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HANDSURGERY

Salvage procedure after malunited distal radius fractures and management of pain and stiffness

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Abstract

Indications for surgical treatment of distal radius fractures (DRF) remain controversial in the literature, especially in elderly patients. Complication rates after operatively treated DRF are low and well documented. These include malunion, degenerative osteoarthritis in the radiocarpal joint and subsequently pain and impaired hand function. If conservative treatment fails then salvage procedures are necessary. This review summarizes the therapeutic options available to treat degenerative osteoarthritis after malunited distal radius fractures, regardless of the initial operative or conservative treatment.

Keywords Distal radius fracture · Malunion · Salvage procedure · Radioscapholunate arthrodesis · Partial wrist fusion

Introduction

Distal radius fractures (DRF) are the most common fractures in the upper extremity. The trend to fix displaced DRF with open reduction and internal fixation using palmar angular stable locking plate systems does not prevent malunion [1–11]. There is evidence that early mobilization after operatively treated distal radius fractures result in a better short-term functional outcome, without an increased risk for secondary loss of reduction or complications [12, 13].

Even though the complication rate after palmar stabilized DRF is low and well documented, in some cases anatomical reconstruction of the articular surface cannot be achieved. Also, if secondary loss of reduction with penetration of the screws into the radiocarpal joint occurs, salvage procedures are needed to manage pain and improve range of motion (ROM) [14–23].

In complex comminuted DRF with secondary loss of reduction and remaining articular deformity, articular malunion is possible. According to Knirk and Jupiter, accurate articular restoration is the most critical factor for a successful functional result, because a step-off greater than 2 mm in the radiocarpal joint has a higher risk for post-traumatic osteoarthritis [24]. This intra-articular step-off, loss of reduction and screw penetration into the radiocarpal joint often lead to postoperative pain, decreased ROM and impaired hand function [1, 25–28]. Dayican et al. [29] analyzed the correlation of an articulation step-off > 2 mm and osteoarthritic changes in conservatively treated intra-articular DRF. They found a significant correlation between an articular step-off > 2 mm and functional outcome. But the arthritic changes appeared to have no obvious influence on hand function. In comparison, Lameijer et al. [30, 31] showed in a systematic review of 19 studies and 733 patients, a high prevalence of post-traumatic osteoarthritis in non-osteoporotic patients following a DRF. They observed an association between limited radial deviation and flexion, but no reduction in grip strength. Here again the articular incongruence led to post-traumatic osteoarthritis.

Nonsurgical treatment of DRF can also result in malunion. The indications for surgery are not clearly defined in the literature and the radiological outcome does not correlate with the functional outcome. Especially in elderly patients,

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there is strong evidence that they may not benefit from surgical treatment [32–36]. Indications for conservative/operative treatment are discussed in detail by Leixnering et al. in "Indications, Surgical Approach, Reduction and Stabilization Techniques of Distal Radius Fractures" [37].

Treatment options of symptomatic malunited distal radius fractures

The main priority in any surgical salvage procedure is to create a stable and painless joint. However, none of the mentioned salvage procedure achieved complete restoration of wrist function, but do reduce pain and enable a minimum of residual ROM to perform normal daily activities [38]. It has to be kept in mind that routine activities require only a ROM of at least 30°–50° of extension, 5° flexion, 10° of radial deviation and 15° of ulnar deviation [39, 40].

If conservative treatment and physiotherapy fail to manage pain or improve hand function, then wrist denervation is the first surgical option [25]. Advantages are that ROM of the wrist is retained and therefore all other options for further salvage procedures are still available. Nowadays, partial wrist joint denervation is performed more frequently, although total wrist joint denervation was first described in 1966 by Albrecht Wilhelm with five skin incisions to denervate all ten terminal nerve branches of the wrist. [41] This technique has the disadvantage of possible loss of skin sensitivity and protective proprioception. Many modifications for partial wrist joint denervation have been published, so pain relief between 50 and 80% [42, 43] and improved Disability of Arm, Shoulder and Hand (DASH) score can be expected. Similar to total wrist denervation, studies have suggested in the past a potentially negative influence on wrist proprioception even if only a neurectomy of the anterior interosseus (AIN) and posterior interosseus nerve (PIN) is performed [44]. However, pain relief usually recedes over time. It is also described that impaired proprioception has a negative influence on wrist stability [45, 46]. These studies suggest that neurectomy of the AIN or PIN affects the neuromuscular control of the wrist. But newer studies showed no evidence for an impaired proprioception after denervation of the wrist [47, 48].

If stiffness persists even after minimum 6 months of conservative treatment, then open or arthroscopic wrist arthrolysis can be considered [49–52]. Arthrolysis of the radiocarpal joint has very specific criteria: when reduced in extension/flexion the wrist should be painless with no anatomical malalignment. The literature suggests an improved ROM, but this temporary improvement is lost over time. Consequently this gain in better ROM should be critically addressed as the reported functional improvements are small, doubtful over the minimal clinical important difference and therefore a notable benefit for the patients is questionable [25].

Wrist arthroplasty as reported in the literature can be used to treat radiocarpal osteoarthritis [53]. Especially in young patients with post-traumatic or primary osteoarthritis, the indications for total wrist arthroplasty are still unclear. Many different modern designs are available, but there is not enough evidence that the long-term outcomes are truly beneficial [25]. Boeckstyns et al. recently published a summary of three systemic reviews [54]. They found that all three reviews include only second- or third-generation implants that are already obsolete [55–57]. The latest and currently available implants show comparable wrist mobility to partial wrist arthrodesis, here again long-term results are missing to make a clear recommendation [54]. The ROM is usually preserved but not improved [58]. There are still problems of carpal component loosening, but implant survival seems better than in the earlier implants [54, 58]. The last option is total wrist arthrodesis which eliminates all wrist motions. This is a well-established procedure to treat pain relief in patients with advanced pancarpal degeneration or post-traumatic osteoarthritis. But it is a permanent solution [25, 59–61]. The internal fixation of total wrist arthrodesis was first described by Mannerfelt and Malmsten [62] in 1971. They used a retrograde rush pin and one or more staples to gain rotatory stability for the arthrodesis. The first Arbeitsgemeinschaft für Osteosynthesefragen (AO) compression plate was used in 1996 by Hastings et al. [63]. 90 patients were reviewed retrospectively. 57 patients were stabilized using plate fixation and 33 had an arthrodesis using a variety of other techniques. All treated patients had post-traumatic osteoarthritis. The union rate was significantly higher and complication rate was lower in the plate fixation group compared to other techniques. Today's newer plates exclude the metacarpal bone fixation in wrist arthrodesis.

Comparison of the results after total wrist arthroplasty or total wrist fusion is difficult, but the trend shows that the DASH is higher after total wrist fusion than after total wrist arthroplasty. In contrast, Nydick et al. [64] compared 7 total wrist arthroplasties to 15 total wrist fusions, after post-traumatic osteoarthritis. They found no significant differences in DASH (the mean DASH score was 38 for the arthrodesis group and 29 for the arthroplasty group), but a significantly better PRWE in the arthroplasty group (73 for the arthrodesis group and 31 for the arthroplasty group). Limitation of this study was the small sample size.

Indications and techniques of corrective osteotomy and ulnar shortening osteotomie after malunited DRF are discussed by Krimmer et al. [65] and Terzis et al. [66].

Radioscapholunate (RSL) arthrodesis

Radioscapholunate (RSL) arthrodesis can be a good option if post-traumatic, painful, radiocarpal osteoarthritical changes occur. Surgical techniques distinguish RSL arthrodesis from dorsal and palmar [26].

Biomechanics of RSL arthrodesis

Mc Nary [67] examined ten fresh frozen cadaveric wrists with RSL arthrodesis including removal of the distal scaphoid and triquetrum. This method showed that the contact forces in the capitolunate joint could be increased by 50%. Triquetrectomy increases ROM, but no increase in the contact force of either the capitolunate or the mid carpal joint. Therefore, additional excision of the triquetrum is recommended.

A design to measure ROM in cadavers of the human wrist was presented in a previous study by Gregory Ian [68]. They biomechanically evaluated ROM primarily in RSL arthrodesis without distal scaphoid and triquetrectomy, followed by distal scaphoid excision, and finally excision of the triquetrum in 12 cadaveric upper limbs. The simple RSL arthrodesis decreased the extension/flexion arc by 23% and the radioulnar arc by 34%. With the additional excision of the distal scaphoid pole, it improved the extension/flexion arc by 36% and the radioulnar arc by 34%. And finally with the excision of the triquetrum, the extension/flexion arc was further improved 13%, and the radioulnar arc by 21%. Furthermore, the additional excision of the triquetrum can successfully treat the combination of symptomatic radiocarpal arthritis and an ulnar impaction syndrome without requiring further surgery to the ulna [69].

Surgical technique from dorsal

A dorsal longitudinal incision between the third and fourth extensor tendon compartment is made. The extensor pollicis longus tendon is temporarily removed from the third extensor compartment. The cartilage surfaces between the radius, scaphoid and lunate have to be removed. Traction on the index and long fingers will facilitate good visualization of the cartilage surfaces under image intensification, the distal pole of the scaphoid is excised. For optimal plate fixation from a dorsal aspect, the tuberculum lister has to be removed. Then the extracted cancellous scaphoid bone is grafted into the defect between radius, scaphoid and lunate for better fusion. There are specially designed plates for the dorsal RSL arthrodesis, for example, the Medartis Trilock RSL Fusion Plate, which has an "H" shape and a sliding hole on one of the long arms. The correct plate positioning is carried out under the image intensifier. The first screw is placed into the sliding hole on the long arm of the plate, followed by the distal fixation of the "H" into the scaphoid and lunate. The remaining screws are then inserted angular stable to complete fixation.

Authors' preferred method: the palmar RSL arthrodesis [38]

The surgical procedure is performed with pneumatic tourniquet of 250 mmHg. A horizontal hand extension at the thumb for better positioning of the hand is placed on the radiolucent operating table. If a previous operative palmar stabilization of the radius was performed, then the same incision for hardware removal and RSL arthrodesis can be used. The incision is extended distally along the FCR tendon and curved to the radial side to expose the scaphoid. Care has to be taken to avoid the superficial branch of the A. radialis which can be seen on the radial edge of the scaphoid.

Capsulotomy is performed to inspect the carpus.

A primary K-wire is drilled through the lunate and scaphoid, to avoid instability, even if the SL ligament remains intact and the lunate is anatomically aligned. Under image intensification, precise resection of the distal third of the scaphoid is carried out (Figs. 1–4). This procedure unlocks the STT joint and lowers the nonunion rate [26].

To correct a DISI or VISI position of the lunate, temporary K-wires are inserted into the lunate and scaphoid as joysticks (Figs. 5, 6). The exact positioning of the lunate in a neutral position is critical to avoid secondary osteoarthritic changes in the midcarpal joint. Then, one K-wire is inserted from the radius into the lunate, and another into the scaphoid after which the joysticks are removed.

An osteotome is used to plane the palmar rim (Fig. 7). A small ulnar bridge of only a few millimeters must be left to avoid deinsertion of the palmar radioulnar ligament, which is an important stabilizer of the DRUG. The wrist is maximally extended to expose the radiocarpal joint. Thereafter, using an osteotome, rongeur or PoweRasp™ from Arthrex, the cartilage of the distal radius between scaphoid and lunate is denuded (Fig. 8).

We use the polyaxial Medartis® palmar RSL fusion plate (Medartis® Aptus®, Switzerland) for fixation of the RSL arthrodesis (Figs. 9, 10). With the aid of the image intensifier, the plate is fixed with a cortical screw in the sliding hole on the long arm of the plate to ensure correct positioning.

Then, two screws are placed into the lunate and two into the scaphoid. The variable angled locking system allows exact screw placement in both carpal bones. Cortical screws can be used for primary fixing of the scaphoid and lunate to the plate and then exchanged for locking screws to increase stability. Positioning of the screws into the scaphoid and lunate has to be done carefully to avoid screw penetration into the midcarpal joint.

All K-wires are removed. In case of ulnar impaction, the screw in the sliding hole is loosened and the carpus distally distracted using a Codman distractor (Fig. 11). The loosened screw is then tightened to fix the plate in position and the

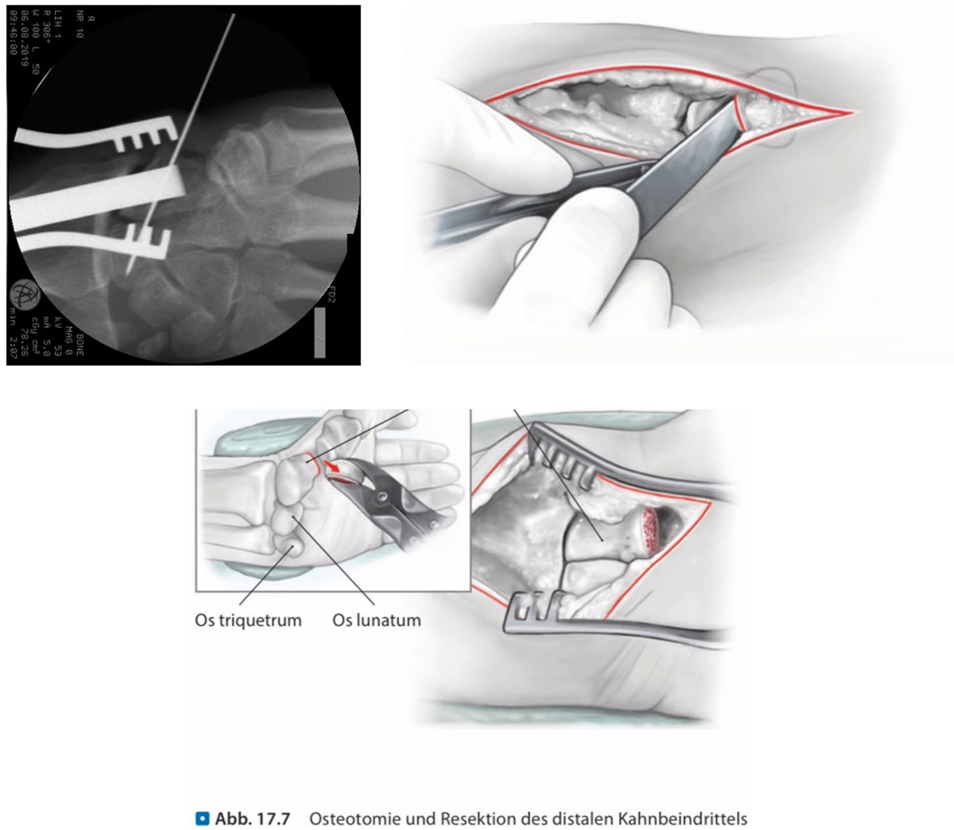

Fig. 1–4 A K-wire is inserted from the scaphoid to the lunate to gain stability. Then using the image intensifier, the distal third of the scaphoid is identified and resected with a chisel (Figs. 2–4 from [38])

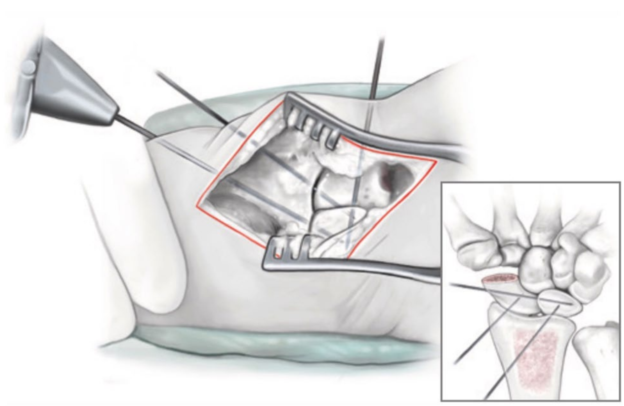

Fig. 5, 6 Reference [38]: to correct a DISI or VISI position of the lunate, temporary K-wires are inserted into the lunate and scaphoid acting as joysticks. First one K-wire is inserted from the scaphoid to the lunate. Thereafter, additional K-wires are placed from the radial styloid to the lunate and scaphoid to fix this position

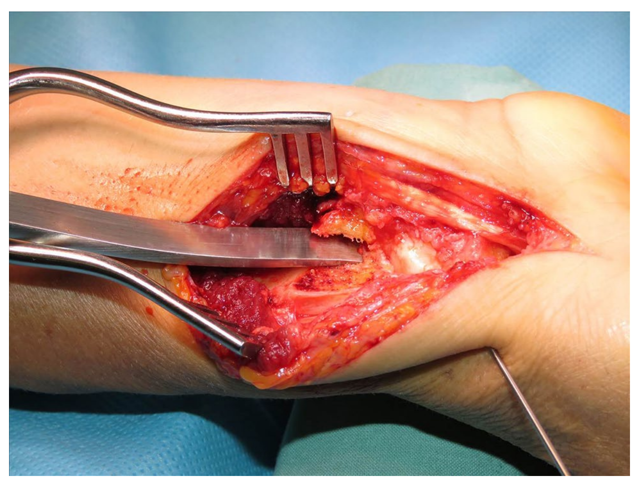

Fig. 7 An osteotome is used to plane the palmar rim. A small ulnar bridge is left to avoid deinsertion of the palmar radioulnar ligament which is an important stabilizer of the distal radioulnar joint

distractor removed. Thereafter, the remaining holes are filled with locking screws.

The cancellous bone graft harvested from the resected palmar rim of the radius and the distal third of the scaphoid is inserted and compacted into the arthrodesis site (Figs. 12, 13). No additional bone grafting is usually necessary.

Postoperative immobilization uses a thermoplastic short-arm splint for 4 weeks. After 2 weeks, the splint is temporarily removed to commence hand therapy and active wrist and finger exercises. Bony fusion can be expected after 3 months and normal activities can be resumed.

One case report is presented in Fig. 14a–d.

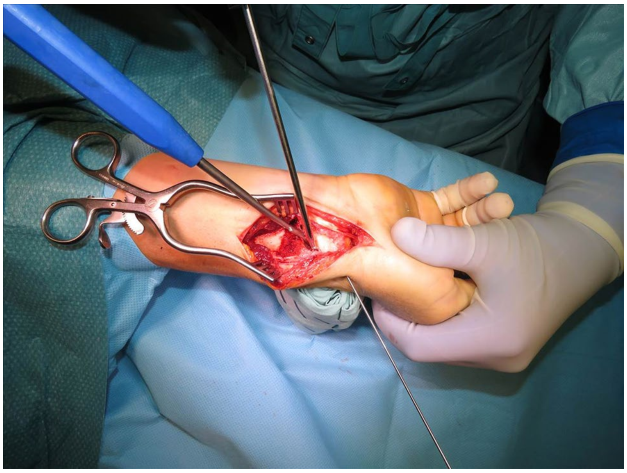

Fig. 8 Then the cartilage surface is denuded with either an osteotome, or rongeur and sometimes also with an arthroscopic device (PoweRasp™ from Arthrex) until cancellous bone is exposed

Results

Garcia Elias in 2001 was the first who reported about the additional distal scaphoidectomy (DSE) in RSL arthrodesis performed from dorsal. He found improved fusion rates, ROM in flexion and radial deviation and less pain [70, 71] and in particular to help prevent secondary midcarpal osteoarthritis [71].

Mühldorfer-Fodor et al. [72] compared RSL arthrodesis with or without additional DSE in 35 patients. A dorsal approach was performed and K-wires were used for internal fixation. The mean follow-up was 28 months. All the patients with additional DSE showed bony healing, whereas three of the patients without additional DSE had a nonunion. In the clinical evaluation, they found no significant difference in patient-reported outcome measurements, grip strength or pain. But there was a significant decreased ROM in radial deviation in the group without DSE.

Quadlbauer et al. [26] retrospectively analyzed eleven patients clinically and radiologically with a mean follow-up of 63 months (range 30–97 months). All patients showed union and no midcarpal degenerative osteoarthritis in the follow-up CT. A palmar approach was used and a DSE was performed in all patients. A mean ROM in extension/flexion of 53°/42°, supination/pronation 81°/85°, radial deviation/ulnar deviation 10°/25° was found.

Montoya-Faivre et al. [73] analyzed 34 patients with RSL arthrodesis with a mean follow-up of 53 months. All operations were performed from the dorsal approach, for internal fixation different materials were used such as K-wires, compression screws, two-prong shape-memory staples and locking plates. Six required a total wrist fusion. They reported a nonunion rate of 29%. In this group, the distal scaphoid pole was not extracted in all cases. After a mean follow-up of 53 months, 64% showed a midcarpal and 46% a STT osteoarthritis.

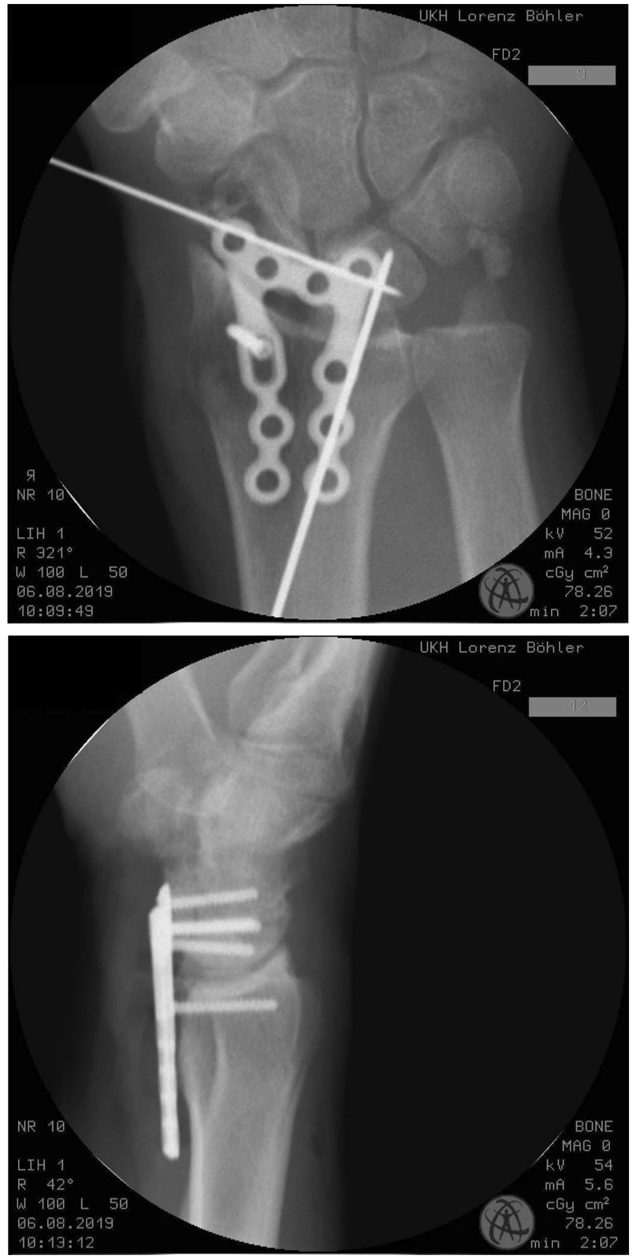

Fig. 9, 10 A straight polyaxial, 2.5 locking frame plate (Trilock RSL fusion plate, Medartis, Switzerland) is used for the final fixation. The plate is first affixed in the sliding hole of the long arm, followed by the carpus and the radius with locking screws

Pain level on visual analog scale (0–10 points) after RSL arthrodesis and DSE varies between 2.2 (2.0–5.2) [26], 3 (1 average at rest, 4 during effort) [73], 4.5 (range 0–8.5) [72]. Very few studies on RSL arthrodesis report patient-reported outcome measures as in the DASH score. Grip strength after

Fig. 11 Reference [38]: in cases of ulnar impaction, the screw in the sliding hole is loosened and the carpus distracted distally with a Codman distractor

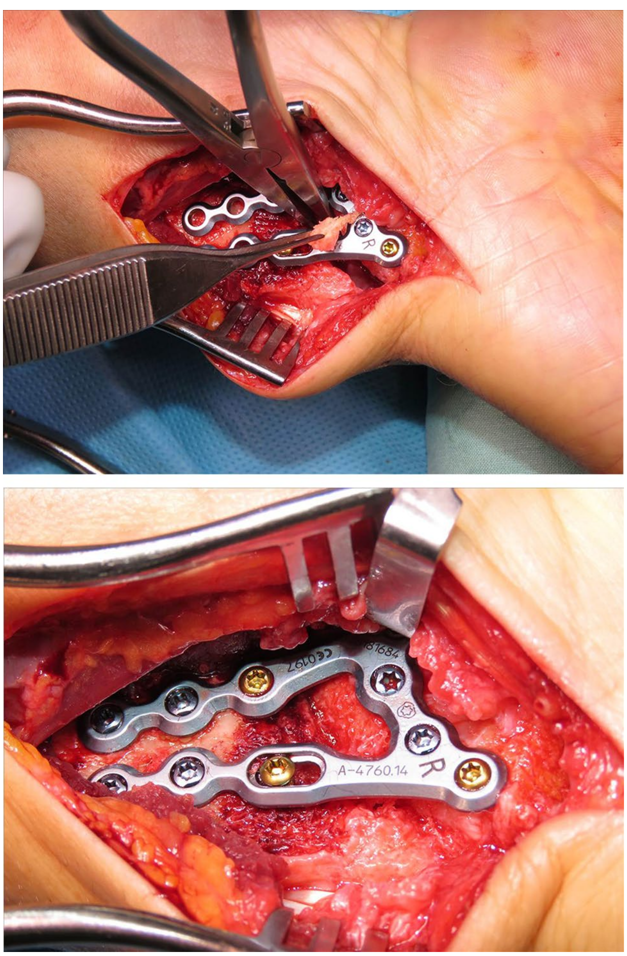

Fig. 12, 13 Cancellous bone graft is compacted into the arthrodesis site

RSL arthrodesis and distal scaphoidectomy varies between 56% [72], 71% [73], and 80% [26] compared to the other hand.

Conclusion

Several factors determine the therapeutic options in patients with post-traumatic osteoarthritis. These include age, activity level, functional demands, residual ROM and radiographic changes.

If pain is foremost and an adequate residual mobility of the wrist is preserved, then denervation of the wrist can be recommended as a first step, because alternative procedures are still possible, should denervation fail.

Open and arthroscopic wrist arthrolysis is indicated if restriction exists only in extension/flexion with no pain or radiocarpal malalignment. Clinical results suggest an improvement in ROM, but these differences are small, questionable over the minimal clinical important difference and therefore unlikely to be noticed by the patients.

New implants for wrist arthroplasty are emerging on the market, but to date insufficient data are available to make any conclusive statements in respect of the longevity. Even though recent studies show promising results, the long-term experience is pending and requires further research. Particularly in young patients, the longevity and load bearing of the implants should be considered when planning the intervention.

Total wrist arthrodesis is recommended in patients, especially if ROM of the wrist is very restricted and all other reconstructive procedures are ineffective. The complication rates are low, when compared to wrist arthroplasty. Only few studies reported a recovery of ROM higher than the functional ROM for wrist arthroplasty.

RSL arthrodesis is a good option in cases where osteoarthritis is limited to the radiocarpal joint with an intact mediocarpal joint. The removal of the distal scaphoid pole appears to have a positive effect on union rate, flexion and radial deviation. It also seems to be critical to remove the distal third and unlock the STT joint. Biomechanical studies have shown that additional removal of the triquetrum improves ROM even further, but clinical studies are still missing.

The surgical techniques used in various studies have to be critically assessed to allow an objective assessment.

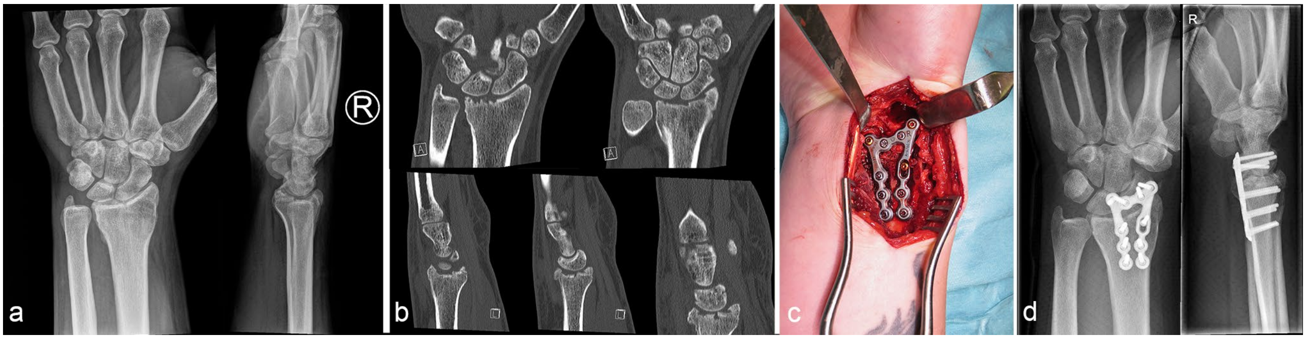

Fig. 14 **a** In August 2018 a 26-year-old male had an accident at work and fractured his radius on his right, dominant hand. The initial treatment at an external hospital included immobilization of the forearm in a cast for 5 weeks. Because of limited range of motion and persisting pain, the patient attended our outpatient department. **b** The conduced CT scans showed a malunited intra-articular distal radius fracture with a step-off more than 2 mm. Range of motion was limited to extension/flexion 30–0–50, pro-/supination 90–0–90, radial/ulnarduction 20–0–30. **c**, **d** After 4 months of conservative treatment including pain medication (NSAR), hand therapy, intra-articular injections and splinting, the patient still showed no significant improvement. RSL Arthrodesis was performed 8 months after the accident, due to persisting pain, intraarticular step-off and incipient osteoarthritis in the radiocarpal joint. The postoperative X-ray showed RSL arthrodesis with additional DSE using the polyaxial palmar RSL fusion plate (Medartis®, Switzerland). The patient was immobilized with thermoplastic short-arm splint for 5 weeks. Hand therapy was commenced 2 weeks after the operation. (Figure 14 was taken from Quadlbauer et al. [74] and reproduced with permission from Springer)

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