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Treatment of Scaphoid Fractures and Nonunions

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Abstract

Scaphoid fractures are common, but present unique challenges because of the particular geometry of the fractures and the tenuous vascular pattern of the scaphoid. Delays in diagnosis and inadequate treatment for acute scaphoid fractures can lead to nonunions and subsequent degenerative wrist arthritis. Improvements in the diagnosis, surgical treatment and implant materials have encouraged a trend towards early internal fixation, even for nondisplaced scaphoid fractures that could potentially be treated nonoperatively. Despite the advent of newly developed fixation techniques, including open and percutaneous fixation, the nonunion rate for scaphoid fractures remains as high as 10% after surgical treatment. Scaphoid nonunions can present with or without avascular necrosis of the proximal pole, and may show a humpback deformity on the radiograph. If left untreated, scaphoid nonunions can progress to carpal collapse and degenerative arthritis. Surgical treatment is directed at correcting the deformity with open reduction and internal fixation with bone grafting. Recently, vascularized bone grafts have gained popularity in the treatment of scaphoid nonunions, particularly in cases with avascular necrosis. This article reviews current concepts regarding the treatment of scaphoid fractures and nonunions.

Keywords

scaphoid; fracture; nonunion; treatment; surgery

The scaphoid is the most commonly fractured carpal bone, accounting for approximately 60% of all carpal fractures.[1] The importance of a correct diagnosis and appropriate treatment of scaphoid fractures lies in its blood supply. The main blood supply to the scaphoid is from the radial artery. Over 80% of the scaphoid surface is covered with articular cartilage. The dorsal scaphoid branches from the radial artery enter the nonarticular portion of the scaphoid at the dorsal ridge at the level of the waist and supply the proximal 70% to 80% of the scaphoid.[2] The volar scaphoid branches from either the radial artery or the superficial palmar branch enter at the distal tubercle and supply the distal 20% to 30% of the scaphoid. Thus, the vascularity of the proximal pole depends entirely on intraosseous blood flow. This tenuous blood supply to the proximal pole of the scaphoid helps to explain the increased frequency of delayed union, nonunion and avascular necrosis (AVN) of scaphoid fractures.

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AVN is reported to occur in 13% to 50% of scaphoid fractures, with an even higher incidence in those involving the proximal one-fifth of the scaphoid.[3,4]

Scaphoid fractures can escape early detection because in many cases they are subtle and the initial symptoms are minimal. Missed scaphoid fractures have a high risk of nonunion or malunion. Nonunion occurs in up to 12% of patients if an occult fracture is not detected and treated.[3,4] Scaphoid nonunions are especially challenging to treat successfully, and if untreated, they can progress to carpal collapse and degenerative arthritis. Early diagnosis and appropriate treatment of an acute scaphoid fracture and the possible consequences of nonunion are critical to avoiding debilitating wrist problems.

CLASSIFICATION

Russe classified scaphoid fractures as horizontal oblique, transverse, or vertical oblique, depending on the obliquity of the fracture line.[5] Vertical oblique fractures, accounting for only 5%, are more likely to be displaced by shear forces, whereas horizontal oblique and transverse fractures have greater compressive forces and are less likely to be displaced. Herbert and Fisher defined scaphoid fractures as stable and unstable, as well as delayed union and nonunion (Table 1).[3] Type A fractures are stable acute fractures, and type B fractures are unstable acute fractures. Although type A fractures can potentially be treated nonoperatively, other types of fractures usually require surgical treatment. Type A fractures include tubercle fractures (A1) and incomplete waist fractures (A2). Type B fractures include distal oblique fractures (B1), complete waist fractures (B2), proximal pole fractures (B3), transscaphoid perilunate dislocation fractures (B4), and comminuted fractures (B5). Type C fractures are delayed unions, and type D fractures are established nonunions, either fibrous (D1) or sclerotic (D2). Based on this classification, other than tubercle and incomplete waist fractures, all other types are considered unstable and surgical treatment should be considered. Prosser and colleagues expanded the classification of distal pole fractures.[6] Type I fractures indicate tuberosity fractures; type II, distal intra-articular fractures; and type III, osteochondral fractures. Approximately 70% to 80% of scaphoid fractures occur at the waist, 10% to 20% at the proximal pole, and the remainder at the distal pole.[7] The least common fractures occurring at the distal pole are more common in children than in adults.

DIAGNOSIS

Scaphoid fractures tend to occur in young adult men between the ages of 15 to 40 years, and are rare under 10 years of age. The typical mechanism of injury is a fall onto a hyperextended and radially deviated wrist. Tenderness in the anatomic snuff box or scaphoid tubercle may suggest a scaphoid fracture. If there is a scaphoid fracture, the wrist's range of motion is slightly restricted and thumb movement may be painful. Reduced grip strength may be noted. It is important to recognize that not all patients have pain over the scaphoid, even if a well-defined fracture is seen on radiographs. Overall, the diagnostic sensitivity (true positive rate) is high for clinical examination, but specificity (true negative rate) approaches only to 74% to 80%.[8,9]

Initial wrist radiographs should include standard posteroanterior (PA), lateral, 45° pronated oblique, and 45° supinated oblique views, as well as a PA view in ulnar deviation (scaphoid view).[10] The scaphoid view may visualize the fracture because the ulnar deviation of the wrist distracts unstable fracture fragments. The sensitivity (true positive rate) of plain radiographs is approximately 70% for scaphoid fractures.[11] If there is a high clinical suspicion of a scaphoid fracture but with no radiographic evidence, a short arm thumb spica cast is usually applied.[12] Follow-up radiographs may show bone resorption or early callus formation adjacent to the fracture site, if an occult fracture did indeed exist. However, this traditional treatment with repeat radiographs and immobilization can lead to a loss of work and has economic implications. It has been reported that 75% to 80% of patients who had clinical suspicion of scaphoid fractures would be immobilized unnecessarily if they underwent traditional treatment.[13] Recently, early definitive evaluation with bone scintigraphy, magnetic resonance imaging (MRI), or computed tomography (CT) has been advocated by many authorities as means of detecting occult scaphoid fractures. Bone scintigraphy has demonstrated 92% to 95% sensitivity and 60% to 95% specificity for scaphoid fractures.[14] On the other hand, MRI has shown 95% to 100% sensitivity and specificity for scaphoid fractures.[15] MRI may be superior to bone scintigraphy due to fewer false-positive results and the ability to identify other causes of wrist pain, such as ligamentous injury, which can not be diagnosed with bone scintigraphy. Drawbacks of MRI are that it is not readily available in most treating centers, it is relatively expensive, and it may not clarify any fracture displacement. CT scans are less costly, more readily available, and give a clearer visualization of fracture displacement than MRI. However, CT scans should be used with caution for triage of nondisplaced scaphoid fractures because false-positive results may frequently occur, perhaps due to misinterpretation of vascular foraminae or other normal lines in the scaphoid. CT scans are therefore useful for ruling out displacements, but not for diagnosing them. If the amount of displacement cannot be ascertained accurately with plain radiograph and whether to recommend surgery relies on this piece of critical information, then having the CT images will be quite helpful in guiding treatment. The amount of displacement by plain radiograph was noted to poorly correlate with the operative findings.[17]

A suggested algorithm in a patient with a suspected scaphoid fracture is to obtain standard radiographic views and a scaphoid view of the wrist (Figure 1). If a scaphoid fracture is identified on the radiographs and appeared nondisplaced, then a CT scan is performed to evaluate fracture displacement. If the radiographs are negative or equivocal, MRI is performed to determine the presence or absence of a scaphoid fracture and to identify other possible causes of the wrist pain. In cases of scaphoid nonunion, preoperative MRI is recommended to assess vascularity of the proximal pole. It is, however, important to recognize that standard MRI shows only 68% accuracy for assessing proximal pole vascularity, while gadolinium enhanced MRI has 83% accuracy.[18]

Casting versus Internal Fixation for Nondisplaced Scaphoid Fractures

Nondisplaced or minimally-displaced scaphoid fractures can be treated by immobilization for 8 to 12 weeks with a thumb spica cast. There is no consensus about whether or not the cast should include the elbow joint; however, an above-elbow cast to avoid motion of the

scaphoid by eliminating forearm rotation may be preferred for the initial immobilization period of 4 to 6 weeks, followed by a short-arm cast. The healing rate of nondisplaced waist scaphoid fractures with cast immobilization is 88% to 95%, provided that treatment is started within 3 weeks following injury.[19] The main disadvantages of cast immobilization, when compared to surgery, are more frequent office visits to check whether the cast fits properly, more frequent radiographs to assess fracture alignment, potential skin breakdown, prolonged immobilization until complete healing has occurred, stiffness of immobilized joints, and a longer time to healing. To avoid such complications, some surgeons recommend early internal fixation even for nondisplaced fractures. Recently, the technique of percutaneous cannulated screw fixation of nondisplaced or minimally-displaced scaphoid fractures has been described in both anatomical and clinical studies and has demonstrated promising results.[20,21] However, the role, benefits, and risks associated with internal fixation of nondisplaced or minimally-displaced scaphoid fractures remain controversial and have not been established.

In a prospective randomized trial of 88 patients with acute nondisplaced or minimally-displaced fractures of the waist of the scaphoid, Dias et al reported that an early return of grip strength and range of motion after open reduction and internal fixation was transient, and the complication rate related to surgery was high.[22] Postoperative complications included scar problems (10 cases), wound infection (1 case), nerve injury (1 case), and algodystrophy (1 case). They concluded that there was no clear overall benefit of early internal fixation compared with cast immobilization for acute nondisplaced or minimally-displaced fractures. On the other hand, a prospective randomized trial conducted by Bond et al, which compared percutaneous internal fixation (11 patients) with cast immobilization (14 patients) for nondisplaced scaphoid fractures, showed an earlier time to union (7 weeks versus 12 weeks with casting) and earlier return to work (8 weeks versus 15 weeks with casting) with internal fixation, with no functional differences between the two groups after two years.[20] No increase in the surgical complication rate was observed. Recently, in a prospective randomized trial of 60 patients with acute fractures of the waist of the scaphoid, faster radiological union and a more rapid return of function, sports and full work activities, were reported after percutaneous screw fixation compared with cast immobilization.[21]

Although there is no consensus concerning the best treatment for nondisplaced or minimally-displaced scaphoid fractures, prolonged cast immobilization is becoming less well tolerated, especially by younger patients who want to return to work and sports early. Patient expectations are now accelerating the trend to fix even nondisplaced scaphoid fractures, although the long-term outcomes do not seem to differ between internal fixation and cast immobilization for such fractures. Economic analyses have also shown that early internal fixation is superior from a social perspective, by returning people back to their duties 9 earlier.[23,24] For nondisplaced complete waist fractures, the decision about surgery or casting needs to be based on the patient's preference (after presenting to the patient the best evidence from the literature) and the surgeon's comfort level with the surgical treatment. Injudicious operative treatment of scaphoid fractures can lead to disastrous outcomes that may not be remedied.

Concerning the fixation techniques, the percutaneous technique is more challenging than the open technique but it has the advantages in that the carpal ligaments are not divided (thereby preserving the ligament support of the wrist), the blood supply to the scaphoid is not interrupted and there is less scarring that can limit wrist motion. Therefore, percutaneous fixation performed by experienced surgeons may be recommended for active patients with a nondisplaced or minimally-displaced scaphoid fracture.

Internal Fixation for Displaced Scaphoid Fractures

Internal fixation is indicated for displaced waist and proximal pole scaphoid fractures because they have a high risk of delayed union, nonunion, or AVN. An unstable scaphoid fracture is defined as a displacement of the fractured fragments by more than 1 mm in any view. Fractures progressively displaced during cast immobilization are also considered as unstable fractures, even if there is no initial displacement. Proximal pole fractures are more likely to progress to nonunion or AVN because of the tenuous blood supply to the proximal pole of the scaphoid; therefore, internal fixation is strongly recommended.

Since Herbert and Fisher introduced a headless compression screw (Herbert screw) in 1984, internal fixation with a headless screw has become the accepted standard surgical technique for treatment of scaphoid fractures.[3] The greatest advantage of this technique is that the headless screw can be recessed below the articular cartilage that covers 80% of the scaphoid surface. The screw can be inserted through both palmar and dorsal approaches. The palmar approach preserves the important dorsal blood supply and provides access to distal pole and waist fractures; however, it disrupts the carpal ligaments and gives poor exposure of the proximal pole. On the other hand, the dorsal approach provides improved exposure of the proximal pole and allows easier screw placement, but can disrupt the tenuous blood supply. Although the choice of approach may depend on an individual surgeon’s preference and experience, the dorsal approach is strongly recommended for fixation of proximal pole fractures because it is technically easier to insert the screw into a small fractured fragment of the proximal pole (Figure 2).[25] The most important consideration during internal fixation of scaphoid fractures with a headless screw is that the screw should be placed within the center of the scaphoid. A high successful union rate of approximately 95% can be achieved following adequate screw fixation of acute scaphoid fractures with both palmar and dorsal approaches; however, screw malpositioning can result in nonunion of scaphoid fractures. The original Herbert screw is not cannulated. Although the compression jig designed for the original Herbert screw facilitates correct placement of the screw, accurate placement of the compression jig is technically demanding. Recently, several cannulated headless compression screws have been developed. Generally, using such cannulated devices is technically easier than using a compression jig. Furthermore, cannulated devices have enabled surgeons to insert the screw percutaneously through both palmar and dorsal approaches. The percutaneous technique had been recommended only for nondisplaced or minimally-displaced scaphoid fractures, but this technique has recently been used even for displaced scaphoid fractures, with reduction of fracture displacement using fluoroscopic or arthroscopic control.[26,27] Reported union rates and complication rates with the percutaneous technique ranged from 94% to 100% and 0% to 30% respectively, which seem to be comparable to those with the open technique.[28] But the data must be interpreted with

caution for the percutaneous technique; these papers are published by highly experienced surgeons facile in applying arthroscopic procedures to treat wrist disorders.

The disadvantages of surgery include the potential for infection, wound complications, injury to nerves, ligaments, or tendons, injury to the vascular supply to the scaphoid, hardware failure or the need for its removal, and other associated risks such as anesthesia complications. Most complications can be avoided if a meticulous surgical procedure is adhered to. Delayed union and nonunion after internal fixation are unusual but can occur if there is a loss of rigid fixation caused by screw malpositioning, inadequate reduction, or AVN of the proximal pole. Electrical or ultrasound bone stimulation to accelerate bone union can be applied for cases of delayed union after internal fixation.

SCAPHOID NONUNIONS

Nonunion of scaphoid fractures can cause scaphoid nonunion advanced collapse (SNAC) that can lead to degenerative osteoarthritic changes of the wrist. The humpback deformity is a condition in which the lateral intrascaphoid angle is increased because of a shortening of the palmar cortical length. The humpback malunion deformity can cause dorsal intercalated segment instability (DISI) because of the dorsal rotation of the lunate together with the proximal scaphoid fragment (Figure 3). The goals of treatment for scaphoid nonunions and malunions are to achieve healing and to correct of any carpal deformities to prevent arthritis of the wrist.[29] Nonoperative treatments of scaphoid nonunions include electrical or ultrasound bone stimulation combined with cast immobilization. Nonunion by conventional terms is a nonhealed scaphoid 6 months after injury, whereas a delayed union is a time frame that is less than 6 months. Although a nondisplaced scaphoid nonunion may be treated nonoperatively, a very long period of cast immobilization (4 to 6 months) is required. Because surgical treatments are more effective than bone stimulation for treatment of scaphoid nonunions, the indication for nonoperative treatment is restricted to patients who cannot have surgery for any reason. Currently available surgical techniques for the treatment of scaphoid nonunions include nonvascularized or vascularized bone grafting, with or without supplementary internal fixation. Unfortunately, salvage procedures may be necessary for scaphoid nonunions when advanced degenerative arthritis is present throughout the wrist. Salvage procedures include limited intercarpal fusion, proximal row carpectomy, scaphoid excision and four-corner fusion, total wrist arthroplasty and total wrist fusion.

Nonvascularized bone grafting

Russe reported that healing of scaphoid nonunions could be achieved by placing iliac cancellous bone grafts into an egg-shaped cavity created within both fractured fragments.[5] Russe subsequently reported a modification of this technique in which two iliac corticocancellous bone grafts are inserted into the excavated scaphoid, with their cancellous sides facing each other, while the remainder of the cavity is filled with cancellous chips. It has been reported that union rates of approximately 90% can be achieved by this Russe procedure.[5,30] The majority of failed cases are due to AVN of the proximal pole. Thus, the Russe procedure is no longer recommended for this type of fracture. One drawback of the Russe procedure is that it is difficult to correct the humpback deformity using this technique.

To correct such a deformity, one can perform an intercalated wedge bone graft. The wedge bone graft can be fixed to the scaphoid fragments with either Kirchner-wire (K-wire) or screws. Recently, a meta-analysis found that screw fixation with wedge grafting had 14 markedly better results (94% union) than K-wire and wedge grafting (77% union).[31] Although screw fixation with wedge grafting can provide highly successful union rates, this technique is technically quite difficult, because of the need to accurately shape the wedge graft, and to place the screw to fixate 3 bone fragments. An alternative technique to correct the humpback deformity and to heal nonunion is temporary K-wire fixation and bone chip grafting, which was introduced by Stark et al.[32] The humpback deformity is corrected by forcefully extending the wrist dorsally before the fragments are transfixed with K-wires. Cancellous bone chips are then packed tightly into the defect. This technique may be far less technically demanding than screw fixation with wedge grafting. Stark et al reported successful union in 97% of 151 scaphoid nonunions,[32] and recently Finsen et al demonstrated success in 90% of 39 nonunions with this technique.[33] Notably, the results were also excellent for proximal pole nonunions in both studies. In the study by Stark et al, only one of 32 proximal pole nonunions failed to heal with this technique.[32] Finsen et al showed that all 14 proximal pole nonunions healed with the same method.[33] They did not clearly describe whether or not nonunions existed with or without AVN of the proximal pole. Information has been limited for cases in which AVN was associated with proximal pole nonunions, but union rates of 40% to 67% have been reported with nonvascularized bone grafting and internal fixation.[34]

Despite many reports in the literature, treatment strategies for scaphoid nonunions remain controversial. Factors that adversely affect outcome in scaphoid nonunions include a long duration of nonunion, AVN of the proximal pole, and failed previous surgery.[35] One must consider the relative risks and benefits of nonvascularized or vascularized bone grafting, when bone grafting is attempted for scaphoid nonunions. Nonvascularized bone grafting is probably sufficient for most waist fracture nonunions without AVN; however, vascularized bone grafting should be considered at least in cases of a long duration of nonunion, AVN of the proximal pole or failed previous surgery.

Vascularized bone grafting

Vascularized bone grafting in the treatment of scaphoid nonunions has gained considerable popularity in recent years. The principal advantage of vascularized bone grafting is a potentially more reliable union after grafting. Several methods of transferring a vascularized bone graft to the scaphoid have been reported in the literature.[35,36] These include the pronator quadratus pedicled bone graft, pedicled grafts based on the ulnar artery or the palmar carpal artery, the radial styloid fasciosteal graft, and pedicled grafts from the index finger metacarpal and the thumb metacarpal. Free vascularized bone grafts from the iliac crest and the medial femoral supracondylar region have also been reported. The vascularized bone graft derived from the dorsal radial aspect of the distal radius, which is nourished by the 1,2 intercompartmental supraretinacular artery (1,2 ICSRA), was described by Zaidemberg et al.[37] Recent papers on vascularized bone grafts in the treatment of scaphoid nonunions have mainly described the use of the 1,2 ICSRA bone graft (Figure 4).

Most of the published studies on vascularized bone grafting for all scaphoid nonunions have reported union rates of 80% to 100%, but only some of the nonunions had AVN.[35,36] This raises the important question of whether or not improvement of the vascularity of the proximal pole would increase rates of union in cases with AVN. Recently, a meta-analysis found that vascularized bone grafting achieved an 88% union rate compared with a 47% union rate with screw and intercalated wedge fixation in scaphoid nonunions with AVN.[31] However, in some reported series, the means of assessing the vascularity of the proximal pole were not described, and in others it was only assessed by the presence of increased density of the proximal fragment on the preoperative radiographs. Perlik and Guildford reported that increased density on the preoperative radiographs has only 40% accuracy for detecting proximal fragment avascularity, and thus many cases that were classified as AVN may actually have had satisfactory vascularity of the proximal pole.[38] In the study by Boyer et al, 6 of 10 proximal pole nonunions healed with the 1,2 ICSRA bone graft.[39] This study included only patients with AVN of the proximal pole, as proven by the absence of punctuate bleeding from the proximal pole at surgery. Straw et al also reported more discouraging results in that only 2 of 16 nonunions with AVN united with the 1,2 ICSRA bone graft.[40] Recently, Chang et al evaluated a large series of 1,2 ICSRA bone grafts that were performed for scaphoid nonunions and showed that 71% of 48 nonunions healed and the union rate was 91% in the absence of AVN and 63% in the presence of AVN.[41] Overall, although most of the results reported to date were obtained from a selection of patients with different indications, the balance of evidence suggests that vascularized bone grafting may improve healing of scaphoid nonunions, particularly in the presence of AVN of the proximal pole. However, it is important to note that a successful outcome is not universal and depends on careful patient and fracture selection and use of appropriate surgical techniques, even when a 1,2 ICSRA bone graft is used for scaphoid nonunions.

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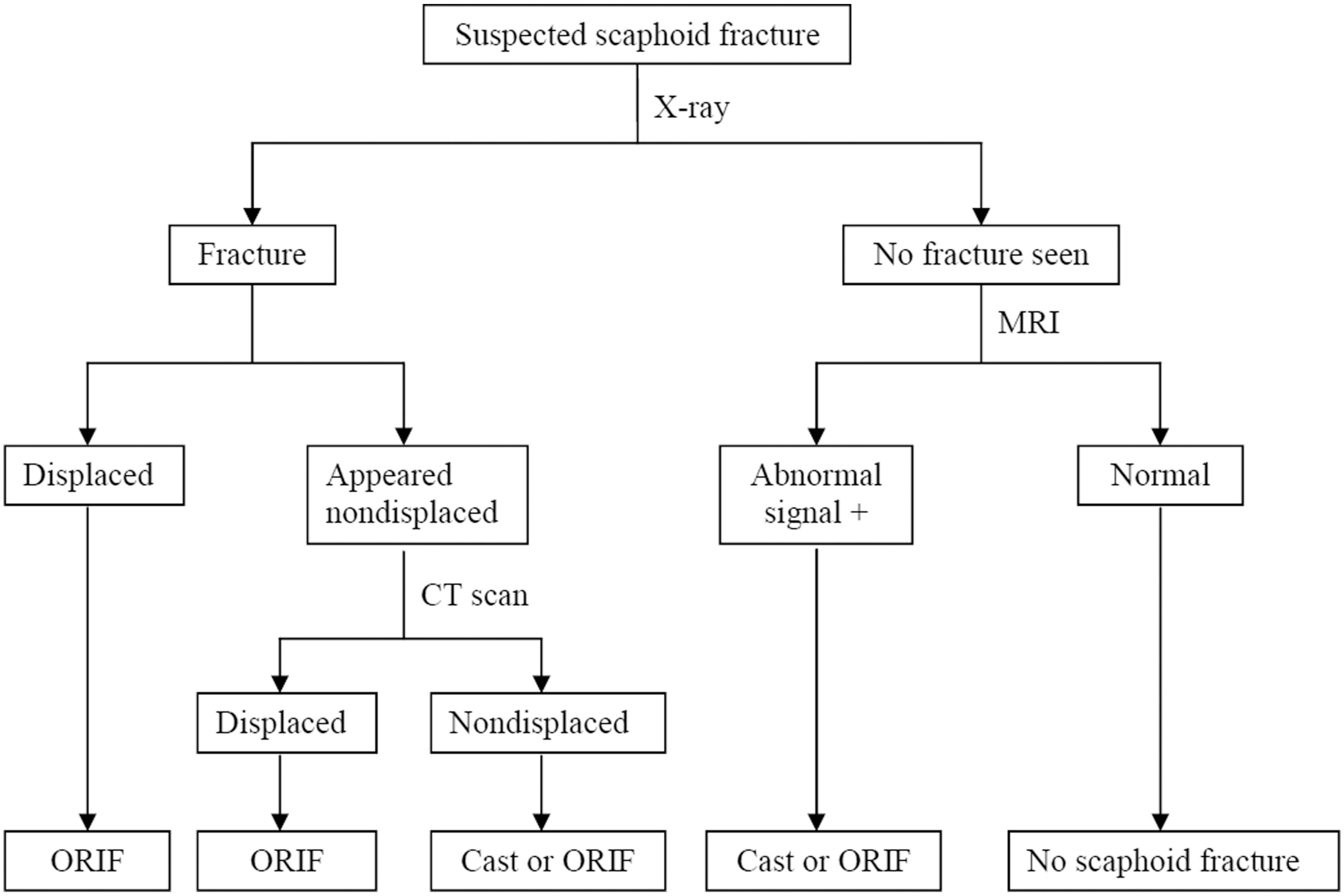
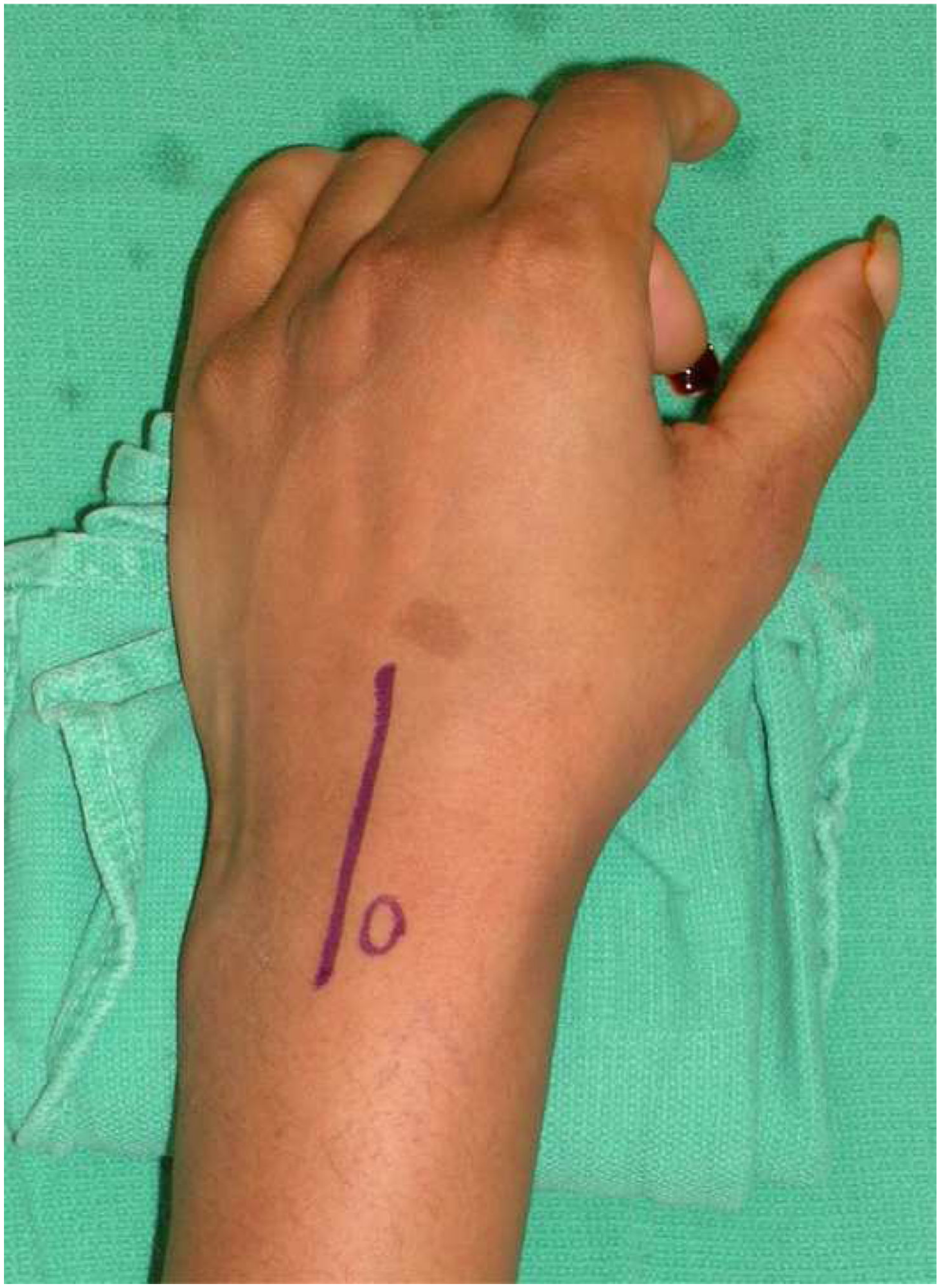


Figure 1.
Algorithm for suspected scaphoid fracture management

A

B



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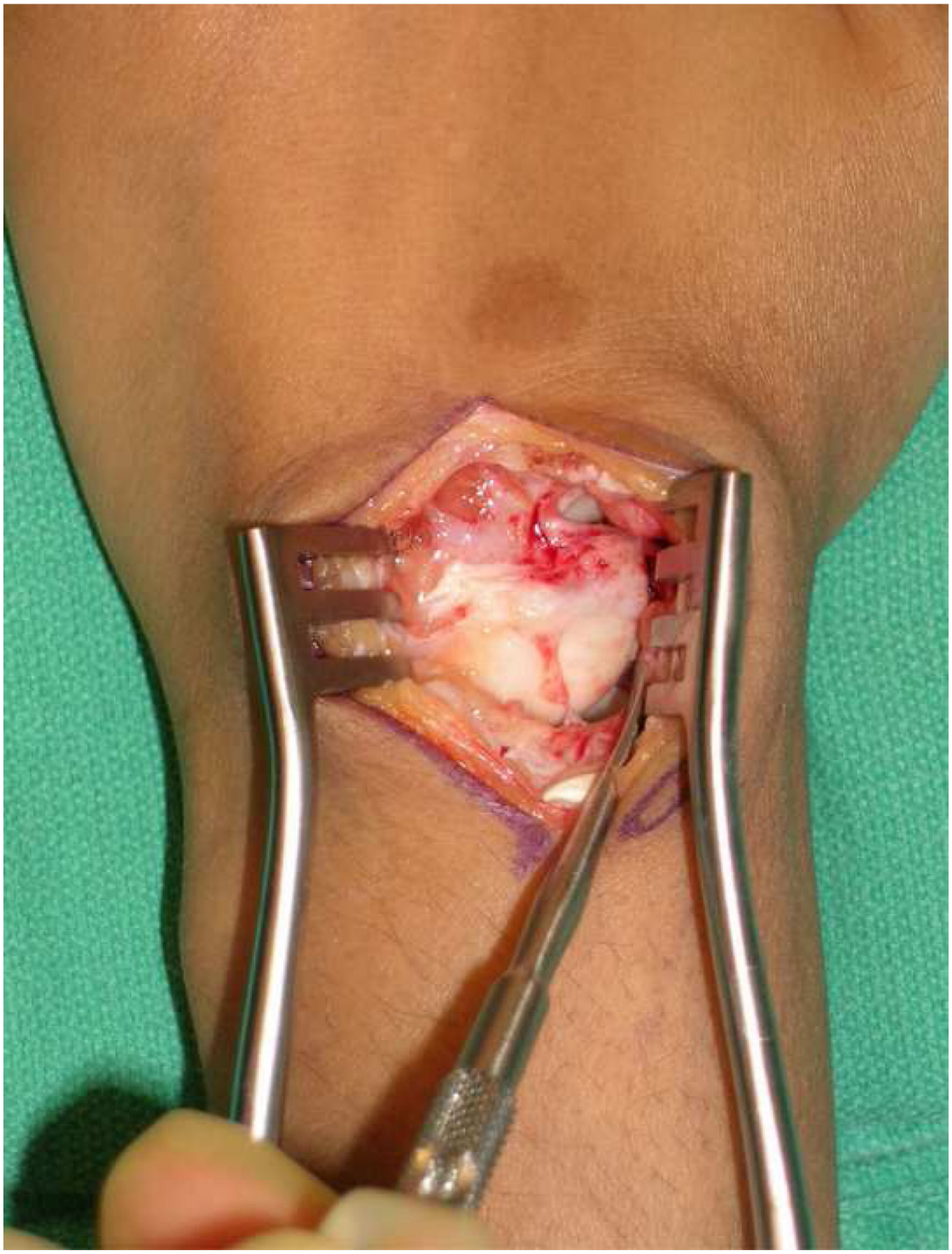

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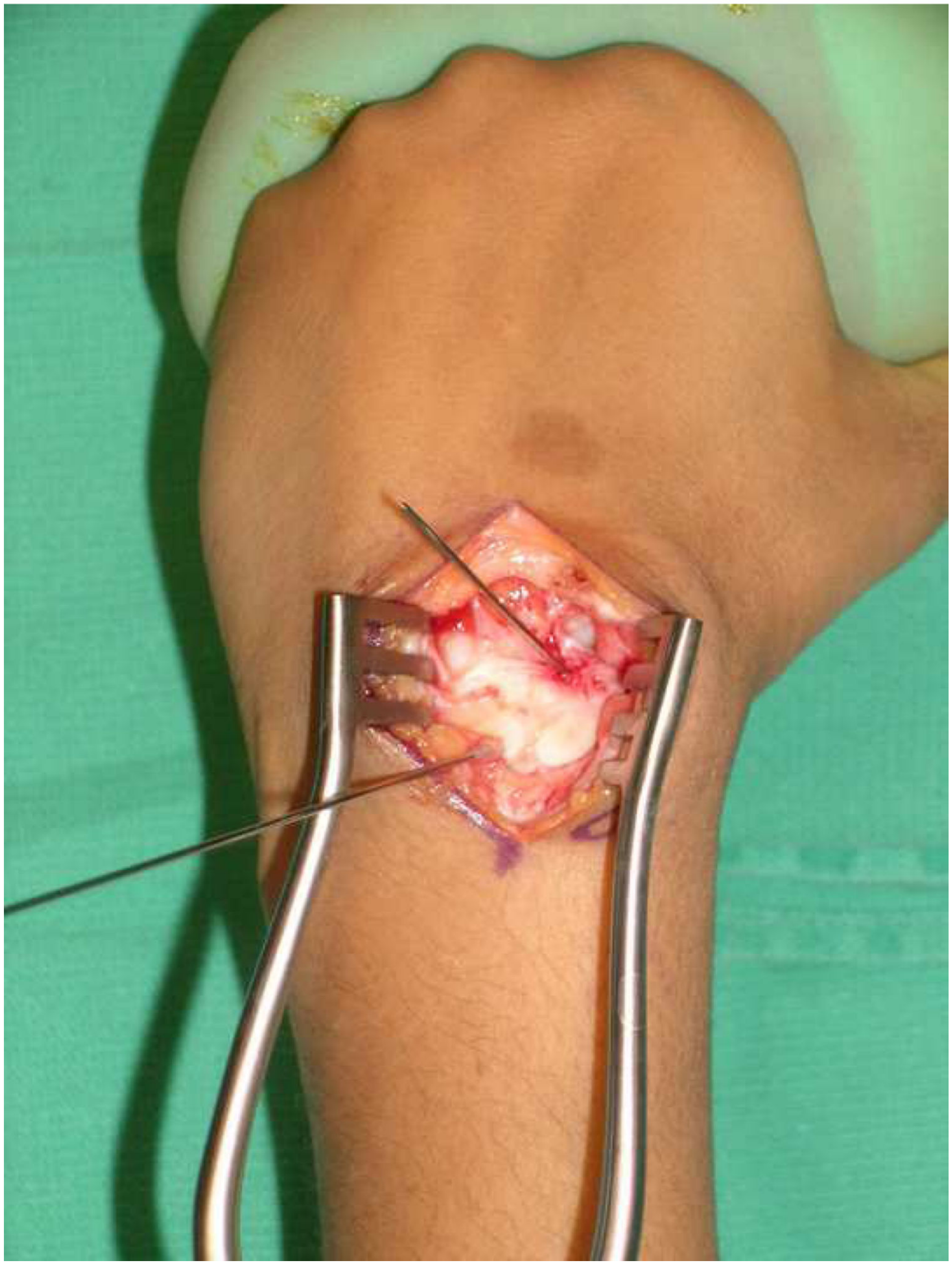

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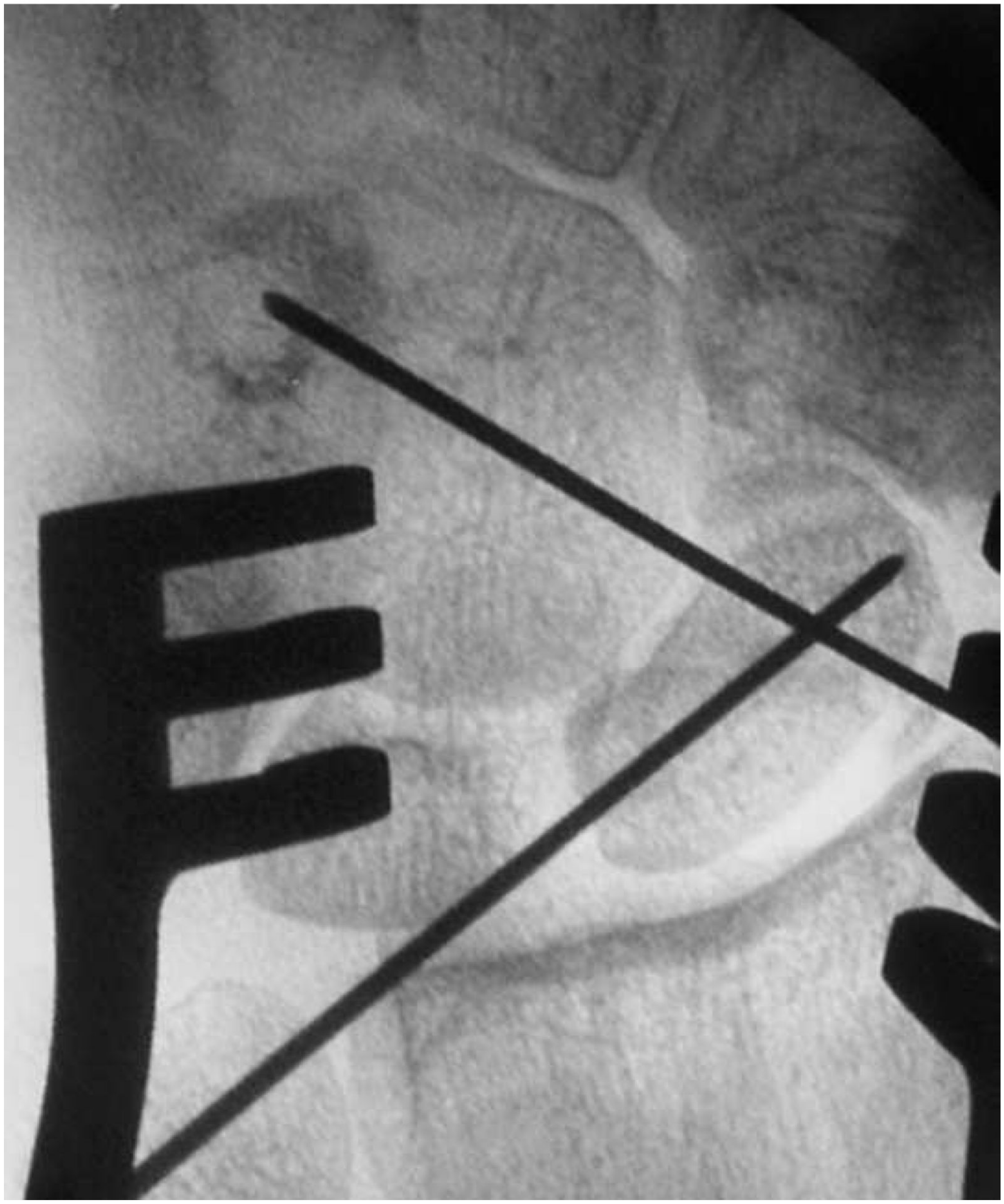

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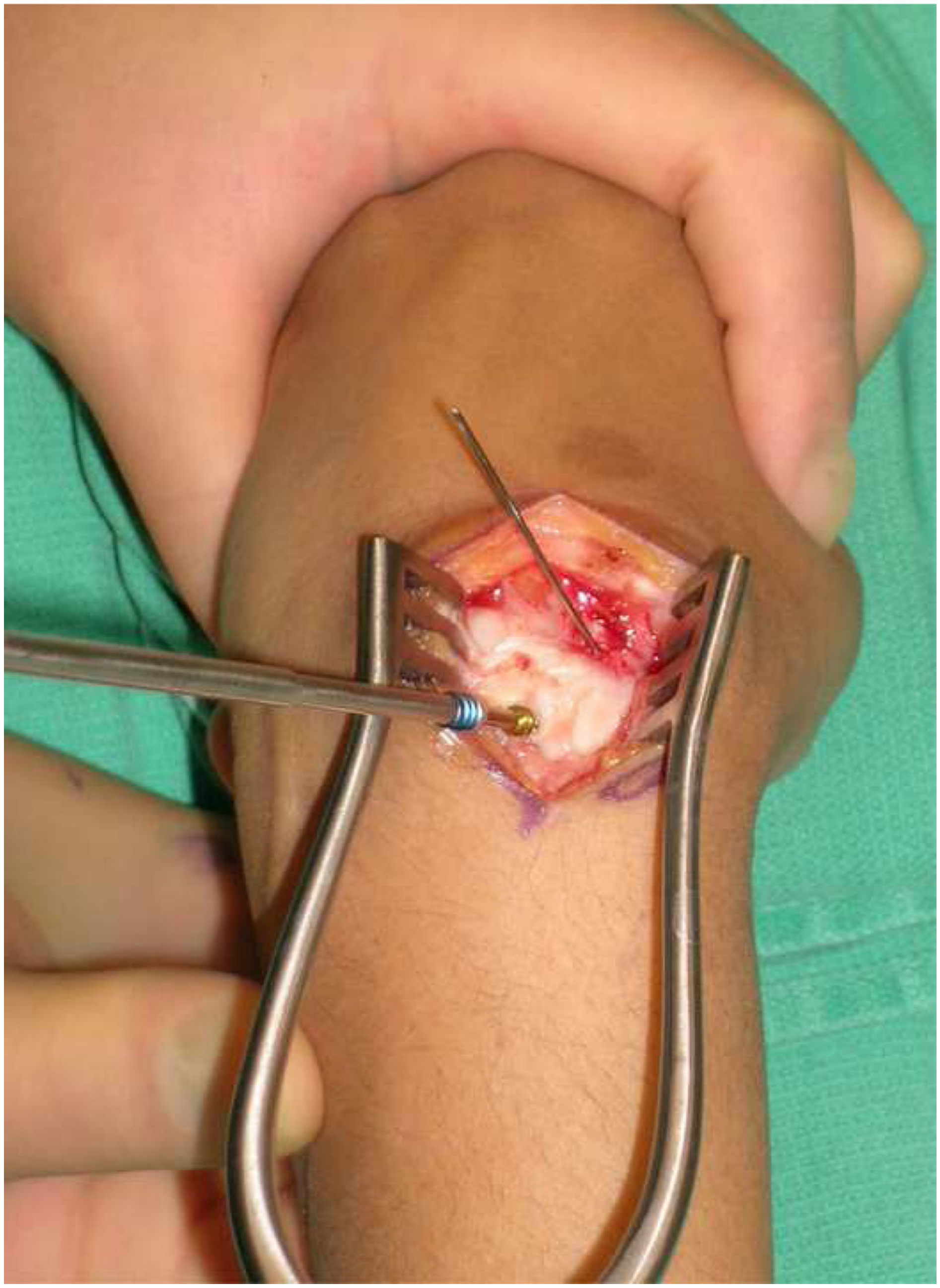


G

Figure 2.
Surgical procedures of screw fixation for a scaphoid fracture with the dorsal approach.
(A) Preoperative X-ray showing a displaced fracture of the waist of the scaphoid.
(B) Skin incision for the dorsal approach.
(C) The scaphoid is exposed by making a longitudinal incision of the wrist capsule between the tendons of the extensor carpi radialis longus and the extensor carpi radialis brevis.
(D) The fracture fragments are reduced by using K-wires inserted as joysticks.

(E) Reduction of the fracture and guidewire placement within the center of the scaphoid is confirmed under fluoroscopy.

(F) An appropriate length screw is inserted and buried below the articular cartilage.

(G) Postoperative X-ray showing proper screw placement within the center of the scaphoid.

A

B

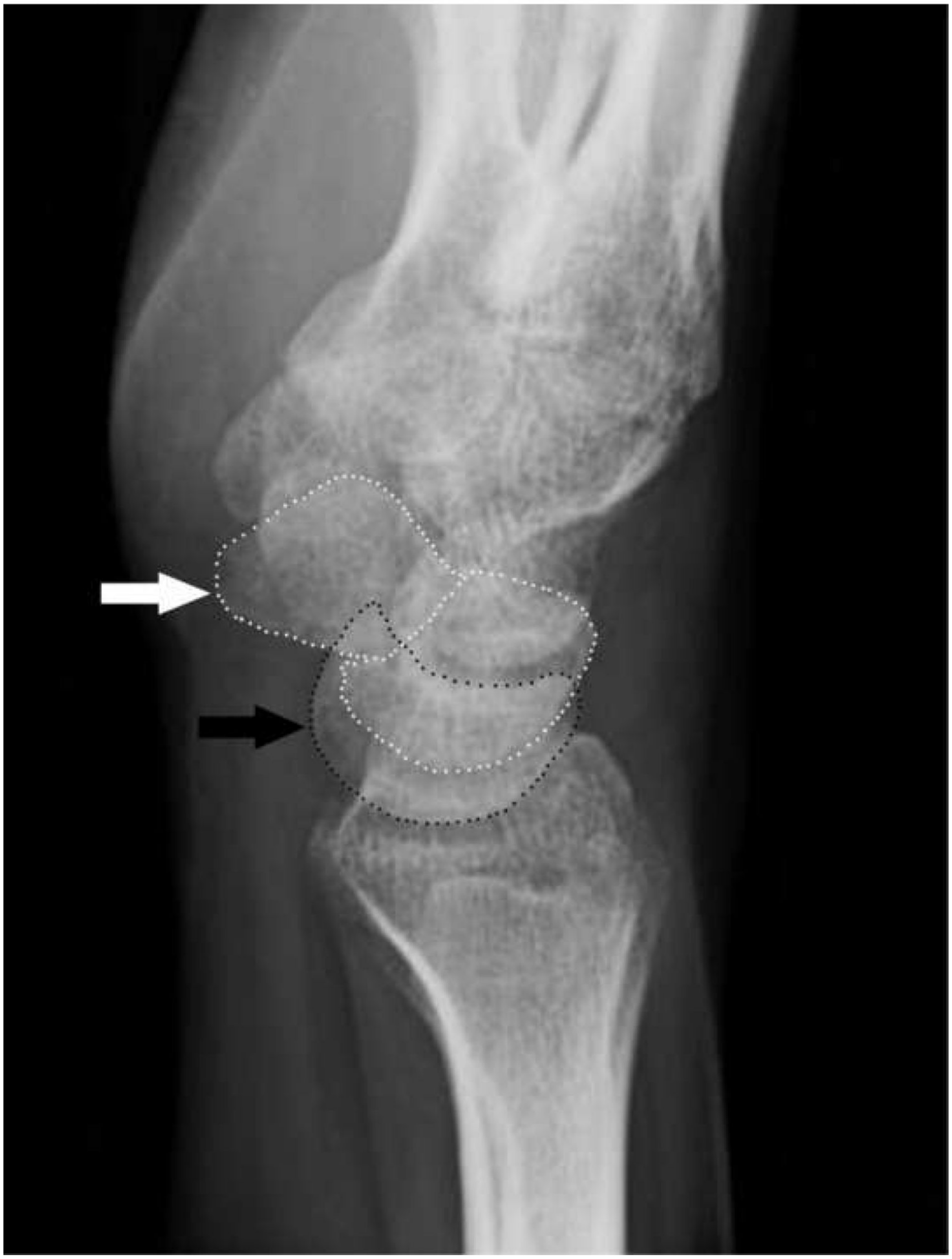


Figure 3.

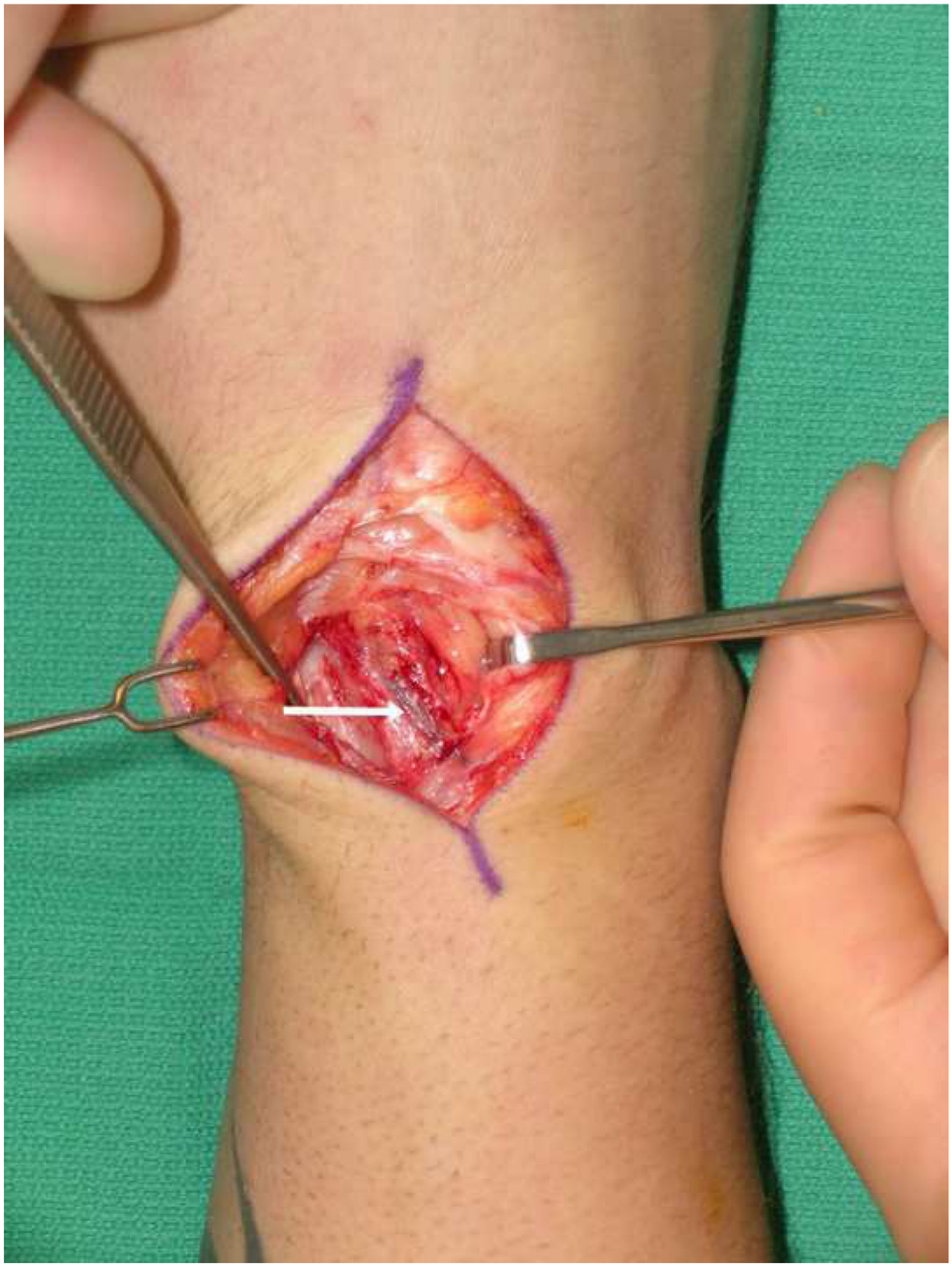
(A) The PA view showing a scaphoid nonunion at the waist.

(B) On the lateral view, the distal scaphoid fragment is flexed (white arrow) whereas the lunate is rotated dorsally with the proximal scaphoid fragment (black arrow), indicating the DISI deformity.

A

B

c



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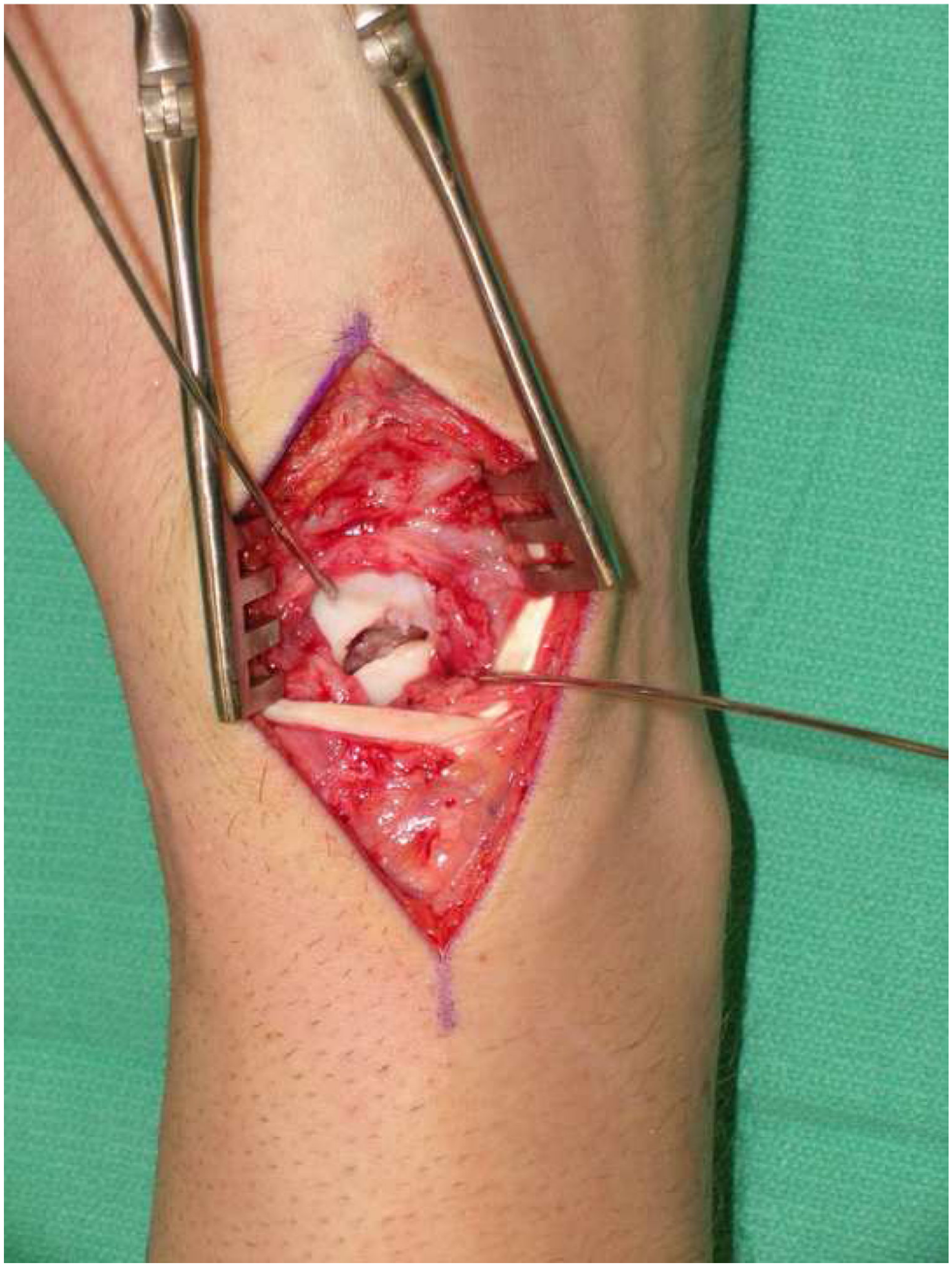

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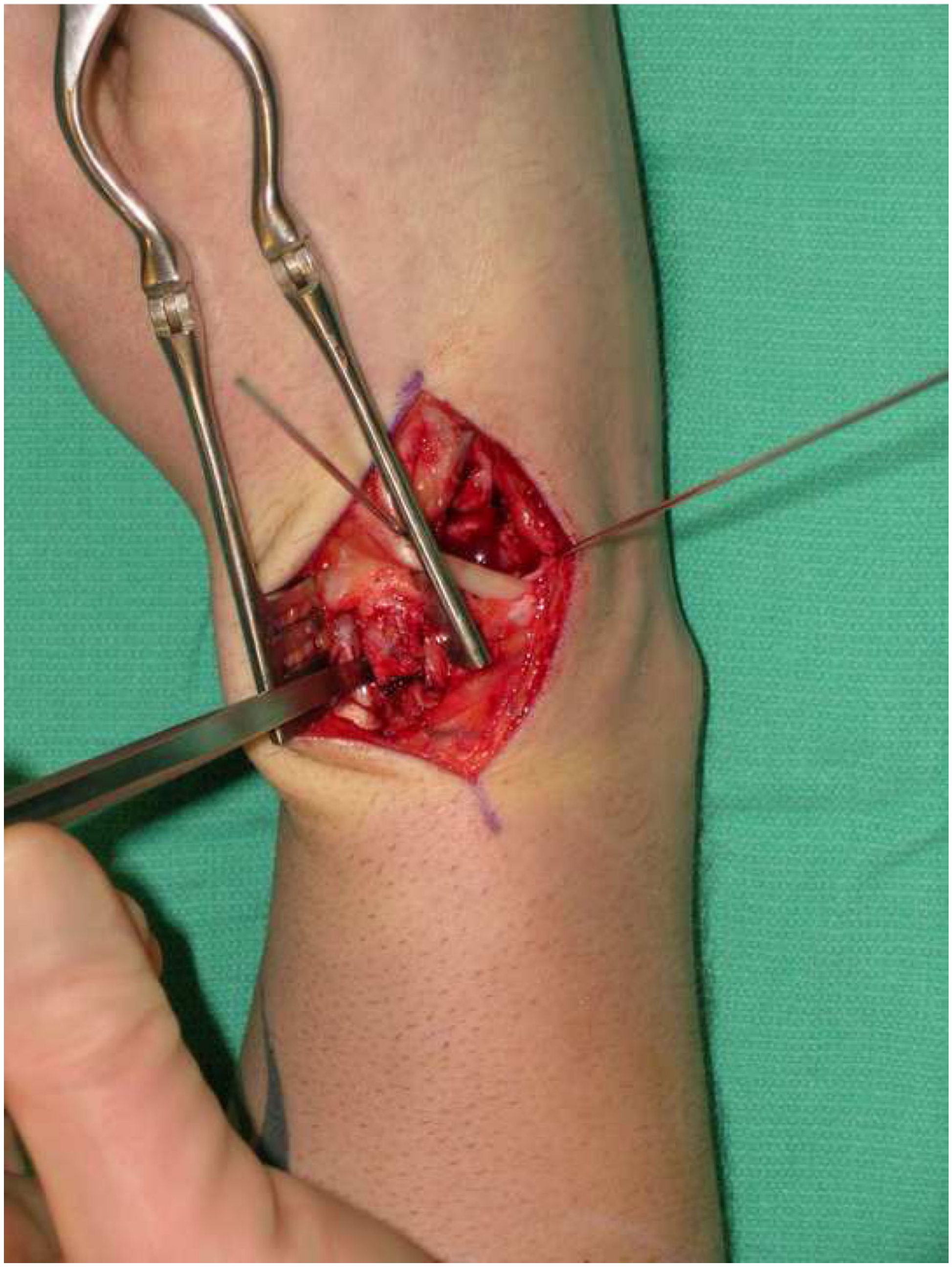

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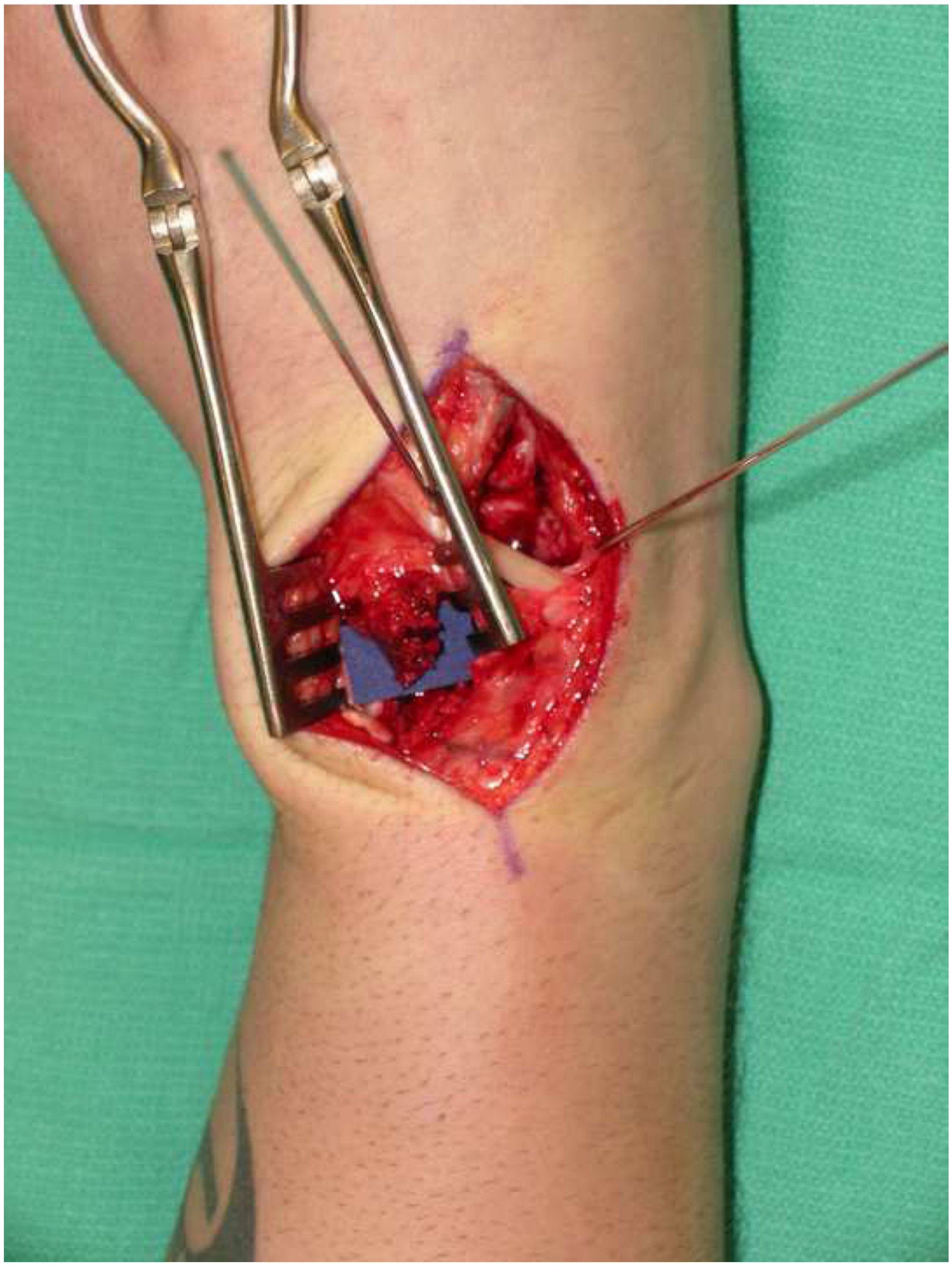

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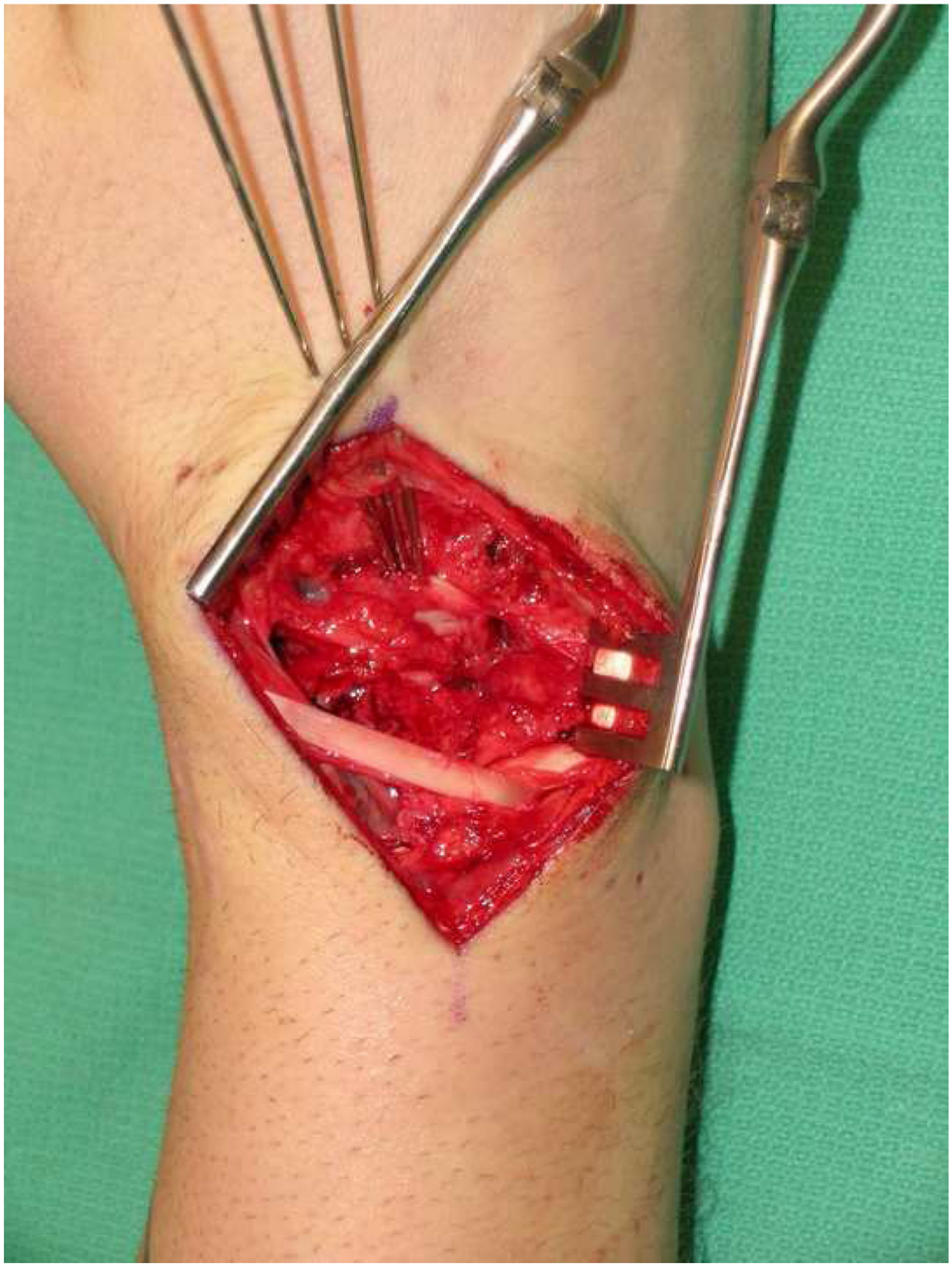

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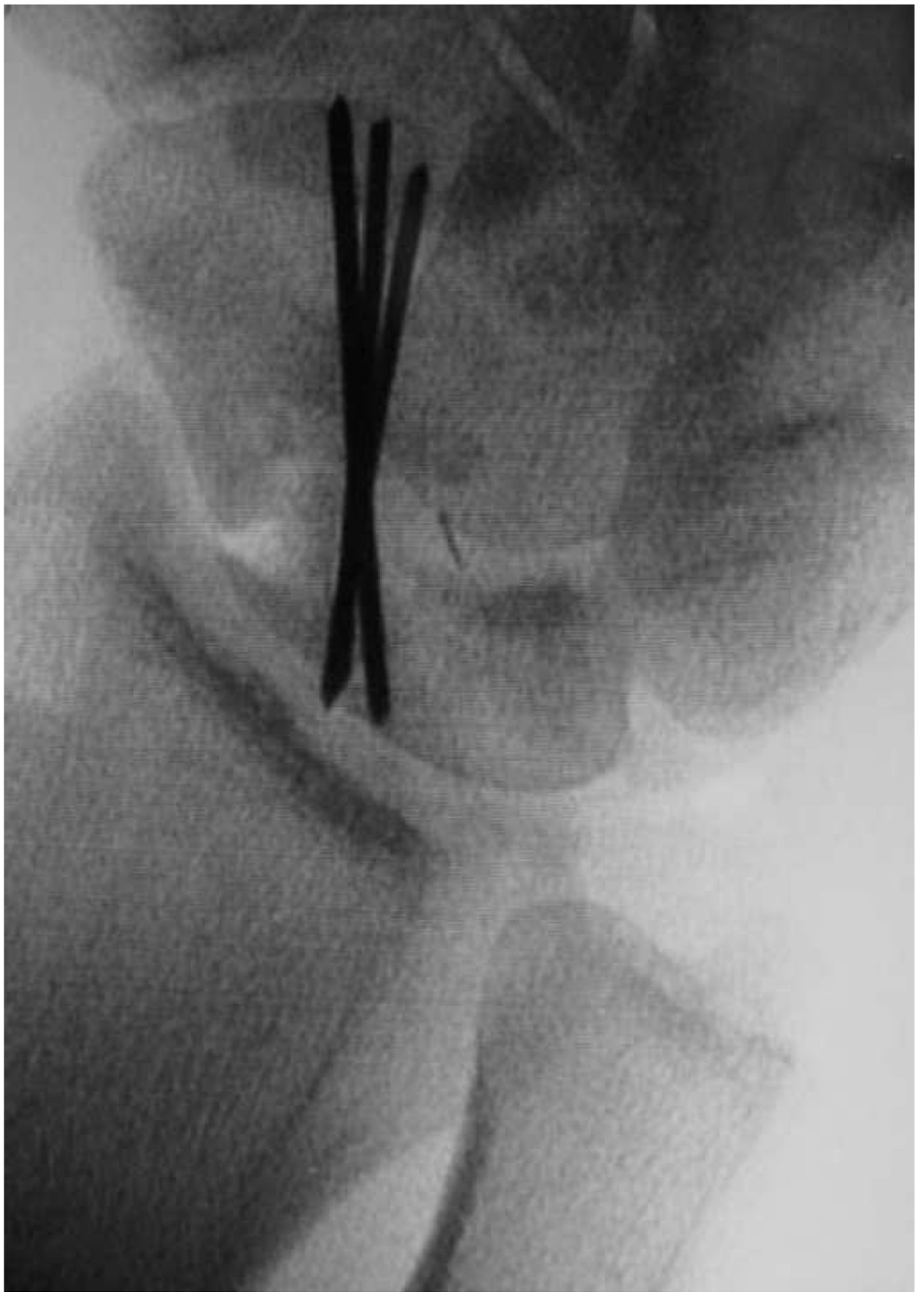

Figure 4.
Surgical procedures of the 1,2 ICSRA vascularized bone graft for a scaphoid nonunion.
(A) X-ray showing a sclerotic proximal pole indicating possible avascular necrosis (arrow pointing to the nonunion line).
(B) MRI confirmed the avascularity of the proximal pole (arrow).
(C) The 1,2 ICSRA is found on the surface of the extensor retinaculum between the first and second extensor compartment (arrow).

(D) Before elevating the graft, the scaphoid is exposed and curetting is performed to remove any fibrous tissue from the nonunion site.

(E) The bone is elevated with the osteotome.

(F) The graft with vascular pedicle is elevated from the distal radius.

(G) The graft is transposed beneath the wrist extensors and impacted into the scaphoid defect. Internal fixation with K-wires is performed.

(H) Proper K-wires placement is confirmed under fluoroscopy.

Table 1

Herbert and Fisher Classification of Scaphoid Fractures

Type A: Stable acute fractures
A1: Tubercle fracture
A2: Incomplete waist fracture
Type B: Unstable acute fractures
B1: Distal oblique fracture
B2: Complete or displaced waist fracture
B3: Proximal pole fracture
B4: Transscaphoid perilunate dislocation fracture
B5: Comminuted fracture
Type C: Delayed union
Type D: Established nonunion
D1: Fibrous union
D2: Pseudarthrosis