Percutaneous Screw Fixation for Acute Scaphoid Fractures Through K-wire-assisted Reduction and Maintenance

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Research article

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Abstract

Background: Percutaneous screw fixation was introduced for acute scaphoid fractures through K-wire-assisted reduction and maintenance, and the effectiveness of the methods was evaluated.

Methods: Ten patients with acute scaphoid fractures were consecutively treated with the proposed technique from January 2015 to December 2018. With the wrist placed in ulnar deviation, one K-wire was introduced perpendicularly through the styloid process of radius into the proximal pole of scaphoid under fluoroscopic guidance. The scaphoid fragment was reduced by dorsiflexing the wrist and translating the distal pole into an extended position. A headless compression screw was then inserted in a standardised manner. Operation time, time to union, time to return to previous activity and complication were recorded. Function outcomes including pain, work status, range of motion (ROM) and grip strength were assessed according to the modified Mayo wrist scoring system.

Results: Final follow-up examination was performed on an average of 12 months (range, 10–15 months) after surgery. No immediate postoperative complication occurred. All scaphoid fractures united at an average of 9.2 weeks (range, 7–11.4 weeks). The following average values were achieved: operation time was 48.2 minutes (range, 38–65 minutes), the time that patients returned to previous activity levels was 9.4 weeks (range, 7–11 weeks) and function scores were 92.5 (range, 80–100). At 3 months post-operation, the wrist range of motion was generally 62.5° wrist extension (range, 50°–70°) and 68.2° wrist flexion (range, 55°–75°). Grip strength was approximately 40.1 kg (range, 28–45 kg) and 83.5% (range, 85%–100%) of the contralateral sides. The mean post-operative height-to-length ratio was 0.61.

Conclusions: Our novel percutaneous screw fixation method is beneficial to minimise injury to the blood supply of the scaphoid. Primary percutaneous screw fixation for acute scaphoid fractures is a superior method with reduced time to bony union, early return to daily activity or employment and predictably lessened complications of wrist stiffness, diminished grip strength, delayed union, non-union and osteonecrosis.

Trial registration: Clinicaltrials.gov; NCT04482868; Registered 19 July 2020-Retrospectively registered.

Background

The scaphoid is the most commonly fractured carpal bone in active adults and accounts for up to 80% of all carpal fractures[1, 2]. Scaphoid fracture is mainly a consequence of fall with hypertension past 95° and radial deviation of the wrist and axial loading from a direct blow[3, 4]. The optimum treatment approach for acute scaphoid fractures is currently under discussion. Cast immobilisation is the main treatment for non-displaced scaphoid fractures, but approximately 20% of the cases fail to heal with conservative treatment[5]. Additionally, non-displaced scaphoid fractures usually require a period of cast immobilisation with time to union ranging from 8 weeks to 12 weeks. Long periods under this procedure may result in wrist stiffness, loss of grip strength, muscle atrophy and disuse osteopenia[6], thereby possibly affecting the function of wrist and hand. Screw fixation of scaphoid fractures has been recommended to minimise the period of cast immobilisation. Displaced and unstable scaphoid fractures have a high risk of non-union and avascular necrosis[7], because these conditions damage the retrograde blood flow to the proximal fracture fragment. Operative treatment is mostly adopted for displaced and unstable scaphoid fractures. An open approach to the scaphoid can provide optimal visualisation of the fracture site for anatomical reduction and satisfactory screw location; however, this method has inherent disadvantages of ligament and capsular dissection and blood vessel damage[8].

In 1970, Streli R[9] adopted percutaneous screw fixation for scaphoid fractures to avoid this potential deficiency. This method could shorten the period of immobilisation and increase bone union rates. Separation of scaphoid fracture fragments commonly occurs during drilling and screw insertion. A gap is produced between fracture fragments and hinders fracture healing. The present study introduces a novel technique of percutaneous screw fixation for acute scaphoid fractures. One K-wire was used to maintain the reduction of scaphoid fractures during drilling, screw insertion and screw fixation for acute scaphoid fractures.

Methods

This retrospective study was approved by the local ethics committee and in accordance with the declaration of Helsinki. From January 2015 to December 2018, 10 patients (seven males and three females) with acute scaphoid fractures were consecutively treated with the proposed technique (Table 1). Among these patients, six were right-handed, and four were left-handed. The average age was 30.9 years (range 16–58 years), and the mean time of injury to treatment was 7.0 days (range, 3–10 days). The patients were initially evaluated because of pain, swelling and limited wrist range of motion. Eight of the injuries resulted from a fall onto the outstretched wrist during sporting event, and two resulted from automobile accidents. According to the classification of Hebert, B1 (distal oblique fracture) occurred in four cases, and B2 (complete waist fracture) was observed in six cases. All scaphoid fractures were diagnosed using standard posteroanterior, lateral and oblique plain radiographs and computed tomography (CT). Pre-operative CT examinations were performed to determine the degree of fracture dislocation and assist in the formulation of surgical plan (Fig. 1).

Table 1
Patient demographics.

Characteristics	Data
Age (years)	30.9 ± 10.2 years
Sex (male : female)	7:3
Smoking (yes : no)	6:4
Dominant : non-dominant hands	8:2
Hands(Right:Left)	6:4
Occupation	
Office worker	2
Manual labourer	6
Sports player	2
Aetiology	
Fall on an outstretched hand	8
Traffic accident	2
Duration from injury to operation (days)	7.0 ± 2.3 years
Fracture type(The classification of Hebert)	
B1	4
B2	6

Continuous variables are expressed as mean with standard deviation(SD).

Brachial plexus anaesthesia was provided. The patient was in a supine position with the operative arm abducted on the hand table. A pneumatic tourniquet was applied above the elbow, and an intravenous antibiotic was administered to prevent infection prior to the operation. Volar percutaneous approach was adopted. With the wrist placed in ulnar deviation, one K-wire was introduced perpendicularly through the styloid process of radius into the proximal pole of scaphoid under fluoroscopic guidance. The scaphoid fragment was reduced by dorsiflexing the wrist and translating the distal pole into an extended position. If the scaphoid fragment is not reduced successfully, then a K-wire is placed into the distal pole from the dorsal side of scaphoid to act as a joystick that reduces the fracture fragments (Fig. 2A,B). After the satisfactory reduction was achieved under fluoroscopic guidance, the starting point for the scaphoid screw was centred in the radial portion of the scaphoid tubercle. The wrist was dorsiflexed, supinated to bring the starting point of view. Scaphoid reduction was maintained while the wrist was dorsiflexed and supinated for placement of the central guidewire. A guide pin was placed down its central axis under fluoroscopic guidance and was driven across the fracture site into the proximal pole (Fig. 2C,D). Another anti-rotation wire was introduced parallel to the former guide pin. A hand reamer was then used to create a drill hole along the guide pin and insert a proper cannulated screw to the subchondral line at the proximal-most aspect of the scaphoid. Under the fixed proximal pole of scaphoid with radial styloid process, a headless compression screw was inserted in standardised manner to avoid widening the fracture gap and achieve compression across the fracture site. After screw placement, screw position and satisfactory scaphoid reduction were confirmed by fluoroscopic imaging. All wires and anti-rotation pin were removed, and the tourniquet was released. The wound was irrigated and covered with a sterile dressing. Finally, the wrist was immobilised in the shirt arm volar splint, leaving the fingers and thumb free. The surgical process is shown in Fig. 3.

After surgery, the arm was elevated to promote venous drainage in the arm. Active digital range-of-motion exercises were started post-operatively. The patient returned for suture removal 2 weeks after surgery, and the splint was removed after 4 weeks. X-rays on AP, lateral, and dedicated scaphoid views were taken at 4, 8, and 12 weeks after surgery for fracture healing assessment (Fig. 4). A CT scan was performed when adequate radiographic evidence union was obtained by plain radiographs.

Operation time, time to union, time to return to previous activity and complications were recorded. According to the modified Mayo wrist scoring system, function outcomes including pain, work status, range of motion (Rom) and grip strength were assessed and graded as excellent (91–100 scores), good (80–90 scores), fair (65–79 scores) and poor (less than 65 scores). Wrist range of motion (flexion, extension) and grip strength were measured by a Jamar dynamometer (Sammons Preston, Inc., Bollingbrook, IL, USA).

Results

Final follow-up examination was performed on an average of 12 months (range, 5–15 months) after surgery. Basic data of patients are listed in Table 1. No immediate postoperative complication occurred. All patients achieved solid union as confirmed by CT scans. All scaphoid fractures united at an average of 9.2 weeks (range, 7-11.4weeks). The following average values were obtained: operation time was 48.2 minutes (range, 38–65minutes), the time patients returned to previous activity levels was 9.4 weeks (range, 7–11 weeks) and function scores were 92.5 (range, 80–100) (Table 2). At 3 months post-operation, the wrist range of motion was generally 62.5° wrist extension (range, 50°–70°) and 68.2° wrist flexion (range, 55°–75°). Grip strength was approximately 40.1 kg (range, 28–45 kg) and 83.5% (range, 85–100%) of the contralateral sides (Table 3). Longitudinal CT revealed that the mean post-operative height-to-length ratio was 0.61, which was within the normal ranges.

Discussion

The scaphoid comprises most of the carpel bones, and its fracture usually affects the mechanical integrity of wrist. Acute scaphoid fractures are usually classified as

Table 2
The average function scores according to Mayo wrist scoring system.

Mayo wrist scoring system	Patients(n = 10)
Excellent (91–100)	5
Good (80–90)	5
Fair (65–79)	0
Poor (< 65)	0

Table 3
Wrist range of motion and grip strength .

	Measurement index	Compared with the contralateral side (%)
Extension (°)	62.5 ± 10.1	91.2 ± 5.1
Flexion (°)	68.2 ± 9.3	89.3 ± 6.9
Grip strength (kg)	40.1 ± 6.2	83.5 ± 7.3

Continuous variables are expressed as mean with standard deviation(SD).

non-displaced and displaced fractures. Cast immobilisation is an adequate treatment for non-displaced scaphoid fracture[6, 10]. Patients are being treated by below elbow scaphoid plaster cast with the thumb immobilised for a long time; however, the morbidity of cast immobilisation has recently attracted attention[11]. The conservative treatment of non-displaced fractures does not allow early return to daily activity and work. When the forearm rotates in the plaster cast, all scaphoid fracture could displace from 1.0 mm to 4.0 mm[12]. Thus, the non-displaced scaphoid fractures can be displaced in casting and high non-union rates. Acute displaced scaphoid fractures treated by casting have high rates of non-union and mal-union of up to 50%[13] Acute and other complications such as carpal instability, humpback deformity, joint stiffness, osteoarthritis, and atrophy of the upper extremity[14]. Operative treatment is offered for patients with acute scaphoid fractures to achieve both a high rate of fracture union and early return to daily activities[15].

The mechanical integrity of the wrist depends on the fascinating anatomy of the scaphoid. More than 70% of the scaphoid is covered by cartilage. Its blood supply is divided into extraosseous and intraosseous categories. Gelberman et al. described that nutrient arteries entering at the dorsal ridge supply the proximal 70–80% of the scaphoid, and those entering at the tubercle supply the distal 20–30%[16]. Morsy et al. reported that the scaphoid generally has two major networks of bony perfusion, one network entering volarly to supply the distal bone portion, and the other entering the dorsal ridge to supply the proximal portion. Approximately 83% of the scaphoid is supplied by the proximal vascular network, and 17% is supplied by the distal vascular network[17]. The main intraosseous vessels run in a retrograde flow to supply majority of the scaphoid. Scaphoid fractures proximal to the wrist can cut off the intraosseous blood supply to the proximal fragment and render the proximal fragment relatively avascular. As a result, the vulnerable blood supply to the proximal fragment greatly affects the scaphoid healing. Successful union of the scaphoid healing requires strains of less than 2%. Any micromotion at the fracture site prevents callus formation and results in high non-union failure.

Open reduction and screw fixation of scaphoid fractures aim to promote callus formation and the associated economic productivity loss[18]. The open approach can provide optimal visualisation of the fracture site to achieve and maintain a satisfying reduction. In this approach, the dorsal capsular structure and volar radiocarpal ligament must be divided, which may damage the blood supply to the proximal fragment. In 1970, Streli [9] presented percutaneous compression screw for scaphoid fractures to avoid these shortcomings. The percutaneous volar or dorsal approach for scaphoid fractures has high union rate and low complication. The dorsal approach for proximal region fracture can provide convenience for percutaneous screw fixation; however, risk of damage occurs for the extensor of thumb and fingers, posterior interosseous and radiocarpal joint. Another disadvantage is that the screw destroys the proximal scaphoid cartilage and the native subchondral bone–cartilage interface, which is important in preventing arthritis[19]. Owing to the loosening or usage of long screws, proximal screw protrusion into the radiocarpal joint may occur post-operatively[20]. Adamany et al. described the palmar percutaneous screw fixation of scaphoid fractures for the first time. In contrast to the dorsal approach, the palmar approach is on the risk of tendon or nerve damage and screw protrusion to the radiocarpal joint[21]. Several authors have adopted the percutaneous technology for treating scaphoid fractures, but the scaphoid fracture might be displaced during drilling and screw insertion.

In this work, the proximal pole of scaphoid was transfixed with 1.5 mm wire placed percutaneously through the styloid process of radius to achieve and maintain the reduction of scaphoid fractures during operation. The fracture is reduced and stabilised in the wrist extension. Our technique has several advantages against operative measures. Firstly, anatomic reduction of scaphoid fracture can be achieved and maintained during operation. Secondly, this technique can avoid injury to scaphoid cartilage and relative ligaments and thus maintain the normal mechanical stability of the wrist. Thirdly, the blood supply to scaphoid fracture fragments is preserved by avoiding damage to extraosseous nutrient arteries. Finally, this technique can shorten the operation time and prevent patients from being exposed to X-ray radiation. Indications of this operation must be strictly confined to non-displaced and displaced acute scaphoid fractures; however, percutaneous screw fixation is not suitable for non-union and comminuted scaphoid fractures due to the following reasons. Firstly, the non-union of scaphoid needs debridement and cancellous bone graft for the bone defect. Secondly, the comminuted fractures need optimal visualisation of the fracture site to achieve anatomical reduction.

This study has several limitations. First is the small sample size; research with a large sample size is underway to provide evidence on the efficacy of this technique. Secondly, no case of small proximal pole less than 20% of scaphoid was included. Finally, this study was not comparative. Future works comparing our technique with others methods would prove its efficacy.

Conclusions

The novel percutaneous screw fixation can minimise injury to the blood supply of the scaphoid. Primary percutaneous screw fixation for acute scaphoid fractures is a superior method that reduces time to bony union, allows early return to daily activity or employment, and predictably lessens the complications of wrist stiffness, diminished grip strength, delayed union, non-union and osteonecrosis. Therefore, this percutaneous screw fixation must be considered as a useful and safe technique for acute scaphoid fractures.

Declarations

Availability of data and materials

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

Ethics approval and consent to participate

All protocols were approved by the Ethics Board of the Third Hospital of Hebei Medical University, and all participants provided informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

The conception and design of the study were proposed by DHT,who also provided advice for revision of the manuscript. JBB collected, analyzed, and prepared the first draft of the paper. LDK, SYT and JL participated in the surgical procedures performed in the study. CJL and LDK contributed to the data collection and analysis. All authors read and approved the final manuscript.

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Figures

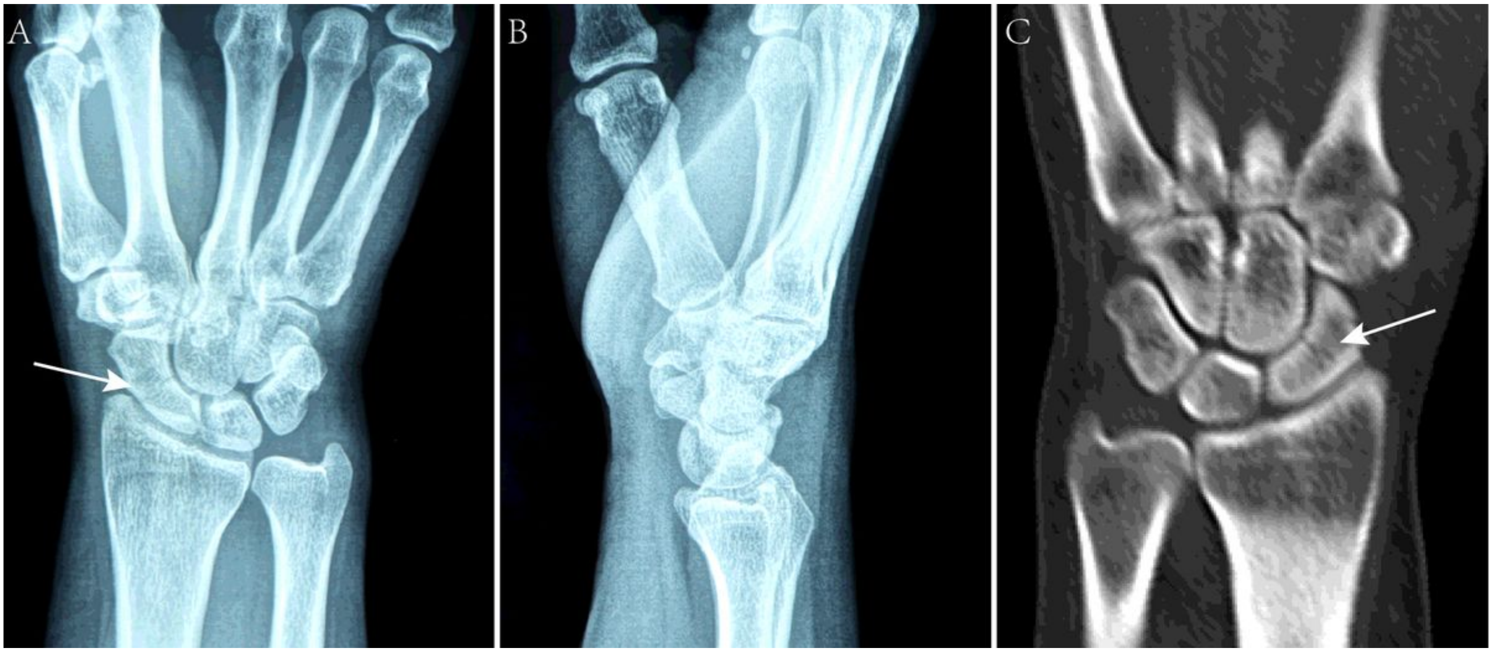

Figure 1

A 51-year-old woman with acute scaphoid fracture in the waist. A,B Preoperative anteroposterior and lateral radiographs; imaging on the day of injury. C Preoperative CT scans with sagittal views.

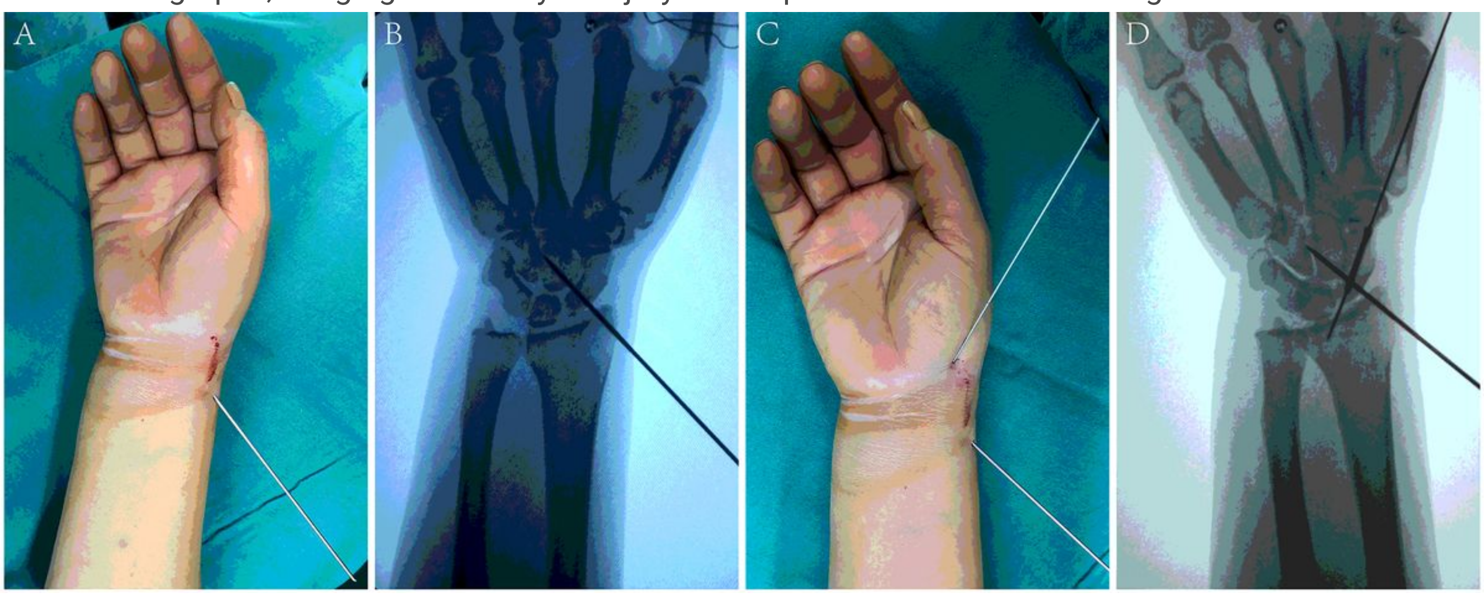

Figure 2

Final intraoperative fluoroscopy showing good fracture reduction assisted by the assisting K-wire(A,B) and screw fixation across a scaphoid fracture(C,D).

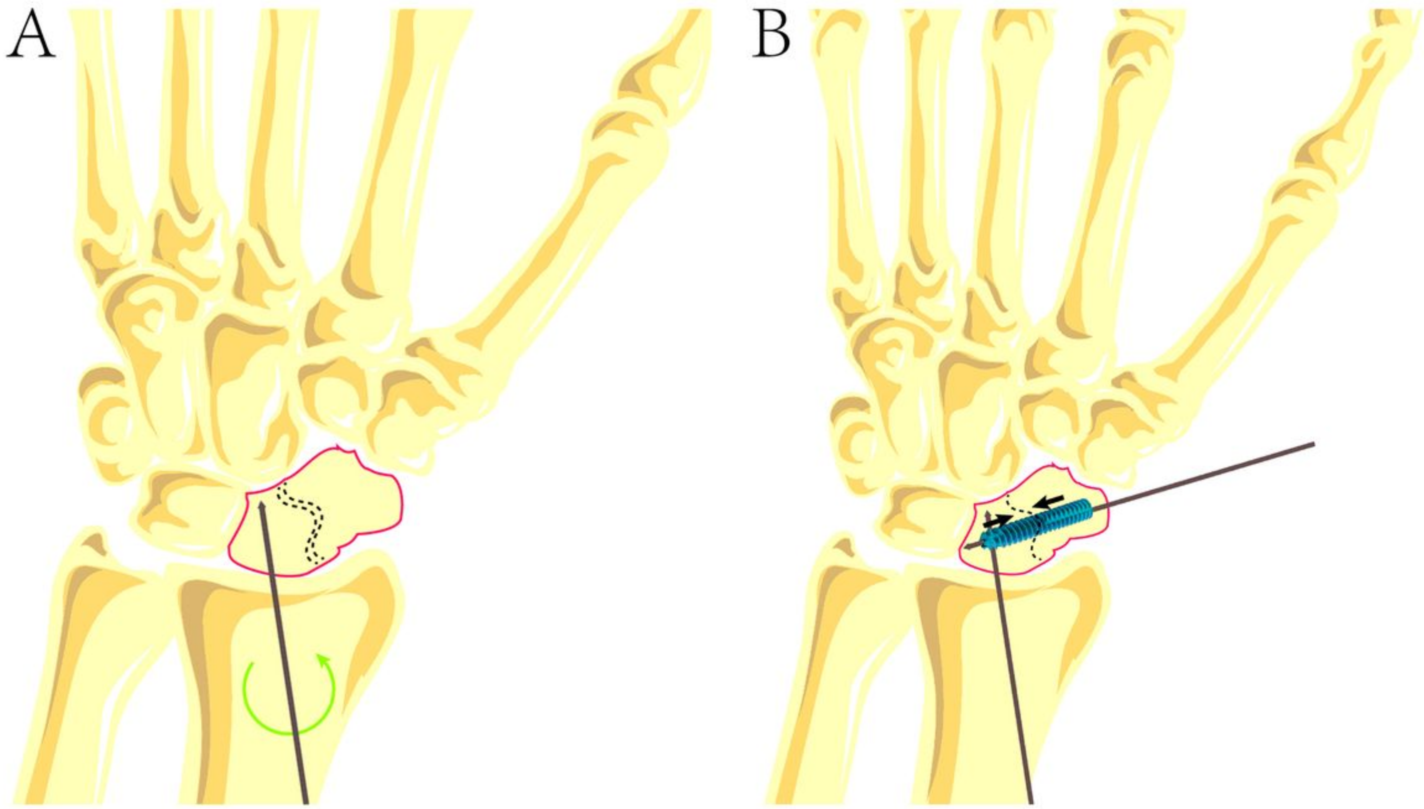

Figure 3

Schematic representation of scaphoid fracture in the waist. The dashed black line represents the fracture line. The green arrow represents reset direction of the assisting K-wire. A Reduction of scaphoid fracture assisted by the assisting K-wire B The image showing screw fixation across a scaphoid fracture.

Figure 4

Radiographs show fuzzy fracture line 1 month after the surgery(A,B). Radiographs show successful fracture healing 3 months after the surgery(C,D).