Operative treatment of distal radius fractures

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The incidence of distal radius fractures is increasing together with the average age of population. Intra-articular incongruity is the most probable cause of unsatisfactory outcome of distal radius fractures in younger and more active patients. Thus, the main goal in the treatment of distal radius fractures should be restoration of articular congruence. A computed tomography (CT) is recommended to help surgeon in preoperative planning in the treatment of comminuted intraarticular fractures. New implants have been designed to provide stable enough fixation for early mobilization after surgery and to lower rather high complication rates related to conventional fixation methods such as external fixation and dorsal plating. The most common complications related to volar fixed angle plating such as flexor and extensor tendon problems, median nerve neuropathy, and screw displacement into the radiocarpal joint are surgeon related and are avoidable with proper education. More randomized prospective studies are needed to prove superiority of any fixation method to another.

Key words:
Distal radius; fracture; operative treatment; plating; external fixation; malpractice; complications

Introduction

Fractures of distal radius are the most common fractures among patients treated at emergency rooms comprising more than 16% of all fractures (1). Annual incidences of distal forearm fractures in Finland and Norway are 36.5 and 38/10 000 population respectively (2, 3) totalling more than 19 000 fractures per year in Finland (population 5.3 million). The incidence of the distal radius fractures increases together with the average age of the population (4).

Inadequate treatment of fractures of forearm is the second most common reason for malpractice compensation in Finland with almost 100 compensated patients per year (5). Malunion of distal radius fractures was found in 73% of the patients who received malpractice compensation during 1997_1999 (6).

Factors affecting outcome

There is still some controversy about the factors affecting the outcome of distal radius fractures. Persistent intra-articular incongruity has been shown to cause a 9,9-fold increased risk of radiological osteoarthritis and restriction of range of motion (ROM) (7, 8). Seventy-six to 91% of fractures of young adults with residual intra-articular incongruity showed arthritis 7 years after the injury compared to 11% of fractures with congruous joint (9, 10). Forward et al. (7) reported that after 38 years follow up grade 0 or 1 arthritic changes were found in 65% of wrists after intra-articular fractures, grade 2 in 30% and grade 3 in 5% of fractures. However, osteoarthritic changes do not always worsen the functional end result (8, 11). Dorsal angulation of radiocarpal joint surface worsens functional outcome considerably when it exceeds 20 degrees (12, 13). Thirty-eight years after the injury...
each ten degrees of dorsal angulation diminishes volar flexion by three degrees (7). Dorsal angulation exceeding 20 degrees caused a 6 and 8 degrees loss of volar flexion 30 and 7 years after the injury (14, 15) respectively. Radial shortening of more than 4 mm associates with decreased forearm rotation at 3 years follow up (16) while radial shortening of 5 mm and 15 degrees loss of radial inclination affects the outcome by causing ulnar wrist pain in 43 to 100% of the patients 1,5-6 (mean 3,5) years after the injury (12).

Although the restoration of dorsal tilt and the reduction of radial shortening form the basic goals of treatment for most fractures of the distal part of the radius it is not as critical as the restoration of articular congruity in young adults (9).

Other factors than radiological dimensions have also considerable effect on the end result of distal radius fractures. Complex regional pain syndrome (CRPS) was found in 62% of the patients with unsatisfactory result ten years after Colles’ fracture (11). At one year after distal radius fracture patients with third-party claims, injury compensation, lower education and other medical comorbidities have a poorer functional outcome (17). Frykman (18) showed in his thesis that shoulder-hand-syndrome (CRPS) can be avoided by proper range of motion exercises during and after plaster cast immobilisation in the treatment of distal radius fracture.

**Indications of operative treatment**

Great hopes were laid on Cochrane database as it was established. Unfortunately so far it has failed to give any evidence-based guidelines in choosing the best conservative (19) or operative (20) treatment method for distal radius fractures. There are also no widely accepted indications for operative treatment. Undisplaced fractures and minimally displaced stable fractures can be treated conservatively with a short arm cast or a removable splint for four to five weeks. Displaced fractures are usually reduced and casted. If the displacement is adequately reduced and retained during five weeks in short arm cast conservative treatment gives a satisfactory result. A clinical and radiographic check up should be done one and two weeks after the reduction with re-evaluation of the treatment method if redisplacement occurs.

In the literature indications of operative treatment vary slightly. In young adults and physically active elderly patient operative indications have been 10-150 dorsal tilt or 250 volar tilt, more than 1-3 mm radial shortening, articular step of more than 1-2 mm. Abramo et al. (21) presented recently their treatment protocol in distal radial fractures with very satisfactory outcome. According to their protocol the criteria for unacceptable displacement were dorsal angulation more than 100 or volar angulation more than 250 and/or ulna plus more than 2 mm and/or articular step of more than 1 mm.

**Preoperative evaluation**

The plain radiographs used for preoperative planning and decision making should be of good quality.

The posterior-anterior (PA) view should be shot with the elbow and shoulder in 90 degrees and the forearm in neutral rotation. The lateral view should be shot in a 20 degrees inclined view where the beam is directed from distal radial to proximal ulnar providing much better assessment of dorsal tilt and articular congruence than a traditional straight lateral (22). Also a 45 degrees pronated oblique view is useful for preoperative assessment. If instability of intercarpal ligament such as scapholunate interosseus ligament (SLIL) or lunotriquetral interosseus ligament (LTIL) is suspected a magnetic resonance imaging should be performed preoperatively unless wrist arthroscopy is included in the operative plan. Computed tomography is often necessary to evaluate intra-articular fragment displacement in comminuted intraarticular distal radius fracture. (Fig. 1)

**Fracture classification**

Several different classifications on distal radius fractures have been presented. Most of them are useful only for scientific purposes with very limited help in daily clinical work. The most used AO classification divides distal radius fractures in three groups and three subgroups. Groups A1-3 include extra-articular fractures, Groups B1-3 partly intra-articular fractures such as volar and dorsal Barton fractures and Groups C1-3 completely intra-articular fractures (23).

**Treatment options**

Percutaneous pinning

Percutaneous pinning alone with closed reduction is suitable for fractures without intra-articular instability and without metaphyseal comminution. A simp-
le extra-articular Colles’ fracture is a typical example. Percutaneous 1.6 mm K-wires can be placed either from the tip of radial styloid and Lister’s tubercle or intrafocally through the fracture line (Kapandji method). A small incision at the tip of the radial styloid and Lister’s tubercle is recommended to check that the superficial branch of radial nerve and extensor pollicis longus tendon are not damaged. If K-wires are left on the skin their tips should be covered with plastic pearls. If they are cut underneath the skin, they should be bent to avoid pin migration. Postoperatively a plaster cast is worn for 2 weeks and a removable splint is worn until 4-5 weeks from operation. K-wires are removed 4-6 weeks postoperatively. Most common complications of this method are pin track infection and iatrogenic lesion of superficial branch of the radial nerve, which may cause CRPS. In a recent study percutaneous K-wire fixation provided results comparable with volar plate fixation (24).

External fixation

Bridging external fixation used to be the first choice in operative treatment of almost any fracture of the distal radius except the volar Barton fracture. It is still the basic method in the armamentarium of several experienced surgeons who are out of their comfort zone treating fractures of distal radius with volar locking plates or other more recently introduced implants. It is based on soft tissue support and ligamentotaxis due to distraction between the second metacarpal bone and the shaft of radius. A longitudinal traction is transmitted mostly through volar radiocarpal ligaments correcting the radial height. However, external fixation cannot reduce depressed lunate fossa and excessive traction may rotate volar fragment. As traction does not properly correct the dorsal tilt of the distal fragment (25) a manual thumb pressure to distal fragment is needed to restore the volar tilt caused by Colles’ fractures. There is usually a gradual loss of the initial distraction force through stress relaxation of soft tissues causing partial loss of immediate improvement in radial height, radial inclination, and volar tilt by the time of fixator removal (26). Additional K-wire fixation is often needed in very unstable dorsally tilted extra-articular and in most intra-articular fractures. In the most comminuted intra-articular fractures a volar buttress plate is recommended to restore sagitally split and volarly dislocated fragments together with external fixator and K-wires.
Indications for bridging external fixation include (27):

1. Temporary management
   a) Severe grade open fracture with extensive tissue loss
   b) Temporizing measure to resuscitate a polytraumatized patient
   c) Pending transfer to a tertiary referral facility for definitive fracture management

2. Definitive management
   a) Unstable extra-articular distal radius fractures
   b) Two-part or selective three-part intra-articular fractures without displacement

3. Combined internal and external fixation (augmented external fixation)
   a) Intra-articular radial styloid fractures
   b) Three-part intra-articular fractures
   c) Following percutaneous reduction of a depressed lunate fragment
   d) Arthroscopic aided reduction of distal radius fractures

Contraindications for bridging external fixation are (27)

1. Ulnar translocation due to unstable distal radioulnar joint
2. Intra-articular volar shear fractures (Barton)
3. Marked metaphyseal comminution
4. Disrupted volar carpal ligaments/radiocarpal dislocations

Non-bridging external fixation was introduced in 1998 to provide an interfragmentary external fixation (28). McQueen (28) and Hayes et al. (29) compared bridging and non-bridging fixation in the treatment of distal radius fractures. They found that fractures treated with bridging external fixator had an increased risk of dorsal malunion and radial shortening compared to non-bridging fixation. However, volar malunion appeared to be more prevalent after nonbridging fixation especially when the volar cortex was comminuted. Non-bridging external fixation can be utilised when there is relatively large and stable distal fragment with enough space for the placement of pins. Non-bridging external fixation allows early mobilisation of the wrist while in bridging external fixation wrist is immobilised for six weeks. Possible complications related to utilisation of bridging and non-bridging external fixators are pin track infection, iatrogenic fracture, lesion of superficial branch of radial nerve, fixator or pin loosening, joint stiffness due to over distraction (Fig. 2).

Fig. 2. a) An iatrogenic metacarpal fracture and a pin track infection after external fixation of distal radius fracture. A reoperation was performed three weeks after the first operation with an external fixator b) and c) Distal pins were placed into the third metacarpal, intramedullary K-wires were used in the fixation of the metacarpal fracture, and additional intrafocal K-wires with tricalcium phosphate bone substitute were utilised in the fixation of radial fracture.
Iatrogenic fractures can be avoided by pre-drilling pin tracks and promptly placing fixator pins parallel. Injury of radial nerve can be avoided by exposing the nerve properly when inserting pins into radius. Placement of the fixator pins and K-wires as well as fracture reductions should always be done under image intensifier.

Dorsal plates
Although distal radius fractures can be easily reached from dorsal approach and dorsally angulated metaphyseal fractures are easy to reduce and fix from the dorsal side complications related to dorsal plating are numerous. The convex shape of distal radius dorsally and convex grooves for extensor tendons in it mean that dorsal plates, low profile or not, cannot be placed further distally than proximal end of Lister's tubercle without disturbing the extensor tendons. The more comminuted the fracture, the more problematic a dorsal approach gets. Also, volar instability cannot be controlled from the dorsal approach and the plate does not bear early motion loading as well as volar fixed angle plates if the volar cortex is comminuted (30, 31). Complications related to dorsal plates are tendon rupture or tenosynovitis leading to reoperation in up to 32%, and a collapse in up to 25% (32, 33). Extensor tendon problems have been less frequent when smaller 2.0 and 2.4 mm intermediate and lateral column plates have been used (34, 35).

Volar fixed-angle plates
Fixed angle volar plates for the fixation of distal radius fractures were introduced in the English literature by Orbay and Fernandez in 2002 (36). After that several different plate designs have been presented. By placing the plate on the volar aspect of the distal radius one can avoid the close contact between the plate and tendons, because on the volar side the distance between the flexor tendons and volar cortex is longer and the plate can be completely covered by repairing the pronator quadratus muscle. Volar approach through the classic Henry approach (37) is recommended. A more ulnar approach through carpal tunnel is related with more median nerve complications (38). Carpal tunnel is not opened unless there are signs of median nerve injury or entrapment preoperatively (39). If a carpal tunnel release is indicated, a separate carpal tunnel incision avoids injury to the palmar cutaneous branch of the median nerve.

Indications for use of volar fixed angle plates include instable intra-or extra-articular either apex dorsal (Smith) or apex volar (Colles) fractures, volar shear fractures (Barton). Volar plates have been successfully utilised in the fixation of osteopenic distal radius fracture in elderly patients (40). Contraindications to the volar plating of the distal radius are fractures of pediatric patients with open physes, open fractures with inadequate soft tissue coverage, and distal articular shear fractures (frequently seen in dislocation of the carpus) where there is insufficient bone distally for capture with the screws. Also, unstable high-energy fractures with considerable comminution (AO C3 fractures) are a relative contraindication to isolated volar plating, and these fractures might require supplemental internal fixation with K-wires or multiple plates or neutralization with an external fixator (41).

Distal locking screws of the fixed angle plate prevent the distal fragments from collapsing dorsally which makes early mobilization possible. Locking screws are needed in the volar fixation of every distal radius fractures except the volar Barton fractures. Volar fixed angle plates are pre-contoured to the anatomical shape of volar side of the distal radius. The direction of the distal locking screws is either fixed by the plate design or it can be adjusted 5-10 degrees. They can be replaced by smooth pegs that may allow closer placement into subchondral bone with less concern of screw head penetration into the joint. However, they don't provide as stable fixation of intra-articular C3 type fractures as threaded screws (42). The volar fixed angle plate has to be properly placed and fracture reduction has to be precise in order to avoid the screw penetration into the joint. This must always be secured by using image intensifier. The lateral view should be taken as a 20 degrees inclined view. Also, the length of screws should be checked with image intensifier from several different projections in order to avoid the screw penetration through the dorsal cortex, which may cause extensor tendon irritation and rupture.

After a stable fixation the wrist is placed in dorsal plaster cast or synthetic splint for two weeks. Finger, elbow and shoulder range of motion exercises are initiated immediately. The sutures are removed 10-14 days after surgery and the wrist is placed in a prefabricated or a custom-made orthopaedic wrist splint, which the patient can remove for the gentle wrist range of motion exercises and for washing. The splint will be removed 5 to 6 after operation. If the fixation is not fully stable, immobilisation will be continued up to 5 weeks from surgery. A recent study showed that there was no difference in the range of motion in wrists im-
mobilized two or six weeks after volar fixed-angle plate fixation of distal radius fractures (43).

Complications of the volar plating are loss of fixation, injury to the palmar cutaneous branch of the median nerve, postoperative carpal tunnel syndrome, flexor pollicis longus and extensor tendon tenosynovitis or rupture, complex regional pain syndrome (CRPS), delayed union, loosening of a single screw, and intraoperative intraarticular screw displacement with 27% overall complication rate. Placement of the plate distal to the edge of pronator quadratus muscle (watershed line) increases the risk of flexor pollicis longus tendinitis or rupture (44).

Egol et al. (45) compared external fixation and locked volar plates in a prospective randomized manner and found an improved range of movement and radiological outcome at three and six months after locked plating, but although the improved early ranges of wrist movement were statistically significant, the actual difference was of little clinical significance. None of the improvements was associated with a better outcome. Furthermore, while the number of complications between the two methods was similar, there was a greater incidence for re-operation in the plating group. Despite this finding, their study showed no evidence for the superiority of one treatment over the other.

Concomitant wrist instability and arthroscopically assisted fracture repair

The three common ligament injuries related to the distal radius fracture are rupture of triangular fibrocartilage complex (TFCC) stabilizing the distal radioulnar joint (DRUJ), scapholunate interosseous ligament (SLIL), and lunotriquetral interosseous ligament (LTIL). Instability of DRUJ may be due to three different patterns. First the dorsal lunate facet fragment may separate from the rest of the radius. This causes either incongruity of sigmoid notch, the joint surface towards ulnar head or insufficiency of the dorsal radioulnar ligament of the TFCC. This can be avoided by stabilizing the dorsal lunate facet fragment with a screw. Second and the most common pattern is a dislocated fracture at the base of ulnar styloid with the TFCC insertion. Stability of distal radioulnar joint should be tested always when fracture of the ulnar styloid is observed. When instability occurs the styloid should be reinserted with a tension band fixation. There is no need to immobilize the rotatory movement of DRUJ after the fixation and early mobilisation program can be followed. The third pattern is purely soft tissue avulsion of the TFCC from its ulnar attachment. This is usually observed at the later stage, but if found at the acute stage a reattachment to ulnar fovea is recommended.

A rupture of SLIL should always be suspected when there is a longitudinal or diagonal intraarticular fracture line in the radial or lunate facets. An increased scapholunate distance (normal 2-3 mm) is a typical sign, but it is not always present. Also an incongruity of the proximal carpal arch (Gilula lines) may be observed. Rupture of the LTIL is very difficult to diagnose without arthroscopy. Thus, whenever there is a suspicion of injury of these three ligaments arthroscopy or arthrotomy with instant ligament repair is recommended together with fracture fixation.

Wrist arthroscopy can provide valuable help to judge the reduction of intraarticular fragments. Also fragments may be reduced very precisely with a help of a probe and K-wires arthroscopically. Usually a volar locking plate or an external fixator is needed for a stable fixation. In a randomized prospective study addition of arthroscopy to fluoroscopically assisted treatment of intra-articular distal radius fractures improved the functional outcome (46).

Bone grafting

If an open reduction of the dorsally displaced distal radius fracture is performed through dorsal approach a metaphyseal bone defect is often created by the surgeon. Bridging external fixation may not be able to keep the reduction without a bone graft. The longer since injury the more probable the need for bone graft. By using volar fixed-angle plates the need for bone graft has been diminished as the reduction is done from the volar approach without tethering the dorsal cortex and its blood supply. In the very comminuted intraarticular fractures caused by high energy trauma there is still a need for bone grafting to shelter small intraarticular fragments stabilized by K-wires and bridging external fixator. Bone graft is usually taken from the iliac crest. There are also various tricalcium phosphate products to substitute autogenous bone graft.
Conclusion

There is not a single method that performs well in the treatment of all kinds of distal radius fractures. Also, no osteosynthesis method gives clearly better results than another in the treatment of the most common type of fractures. Surgeons treating fractures of distal radius should build an armamentarium of different methods that they are familiar enough with. Every new method needs to be properly learned before starting to use it. All surgeons do not need to treat all the most difficult fractures and instability related to distal radius fractures. A referral to a unit that is better prepared to treat more difficult fractures usually means more efficient treatment with less reoperations and less complications.

References:

8. Forward DP, Davis TRC, Sithole JS: Do young patients with malunion fractures of the radius develop an armamentarium of different methods that they are familiar enough with. Every new method needs to be properly learned before starting to use it. All surgeons do not need to treat all the most difficult fractures and instability related to distal radius fractures. A referral to a unit that is better prepared to treat more difficult fractures usually means more efficient treatment with less reoperations and less complications.

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