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Distal Forearm Fractures: the Analytical Approach to Treatment

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SUMMARY

Background. Although distal radius fractures are in the centre of orthopedic surgeons' attention, the rate of unsatisfactory treatment results remains very high. This study evaluates the analytical approach to distal radius fracture treatment.

Material and methods. We observed 59 patients divided into 4 groups according to a modified Fernandez classification, regarding the patomechanism of injury: 1. bending extraarticular fractures; 2. shearing fractures; 3. comminuted fractures, and 4. malunions. We also took account of patients' compliance and demands. 1st and 2nd group patients underwent ORIF, the 3rd group was subjected to external fixation, and the 4th group underwent radial corrective osteotomy with plating.

Results. We obtained 53% good, 40% satisfactory and 7% poor results according to the Mattis score.

Conclusions. We consider such analytical approach to distal forearm fracture treatment very promising and well-founded.

Key words: distal radius fractures; volar plating; ligamentotaxis; distal radius external fixation, Colles fractures, Fernandez classification

BACKGROUND

The world orthopedic community has been familiar with distal radius fractures for almost two centuries. In 1814, a brief article was published in the Edinburgh Journal of Medicine and Surgery where A. Colles summarized his observations and logically proved the anatomic nature of the injury. Since then many orthopedic surgeons have paid considerable attention to this type of fracture, proposing various theories which could explain the biomechanics of the injury and developing numerous devices for its treatment. However, nowadays the outcome of these fractures often does not justify their reputation of simple and "easily-treated" injuries and the complication rate following distal radius fractures remains very high. This rate varies from 6 to 80 percent, with a mean figure of 20-30% [1].

Analyses of distal radius fracture complications have revealed the following structure: a considerable proportion of complications are caused by inappropriate conservative treatment: the rate of redisplacement in cast amounts to about a fourth of fractures treated conservatively; redisplacement may lead to malunions and nonunions, which, in turn, can cause of residual deformity, pain syndromes and trophic disorders. More importantly, the surgical success rate after redisplacement remains low [2]. Another large group of complications occurs after the surgery. This group includes such significant complications as flexor and extensor tendon disorders, including synovitis and ruptures; infection, trophic disorders, including complex regional pain syndrome; fixation loss and redisplacement, infection, nerve and vascular injuries, delayed bone union and compartment syndrome. Notably, the loss of fixation can occur even if fixed-angle devices are employed .

The relatively high complication rate in both conservative and surgical treatment may be regarded as suggestive of a misunderstanding of the nature of the morphology and biomechanics of the injury. The anatomy of the region can be described with some quantitative parameters. In 1951, Gartland and Werley published a study on the evaluation of healed Colles fractures that emphasized restoration of the volar tilt to 11° and radial inclination to 23° to "compensate adequately for the loss of correction which will occur" after conservative treatment of extraarticular Colles fractures [3]. Reliable evidence of a direct relation between the anatomy of the healed fracture and the functional outcome can be found in the literature. Another notable feature in distal radius fracture anatomy is the involvement of the distal radioulnar joint (DRUJ). In their study of DRUJ, Palmer and Werner described the ligamentous and cartilaginous structure that suspended the distal radius and ulnar carpus from the distal ulna [4]. Pain and tenderness around the ulnar styloid after a wrist injury is very resistant to treatment. Consequently, this structure has gained the epithet of "chronic backache of wrist fractures". The authors emphasized the importance of the precise anatomic relations between the distal radius and ulna and the ulnar carpus, and warned that even minor modifications to these relations lead to significant load-pattern changes.

The pathomechanism of distal radius fractures has been the subject of multiple investigations, the first of which was carried out by Dupuytren [5]. The classical idea is that the reason for a fracture is a fall on a hyperextended wrist. Dupuytren's theory emphasizes the role of compression forces transmitted through the carpal bones to the distal part of the radius after a fall on the wrist in extension-pronation; it is at this moment that a fracture occurs . The avulsion theory places emphasis on the tensile force transmitted by the volar wrist ligaments, which leads to avulsion of the dorsal radial cortex. The incurvation theory notes the bending forces: after a fall onto an outstretched hand the body continues moving towards it, the wrist is placed in a hyperextended position and the radius is positioned against the articular facets of the bones of the first carpal row – this produces the fracture. It is reasonable to conclude that each theory contributes partially to the fracture pathomechanism. A fact of note is the predominance of tensile forces in the region of the distal radius, fragility of the distal dorsal cortex and the correspondence between the articular facets of the first carpal row bones and the distal radius.

Classification is a very important aspect which may help to decide on appropriate treatment through understanding injury morphology and biomechanics. Contemporary classifications take account of the pathomechanism, fracture patterns and treatment issues.

D. L. Fernandez (1993) chose to base his classification groups on the mechanism of the injury and divided distal radius fractures into five major types [6]. Type 1 encompasses bending fractures, which result from the combination of the above-mentioned mechanisms: axial compression transmitted from the hand, the tensile stress of the volar carpal ligaments and dorsal cortex avulsion and the overextension after the application of bending forces. Type 1 fractures are generally considered stable and may be treated by closed reduction – cast immobilization. Type 2 comprises shearing fractures (Barton's and reverse Barton's fractures, radial styloid). The mechanism bears some resemblance to the bending mechanism, but the force is applied directly to a clenched fist (a blow or a bike accident). The force is big enough to shear off the volar lip of the radial articular surface, thus chipping off an articular fragment in conjunction with volar subluxation of the carpus. Such fractures are extremely unstable because of the obliquity of the fracture line and are suitable for internal fixation. Type 3 comprises compression fractures of the joint surfaces. Here the predominant force is axial load with impaction of the articular surface of the radius by the scaphoid and lunate bones. The force is usually associated with falls from a considerable height. These fractures demand internal fixation and sometimes bone grafting. Type 4 consists of avulsion injuries, caused by a wrist torsional injury. Such injury in general is caused by high energy and is often a component of radiocarpal dislocation. Type 5 encompasses combined fractures. The mechanism of the injury combines all the above-mentioned forces and requires a combination of fixation methods.

The aim of treatment of distal radius fractures is obvious: to obtain and maintain anatomic reduction and to restore normal wrist function. Nowadays the orthopedic surgeon is armed with multiple devices to fix the fracture: dozens of variously shaped plates with or without angular stability and external fixation devices with bridging or non-bridging philosophy of fixation; also arum pins, K-wires, Rush nails, some kinds of intramedullary hardware: so-called micronail and nail-plate.

The choice of a fixation method depends above all upon the fracture pattern. Other factors that should not be neglected include bone density in the region, soft tissue status and the demands of the patient. Basically the hardware can be subdivided into 3 groups: pins and wires; external fixators and plates, each of them with its own advantages and disadvantages. Percutaneous pinning is a relatively simple and mini-invasive procedure, useful in case of unstable extra-articular or intra-articular easily reducible fractures. The contraindications to percutaneous pinning include osteoporosis and the presence of a large area of comminution.

Among the functions of the external fixator, there are joint distraction, compression, neutralization and a buttress function. Distraction favours, above all, indirect reposition via ligamentotaxis i.e. tension on the capsuloligamentous attachments and some kind of vacuum effect ; distraction may also help in stabilizing the fracture. The neutralizing role is played in combination with distal radius plating when the plate fixation is not rigid enough to prevent secondary displacement. The buttress function is associated with the bridging (transarticular) form of fixation. Among its disadvantages are pin- or wire-tract infection, joint stiffness in transarticular fixators, median and superficial radial nerve injuries and loss of reduction, and the total complication rate remains very high-up to 2/3 of patients [7,8]. Nevertheless this kind of fixator is indispensable in case of soft tissue damage in patients with multiple injuries.

New trends in plate design involve new anatomic fragment-specific shape: e.g. π-plates, T-plates, L-plates. The idea of fragment-specific fixation comes from Melone (1993) and Rikkli and Regazzoni (1996) [9, 10]. Both papers noted the importance of reconstruction of all fragments of the joint surface and making it congruent. The latter paper presented an original three-column concept of the biomechanic structure of the distal forearm and stated that stable internal fixation of many fractures can be achieved with small implants placed strategically to support these three columns. This idea was developed by P. Medoff and resulted in the development of a series of fragment-specific implants: Volar Bearing Plate™, Volar Peg Plate™, Volar Buttress Pin™, Radial Pin Plate™, Ulnar Sled™, Small Fragment Clamp™ and others [11].

The other trend affects the new material development. Most distal radius plates are manufactured from a titanium alloy. Such implants are quite solid and at the same time flexible, which promotes anatomic contouring. However, the surface characteristics of titanium are substantially rougher than those of stainless steel, which may lead to tendon irritation or even rupture .

A knowledge of the physical properties of the material may also help in solving the problem of polyaxial locking of screws, one example being the patented SmartLock polyaxial locking technology. The screws in the system are made of a titanium alloy (Grade V) and so are slightly harder than the plates, which are made from commercially pure titanium (Grade II). The thread in the head of the harder screw reshapes the softer titanium of the plate, thus creating a secure form-fitting geometry. This process results in a solid, locked connection between the head of the screw and the plate.

The problem of implant removal has led to using biodegradable materials for plating. By blending several rigid and elastic polymers, the Inion Ltd. company developed materials for implants in orthopedic surgery whose strength decreases by 10-12 week after implantation and which degrade entirely in 2-4 years. The devleopers claim that this biodegradable system minimizes the chance of tendon irritation or rupture, provides for polyaxial screw locking and simplifies intra- and post-operative radiographic evaluation of the treatment.

MATERIALS AND METHODS

We treated 87 patients with distal forearm fractures (51 females and 34 males aged 15 to 81 years) at the emergency traumatology department of the City Clinical Hospital #20 from January 2004 to May 2008.

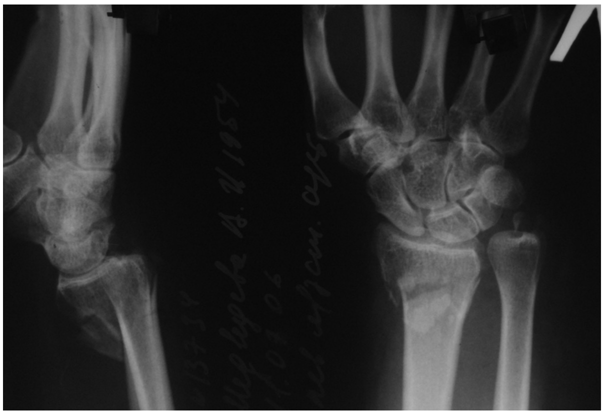
The selection of a treatment plan accounted for the following aspects:

1. The fracture pattern. We modified the Fernandez classification. The first group was comprised by bending extraarticular fractures. The second group encompassed shearing fractures with an oblique fracture plane. The third group was formed by intraarticular comminuted fractures. To these we added a fourth group, involving the sequelae of inappropriate treatment of distal radius fractures, mainly malunions.
2. Patient age and concomitant medical conditions. We also looked at the patient's occupation, capacity for work and demands.
3. Patient's consent to the operation.
4. Patient's compliance, i.e. his or her willingness to follow the doctor's recommendations, do exercises to improve wrist range of motion and observe the pins or an external fixator.

The main criterion in fracture management was fracture pattern. Thus, group 1 fractures were treated conservatively if reduction could be achieved. Non-reducible group 1 fractures underwent open reduction and internal fixation (volar plating). Group 2 fractures underwent ORIF. Implant choice depended on bone quality and the demands of the patients. Low bone density and the willingness of the patient to practice sport or perform manual labour shortly after the surgery were indications for using angular-stable implants. We used Numelock distal radius plates (Stryker) and LCP T-plates (Synthes) (Fig. 1). In patients with good bone quality and lesser demands we applied buttress T-plates (CHM) and biodegradable distal radius plates (Inion) (Fig. 2). In case of articular fragment impaction, we used autografting of bone from the iliac crest. In cases of severe displacement, we rejected buttress plates as not rigid enough to resist shearing forces and combined internal fixation with the ExFix. After the surgery we did not apply casting. The patients were allowed to practice movements in the hand and elbow joints.

Comminuted group 3 fractures were manly indications for external fixation. After assembling the apparatus module, we applied distraction until articular facet height was restored via ligamentotaxis. We applied the Ilizarov ring device and Monotube Triax device (Stryker) (Fig. 3).

The surgery was performed only in consenting patients, otherwise a closed reduction and cast immobilization was used regardless of fracture type. Another condition for the surgery was satisfactory somatic health of the patient.



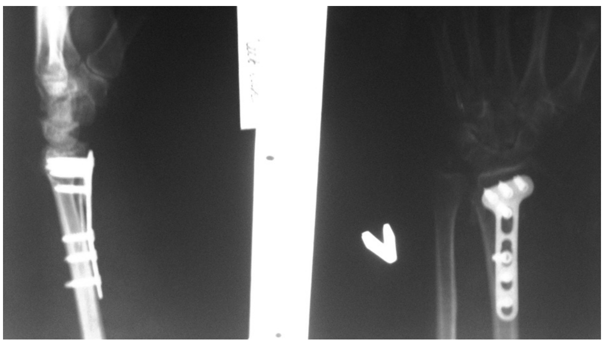


Fig. 1. Female patient, 53, fell onto her outstretched hand. The intraarticular shearing fracture was classified into the 2nd group. Surgery on the 4th day after the injury

Distal radius malunions were treated by osteotomy with bone grafting to restore distal radial height and volar tilt. In case of difficulties eliminating ulnar head subluxation, we used Darrach's procedure.

Compliance was of importance during preoperative planning, especially in the case of external fixation because of the relative inconvenience of the device, which demands much patience and tidiness from the patient.

The results were assessed with E. R. Mattis' score (1985) (Tab. 1)

A good result (a score of 70-75 points) is defined as adequate and timely union of the fracture with full functional restoration.

A satisfactory result (65-69 points) is defined as a persisting anatomical impairment with impairment of wrist function (ROM restriction not exceeding 20 degrees).

Fig. 2. 61-year old female. Injury after a fall on a skating rink. The extraarticular bending fracture was classified into the 1st group. Surgery on the 5th day after the injury: open reduction and internal fixation with a biodegradable plate. Outcome at 2 months

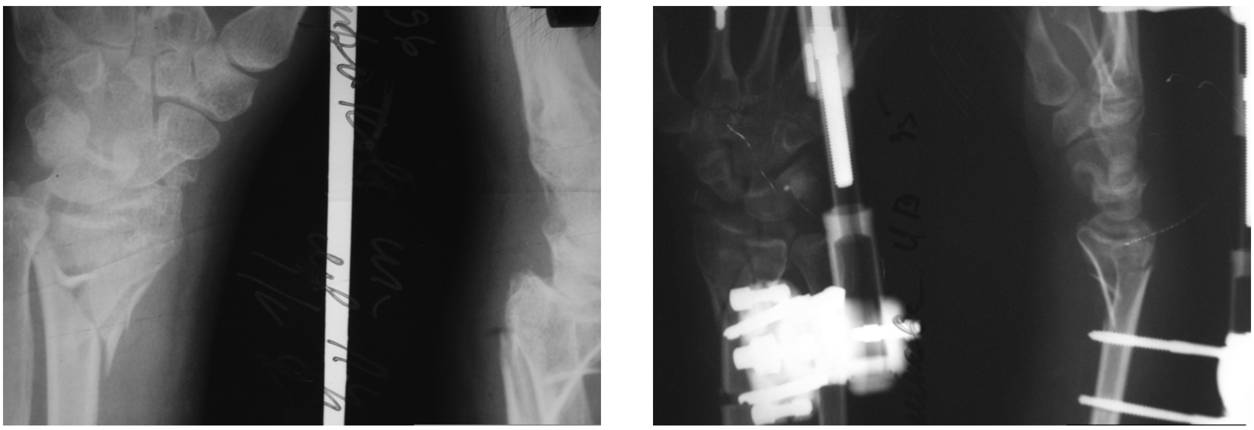


Fig. 3. Female patient, 44, fell onto her outstretched hand. Comminuted fracture – 3rd group. Surgery on the day of the injury. „Monotube" External Fixator

Tab. 1. E.R. Mattis' Score (1985)

№	Signs	Score
1	Pain (permanent, on exertion, on over-exertion, no pain)	1…5
2	Fracture union (delayed, normal)	4…5
3	Fracture displacement (yes-no)	2…5
4	Loss of radial height (0-6%)	2…5
5	wrist and carpal joint function	3…5
6	Elbow and shoulder joint ROM (on the affected side)	3…5
7	Soft tissue trophics (hypotrophy, muscular strength)	2…5
8	Cosmetic defect (bony deformity, scar)	2…5
9	Need of further treatment (surgery, conservative, outpatient or in-hospital)	2…5
10	Affected limb's functions	15…25

A poor result (below 65 points) is characterized by contractures and severe deformities that considerably impair wrist functions.

RESULTS

We assessed the remote results in 59 patients.

In group 1 (7 patients), we obtained 5 good and 2 satisfactory results. In group 2 (15 patients), we obtained 10 good results (70-75 scores), 4 satisfactory results (65-69 scores) and one poor result. In group 3 (32 patients), we obtained 11 good results, 18 satisfactory results and 3 poor results. In the group 4 (5 patients), all results were surprisingly good. The total good result rate is 31 patients (53%), with 24 patients with a satisfactory result (40%) and 7 (7%) with a poor result. The satisfactory results in the group 1 and 2 patients were characterized by moderate (less than 200) wrist movement restriction. The poor result in the 2nd group was characterized by loss of reduction 5 weeks after the surgery. The patient underwent conservative treatment (physiotherapy, NSAIDs). The satisfactory and poor results in the 3rd group were mainly characterized by trophic disturbances: wrist and hand swelling, hyperhydrosis, stiffness, tenderness of various severity. There were three cases of superficial wire-tract infection, all subsiding easily after implant removal.

DISCUSSION

We used a volar approach because we consider it biomechanically more suitable (more chances of resisting the tensile forces). Also, the level volar surface of the distal radius simplifies plate positioning. This opinion is prevalent in contemporary sources.

The first conclusion which ensues from our study is that the results obtained with plating are noticeably better than the results of external fixation. Margaliot Zvi et al. (2005) and Rizzo et al. (2008) did not see any significant differences between the two treatments [12,13]. The authors compared patients with relatively similar fracture patterns (3rd type according to the Fernandez classification). In our study the fracture patterns in the plating and external fixation groups were quite different. Also noticeable is the high rate of high-energy traumas and of soft tissue problems in the 3rd group of patients. The solitary poor result in the plating group is due, in our opinion, to preoperative misdetermination of the injury pattern: intraoperatively we found a 3-fragment compression fracture with distal radioulnar joint impairment. Retrospectively we regard that such a fracture should be fixed by a combination of plating and external fixation.

Another interesting finding is the result of treatment of group 4 fractures. Henry (2007) reports similar results in 19 patients [14]. J. Van Cauwelaert de Wyels et al. (2003) reported on 21 patients who underwent corrective osteotomy sometimes combined with a Darrach or Sauve-Kapandji procedure [15]. The authors emphasized the importance of ulnar surgery. Thus, regardless of the low number of patients with distal radius malunions we judge this treatment strategy (corrective osteotomy and bone grafting combined with ulnar surgery) to be natural and effective. Surgery of the ulna constitutes an additional trauma to the distal forearm, but it does help to restore the ligamentous imbalance and biomechanical "forearm-hand" axis, which improves wrist movements.

CONCLUSIONS

1. Successful treatment of a distal forearm fracture depends on understanding the pathomechanism of the injury and attention to the bony-ligamentous structure of the distal forearm.
2. Accurate preoperative planning including injury mechanism analysis, radiographic assessment and patient characteristics is mandatory.
3. The analytical approach to distal forearm fracture treatment has proven very promising and well-founded.

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