of the fixation. Postoperatively, a variety of immobilization protocols may be used [6, 8]. If adequate rigid fixation is achieved, early active range of motion may be considered (2 weeks postoperatively) [8]. Alternatively, immobilization from 6 to 12 weeks may be used with an above or below elbow cast (thumb spica or Colles' cast) [6]. It is our preference to immobilize for 6 weeks in a short-arm thumb spica cast and then begin gradual range of motion exercises once union has been achieved.

Management Chosen

In this case, both clinical and radiographic factors contributed to our management decision. We did not entertain a course of further immobilization for two main reasons. First, the patient is an elite hockey player and wished to return to training as soon as possible. Second, a 6-week trial of cast immobilization had already been attempted with no further evidence of progression of union. Radiographic factors (based on preoperative imaging) and our intraoperative assessment contributed to our decision to perform internal fixation with a headless compression screw without bone graft. Based on preoperative imaging (Figs. 7.1 and 7.2), there was minimal displacement, no humpback deformity, minimal sclerosis (less than 1 mm), and no avascular necrosis. Given these factors, our level of suspicion for requiring bone graft was low. However, there was mild cystic formation on the imaging, and the duration since injury was 7 months; therefore, we felt inclined to visually inspect the nonunion intraoperatively. Intraoperative evaluation can be performed arthroscopically or via a volar open approach to the scaphoid. We generally use our preoperative level of suspicion for requiring bone graft to determine whether we assess the scaphoid arthroscopically or through an open volar approach. Arthroscopic evaluation provides the benefit of reduced morbidity if an open approach is not required for a bone graft; however, an open approach

allows the surgeon to apply stress across the nonunion that may be more difficult to do arthroscopically. As described above, the duration since injury in this patient is beyond the 6-month window some authors describe for suitability of not requiring a bone graft [9]. Also, there was mild cystic formation at the nonunion site, so we therefore elected to do an open volar approach to the scaphoid because we felt that bone grafting may be necessary and prepared the patient for this possibility.

Surgical Technique

Intraoperatively, the location of the nonunion site was confirmed with X-ray. In this case, the fracture line was evident; however, the cartilaginous cap was preserved despite the presence of nonunion. The two fragments did not move differentially to one another. Therefore, the use of bone graft was judged not to be necessary. Next, the scaphoid was prepared for placement of an Acutrak 2 (Acumed, Oregon, USA) compression screw from distal to proximal. The screw was delivered and confirmed to be in adequate position using intraoperative imaging (Fig. 7.5a and b).

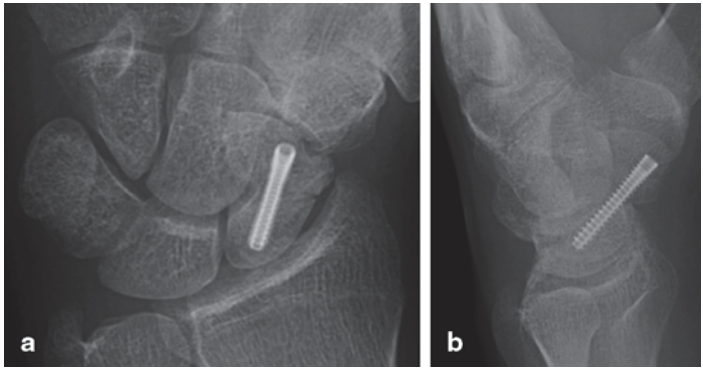

Fig. 7.5 Postoperative (2 weeks). **a** PA X-ray of the left wrist demonstrating hardware in good position with compression of the nonunion **b** and lateral X-ray of the left wrist with normal alignment of the scaphoid and no DISI deformity. (Published with kind permission of © Christopher Doherty and Ruby Grewal, 2015. All rights reserved)

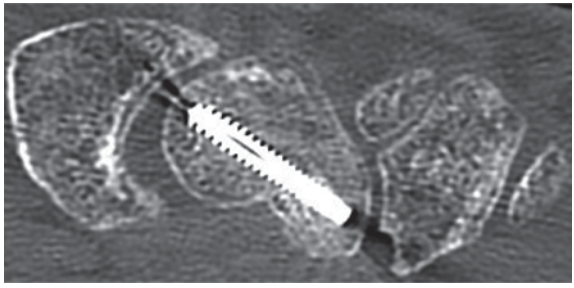

Fig. 7.6 Computed tomography at 6 weeks postoperatively showing evidence of union across the fracture with cannulated screw in good position. (Published with kind permission of © Christopher Doherty and Ruby Grewal, 2015. All rights reserved)

The patient was then placed in a short-arm thumb spica cast for 6 weeks. The patient was discharged home the day of the procedure. His postoperative recovery was unremarkable.

Clinical Course and Outcome

At 6 weeks postoperatively, the patient returned to the clinic and had a CT of the scaphoid to evaluate bone healing (Fig. 7.6). CT is chosen to evaluate union as opposed to X-ray because it is a more reliable modality, the cost difference is marginal at our center, and it provides a more definitive assessment of union [2, 10]. The cast was removed, and on physical examination, there was no tenderness to palpation over the anatomic snuffbox. The CT scan demonstrated radiographic union, and this was quantified using the method described by Singh et al. and judged to be approximately 83 % [10]. Therefore, based on the clinical and CT findings, the nonunion was judged to be united and the cast was removed for range of motion exercises. The patient was placed in a protective splint and instructed to begin passive and active range of motion exercises at the wrist with a gradual return to activity. He was asked to delay strength training until 10 weeks postoperatively.

The patient next returned to clinic 5 months postoperatively. He demonstrated excellent range of motion. Pronation and supi-

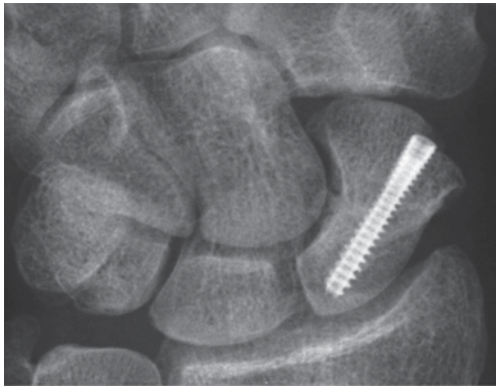

Fig. 7.7 PA X-ray of the left wrist at 5 months postoperatively demonstrating fracture union. (Published with kind permission of © Christopher Doherty and Ruby Grewal, 2015. All rights reserved)

nation were full. Extension and flexion at the wrist were 60° and 50°, respectively. Grip strength was 48 kg on the left side and 49 kg on the right. There was no pain at the wrist. The disabilities of the arm, shoulder and hand (DASH) and patient-rated wrist evaluation (PRWE) scores were both 0 (0 being the best possible score), indicating that he did not report any pain or disability. Figure 7.7 is an X-ray demonstrating excellent union across the waist of the scaphoid. The patient was advised to return to full activity without restriction.

At the 1-year follow-up, the patient reported no pain at the wrist with any limitations on his ability to play hockey. His wrist flexion was 75° and extension 80°. Grip strength on the left hand was 55 kg and that on the right was 60 kg.

Clinical Pearls/Pitfalls

- The most important step in deciding to proceed with internal fixation without bone graft is case selection. This decision should be based on clinical, radiographic, and intraoperative assessments. Clinically, the duration since injury is an important

factor to consider. Injuries in closer proximity to the procedure are more likely to have an opportunity to heal in comparison with those more remote from the procedure.
- Careful radiographic assessment is required to ensure that the fracture is minimally displaced across the waist of the scaphoid, without a significant humpback deformity and without evidence of AVN.

Intraoperative inspection is felt to be a key step in determining whether internal fixation alone is appropriate. This can be done arthroscopically or via an open volar approach based on the degree of suspicion that bone graft is required. It can be helpful to place a k-wire into the nonunion site intraoperatively to help identify the location of the fracture. In addition, we look for an intact cartilaginous cap as an indicator that bone grafting is not required (Fig. 7.4). It is important to be ready to bone graft if necessary; therefore, the patient should be consented and donor site prepared for this.

Literature Review and Discussion

Scaphoid nonunion is a nonhealing scaphoid fracture after 6 months of injury [11]. Nonoperative measures may be a consideration in the early course of treatment, particularly if the patient presents relatively close to the 6-month mark post-injury or if they have not had an appropriate course of immobilization. However, distinguishing between a delayed union (a fracture amenable to union with a course of immobilization) and a nonunion (which will require surgical fixation) can be difficult as there is little evidence in the literature to guide this decision. Percutaneous screw fixation has been described as an effective means to manage acute scaphoid waist fractures [12]. This philosophy has been extended to management of scaphoid waist nonunions that are nondisplaced and do not have evidence of significant sclerosis or bone loss at the fracture site [8]. Slade et al. studied 15 consecutive patients with scaphoid fibrous union or scaphoid nonunion with-

out substantial sclerosis (less than 1 mm) treated with arthroscopically assisted percutaneous internal fixation without bone graft [8]. Arthroscopy was used to confirm fibrous union or an intact cartilaginous cap around a scaphoid nonunion. This study showed that all scaphoids went on to union at an average of 14 weeks postoperatively. The average range of motion was 49° extension and 61° flexion. Time to postoperative union was significantly increased as the time from injury to surgical intervention increased [8]. Prevention of micromotion at the fracture site is thought to be the key mechanism of healing with this technique in comparison with cast immobilization [8]. Saint-Cyr et al. presented their retrospective series of patients with delayed and nonunion of the scaphoid treated with dorsal percutaneous rigid fixation without bone graft [13]. They report a union rate of 100 % with no significant complications. The delayed union group had an earlier time to union (mean 7 weeks) versus the established nonunion group (mean 13 weeks). The average grip strength was 39 kg in the affected hand as compared to 45 kg in the unaffected hand [13]. Some authors have widened the indications for this technique. Mahmoud and Kapton presented a series of 27 consecutive patients who had nondisplaced scaphoid nonunions with substantial bone resorption (2 mm) treated with percutaneous internal fixation without bone graft [14]. They demonstrated that all fractures went on to union at a mean 11.6 weeks with an improvement in pain and range of motion [14]. Jeon et al. reported two cases of skeletally immature patients (aged 13 and 15 years) with scaphoid nonunions managed with percutaneous internal fixation [15]. Both cases went on to scaphoid union with good clinical outcomes. A percutaneous approach to internal fixation of scaphoid nonunions is a popular technique for accessing the scaphoid, but it can be technically demanding. Accurate guide wire and subsequent screw placement can be difficult. Careful examination of the intraoperative images is essential to ensure that the screw is not malpositioned or prominent. Complications of this approach must be considered. Bushnell et al. retrospectively reviewed 24 patients undergoing dorsal percutaneous cannulated screw fixation for acute undisplaced scaphoid waist fractures [16]. They report a major complication rate of 21 % (nonunion, hardware

problems, and postoperative proximal pole fracture) and a minor complication rate of 8 % (intraoperative breakage of a cannulated screw and intraoperative breakage of a guide wire) [16]. These risks must be balanced against risks relevant to an open approach, such as soft tissue stripping, volar radiocarpal ligament division, neuroma, blood supply disruption, and scarring [13]. Scaphoid nonunion is a challenging problem for the surgeon. Several options exist for managing this condition. Patients with an undisplaced waist nonunion with minimal sclerosis and no change in the architecture of the scaphoid can be considered for rigid internal fixation without bone grafting. We present a case demonstrating that this technique is effective at establishing union with good clinical outcomes and early return to activity.

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