



# Practicability of a locking plate for difficult pathologies of the scaphoid

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## Abstract

**Introduction** Headless compressions screws are the most implanted devices for scaphoid fractures and nonunions. For cases when screw osteosynthesis is not possible, a special locking plate for scaphoid reconstruction has been developed. The purpose of this study was to evaluate the safety and practicability of this device for difficult scaphoid pathologies.

**Materials and methods** Between March 2010 and December 2014, 20 patients (age range 16–59 years) were treated with scaphoid locking plate osteosynthesis. In 17 cases it was due to scaphoid nonunion or delayed union and in three cases to treat a complex multi-fragmentary fracture of the scaphoid. Most of the initial fractures were located either in the proximal third ( $n=9$ ) or the middle third ( $n=8$ ) of the scaphoid.

**Results** Mean follow-up was  $14.6 \pm 8.9$  months (range 2–30 months). All three scaphoid fractures (100%) showed bony healing in the CT scan after  $2.7 \pm 0.6$  months. 15 of 17 (88.2%) patients with scaphoid nonunion demonstrated bony healing in the latest CT scan at an average of  $6.2 \pm 8.1$  months (range 2–11 months) after scaphoid reconstruction. Range of motion (extension/flexion) was  $104^\circ \pm 18.4^\circ$  (range  $80^\circ$ – $150^\circ$ ) and about one third less than the unaffected side. The average grip strength averaged 38.2 kg on the operated side and 44.1 kg on the unaffected side after surgery.

13 plates (65%) had to be removed due to impaction of the plate or protrusion of the screws.

**Conclusions** This new locking device for scaphoid reconstruction seems to be a safe, useful and reliable tool in the treatment of difficult nonunions or multi-fragmentary scaphoid fractures. The practicability is convincing and satisfying fusion rates can be accomplished. However, most patients require hardware removal. We recommend using this plate as a rescue option when a stable osteosynthesis is necessary for the healing process and screw fixation has already failed or is not possible.

**Keywords** Scaphoid · Nonunion · Comminuted scaphoid fracture · Locking plate · Fixation

## Introduction

Unstable fractures as well as nonunions of the scaphoid need to be treated by surgery. Left untreated, the scaphoid nonunion collapses into a humpback deformity and the lunate,

together with the proximal pole, into a dorsal intercalated segment instability which might end in an advanced carpal collapse [1–9].

The aim of scaphoid reconstruction is to achieve stability and bony healing of vital bone and subsequently re-union of the scaphoid in the original anatomical form and shape [10–14]. In most patients this can be achieved by using a compression screw [15, 16]. Treatment options have been improved by the development of cannulated and self-drilling compression screws as well as angular stable systems, resulting in lower nonunion rates [17]. Some authors recommend using two headless compression screws in unstable scaphoid fractures and in scaphoid nonunions of the waist [18, 19]. Scaphoid reconstruction however remains a demanding operative procedure.

The idea of using a plate for difficult pathologies of the scaphoid is not totally new. In 1977 Ender described the

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treatment for scaphoid nonunion with a hook plate [20]. An iliac crest bone graft was used; the hook plate was fixed in the distal portion of the scaphoid by screw and in the proximal fragment with a staved hook. Other authors have described a plate fixation of the scaphoid using a dorsal approach [21]. However, palmar cortical loss and severe humpback deformity complicate dorsal plating.

Recently, a scaphoid palmar locking plate was designed for the treatment of difficult scaphoid fractures and non-unions. The plate is placed on the palmar surface of the scaphoid. The aim of this study is to evaluate the safety, practicability and reliability of this new device for difficult scaphoid pathologies.

## Materials and methods

Between March 2010 and December 2014, 20 patients were treated using the 1.5 scaphoid palmar locking plate (Medartis AG, Basel, Switzerland). The indication for using the scaphoid palmar locking plate was either a complex fracture of the scaphoid or scaphoid nonunion or delayed union. Patients with avascular necrosis of the proximal pole were not treated. Scaphoid nonunion was defined as failure of union with or without treatment after 4 months.

## Surgical technique

A palmar approach radially of the flexor carpi radialis tendon was used in all patients to expose the scaphoid. Then the palmar wrist capsule as well as the radioscapocapitate ligament (partially) was incised. Removal of headless compression screws or Kirschner wires due to previous surgery was required in some cases. In patients with scaphoid nonunion, a thorough debridement of the pseudarthrosis was performed until punctual bleeding was achieved at both the proximal and the distal poles of the scaphoid. Bone grafting was used if needed. In cases of bone loss due to scaphoid cysts or nonunion, bone graft was either harvested from the iliac crest or the distal radius. After appropriate anatomical realignment of the scaphoid the stabilization of the scaphoid was performed using an anatomically preshaped plate on the palmar surface. Locking screws were used for fixation. Up to three screws were placed on each side of the 0.8-mm profile locking plate. In some cases, the scaphoid was provisionally stabilized using a Kirschner wire to maintain the reduction. Restoration of length and shape were controlled clinically and fluoroscopically.

The wrist and thumb were immobilized after surgery with a short arm cast including the MP-joint of the thumb.

**Table 1** Demographics

Patients available for follow-up	20
Gender	15 male, 5 females
Affected hand	10 right, 10 left
Mean age at the time of the operation (average $\pm$ SD in years)	33.1 $\pm$ 14.0
Mean follow-up after operation (average $\pm$ SD in months)	14.6 $\pm$ 8.9
Immobilization after surgery (average $\pm$ SD in weeks)	9.5 $\pm$ 2.6

## Assessments

The patient charts were retrospectively analyzed. Wrist movement (flexion and extension) as well as forearm rotation was measured. Grip strength was assessed for each hand using a Jamar Hand Dynamometer (Sammons Preston Rolyan, Bolingbrook, IL, USA) on handle position two with seated patients in neutral wrist position and elbow by their side flexed to a right angle and repeated three times. The average grip strength was calculated for the left and the right hand.

The functional outcome was calculated by the Mayo Wrist Score [11]. A patient questionnaire assessing occupation, satisfaction with the procedure and complications was completed at follow-up.

## Statistical analysis

Means and standard deviations (SD) of variables were tabulated for 20 patients.

## Results

We retrospectively analyzed 20 patients after plate osteosynthesis of the scaphoid at a mean follow-up of 14.6  $\pm$  8.9 months (range 2–30 months). The patients' characteristics are summarized in Table 1.

17 of the patients were treated due to scaphoid nonunion or delayed union and three patients because of fractures with pre-existing scaphoid bone cysts. In these cases, headless compression screws did not appear to be appropriate treatment options.

Most of the initial fractures were located in the proximal third of the scaphoid (9 patients), followed by the middle third (8 patients) and the distal third (3 patients).

In 16 patients the locking plate fixation was used as primary option. Four patients have had surgery to treat scaphoid pathologies before. In three of the four patients headless

compressions screws were used and in one patient Kirschner wire osteosynthesis.

Time between trauma and operation was  $27 \pm 2.6$  days in the three patients with multi-fragmentary fractures.

### Operation and post-operative treatment

The mean duration of the procedure was  $104.7 \pm 14.0$  min. 18 patients were operated under general anesthesia and two patients under brachial plexus block. As four patients already had prior surgery, hardware removal was additionally performed during osteosynthesis of the scaphoid. Bone grafts were harvested from the iliac crest (18 patients) and from the distal radius (one patient). One patient with a multi-fragmentary scaphoid fracture did not require bone grafting. The mean length of in-hospital stay was  $5.3 \pm 1.0$  days. No major complications occurred during surgery. There have been no complications at the donor site (iliac crest and radius).

Post-operative immobilization was performed for  $9.5 \pm 2.6$  weeks (range 6–14 weeks).

### Healing rate, complications and hardware removal

In all of the three scaphoid fractures (100%) bony healing in the CT scan was achieved after  $2.7 \pm 0.6$  months. There were no complications in the postoperative course. Two of the three scaphoid plates (66.7%) had to be removed due to perception of interference by patients, which resolved after removal. Case example 1 demonstrates one of these cases.

15 of 17 (88.2%) patients with scaphoid nonunions showed bony healing in the latest CT scan at an average of 6.2 months (range 2–11 months) after scaphoid reconstruction.

After bony healing, hardware removal had to be performed in 10 of 15 patients (66.7%). Reasons for hardware removal were mechanical blockage of wrist flexion (6 patients) and/or perception of interference by patient (8 patients). Removal of Kirschner wires was performed in 2 patients additionally to plate removal, and in one patient hardware removal was combined with curettage of a newly developed scaphoid cyst and bone grafting (case example 2). After hardware removal, all patients' complaints resolved.

In 2 of the 17 (11.8%) patients with scaphoid nonunions, bony healing could not be achieved after 12 months.

One patient suffered from plate and screw breakage. Therefore, operative revision with hardware removal, reconstruction with bone graft from the iliac crest and stabilization using Kirschner wires was performed 22 months after the initial operation. Bony healing was achieved after 4 months and the patient was satisfied with the final outcome.

The second patient also suffered from screw breakage (Fig. 1). Operative revision with hardware removal and the use of a free vascularized bone graft from the medial femoral



Fig. 1 Example for screw breakage

condyle and osteosynthesis by Kirschner wires and scaphoid screw was performed 18 months after the initial operation. One year later, bony healing was still not achieved. Unfortunately, the patient was lost to follow-up.

### Motion and grip strength

The clinical results of all 20 patients showed an average range of motion (ROM) for wrist extension and flexion of  $104^\circ \pm 18.4^\circ$  (range  $80^\circ$ – $150^\circ$ ) of the affected side in comparison of  $154^\circ \pm 10.1^\circ$  (range  $140^\circ$ – $180^\circ$ ) of the healthy side at the last record. Pronation and supination were feasible without limitation. Table 2 shows the hand function in detail.

The average grip strength was  $38.2 \pm 9.4$  kg (range 22–55 kg) on the operated side and  $44.1 \pm 10.5$  kg (range 26–75 kg) on the unaffected side after surgery.

### Mayo Wrist Score, assessment of pain and sickness absence

The mean Mayo Wrist Score was  $76.8 \pm 19.1$  at follow-up. According to the Mayo Wrist Score interpretation, 4/20 (20%) patients were rated excellent, 8/20 (40%) good and 6/20 (30%) satisfactory. The two patients (10%) without bony healing after the initial operation were rated as poor.

Twelve patients were free of pain, seven patients had moderate pain and one patient was in severe pain. 19/20 (95%) patients were satisfied with the operation, 18/20

**Table 2** Hand function

	Average $\pm$ SD scaphoid nonunion (SN) ( $n = 17$ )	Comparison to contralateral wrist <sup>a</sup> SN (%)	Average $\pm$ SD scaphoid fracture (SF) ( $n = 3$ )	Comparison to contralateral wrist <sup>a</sup> SF (%)
Extension of the affected wrist	54.4 $\pm$ 9.0	74.2	46.7 $\pm$ 5.8	63.7
Flexion of the affected wrist	54.1 $\pm$ 17.0	68.2	40.0 $\pm$ 0.0	52.2
Pronation of the affected wrist	90.0 $\pm$ 0.0	100	90.0 $\pm$ 0.0	100
Supination of the affected wrist	89.4 $\pm$ 2.4	99.3	90.0 $\pm$ 0.0	100

<sup>a</sup>Values presented as percentage (postoperative motion affected hand/postoperative motion contralateral hand)

(90%) patients would have had surgery again knowing the final outcome.

All 18 patients with bony healing returned to work, including 4 heavy manual workers. All patients, who received workers compensation ( $n = 6$ ), were able to return to work.

## Discussion

Despite therapeutic improvements, treatment of scaphoid pathologies like multi-fragmentary fractures, fractures with additionally bone cysts or nonunions of the scaphoid waist with humpback deformity remains demanding. Although there is a variety of bone graft options, a sufficiently stable scaphoid reconstruction is needed for bony healing [22–27]. Union and stability have been improved with the establishment of using headless compression screws [15].

Quadlbauer et al. demonstrated in a retrospective study that using two headless compression screws in unstable scaphoid fractures or scaphoid nonunions of the waist results in higher union rates compared to only one screw. Additionally they proposed that using extracorporeal shockwave therapy after scaphoid stabilization with either two scaphoid screws or a plate increases the vascularity and the rotational stability [18, 19].

The development of new locking plates offers an additional option for scaphoid reconstruction. Biomechanical studies demonstrated greater stability for scaphoid plate fixation in comparison to single compression screw fixation [28, 29, 17, 30].

In this study, we investigated the mid-term clinical outcomes of patients with complex scaphoid pathologies who were treated with locking plate fixation and showed.

No major complications occurred and healing rates as well as clinical outcomes were satisfying.

Recently, several studies regarding scaphoid locking plate usage have been published [31–34]. The authors mainly used the scaphoid plate in nonunions. In addition to the treatment of scaphoid nonunion, we reported our experience with the new plate in three patients with complex scaphoid fractures.

The healing rate in our nonunion group is comparable to other studies using the locking plate in nonunion cases. Leixnering et al. reported the first clinical experience with this adjustable plate in a smaller cohort and described bony healing of all scaphoids [33]. In their study 11 patients with scaphoid nonunion were operated and healed after a mean of 4 months (2–7 months).

Another retrospective study described the clinical and radiographic evidence for union in 18 of 20 patients with a follow-up of 6 months using palmar plate locking fixation [31]. All patients suffered from scaphoid nonunion with humpback deformity. 11 of 20 patients demonstrated additional avascular necrosis of the proximal scaphoid pole. Therefore, all patients were treated with a pedicled vascularized palmar carpal artery bone graft combined with the scaphoid locking plate. In 18 cases bony healing could be achieved after 4.7 months (90%). Esteban-Feliu et al. reported the clinical and radiological outcomes of 15 patients with scaphoid nonunion treated with palmar scaphoid plate osteosynthesis with minimum 3 years follow-up [32]. In 13 of 15 patients (87%) bony healing was observed at an average of 5 months after surgery.

The healing rates of the mentioned studies were comparable, yet the types of bone grafts used varied. Leixnering et al. used autogenous spongy bone from the iliac crest, whereas Doods et al. combined plate fixation with a pedicled vascularized palmar carpal artery bone graft and Esteban-Feliu et al. used wedge-shaped bone grafts, which were harvested from the distal radius [31–33]. In our study, we used non-vascularized grafts from the iliac crest in all 17 cases of nonunion. In the fracture group, one patient was treated with a bone graft from the iliac crest, one from the distal radius and in one case no bone graft was needed. It still remains unclear, if the type of bone graft that is used in combination with the scaphoid plate influences the healing rate. Schmidle et al. developed a treatment algorithm for bone graft selection in scaphoid nonunion based on the assessment of bone structure on 2D-CT scan with information on the 3D-CT fracture location [35]. This approach might assist decision-making whether a vascularized or a non-vascularized bone

graft should be used in the treatment of scaphoid nonunions. However, this algorithm was not used in our study or other studies using the scaphoid locking plate.

There are some differences in the clinical results of the published studies, particular regarding range of motion (extension/flexion). Esteban-Feliu et al. described a mean ROM of 94° of the affected wrists after surgery [32]. In our study the mean ROM was slightly better with a mean of 104°. Doods et al. reported a mean flexion of 58° and a mean extension of 62° post-operatively [31]. The results of the study by Leixnering et al. were the most favorable with a mean ROM of 177° [33]. Reasons for these variances might be the different clinical entities of scaphoid pathologies as well as the use of different types of bone grafts. It is worth noting, that in our study the clinical outcome of patients with scaphoid fracture was inferior compared to the nonunion group. One reason for this could be, that we only used the palmar locking plate in very complex fractures where no other option seemed to be feasible. However, due to the small sample size, a detailed statistical analysis was not possible and therefore our results remain descriptive.

The union rate and the clinical outcome were comparable to most other series, yet Esteban-Feliu et al. described unsatisfactory results with the palmar scaphoid plate due to complications [32]. These included one breakage of the plate and 3 patients with screw back-out. One explanation might be, that they only used non-locking screws. The authors also noted an impingement between the radial styloid and the scaphoid plate in 6 patients, which resulted in hardware removal in 5 patients [32]. To avoid potential complications such as radiocarpal plate impingement and tendon rupture, Sanders et al. recommended plate removal after 4 months in a study with a mini-condylar plate for scaphoid pathologies [36].

Doods et al. suggested placing the plate a little more distally to avoid impingement of the palmar scaphoid plate proximally [31]. In their study hardware removal was performed in four patients (20%) due to impingement of the plate on the palmar aspect of the radio-scaphoid articulation.

In our study, plate breakage occurred in one patient without bony healing and one screw breakage in another patient without healing. Breakage of the plate or screw could be caused by absence of bone healing. Hardware removal was performed in two-thirds of the patients mainly due to impingement both objectively and subjectively. This is a major disadvantage of the palmar plate, but not a complication. We believe that it is very important to share this knowledge with the patient before the procedure.

## Personal experience with practicability and reliability

The positioning of the used locking plate requires meticulous knowledge of the anatomy of the scaphoid and a precise surgical technique. Also contouring the plate appropriately can be challenging since most of the surface of the scaphoid is covered by cartilage. Using the anatomically preshaped plate allows an accurate palmar positioning. The use of locking screws permits monocortical screw fixation and hence reduces the risk of intra-articular screw positioning. In contrast to screw fixation with a headless compression screw, the plate provides a good rotational stability. For individual reconstructive options, it would be worthwhile to have the locking device in different sizes.

As in most other studies, our analysis has some limitations. It is a retrospective review of a new device for scaphoid fixation, but in a relatively small number of patients. The group of patients is a heterogeneous group including nonunions ( $n = 17$ ) and scaphoid fractures ( $n = 3$ ). As the minimal follow-up is 2 months, these patients might not have reached their final range of motion or grip strength and a comparison of these data to the uninjured hand is limited.

## Conclusion

Indications for using the new locking device are complex scaphoid nonunions, for example, with a tiny proximal pole fracture fragment or after failed primary surgery. It can also be used in multi-fragmentary and other complex scaphoid fractures. The practicability is satisfactory and acceptable fusion rates can be achieved. Due to possible intra-articular impingement, hardware removal is likely. We currently use this plate as a salvage procedure in situations, which require a very stable osteosynthesis.

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## Compliance with ethical standards

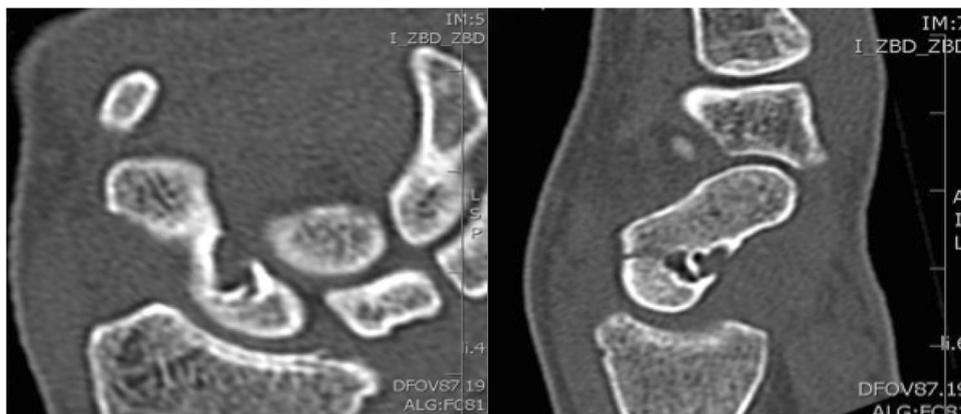
**Conflict of interest** Michael Sauerbier has a consulting contract with Medartis AG, Switzerland. The other authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

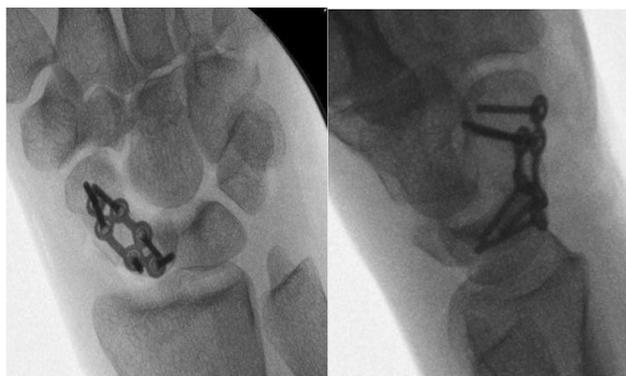
## Appendix: case examples

### Case example 1

A 43-year-old patient presented with a scaphoid fracture of the proximal third of the scaphoid and a pre-existing cyst of the left wrist.



After removal of the cyst, cancellous bone was used from the distal radius and osteosynthesis was performed with the angular stable scaphoid plate.

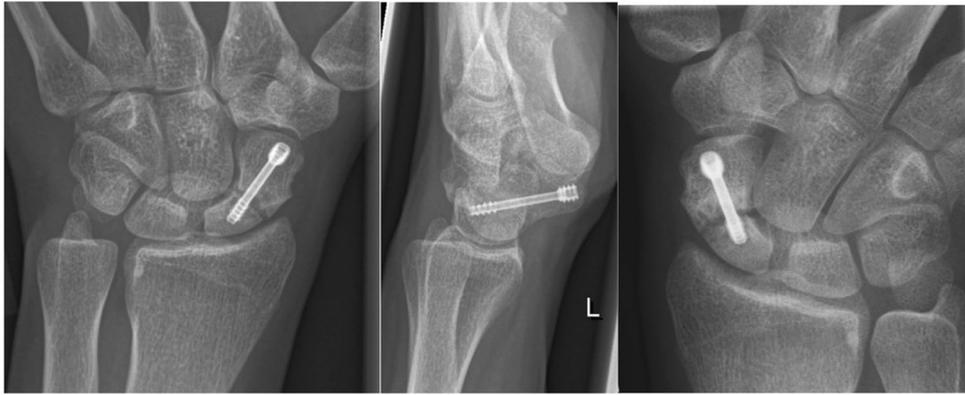


Four months later CT showed bony healing.

The plate was removed 6 months after osteosynthesis because of mechanical irritation during wrist flexion. After the hardware removal the patient reported to be highly satisfied with the result. The range of motion for wrist extension and flexion was 140° with free pronation and supination.

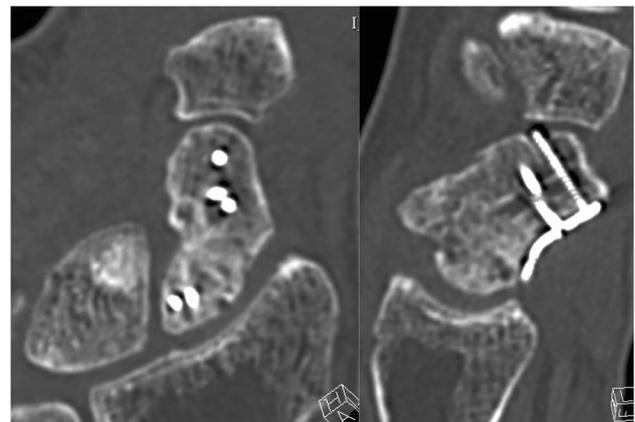
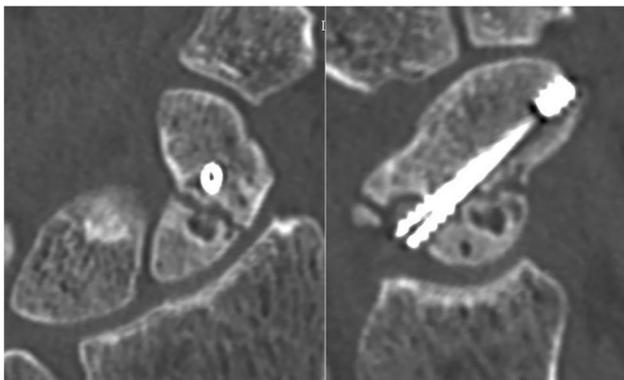
### Case example 2

A 29-year-old patient presented with scaphoid nonunion on the left side 7 months after scaphoid fracture that had been treated with scaphoid screw elsewhere.



The CT scans show the nonunion and insufficient fixation of the fragments.

After 8 weeks of immobilization the CT scan showed bony healing.



Revision surgery with removal of the screw and excision of the pseudarthrosis was performed. Cancellous bone graft from the distal radius was used and the scaphoid was stabilized with the locking plate.



The plate was removed after 10 months due to perception of interference by the patient. The patient was very satisfied with the result.

The X-ray in Stecher's view as well the CT scans show the reconstructed scaphoid.



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