Dorsally displaced distal radius fractures treated by fixed-angle volar plating: Grip and pronosupination strength recovery. A prospective study

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Summary
Introduction: Malunion following open reduction and internal fixation of distal radius fracture threatens wrist function. Fixed-angle palmar plates provide rigid fixation that is stable over time; however, the pronator quadratus sectioning required by the anterior approach entails a risk of pronation strength loss and of distal radioulnar joint destabilization. The present study assessed recovery of grip, pronation and supination strength following such internal fixation.

Patients and method: A prospective study included 26 distal radial fractures with dorsal displacement, osteosynthesized using a fixed-angle palmar plate, in 25 patients (mean age: 47.5 years; range: 17–72 years). Assessment concerned the classical parameters, plus grip and pronosupination strength recovery.

Results: At a mean 14 months follow-up (range: 6–30 months), patients had recovered 91% grip strength, 88% pronation strength and 85% supination strength with respect to the healthy side. Complications comprised three cases of malunion, two of reflex sympathetic dystrophy syndrome, and four of post-traumatic carpal tunnel syndrome.

Discussion: A study of the literature found 75–95% grip strength recovery following osteosynthesis using fixed-angle plates. Few studies, however, have focused on pronosupination strength, and none reported its evolution following osteosynthesis.

Conclusion: The present study found no drawbacks associated with a technique which usually involves sectioning the pronator quadratus. Except in case of malunion or joint stiffness, fixed-angle palmar plate osteosynthesis was followed by recovery of grip and pronosupination strength.

Level of evidence: Level IV: prospective non-randomized, non-comparative observational study.
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Introduction

Reduction defect and secondary displacement following distal radius fracture osteosynthesis can impair wrist function. The 2000 Sofcot symposium [1] reported that more than 30% of peroperative reductions fail to be conserved. Fixed-angle palmar plates were subsequently developed and provide more rigid fixation that is stable over time [2–8], which accounts for the current vogue.

An anterior approach to the distal radius requires pronator quadratus sectioning, entailing a risk of pronation strength loss and possible destabilization of the distal radioulnar joint. Johnson and Shrewsbury [9], followed by Stuart [10], first showed this muscle to combine the functions of pronation, by its superficial bundle, and distal radioulnar joint stabilization, by its deep bundle.

Recovery of grip and pronosupination strength was assessed in a series of 26 distal radius fractures managed by fixed-angle palmar plate.

Patients and method

Patients

A single-center continuous non-randomized and non-comparative prospective study recruited 25 patients (14 male, 11 female) presenting with distal radius fracture with dorsal displacement, managed by fixed-angle palmar plate, between January 2007 and May 2008. Three cases involved bilateral fracture. Twenty-six fractures in all were managed by fixed-angle palmar plate, and two conservatively.

Inclusion criteria were:

- potentially unstable lesion on Lafontaine’s radiologic criteria [11]: posterior displacement greater than 20°, dorsal comminution, intra-articular fracture site, distal radius epiphysis comminution, associated ulnar fracture;
- no prior or concomitant forearm lesion liable to impair pronosupination;
- patient in work;
- minimum 6 months follow-up.

Mean age was 47.5 years (range: 17–72 years); only one patient was over 65 years of age (a farmer, still at work, free of osteoporosis). Thirteen cases (52%) involved the dominant side. The radius fracture was isolated in 15 cases and associated with other lesion(s) in 11. There were five cases of distal paresthesia (four in the medial and one in the ulnar nerve territory); four skin breaks; and eight remote fractures (contralateral wrist, cervical spine, rib, pelvis, ankle or calcaneus). The mechanism was of high kinetic energy in 13 cases. On the 2000 Sofcot classification [1], there were 12 extra-articular and 14 extra-intra-articular fractures (seven intraradiocarpal, one distal radioulnar and six intraradioncarpal and distal radioulnar). Radiocarpal impaction was observed in five cases. The ulnar side was involved in 18 cases, with distal ulnar styloid fracture in seven cases, proximal styloid fracture in eight, suspected triangular fibrocartilage complex (TFCC) lesion in three, and probable associated carpal lesion in one. Table 1 shows distribution on Laulan et al.’s MEU classification [12]. Mean frontal radial inclination was 15° (range: 5° to 20°), lateral radial glenoid anteversion –26° (–14° to –50°) and ulnar variance +3.6 mm (–2 to +15).

Surgery

All surgery was performed under pneumatic tourniquet and visual control, using a classic Henry approach. Particular attention was paid to the pronator quadratus muscle: its volume varies greatly and was classified as normal (n = 10), hypertrophic (n = 10) or hypotrophic (n = 6). The suture at end of surgery was judged solid in seven cases, weak in seven and impossible in 12; in these 12 cases, the muscle body was retracted and the aponeurosis not solid enough for suture. The bone showed normal resistance in 24 cases, and was osteoporotic in two women (aged 52 and 53 years).

In 12 cases, the osteosynthesis plate was a Matrix® (Stryker, Pusignan, France), in 10 a DRP 2.4® (Synthes, Etupes, France) and in four a DVR® (Depuy, Saint-Priest, France). Osteosynthesis of the ulnar styloid was performed in only one case.

Postoperative care comprised 20 days brace immobilization, except in the first 54 patients, in whom 20 days cast immobilization was applied. Rehabilitation was not systematic and was prescribed for eight patients at D45 for notable joint stiffness with 50% range of motion (ROM) as compared to the non-operated side.

Revision

Clinical functional assessment, at 20 days, 45 days, 3 months, 6 months and last follow-up, concerned ROM and grip and pronosupination strength recovery as compared to the non-operated side. Measurements were taken using portable apparatuses.

Grip strength was measured classically on a Jamar® dynamometer (Sammons Preston Rolyan, Bolingbrook, IL).

Pronosupination moment was measured on a Baseline® Hydraulic Wrist Dynamometer (Fabrication Enterprises Inc., Elmsford, NY) (Fig. 1), a portable apparatus with several kinds of handle. Moment was measured in pronation then in supination, with the hand initially in neutral position, shoulder to the body, using a 30-mm-diameter cylindrical handle which placed the wrist in approximately 20° inclination, thus reproducing the movement of screwing/unscrewing using a screwdriver; the surface of the cylindrical handle was relatively non-adherent, so that the subject needed func-

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Pronator quadratus status was determined during these revision operations: in the cases of "solid" pronator quadratus suture (five cases), continuous muscle was found covering all the material in one case, atrophic, more or less dehiscent muscle showing little contraction in response to electric lancet stimulation in three and, in one case, simple fibrous tissue without identifiable muscle fibers, indicating suture breakdown.

The grip strength recovery results showed a mean grip strength of 40.6 kg (range: 20 to 54 kg) (Fig. 2), mean pronation moment of 71.7 kg.cm (40 to 120) (Fig. 3) and supination moment of 74.02 kg.cm (30 to 130). There was no loss of strength following removal of material. Compared to the healthy side (Fig. 4), grip strength showed a tendency to recover slightly more quickly than pronosupination strength, although the difference was not significant. The pronation and supination recovery curves were perfectly superimposable. At a mean 14 months follow-up, grip strength was 91% that of the healthy side. Pronation and supination strengths

Statistics

Data were analyzed on Chi² independence test, with a 5% significance threshold. When numbers were too small, Pearson’s correlation coefficients were used. Analysis used StatView 4.0 software.

Results

Mean follow-up for the 26 fractures was 14 months (range: 6 to 30 months). In the three bilateral cases, strength could not be compared contralaterally, and these cases were excluded from analysis.

There were 10 complications: one severe local edema associated with a 5 m fall; three malunions on the Sofcot criteria [1], related to one reduction defect, and two cases of secondary correction loss due to over-proximal plate positioning; four post-traumatic carpal tunnel syndromes, requiring secondary medial nerve release in three cases, with removal of material between months 4 and 9; and two syndromes suggestive of mild regressive reflex sympathetic dystrophy. Systematic removal of material was performed in 13 cases, at a mean 11 months (range: 4 to 30 months), bringing the total of material ablations to 16. In one case, ablation disclosed a nascent asymmetrical flexor digitorum profundus lesion.
were equivalent, at respectively 88% and 85% of healthy-side values.

Factors influencing functional recovery were investigated. There was a moderate correlation between malunion and poor recovery of grip and pronation strength (Pearson coefficient respectively 0.23 and 0.28) and a weak correlation between malunion and poor recovery of supination strength (Pearson coefficient 0.08): evolution towards malunion impaired recovery of pronation and grip more than of supination.

Fracture type (extra- or intra-articular) on the Sofcot classification did not, in the present series, correlate significantly with recovery of grip (\(P = 0.4\)), pronation (\(P = 0.4\)) or supination strength (Pearson coefficient, 0.02) independently of the other factors.

Distal radioulnar joint lesion (proximal cubital styloid fracture and/or suspected TFCC lesion on the Sofcot classification) did not correlate significantly with recovery of grip (\(P = 0.21\)), pronation (\(P = 0.68\)) or supination strength (\(P = 0.255\)).

Remote joint stiffness correlated moderately with grip, pronation and supination strength recovery (Pearson coefficient respectively 0.44, 0.33 and 0.45). Supination strength recovery was the most affected by joint stiffness.

The solidity of the pronator quadratus muscle suture influenced recovery of grip and pronation strength, but only moderately (Pearson coefficient respectively 0.32 and 0.33). Supination strength recovery seemed unaffected by pronator quadratus suture solidity at end of surgery (Pearson coefficient, 0.15).

The radiological results (Fig. 5) showed frontal radial inclination (around 22°) and lateral radial glenoid anteverision to be generally stable. In contrast, ulnar variance tended to deteriorate, from an immediate postoperative value of -1.2 mm to +0.37 mm at 1 year.

**Discussion**

Grip strength assessment is part of the functional check-up following distal radius osteosynthesis. Certain authors have reported recovery as compared to the healthy side, ranging from 75% at 12 months for Wei et al. [13] and Chung et al. [14] to 95% at 16 months for Pichon et al. [15]. The present recovery level of 91% at 14 months is in agreement with these reports. Wei et al. [13] and Rozental et al. [16], in prospective randomized studies, reported rapid recovery after fixed-angle plate osteosynthesis. In the present series, grip strength had almost fully recovered by 6 months. In the above reports [13,16], however, at 1 year there was no significant difference in grip strength recovery as compared to osteosynthesis by K-wire or external fixator.

Pronosupination strength recovery does not presently feature in functional assessment of the wrist. Distal radius fracture, however, is frequently associated with ligament lesions, as shown by Fontes et al. [17], Laulan and Bismuth [18], the 2000 Sofcot Symposium [1] and, more recently, Forward et al. [19] and Chen and Jupiter [20] in 2007. Whether the lesions are intracarpal or involve the TFCC, they may impair pronosupination strength. Various authors [21–24] have studied healthy subjects, in order to determine ideal pronosupination measurement conditions and obtain reference values. The apparatus used enabled electronic measurement of the torque exerted on the handle by a wrist held vertically, with significant variants from study to study. Differences in control groups and examination conditions probably explain the wide variations in results (moment ranging from 36 to 126 kg.cm in pronation and 39 to 148 kg.cm in supination). Depending on sex, body mass index and whether the dominant side is being measured, recorded strength can vary as much as two-fold according to Herzberg et al. [24]. Timm et al. [21], O’Sullivan and Galloway [22] and Herzberg et al. [24] reported greater supination than pronation strength; only Matsuoka et al. [23] found the force developed during pronation (with the hand in 60° supination) to be greater. Finally, Herzberg et al. [24] demonstrated a fatigue effect, with strength decreasing regularly over three consecutive trials; this suggests that, in consultation, a single measurement should be made. The present findings show that pronosupination strength recovered more slowly than grip, remaining slightly lower at 1 year. Pronosupination strength recovered regularly as of the sixth month (the interval required for consolidation) then stabilized as of 18 months (Fig. 4).

The pronator quadratus is a triangular muscle extending forward of the distal extremity of the forearm skeleton. Johnson and Shrewsbury [9] and Stuart [10] demonstrated that there are systematically two (sometimes three) muscle heads: one superficial and one deep. Several functions are attributed to it. It has a pronatory function, being one of the main pronator muscles along with pronator teres. According to Haugstvedt al. [25], the two pronator quadratus heads develop a greater torque couple during pronation than the pronator teres, making it the main forearm pronator. Stuart’s 1996 electromyogram study [10] confirmed this, although it was questioned, notably by Gordon et al. [26], who reported greater electrical activity during pronation in the pronator teres. There is also a distal radioulnar stabilization function: Stuart [10] demonstrated that the deep head of the pronator quadratus opposes radioulnar diastasis during pronosupination and grip. Gordon et al. [26] confirmed this stabilization function, with deep head activity continuing during supination. Gofton et al. [27], in a cadaver study in which they sequentially sectioned the various radioulnar strains, showed that the pronator quadratus opposes supination and not pronation. Boileau et al. [28] showed that a pronator quadratus section, particularly deep, impairs the radioulnar joint stability.

**Figure 5** Evolution of X-ray parameters.
stabilization structures, demonstrated the stabilizatory role of the pronator quadratus, but recommended further studies to determine its exact function. The pronator quadratus is certainly more a distal radioulnar stabilizer than a forearm pronator, and this function must be respected when performing the Henry approach, avoiding any exposure of the medial side of the radius. Finally, the pronator quadratus protects the flexor tendons from the osteosynthesis material; this function was described by Erhard et al. [28] and is probably variable: the design of certain plates means that they have to be positioned very distally from the radius, practically under the edge of the pronator quadratus muscle body. Drobetz et al. [29], using an anatomic model of distal radius fracture osteosynthesized by an LCP 2.4 palmar plate, demonstrated that conserving radius length required placing the screw as close as possible to the subchondral bone; in this situation, the plate is not covered by the pronator quadratus muscle body (Fig. 6), and may threaten the flexor tendons. Obert [30] stressed the interest of the latest generation of plates, better adapted to distal radius morphology.

The classic anterior approach involves complete vertical full-body sectioning of the pronator quadratus muscle. It has good cicatization potential, having a large anastomotic arterial network between the anterior interosseous, radial and ulnar arteries [31]. Even so, muscle suture is often unsure or even impossible, as the fleshy transverse fibers, often retracted at the end of surgery, and aponeurosis do not provide a solid anchorage for the suture stitches. Very few reports include the way of proceeding: Pichon et al. [6] used a single suture; Kamano et al. [2] performed suture and then immobilized the wrist for 2 weeks: they simply observe that they found no signs of pronator quadratus muscle impairment.

Several surgeons have sought to conserve the pronator quadratus muscle, either with an outward-return running suture [28] – which, in our admittedly reduced experience, seemed less solid than the authors reported — or by muscle release, passing the plate under the pronator quadratus, as described by Dos Remedios et al. [32] and, on a minimally invasive approach, Imatani et al. [33]. The latter techniques, which do not involve broad opening of the aponeurosis, entail a risk of compartment syndrome, as Chen and Jupiter [20] point out. Two cases of compartment syndrome following closed trauma without associated radius fracture, were reported by Summerfield et al. [34] in 1997 and then by Schumer [35] in 2004; diagnosis was confirmed by measuring intramuscular pressure. This compartment syndrome is explained by the fact that the pronator quadratus muscle lies in an independent compartment, separate from the other forearm muscle compartments; Gerber and Masquelet [36] likewise showed that the pronator quadratus is systematically covered by a fine but solid fascia.

The present study involved certain limitations: small series; use of different plate models, which could induce bias; and lack of postoperative imaging to assess pronator quadratus aspect. Further studies should provide more precise assessment of recovery of strength after osteosynthesis for distal radius fracture.

**Conclusion**

Analysis of the recovery of grip strength and especially of pronosupination strength found no harmful effect of fixed-angle palmar plate osteosynthesis, despite impact on the pronator quadratus muscle. In the absence of malunion or joint stiffness, this technique allows recovery of grip and pronosupination strength. Finally, measuring pronosupination strength seems to us to be an excellent means of assessing overall recovery of wrist function: to mobilize the dynamometer in rotation, the patient needs to have a functioning hand, with sufficient grip strength, a stable radioulnar joint and adequate muscles.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.

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**References**


**Figure 6** Anatomic preparation: LCP 2.4° plate in position under pronator quadratus.


