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HANDSURGERY

Corrective osteotomy after malunited distal radius fractures

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Abstract
Posttraumatic malunion or secondary dislocation can cause wrist joint incongruency. Uncorrected malalignment increases the risk of secondary degenerative changes and chronic pain. Therefore, early correction using the available fixed-angle devices, cancellous bone grafting only becomes necessary in larger bony defects. Premounting the plate through a palmar approach with regard to the desired correction angles leads to predictable results by precise correction. In case of posttraumatic growth arrest with larger discrepancy of the radius and the ulna, a two-staged procedure is advisable.

Keywords Distal radius · Corrective osteotomy · Growth arrest · Locking plates · Malformation DRUJ

Introduction

Incorrectly healed distal radius fractures are still challenging to treat. The resulting complications range from pain, loss in range of motion, and strength to an aesthetic difference in external appearance and ultimately in posttraumatic osteoarthritis. Since these consequences are well documented, the current trend opts for performing early corrective surgery, to prevent osteoarthritic changes and manage pain.

Indications

Due to the improved diagnostic tools such as computer tomography (CT) scans, which are now standard procedure for intra-articular and complex distal radius fractures, as well as 3D reconstruction, a better understanding of the fracture morphology is possible. In addition, further development of osteosynthesis material with the numerous types of fixed-angle plates, specifically designed to accommodate a particular fracture morphology, helps to enhance postoperative outcome and avoid secondary dislocations.

In the past when postoperative malalignment occurred, corrective osteotomy was only performed after complete osseous consolidation. Nowadays, the opposite is true, the earlier the malalignment is corrected, the sooner a rapid improvement in discomfort, with consequential damage in the form of posttraumatic osteoarthritis or the development of a complex regional pain syndrome (CRPS) can be avoided [1]. An existing CRPS sustained by malalignment usually improves after correction.

If extra-articular fractures heal malaligned with dorsopalmar, and radioulnar inclination or radial shortening occurs [2], a corrective osteotomy is always necessary. But in an intra-articular malalignment, the indication always depends on the development of offset in the region of the articular surface. Coexisting incongruency of the distal radioulnar joint (DRUJ) and an ulnar impaction syndrome resulting from radial shortening often cause ulnocarpal pain. However, the radiological image does not always correlate with the clinical picture. In relatively young patients, the focus is on preventative measures, such as the avoidance of posttraumatic osteoarthritis [21].

In elderly patients, however, the focus is on subjective discomfort. Thus if a patient is largely pain free, then the indication for corrective osteotomy should be carefully considered.

If CRPS occurs after a distal radius fracture, carpal tunnel syndrome as well as malalignment must be ruled out, as it can cause severe problems. If the fracture is still malaligned even after operative or conservative treatment, then corrective surgery should be performed as soon as possible (Fig. 1a, b).

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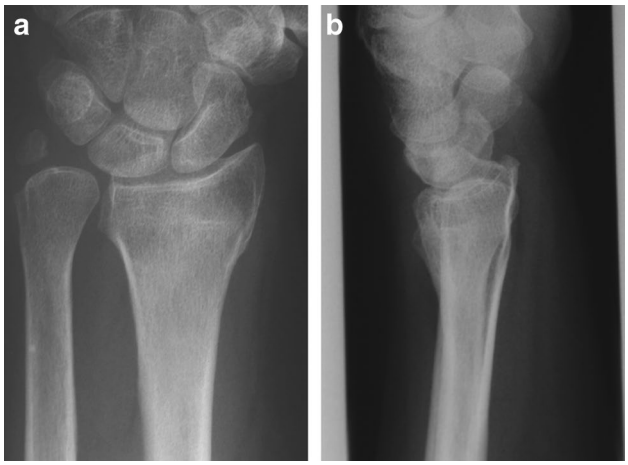

Fig. 1 X-ray of a wrist with a distal radius fracture that has healed in malalignment with a dorsal tilt of 30° and an ulna plus situation of 2 mm, **a** PA radiograph **b** lateral radiograph

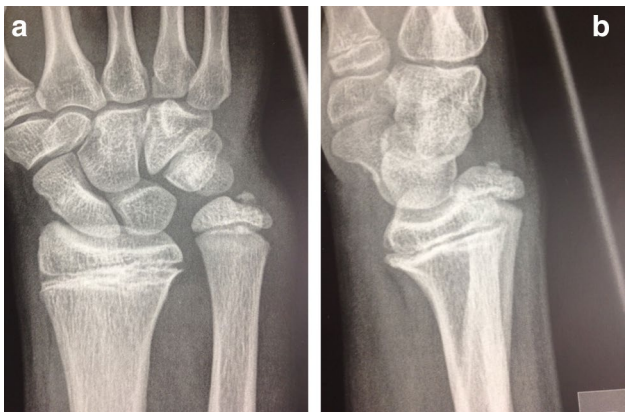

Fig. 2 X-ray of the wrist of a 14-year-old female patient wrist ulna plus of 2 cm and increased palmar tilt of the radius to 30°, **a** PA radiograph **b** lateral radiograph

Posttraumatic growth disorders

In posttraumatic growth disorders of the radius (Fig. 2a, b), considerable length deficits often occur as a result of early closure of the epiphyseal plate. Due to the soft tissue situation, a single procedure would be inadvisable. Therefore, a primary distraction osteotomy should be performed to achieve the desired length compensation and thereafter, the internal fixation using angular stable plate osteosynthesis. This ensures good adaptation of soft tissue and prevents large bone grafts.

Diagnosis

Clinical examination must include the criteria: range of motion, grip strength using a dynamometer to compare sides, a pain assessment, and patient-reported outcome measurements. Not only are the X-rays in posterior–anterior (pa) and lateral planes necessary, but also a current CT scan. This enables precise analysis of malalignment, for example, offsets in the region of the articular surface can only be reliably assessed on a CT scan. Furthermore, prior to performing a corrective osteotomy, it is necessary to radiologically rule out any severe osteoarthritis in the radiocarpal and distal radioulnar joint. Advanced osteoarthritis can be a contraindication for corrective osteotomy.

If additional congenital malalignment is suspected, then both wrists need to be radiographed [3].

The importance of the CT scan for diagnosis and preoperative planning is discussed in detail by Hintringer et al. [13]

Surgical procedure

Extraarticular malalignment

Previously, corrective osteotomy for dorsal malalignment used a dorsal approach and in palmar malalignment, a palmar approach. However, as precise anatomical reduction and positioning were problematic using the dorsal approach, Lanz and his team provisionally mounted the distal correction plate using a palmar approach long before locking plates became available [4, 5]. With the introduction of fixed-angle implants [18] and two-row distal support, this method became standard [6, 20]. They allow to perform the procedure even in case of poor bone quality and additionally avoid the need for bonegraft of the iliac crest with all the inherent risks [17].

The standard approach for distal radius fractures is presented in detail by Leixnering et al. [14]

The Lanz procedure extends the palmar approach distally in a Y shape to enhance access. This approach is used if no significant shortening exists, and in distal radius fractures. It enters between the flexor carpi radialis (FCR) tendon and the radial artery. If radial malalignment with distinct shortening does occur, the approach is radial to the radial artery to allow subperiosteal detachment of the 1st–3rd extensor tendon sheath and thereby avoid any impairment to the soft tissue. The third extensor tendon sheath is always opened to avoid secondary rupture of the extensor pollicis longus (EPL) tendon due to sharp osteotomy edges or hematoma formation (Fig. 3).

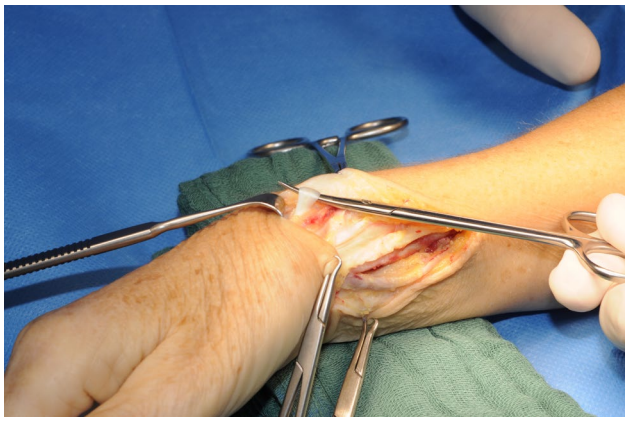

Fig. 3 Intraoperative opening of the third extensor tendon sheath

Following exposure of the palmar distal radial surface, the correction plate is provisionally positioned and distally affixed with four screws. The first screw is a cortical screw, and the other fixed-angle screws are only partially inserted (remain unlocked). Due to the dorsal tilt, the distal screws need to be predrilled in a proximal direction to avoid intra-articular penetration. The distal part of the correction plate runs parallel to the articular surface of the radius. In cases of severe malalignment, the watershed line is often obscured; therefore, the plate position has to be verified with an image intensifier. If there is loss of inclination in the PA plane, the premounted plate must be angled proximally toward the ulnar side (Fig. 4a, b).

To correct the dorsal tilt, the mounted plate must be angled proximally from the radial shaft. The angle between the plate and the radial shaft determines the correction angle. This angle can be precisely measured with the specially designed calibration instrument developed by the Medartis company (Medartis AG, Basel, Switzerland) (Fig. 5).

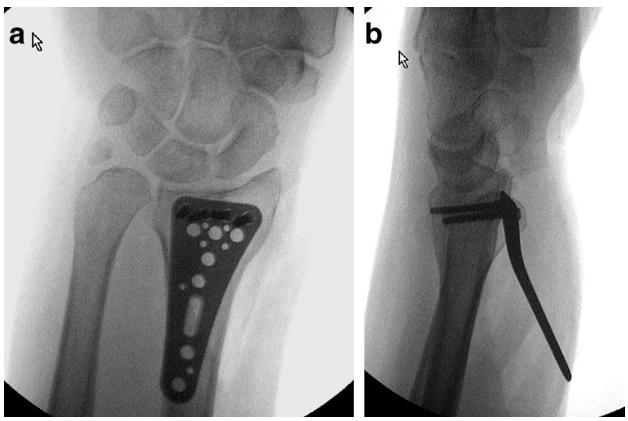

Fig. 4 Intraoperative plate fixation protruding at the desired correction angles. **a** PA view **b** lateral view

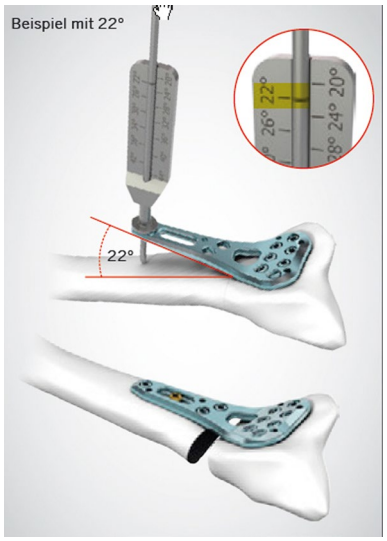

Fig. 5 Instrumentation for setting the desired correction angle (courtesy of Medartis AG, Basel, Switzerland)

Once the angle is determined, the plate is removed, and the osteotomy site can be established with the image intensifier. It can be marked with a Kirschner wire but usually corresponds to the former fracture line. The osteotomy must be performed just proximally to the DRUJ, to avoid damaging the articular surfaces. During the osteotomy, the extensor tendons are protected with a Hohmann bone lever, positioned subperiosteally. To avoid thermal necroses a single-use saw blades should always be used. The plate is then re-mounted using the originally drilled holes and is adjusted against the radial shaft proximally and centrally, resulting in accurate angle alignment of the articular surface. Temporary plate fixation with blunt reduction forceps enable the corrected position to be checked with the image intensifier. The ulna must also be correctly aligned in a neutral or slightly minus position (− 1 mm). A nonunion retractor in the osteotomy gap facilitates length compensation, especially when the gap is relatively wide (Fig. 6). Finally, the remaining shaft holes are filled with fixed-angle screws.

When malalignment with palmar tilt of the articular surface of the radius occurs, the dorsal cortical bone can be preserved using the palmar folding open osteotomy, the so-called "open book technique" [21]. The modern standard fixed-angle plate with two-row distal support system, can accommodate an osteotomy gap of 6–8 mm without requiring a bone grafting, provided that the bone quality is adequate [7]. In larger defects, a cancellous or corticocancellous iliac crest bone graft is necessary, which is affixed with a plate screw. An alternative bone or allogenic femoral head bone can be substituted, but the delayed or prolonged healing time is an added disadvantage.

Fig. 6 Length compensation with nonunion retractor

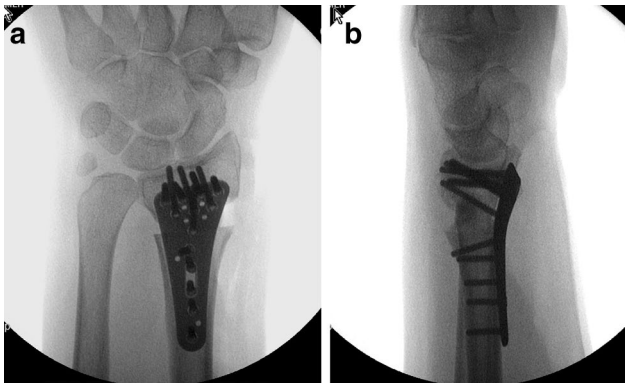

Fig. 7 Correction with restoration of the articular angles at the radius and length compensation of ulna − 1 mm, **a** PA view **b** lateral view

If the follow-up X-ray after 4 weeks immobilization in a thermoplastic splint shows healing, then the functional follow-up treatment can be commenced. (Fig. 7a, b).

An ulnar shortening osteotomy is a good alternative to correct ulnar impaction syndrome when anatomical alignment of the distal radius with correct inclination of the articular surfaces occurs. This method has become a reliable and standard procedure using fixed-angle ulnar shortening plates. The article by Terzis et al. [15] "Ulnar shortening osteotomy as a treatment of symptomatic ulnar impaction syndrome after malunited distal radius fractures" describes this procedure in detail.

Intra-articular malalignment

To achieve visibility/direct access to the intra-articular malalignment and articular surface, the dorsal approach is used to perform the correction. As in dorsal fracture management, the approach is via the third extensor tendon sheath and subperiosteal exposure of the dorsal radius with access to the articular surface. The osteotomy follows the former fracture line using a thin sharp chisel.

Alternatively, it is possible to perform an arthroscopy-assisted correction [8] as good alternative to assist in the osteotomy procedure. Thereafter, K-wires can be used to act as joysticks to facilitate adjustment of the correction position. K-wires can temporarily maintain this correction outcome. The best choice of osteosynthesis, whether plate or only screws, depends entirely on the type of fracture that occurs (Fig. 8a–d).

Arthroscopic treatment of intra-articular distal radius fractures is presented by Kastenberger et al. [16]

Growth disorders in the region of the radius

Posttraumatic growth disorders due to premature complete or partial closure of the epiphyseal plate often present with substantial longitudinal defects. A two-stage procedure is necessary to provide the adequate surgical treatment [9, 10].

To compensate the defect, the primary procedure involves the placing of a distraction fixator with an additional Schanz screw and a connecting rod at right angles to the distraction plane to prevent palmar tilting of the distal radius fragment

Fig. 8 Correction of intra-articular offset formation following distal radius fracture. **a** Preoperative coronal CT scan of the wrist. **b** Preoperative sagittal CT scan of the wrist. **c** Postoperative coronal CT scan of the wrist following correction from dorsal with screw osteosynthesis. **d** Postoperative sagittal CT scan of the wrist following correction from dorsal with screw osteosynthesis

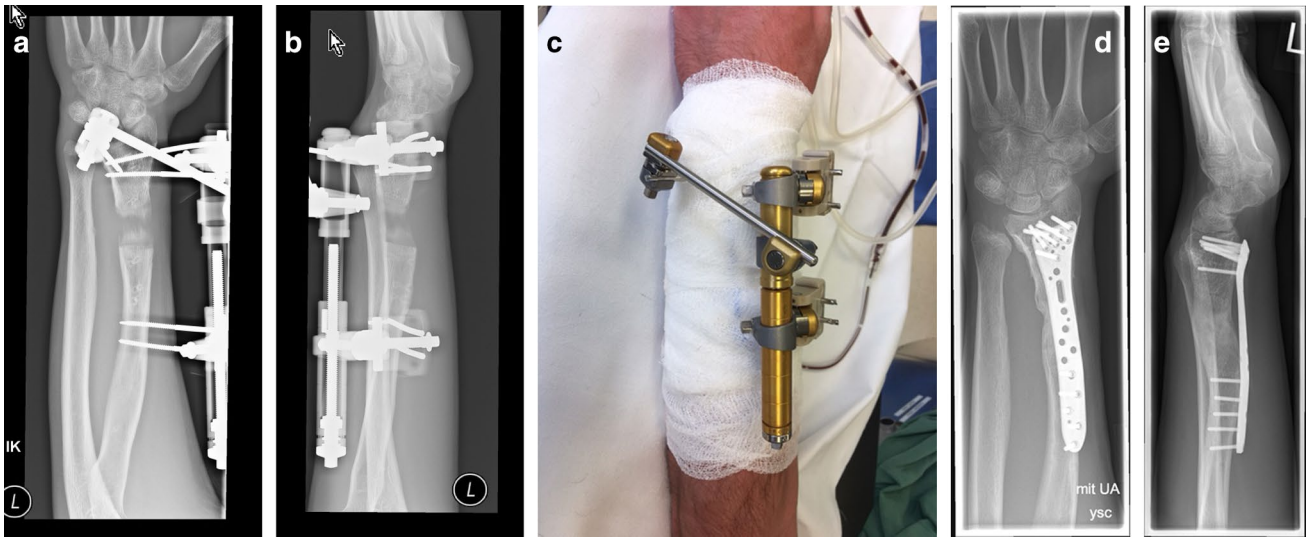

Fig. 9 Correction of substantial radial shortening (preop. see Fig. 2). **a**, **b** PA and lateral view distraction fixator in situ **c** take note of mounting with additional transverse rod **d**, **e** procedural switch to palmar plate osteosynthesis following length compensation

during distraction (Fig. 9a–c). The osteotomy is carried out proximal to the distal Schanz screws and DRUJ. Distraction starts at approx. 0.5 mm increments per day 1 week after surgery. The distraction phase is variable and can take weeks or even several months until the desired length compensation is reached. The second operation bridges the defect zone by plate osteosynthesis after removal of the the fixator (Fig. 9d, e).

Preoperative 3D planning

Preoperative 3D planning of correction osteotomy is a relatively recent development. A CT scan is made of the injured wrist as well as the opposite extremity for comparative purposes. The malalignment can now be analyzed computer assisted. The required templates are made using a 3D printer [11]. In some cases, custom-made correction plates can be ordered. The 3D alternative is recommended especially in the case of complex and intra-articular malalignments [12]. The benefit is reliable predictability of postoperative outcome.

Conclusion

The palmar approach for a correction osteotomy represents a reliable procedure for restoring the articular surface and congruency of the DRUJ. Bone grafting is only necessary in case of larger osteotomy gaps or severe osteoporosis. Intra-articular correction is preferably performed via a dorsal approach with direct visibility to the articular surface or, with additionally assisted arthroscopy. Malunion due to growth arrest and larger length discrepancies should preferably be corrected in a two-staged procedure. Advantages include good healing without bone grafting and slow adaption of the ligaments and soft tissue. For complex intra-articular correction, 3-D planning offers a favorable solution.

Conflict of interest Consultant of Medartis Company, Basel, Switzerland.

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