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HANDSURGERY

Early complications and radiological outcome after distal radius fractures stabilized by volar angular stable locking plate

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Abstract

Introduction Distal radius fractures (DRF) are the most common fractures of the upper extremities. The incidence is expected to continue rising in the next years due to the increased life expectancy. Palmar locking plate stabilizing has since become the standard treatment for dorsally displaced DRF with a complication rate of 8–39% reported in the literature. Main aim of this study was to investigate the incidence of complications after DRF stabilization using palmar angular stable locking plate.

Methods A retrospective medical records review conducted from January 2013 to December 2016 included a total of 392 patients with DRF, that were stabilized using palmar angular stable locking plate and showed a minimum follow-up of 3 months. The group comprised 259 female and 133 male patients with a mean follow-up interval of 11 months (range 3–52 months). All recorded complications were documented. Range of motion (ROM) in extension, flexion, supination, pronation, radial- and ulnar deviation of the last follow-up was noted. Age was divided into younger than 65 years (< 65 years) and older than 65 years (≥ 65 years). The primary, immediate postoperative and final checkup radiographs were scrutinized for alignment and intra-articular step-off.

Results A total of 51 (13%) early and 17 late (4%) complications were recorded in 392 patients. The most common complications included carpal tunnel syndrome (3%), complex regional pain syndrome (3%) and loss of reduction (2%). Of the 68 complications, only 25 (6%) were directly related to the plate. 73% of all complications occurred in AO type C fractures. Patients without complications showed a significantly better ROM in extension, flexion, pronation and supination than patients with complications. No significant differences in incidence of complications, ROM or loss of reduction could be found between patients over and under 65 years of age. Gender and type of immobilization showed no significant influence on the complication rate.

Conclusions Stabilization of DRF by palmar angular stable locking plate is a safe form of treatment. In the majority of the cases a good clinical and radiological outcome with no complications was documented. Gender and type of immobilization had no impact on the complication rate and an age over 65 years is not associated with an increased risk for complications or restricted ROM.

Keywords Distal radius fracture · Volar locking plate · Complications · Outcome · Elderly

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Introduction

Distal radius fractures (DRF) are the most common fractures in the upper extremities and the incidence is worldwide on the increase [1–5]. Two peaks prevail, first at the age of 10 and then again over 60 [6]. Due to a growing population in the industrial countries and the resulting increase in life expectancy, a 50% rise in incidence till 2030 can be predicted [7]. Especially white women over the age of 60 have a 15% higher risk of DRF than men of similar age, who's lifetime risk approximates 2% [8]. In addition, particularly in the elderly, DRFs are often associated with poor bone quality and osteoporosis [9].

In the last decade, a major turnaround from k-wires and external fixators to angular stable locking plates occurred. Thus, dorsally displaced DRF could be stabilized from palmar aspect without the increased risk of irritation to the tendons dorsally [10–12]. Additionally, palmar locking plates provide enough stability to enable the functional treatment after surgery without splinting. Thereby significantly improving range of motion and results in functional outcome when compared to an immobilization can be achieved [13].

Due to the increased number of DRFs, stabilization methods and complications are of interest in the literature [13, 14]. Many studies reported up to 39% complication rates in palmar stabilized DRF [2, 15–20]. Typical complications included: changes in sensibility, tendon irritation and rupture, hardware malfunction, infection, complex regional pain syndrome (CRPS), and arthritis [16, 17, 21].

Aim of this retrospective study of medical records including the radiographic data was to analyze complications of the outcomes after DRFs that were stabilized using palmar angular stable locking plates.

Materials and methods

Institutional review board approval was obtained for this retrospective study including radiological records.

All medical case histories of patients treated by palmar angular stable locking plate from 01 January 2013 to 31 December 2016 with a minimum follow-up of 3 months were reviewed. These patients were all treated at our hospital, which is certified as a European Hand Trauma Center by the Hand Trauma Committee of the Federation of European Societies for Surgery of the Hand (FESSH).

Indications for surgery included a displaced DRF with a dorsal tilt of more than 15°, an intra-articular step off, a radial shortening of more than 2 mm or an incongruency in the distal radioulnar joint in the standard radiographs.

Inclusion criteria stipulated: (1) age 18 or older, (2) isolated acute displaced DRF, (3) surgical procedure by open reduction and stabilization using only palmar locking plates, (4) follow-up interval of 3 months or longer. Exclusion criteria included: (1) below 18 years of age, (2) open fractures, (3) patients who received the palmar plate fixation in another hospital, (4) polytrauma, (5) additional injuries to the involved hand, (6) corrective osteotomies, (7) bilateral DRF, (8) DRF stabilized with additional k-wires, screws or external fixator, (9) follow-up interval shorter than 3 months and (10) injuries of the distal radius in the past.

A total of 1.076 patients were stabilized between 2013 and 2016 with palmar locking plate. Of these, 253 patients had to be excluded (not eligible), and a further 431, because the follow-up interval was shorter than 3 months. Therefore, the final analysis totaled 392 patients.

Surgical procedure

All procedures were performed with either general or regional anaesthesia in a supine position, using fluoroscopic assistance and a pneumatic arm tourniquet at 250 mmHg.

The standard palmar-radial approach over the flexor carpi radialis tendon was chosen. The flexor carpi radialis tendon was retracted ulnarly and the forearm fascia was opened. The pronator quadratus was incised radially and elevated off the radius.

Using the image intensifier, the fracture was reduced and, if necessary, temporarily fixed with K-wires. The palmar angular stable plate (Medartis® Aptus® 2.5 trilock distal radius locking plate) was placed on the palmar aspect of the distal radius and initially fixed at the gliding hole using a bicortical screw. After ensuring exact positioning of the plate under image intensifier, the remaining plate holes were filled with angular stable screws. Care was taken that the screws at the articular surface were placed subchondrally to prevent intra-articular protrusion. The pronator quadratus was sutured if possible. Previous studies already showed no influence of a pronator quadratus refixation on the outcome [22]. Therefore, a refixation was not analyzed.

In 366 patients the Medartis® Aptus® 2.5 correction plate, in 15 patients the flexor pollicis longus (FPL), in 7 patients the fracture plate, in 3 patients the frame plate and in 1 patient the adaptive plate was used.

Carpal tunnel release was only performed if the patients showed preoperative symptoms of median nerve compression. In this study, only two patients required carpal tunnel release surgery, which was performed together with the stabilization of the DRF.

All patients received the same padded dressing immediately after wound closure as part of the postoperative dressing. On the first postoperative day, the dressing was changed for either a thermoplastic splint or nonremovable plaster cast for 5 weeks. Type of fixation was determined by the operating surgeon.

All patients started occupational therapy of the free joints (shoulder, elbow, fingers) on the first postoperative day. After cast or splint removal the wrist was then included in the hand therapy programme.

Medical record reviews

All patients that complied with the criteria were eligible, and therefore, included in our retrospective medical records study. Range of motion (ROM) in extension, flexion, supination, pronation, radial- and ulnar deviation of the final checkup was documented. Demographic data included age, gender, injured hand, interval between surgery and follow-up. To analyze the incidence of complications depending on age, the patients were divided into younger than 65 (65 years) and equal or older than 65 years (≥ 65 years) according to the definition of the World Health Organization (WHO) for geriatric designation [23, 24]. To analyze at what stage the complications occurred, follow-up intervals were divided into under (< 3 months) and over 3 months (≥ 3 months). CRPS was diagnosed clinically on the basis of the Veldman´s criteria [25]. All types of revision surgeries were recorded.

All the intraoperative complications that were documented in the surgical write ups were charted. Each return evaluation was analyzed for complication.

Frequency and reason for hardware removal was gleaned from the medical records, although hardware removal was not regarded as a complication in itself. Complications associated with hardware removal were analyzed separately.

Radiological reviews

Routine follow-up treatment included a standard radiological check in two planes (anteroposterior and lateral view). The primary (pre-reduction), immediate postoperative as well as radiographs at the final follow-up examination were checked for alignment and intra-articular step-off. The fractures were classified according to the Association for the Study of Internal Fixation (AO) classification by Müller et al. [26]. Additionally, fractures of the processus styloideus ulnae were documented and classified into fractures of the tip, base or tip and base.

A satisfactory reduction was defined as 10° of dorsal tilt, 2 mm of radial shortening, and 1 mm of articular incongruity [16].

In the anteroposterior radiographs, radial inclination and ulnar variance according to Gelberman and in the lateral radiographs, the palmar tilt was measured [27]. Fracture healing was defined as bony bridging of the radial, ulnar, and dorsal cortical aspects of the distal part of the radius [15].

The lateral X-ray verified the plate position and was subsequently classified according to Soong et al. in Grade 0, I and II [28]. The Medartis® Aptus® FPL plate and frame plate were excluded from the Soong classification. The specific design of the FPL plate (gap in the plate for the FPL tendon), allows a placement distal to the Watershed line.

Statistical analyses

Shapiro-test was used to test the assumption of normal distribution of scaled parameters. Since this assumption could not be maintained, the outcome was analyzed non-parametrically using Mann–Whitney *U* test.

To compare scaled parameters between Soong grades (grade 0, I and II) and type of processus styloideus ulnae (tip, base, tip and base) fractures, the Kruskal–Wallis-test was used. If Kruskal–Wallis-test was significant, posthoc analysis was performed using the Mann–Whitney *U* test. Chi square was used for testing categorical data.

Pearson's bivariant correlation was run for analyzing relations between radiological parameter and ROM at the final check-up. Strength of the Pearson correlation coefficient (r) was classified according to Cohen [29] in small ($0.1 < |r| < 0.3$), medium ($0.3 < |r| < 0.5$) and strong ($|r| > 0.5$).

Threshold for statistical significance was $p < 0.05$.

Patient population

A total of 392 patients (259 women, 133 men) were included in this study with a mean follow-up interval of 11 months (range 3–52 months). The mean age was 57 ± 14 years (range 22–86), whereby 285 (73%) patients were below and 107 (27%) over 65 years of age. In 183 (47%) cases the right hand was injured and 209 (53%) the left hand. At final follow-up, mean ROM in extension was 66 ± 19°, in flexion 64 ± 19°, in supination 84 ± 12°, in pronation 86 ± 10°, in radial deviation 16 ± 8° and ulnar deviation 32 ± 13°.

All intraoperative X-rays showed a satisfactory result.

Detailed demographic data is given in Table 1.

Results

A total of 51 early (13.0%) and 17 late (4.3%) complications occurred in 64 patients within a mean of 3.47 ± 2.61 months. 51/68 (75%) complications occurred within the first 3 months and 17/68 (25%) thereafter. 25/392 (6%) were plate related and 43/392 (11%) not plate related complications. Complications and mean date of occurrence is shown in Table 2.

Table 1 Patients demographic and fracture classified according to the AO classification

Age in years[a]		57 ± 14 (22–86)
Patient classification	< 65/≥ 65 a	285/107
Complications	Y/N	64/328
Gender	F/M	259/133
Injured Hand	R/L	183/209
Plate removal	Y/N	125/267
Fracture ulnar styloid	Y/N	228/164
Soong classification	0/I/II	246/116/12
Postoperative immobilization	S/C	228/164
AO classification	A2	54
	A3	31
	B1	1
	B2	28
	B3	15
	C1	32
	C2	51
	C3	180

SD standard deviation, *a* years, *Y* yes, *N* no, *F* female, *M* male, *R* right, *L* left, *S* thermoplastic splint, *C* cast, *AO* association for the study of internal fixation

[a]Age in years scaled as mean value ± SD (range)

The mean age of patients with complications was 58.0 ± 11.8 years, 42% men and 58% women. No significant difference was found in frequency of complications between women and men ($p = 0.13$). There was also no significant difference in mean age of patients ($p = 0.71$) with (58 ± 12 years) or without (57 ± 14 years) complications. Further, patients over 65 [16/107 (15%)] did not show a significantly higher rate of complications than those under 65 years [48/285 (17%)] ($p = 0.65$). The rate of loss of reduction was also not significantly increased between the groups [7/285 (2.5%) < 65 years; 2/107 (2%) ≥ 65 years ($p = 0.73$)].

In 47 out of 64 (73%) patients with complications, they occurred in AO type C1 – C3, whereas the type C3 fractures showed the highest complication rate with 34/180 (19%) patients and 53% of all complications. In type C1 and C2 only 6% and respectively 14% of all fractures were found. However, in type B1 and B3 fractures no complications occurred. Incidence of complications didn´t differ significantly between AO type A, B and C fractures ($p = 0.19$).

The most common complications included CTS and CRPS, 11 patients in each case, and loss of reduction in 9 patients. All patients with a CRPS, expect for four, were treated conservatively [splinting, hand therapy, dimethylsulphoxide (DMSO) ointment, Non-steroidal anti-inflammatory drugs and vitamin E]. In these four cases a plate removal was performed. Patients with CTS were treated by endoscopic carpal tunnel release and hardware removal. Two patients showed with acute median nerve compression symptoms on admission and required a carpal tunnel release together with DRF stabilization. Two patients presented with a post-operative hematoma, which necessitated surgical exploration and evacuation of the hematoma.

Nine patients showed a loss of reduction within 1.3 ± 0.4 months. Two of these cases had a revision of the palmar plate and additional dorsal stabilization, 5 required intra-articular screw removal and in the other 2, a reoperation with a second palmar plate was necessary. Figure 1 shows an example of loss of reduction and additional dorsal stabilization.

Table 2 Occurrence of complications (months) after distal radius fractures stabilized by angular stable volar locking plate (mean ± SD; range)

	N (%)	Plate related Y/N	Mean ± SD, range (months)
Early complication < 3 months (*n* = 51; 13.1%)			
CRPS	11 (2.8%)	N	1.99 ± 1.16 (0.26–4.80)
CTS	11 (2.8%)	N	2.42 ± 2.86 (0.5 ± 9.45)
Deep infection	2 (0.5%)	Y	1.12 ± 0.84 (0.53–1.71)
Intra-articular screw	5 (1.2%)	Y	1.69 ± 0.77 (0.89–2.96)
Loss of reduction	9 (2.3%)	Y	1.28 ± 0.40 (0.62–1.87)
Secondary bleeding	2 (0.5%)	N	0.18 ± 0.26 (0.00–0.36)
Screw loosening	4 (1.0%)	Y	2.49 ± 3.19 (0.33–7.23)
Superficial infection	3 (0.8%)	N	0.80 ± 1.26 (0.03–2.23)
Tendon rupture (EPL)	4 (1.0%)	N	0.77 ± 0.68 (0.10–1.68)
Late complications ≥ 3 months (*n* = 17; 4.3%)			
Median nerve neuritis	8 (2.0%)	N	9.94 ± 9.43 (2.07–27.63)
Tendon irritation	5 (1.2%)	Y	7.60 ± 5.08 (1.00–15.00)
Ulnar Impaction Syndrome	4 (1.0%)	N	11.43 ± 6.13 (4.70–18.33)
Total	68/392 (17.3%)	25 (6%) plate related	3.47 ± 2.61 (0.00–27.63)

N number, *SD* standard deviation, *Y* yes, *N* no, *CRPS* complex regional pain syndrome, *CTS* carpal tunnel syndrome, *EPL* extensor pollicis longus tendon

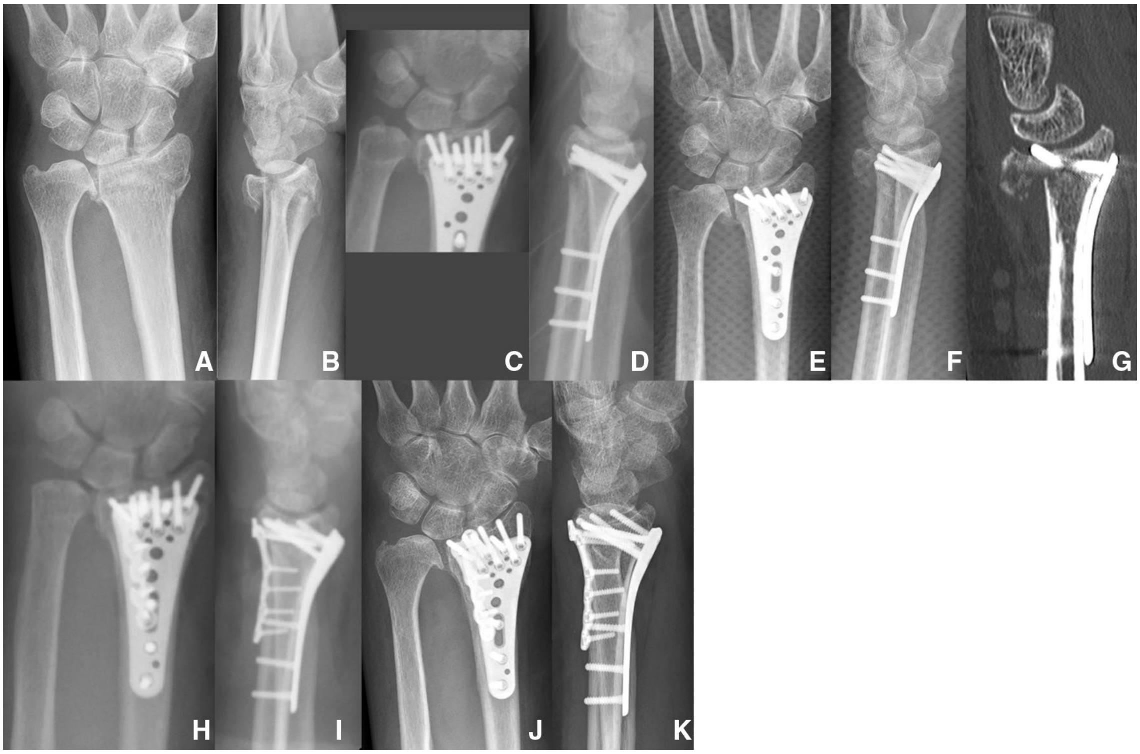

Fig. 1 **a**–**k** **a, b** 65 year old women with an AO type C fracture to her left wrist; **c, d** X-rays intraoperatively with an anatomical reconstruction of the distal radius; **e**–**g** X-rays and CT of the wrist 2 weeks after surgery with loss of reduction of the dorsal fragment and intra-articular screws; **h**, **i** revision surgery at 3 weeks post op. The original plate remained in situ, and only the distal screws were removed. Subsequently, the dorsal fragment was reduced and the distal radius fracture additionally stabilized with a dorsally positioned plate. **j**, **k** Radiological result 4 months after revision surgery with no further loss of reduction

Tendon irritation was seen in five patients. In one case there was irritation of the EPL tendon, another of the flexor digitorum profundus tendon of the index finger, a third of the flexor pollicis longus tendon, and in two cases nonspecific irritation of the extensor tendons. In all three patients with flexor tendon irritation the Medartis® Aptus® correction plate was used. Dorsally protruding screws were seen in all three patients with extensor tendon irritation. All patients were treated by plate or screw removal. Rupture of the extensor pollicis longus (EPL) tendon occurred in 4 cases and were treated by an extensor indicis transfer and plate removal. In the performed CT scans no protruding screws as a cause for the tendon rupture were found. No flexor tendon rupture occurred in our series.

Screw loosening was seen in four patients within a mean of 2.5 ± 3.2 months. Three patients required revision surgery with screw removal, one patient was pain free and refused any further treatment.

Infections were observed in 5 cases, two deep infections and three superficial. Deep infections were treated with debridement and hardware removal, while the superficial infections healed conservatively, with antibiotics and splinting.

Ulnar impaction syndrome was seen in 4 cases, which were treated by ulnar shortening osteotomy. In these cases no loss of reduction in the postoperative X-rays were found.

No significant differences could be found in incidence of complication and plate type ($p = 0.22$) or choice of postoperative immobilization used: 33/64 (52%) cast, 31/64 (48%) thermoplastic splint ($p = 0.09$).

The hardware was removed in 125/392 (32%) of the patients within a mean of 10.8 ± 6.2 months. Forty two patients showed a plate position Soong grade 0, 62 Soong grade I, and 14 Soong grade II. Soong grade I and II showed no higher rate of hardware removal ($p = 0.40$) and complications ($p = 0.77$) than Soong 0.

Complications after plate removal occurred in 5/125 (4%) patients. Three patients had paresthesias of the median nerve, one patient was seen with an infection and another with a hematoma as a result of an injury to the radial artery.

Radiological and clinical results

At final check-up, all fractures showed bony healing. Palmar tilt was reconstructed in mean to $1.94 \pm 6.33°$, radial inclination $24.00 \pm 4.52°$ and ulnar variance 0.14 ± 0.21 mm. From the postoperative measurement to the last follow-up there was a mean loss of reduction in palmar tilt of 1.06 ± 3.93° and in radial inclination 1.72 ± 2.81°. There was no significant loss of reduction in palmar tilt ($p = 0.17$) and radial inclination ($p = 0.70$) between patients over and under 65 years of age. As well ROM in extension, flexion, radial/ulnar deviation, supination and pronation did not differ significantly between the groups. Detailed information is given in Table 3.

228 (58%) of the 392 patients showed an additional fracture of the ulnar styloid. 59/228 (26%) had a fracture at the tip, 165/228 (72%) at the base and another 4/228 (2%) a fracture at both base and tip. Patients without an additional fracture of the ulnar styloid showed significantly better ROM in extension ($p < 0.01$) and flexion ($p = 0.03$) than patients with this additional injury and a significantly longer follow-up interval ($p = 0.04$). No significant differences ($p > 0.05$) in respect of ROM in extension, flexion, radial/ulnar deviation, supination and pronation could be found between patients with a fracture of the ulnar styloid at the tip, base and base/tip. Detailed information is given in Table 3.

Bivariant correlation analysis showed a significant small positive correlation ($r = 0.10$, $p = 0.04$) between the radial inclination and pronation. For the last palmar tilt, ulnar variance, loss of reduction in palmar tilt and radial inclination no significant correlation to ROM could be found.

Patients, presenting with a complication, had a significantly lower ROM in extension ($p < 0.001$), flexion ($p < 0.001$), ulnar abduction ($p < 0.001$), supination ($p < 0.001$) and pronation ($p < 0.01$) than those without complications. Detailed information is given in Table 3.

Discussion

Distal radius fractures are the most common fractures in the upper extremities with an incidence of 70–160 per 100.000 persons per year. Due to an ageing population, the incidence is estimated to increase significantly in the next years [1, 4]. Therefore, the optimal treatment and potentially occurring complications should be addressed in the literature [30, 31].

Main aim in treating DRF is an exact reconstruction of the articular surface, stable internal fixation and early wrist mobilization [32–34]. In the last years, open reduction and palmar angular stable plate fixation became the preferred method of treatment. Thus, dorsally displaced fractures could be stabilized from palmar aspect which provided sufficient stability to enable early mobilization without any increased risk of complications [13]. The treatment of DRF greatly improved with the palmar angular stable plate, as it proved technically simpler. Previous studies showed a better short-term functional outcome and lower complication rate than K-Wire fixation or external fixator [19, 35–37].

Initial reports by Orbay et al. [38, 39] suggested a low complication rate after palmar fixed DRF. Complication rate of 17% in this study is comparable to previously published studies, ranging from 8 to 39% [13, 15, 16, 18, 40–45]. The low complication rate reflects familiarity with the implant, and the high numbers of DRFs treated by palmar locking plate (average 269 DRF/year). In addition, one implant system was uniformly used, which is known to lower the risk of complications [45].

Most common complications in our study were CTS (11/392; 2.8%), CRPS (11/392; 2.8%) and loss of reduction

Table 3 Range of motion (mean ± SD) and follow-up interval (months) in Patients with distal radius fractures stabilized by palmar angular stable plate

	Complications	No Complications	*p*	Fracture of the ulnar styloid	No fracture of the ulnar styloid	*p*	< 65 years	≥ 65 years	*p*
Mean follow-up interval (mo)	13 ± 10	11 ± 6	0.06	11 ± 7	12 ± 7	0.04	12 ± 7	10 ± 6	< 0.01
Extension (°)	58 ± 22	68 ± 18	< 0.001	64 ± 19	69 ± 19	< 0.01	67 ± 19	66 ± 19	0.72
Flexion (°)	55 ± 21	65 ± 20	< 0.001	62 ± 21	66 ± 21	0.03	63 ± 21	64 ± 21	0.72
Extension/flexion (°)	113 ± 38	133 ± 36	< 0.001	126 ± 37	135 ± 37	0.01	130 ± 17	130 ± 37	1.00
Supination (°)	78 ± 18	85 ± 11	< 0.001	84 ± 14	85 ± 10	0.81	84 ± 13	85 ± 10	0.62
Pronation (°)	81 ± 16	86 ± 8	< 0.01	85 ± 11	86 ± 8	0.42	85 ± 10	86 ± 10	0.26
Supination/pronation (°)	159 ± 32	172 ± 17	< 0.001	169 ± 24	171 ± 16	0.98	169 ± 22	171 ± 19	0.35
Radial deviation (°)	16 ± 9	16 ± 8	0.59	17 ± 9	15 ± 6	0.15	16 ± 8	15 ± 8	0.07
Ulnar deviation (°)	26 ± 12	34 ± 12	< 0.001	31 ± 13	34 ± 12	0.07	32 ± 12	33 ± 13	0.16
Radial/ulnar deviation (°)	42 ± 14	49 ± 12	< 0.001	47 ± 14	48 ± 11	0.39	48 ± 13	48 ± 13	0.88

SD standard deviation, ° degrees, *mo* months

(9/392; 2.3%). These findings correspond with the findings in the literature. CTS is reported with an incidence between 3–8% and CRPS 1–6% [19, 46, 47].

It remains unclear whether the risk factors for CTS are related to fractures of the distal radius itself (with or without deformity), or with or without palmar plating. As CTS is generally very common, it is quite possible that many patients with DRF have a preexisting undiagnosed CTS that then becomes symptomatic or to their attention after injury [44]. We, therefore, doubt that CTS is a direct complication after surgically treated DRF and that the palmar plate is questionable as an elicitor.

CRPS is closely associated with injuries to the distal radius and remains a clinical diagnosis [47]. The pathomechanism is still not fully researched, but might be related to an over excretion of cytokinins, mitochondrial dysfunction in the affected extremity, and there is a genetic predisposition [48–50]. We strongly agree with Esenwein et al. [19] that CRPS is a complication, that cannot be influenced by the surgeon. Zollinger et al. [51] in a double-blinded randomized trial showed that patients with DRF who were administered 500 mg vitamin C had a lower prevalence in CRPS than patients that were given a placebo.

Esenwein et al. [19], Arora et al. [16] and Soong et al. [45] reported intra-articular screws in 0.5–1.3% of the cases. Other studies made no mention of this complication [42, 43]. Intra-articular screws are not only caused by a malpositioning, but also due to the loss of reduction, and secondary fracture dislocation (Fig. 1). Even angular stable plates do not exclude secondary displacement [19]. In our series, the rate was a little higher than in previous reports. Five of 9 patients showed a loss of reduction with screws protruding dorsally into the radiocarpal joint. 8/9 (89%) patients had AO type C fractures [(7/9 (78%) AO type C3)], which reflects the higher risk of secondary displacement in comminuted fractures. In addition, loss of reduction and screw penetration can also lead to destruction of the radiocarpal joint, resulting in malunion, osteoarthritis and clinical failure. In these cases, salvage procedures are often necessary to relieve symptoms and improve ROM, when conservative treatment fails. Over the last years palmar scapholunate arthrodesis and distal scaphoidectomy have shown improvements in pain relief and ROM after malunited DRF, but only if the osteoarthritis is limited to the radiocarpal joint and the midcarpal joint is not involved [2, 14, 20, 52–55].

Tendon rupture is another common complication and quoted in the literature in about 1.7% of all cases [46]. Rupture of the EPL tendon is not only limited to surgically treated DRF but can also be related to the fracture itself, due to an altered blood supply. EPL ruptures are also seen in 5% of conservatively treated DRF [56]. Arora et al. [16] reviewed 141 patients and found a complication rate of approximately 27%. Two (1.4%) patients showed a rupture of the EPL tendon (1.4%), 4 (2.8%) a synovitis of the extensor tendons, 2 (1.4%) a flexor pollicis longus rupture and 9 (6%) a flexor tendon irritation. Drobetz et al. [41] reported about 6/41 (15%) FPL ruptures. Esenwein et al. [19] showed in a review of 665 DRFs, 3 cases (0.5%) of extensor tendon and another 3 (0.5%) of flexor tendon ruptures. Tendinitis of the extensor tendons are frequently caused by dorsally protruding screws, but not necessarily. To prevent this complication Kumar et al. introduced the tangential view in 2001. The exact positioning of the wrist is technically challenging, but allows intraoperative detection of dorsally protruding screws [57, 58].

Flexor tendon tendinitis and rupture are often caused by plates positioned too distally, with disregard to the Watershed line [28]. In addition, an inadequate reduction with dorsal displacement, causes strain on the flexor tendons, predisposing them to irritation and rupture [59].

Our review showed the incidence of extensor tendon rupture (EPL) at 4/392 (1%). However, there was no case of flexor tendon rupture. Tendon irritation occurred in 5/392 (1,2%) cases (2 flexor tendons and 3 extensor tendons). All extensor tendon irritations were caused by dorsally protruding screws. In these cases, plate or screw removal were performed.

Treatment of DRF in the elderly is controversially discussed in the literature and is largely based on retrospective reviews with nonrandomized treatment and short follow-up intervals [44, 60]. Arora et al. [15] showed in prospective randomized trial, a significantly inferior radiological outcome in patients over 65 years treated conservatively with a cast compared to surgically treated patients. However, no differences in DASH Score, PRWE Score or range of motion could be found between the groups 1 year after surgery. They concluded that an anatomical reconstruction of the distal radius shows no improvement in ROM and the ability to accomplish daily life activities. Two systemic reviews also suggest that a conservative treatment results in poorer radiological outcome, but fewer complications with no clinical significant functional differences compared to surgical treatment in patients over 60 years of age [60, 61]. Our series found no significant increased risk for complications, loss of reduction and decrease in ROM between patients over and under 65 years of age. Osteoporosis and poor bone quality are often seen in elderly patients with DRF [9]. Lee et al. found in osteoporotic women over 50 years with DRF stabilized by palmar locking plate, the same radiological and clinical outcome than patients without osteoporosis [62]. Equally, the risk for a loss of reduction was not significantly increased in patients over 65 years of age in this study. Therefore, reduced bone quality as a decisive factor for loss of reduction is questionable.

There are several limitations to this study, which have to be considered before interpretation. The most serious problem as in all retrospective studies and big trauma centers, was the lack of follow-up: 431 patients were excluded because the follow-up was less than 3 months. Thus, the complication rate in this study may be biased. On the one hand, one might assume that patients who do not come back have no problems, and therefore, the complication rate is overestimated. But on the other hand, they may have transferred to another hospital.

As the mean follow-up interval was 11 months with a minimum of 3 months not all complications that typically occur at a later date, for example tendon rupture, are covered in this study. Nevertheless, not all patients would have regained full ROM, therefore, the ultimate ROM could be better than reported in this study. Due to its design, functional outcome questionnaires could not be assessed, ROM in radial-/ulnar deviation and dominant/non-dominant hand was not reported in all patients. Before surgery not all of the patients had a CT scan of the distal radius. Due to this OA classification was performed using X-rays as well, and therefore, can be biased.

We did not limit the inclusion criteria to particular surgeons. It is well known that the complications rate is significantly influenced by surgeon experience [40]. In this study, residents also stabilized DRFs, but at least one trauma specialist assisted the operation. For this reason, the complication rate in this study may be higher than in other studies.

Contrary to other studies [63], patients without an additional fracture of the ulnar styloid showed significantly better ROM in extension and flexion. But the longer follow-up interval of patients without ulnar styloid fractures was significant and may have had an impact on the final ROM. But differences were small with a mean of 5° in extension and 4 in flexion. It is very questionable that these clinical differences would cause a noticeable effect on the patients in their daily activities.

Conclusion

Surgical treatment of DRF is a safe procedure resulting in a good clinical outcome without complications in the majority of the cases. But despite the improved implants there are still risks and difficulties which have to be considered by the treating surgeons.

A total of 51 (13%) early and 17 (4%) late complications occurred in 392 patients, the most common being loss of reduction, CTS and CRPS. Although it is questionable that CTS and CRPS complications have a direct correlation to palmar plating. Therefore, 43/392 (11%) are procedure-specific and only 25/292 (6%) are plate related.

Patients with complications showed a significantly reduced ROM in extension, flexion, ulnar abduction, supination and pronation compared to those without complications.

AO type C fractures presented the highest risk for complications accounting for 73% of all complications. Comparing to AO type A and B, no significant increased incidence was noted. Age over 65 years was not associated with a higher complication rate, loss of reduction or reduced ROM compared to under 65. Gender and type of postoperative immobilization showed no significant increased risk for complications.

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Compliance with ethical standards

Conflict of interest The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Institutional review board approval was obtained for this study

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