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ORIGINAL ARTICLE

Plate fixation of distal radius fracture and related complications

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Abstract
Introduction Distal radius fractures are common. In cases where surgical treatment is needed, volar plates can be used to obtain stable, long-lasting fixation. The design of these plates has continually improved over the years, but complications remain a problem.
Purpose The goal of this study was to evaluate the types of complications that occur with different types of volar plates with a view towards preventing them.
Materials and methods The emergency department at our hospital saw 524 patients with distal radius fractures between 2006 and 2008. Some of these were treated surgically with a volar plate. All of the post-operative complications were documented.
Results With a minimum follow-up of 6 months, 152 patients who had undergone plate fixation were reviewed: 31 had received plates with non-locking screws or uniaxial locking screws and 121 had received plates with polyaxial locking screws. The complication rate was similar in these two groups (16.1 and 16.5 %, respectively). The main complications were tendon ruptures and problems related to the plate itself.
Discussion Plate-related complications have been described in published studies, but few of these studies link them to the plate design or surgical technique. Manufacturers must continue to refine these plates to minimise their thickness while keeping their strength. Surgeons must be sure to use a highly exacting technique.

Keywords Distal radius fracture · Volar plate · Osteosynthesis · Complications

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Introduction

Dorsally displaced distal radius fractures are common, but little consensus exists on how to best treat them [1]. Over the past 5 years, an increasing number of studies have reported on the outcomes of fracture fixation with volar plates, which provide stable, long-lasting fixation. The design of these plates has been continuously improving over the years, to the point where four generations of plates now exist [2]. The first-generation plates validated the volar fixation concept. These were standard T-plates or regular epiphyseal plates, which were limited in terms of their shape and the number of epiphyseal screws that could be used. With the second generation of plates, the use of locking screws improved the strength of the construct in osteoporotic bone; three screws were located in the epiphysis and three in the diaphysis [3]. However, these plates were tricky to use in daily practice [4, 5]. A third-generation plate quickly followed. The use of polyaxial locking screws allowed the surgeon to place the plate in the "best location". The polyaxial nature of the screws [±10°–20°) made the plates more difficult to manufacture: the screws must remain buried and the plate cannot be more than 2 mm thick; otherwise, flexor apparatus complications can occur. The advantage of this polyaxial (variable angle) feature is that it allows the surgeon to drive a screw into the styloid. The fourth generation of plates was simultaneously

introduced by implant manufacturers and surgeon-designers. Because of their anatomical design, they can be placed in the optimal location on the radius surface, since the lateral (ulnar) column is more distal than the medial (radial) column [6]. The goal of the current study was to retrospectively evaluate the medium-term complications related to these various types of plates to better understand these complications and eventually prevent them.

Materials and methods

Patient population

Between 2006 and 2008, 524 patients presented with a distal radius fracture at the Emergency Department of our University's Hospital Centre. Of these patients, 152 were treated surgically by plate fixation. This group consisted of 65.8 % women with an average age of 66.4 years and 34.2 % men with an average age of 49.5 years. Nine different surgeons performed these procedures during that time.

First- and second-generation plates were used in our early cases: DePuy/ACE distal radius plate (first generation) with 3.5-mm non-locking screws and Synthes® T-Plate (second generation) with 3.5-mm locking screws. Our later cases were treated with third-generation plates (ITS PROlock radius locking plate with 2.7-mm screws) or two types of fourth-generation anatomical plates: 1.9-mm-thick Stryker® VariAx™ plate and 2.5-mm-thick NEWCLIP distal radius plate. The locking system in these plates consisted of polyaxial holes that allow ±15° screw angulation, thus locking cones of up to 30°. The following numbers of patients were treated with these various plates: 29 DePuy/ACE plates, two Synthes® plates, 73 ITS plates, 28 VariAx™ plates and 18 NEWCLIP plates. The demographic characteristics of the patient population are given in Table 1.

Table 1 Demographic characteristics of the patient population

Year	First- and second-generation plates		Third- and fourth-generation plates	
Number of patients	31		121	
Gender	Women	Men	Women	Men
	20	11	80	41
Age	57.5 years		61.6 years	
Type of plate	29 DePuy/ACE		73 ITS	
	2 Synthes®		30 VariAx™	
			18 NEWCLIP	

Surgical technique

With the subject supine, the upper limb was placed on an arm board and a tourniquet was placed proximally on the upper arm. Henry's volar approach was used. The fracture was reduced with external and direct manoeuvres under fluoroscopic control. The type of plate was chosen by the surgeon. The plate and screw positions were verified to ensure they did not protrude into the intra-articular space or the dorsal side of the radius. The incision was closed in two layers, with a running intradermal suture used in the skin. The use of a drain was left to the surgeon's discretion.

Post-operative immobilization consisted of a compressive dressing. Depending on the surgeon's impression of the bone quality and construct stability during the surgery, the fractured wrist was immobilized with a removable splint for 2–3 weeks (in most cases) or a cast for 15–30 days.

Evaluation of complications

The complications for each type of plate were retrospectively evaluated at least 6 months after the procedure. Patient files were reviewed by a surgeon other than the one who performed the procedure. The following information was recorded for each patient:

- Gender
- Age at the time of fracture
- Type of plate used; the various plates were separated into uniaxial first- and second-generation plates (older plates) and polyaxial third- and fourth-generation plates (newer plates).
- Clinical or radiological complications, along with when they occurred.

The diagnosis of complex regional pain syndrome (CRPS) was based on criteria related to pain, neurovegetative symptoms and loss of function [7]. Carpal tunnel syndrome, other than in cases where the symptoms appeared at the same time as the initial injury, was confirmed with an electromyogram.

Results

Overall complication rate

The overall complication rate for all plates was 16.4: 16.1 % for older plates and 16.5 % for newer ones. The following complications were observed and are described in more detail below: complex regional pain syndrome, tendon ruptures (extensor or flexor), implant-related problems and carpal tunnel syndrome (Table 2).

Table 2 Distribution of complications by plate type

	First- and second-generation plates ($N = 31$)	Third- and fourth-generation plates ($N = 121$)
Complex regional pain syndrome	2 (6.4 %)	5 (4.1 %)
Tendon rupture	0	6 (5 %)
Extensor		4 (3.4 %)
Flexor		2 (1.6 %)
Implant-related problems	2 (6.4 %)	5 (4.1 %)
Carpal tunnel syndrome	1 (3.2 %)	4 (3.4 %)
Secondary	1 (3.2 %)	1 (0.8 %)
Total	5 (16.1 %)	20 (16.5 %)

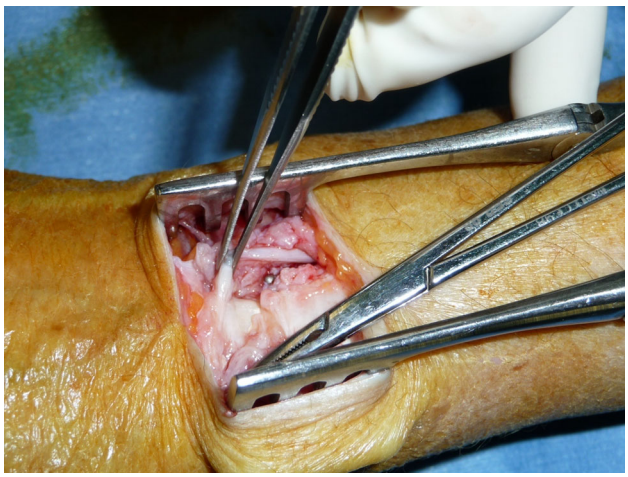

Fig. 1 Intra-operative photograph of female patient with ruptured extensor pollicis longus and screw protruding into Lister's tubercle

Complex regional pain syndrome

There were two cases of complex regional pain syndrome with the older plates (6.4 % rate): one 63-year-old man (DePuy/ACE plate) and one 59-year-old woman (DePuy/ACE plate). There were five cases of complex regional pain syndrome with the newer plates (rate of 4.1 %, nearly identical): three women around 60 years of age (ITS plate), one 62-year-old woman (VariAx^{TM} plate) and one 59-year-old woman (NEWCLIP plate) who also presented a flexor pollicis longus (FPL) tendon rupture at 9 months post-operative.

Tendon ruptures

There were six cases of tendon ruptures for all plate types combined (3.9 %). There were four extensor pollicis longus (EPL) ruptures, of which two were linked to the screw protruding from the dorsal side of the radius and two FPL ruptures. The extensor and flexor tendon rupture cases are described separately.

There were four extensor tendon ruptures in all: none with the older plates and four with the newer plates (3.4 %). One occurred in a 66-year-old woman, 9 months after she had been surgically treated with an ITS plate. During the surgical revision, one screw was found to be protruding and Lister's tubercle was no longer present (Fig. 1). The extensor indicis was transferred. The other case of EPL rupture occurred in a 67-year-old woman at 45 days post-operative. The patient refused a further surgical procedure. There were two other cases with fourth-generation plates: one occurred in a 69-year-old woman 3 months after surgery (NEWCLIP plate) and the other in a 65-year-old woman at 8 months post-operative (VariAx^{TM} plate). Both cases were surgically revised. Upon surgical revision, the screw was found to protrude in the path of the EPL along Lister's tubercle in the former case and in the latter case there was no implant interference.

There were two cases of flexor tendon rupture in all: none with the older plates and two with the newer plates (1.6 %). The two flexor pollicis longus ruptures occurred at 9 months post-operative in a 59-year-old woman (NEWCLIP plate) who had complex regional pain syndrome (mentioned previously) and 5 months after surgery in a 61-year-old woman (NEWCLIP plate). Upon surgical revision of the former patient, the rupture was located at the plate's edge and intra-operative damage to the flexor indicis profundus was noted, along with extensive synovitis across from the end of the plate; in the other patient, we could not identify a mechanical cause related to the plate or screws.

Implant-related problems

There were two complications identified when non-locking plates were used: one man with plate impingement at the radial styloid (DePuy/ACE plate) and one woman in whom the screw backed out (DePuy/ACE plate) (Fig. 2). The plate and screws were removed in this latter patient; this was the sole case of removal in this series. There were five cases of implant-related problems noted during the review of patients who were treated with locking plates: two women in whom a screw backed out (ITS plate), one woman with plate impingement (ITS plate) and one 80-year-old woman (VariAx^{TM} plate) who presented with a collapsed fracture at her 2-month follow-up visit. In the latter patient, the intra-articular screw projected into the joint but did not affect her function (Fig. 3). At her 9-month post-operative follow-up, her DASH functional

score was 13 out of 100. The possible mechanical complications of the volar plate are summarised in Fig. 4.

Nerve involvement

There was one case of carpal tunnel syndrome with the older plates: a 64-year-old man (DePuy/ACE plate) who presented with residual signs of hypoesthesia in the thumb pad and did not receive additional surgery. In the patients treated with the newer plates, there was one case of nerve involvement in a 64-year-old woman whose symptoms were related to the initial injury, requiring surgical release during the fracture fixation procedure (ITS plate); one 66-year-old woman required surgical release 9 months post-operative in combination with the transfer of the extensor indicis due to rupture of the EPL (ITS plate); one 38-year-old male had symptoms related to the injury event that required surgical release during the fracture fixation (ITS plate) procedure. One 32-year-old man, who was operated 24 h after the injury event, experienced paraesthesia of the median nerve territory while he was waiting for the surgical procedure. Surgical release was performed during the fracture fixation procedure (NEWCLIP plate). In all, there were three cases of acute nerve involvement related to the fracture event itself. Secondary syndromes, which could be interpreted as fracture-related or implant-related complications, were present in two cases: one patient who received an older-generation plate and one who received a newer-generation plate.

Fig. 2 Lateral X-ray of ITS plate with screw that has backed out

Discussion

In all, 152 patients were reviewed for this study. The number of patients included in this series is fairly large in comparison with other published studies on the use of volar plates in the wrist (Table 3). Our patient population was about two-thirds women and one-third men, with the women being older than the men (average age of 66.4 vs.

Fig. 3 Lateral and A/P X-rays of fracture fixation with intra-articular screw; no functional impairment

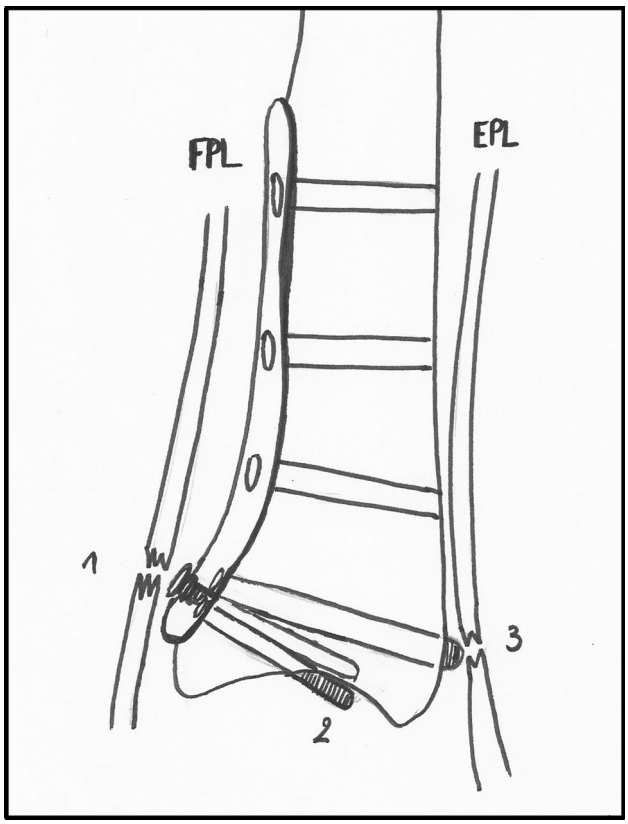

Fig. 4 Possible mechanical complications of volar plate: *1* rupture of FPL because of plate impingement, screw backed out or the edge of the plate, *2* intra-articular screw and *3* rupture of the EPL because of the protrusion of a screw along the Lister's tubercle

49.5 years, respectively). This gender distribution is similar to that of other published studies [8]. The overall complication rate in the current study was similar to the rates reported in other published studies (Table 3). Only one study reported the same four types of complications as are reported here [9].

Complex regional pain syndrome is a classical complication of distal radius fractures. This condition includes joint or extremity pain leading to disability, trophic and vasomotor problems, delayed demineralisation during bone growth, and frequent shifts to other locations. Its rate varies widely but is generally lower in retrospective series [7, 10].

The tendon rupture rate in the current study was 3.9 %, which is in the same range as published rates of 2–14 % [9, 11–13]. The flexor tendons are at risk of injury following a distal radius fracture if the reduction is incomplete or secondary displacement occurs. The main tendons involved are the flexor pollicis longus and the flexor indicis superficialis and profundus. These ruptures can be attributed to mechanical impingement between the plate and flexor tendons. This risk is increased if the plate extends past the bone [14, 15] or if the styloid screw is not buried deep enough in the plate.

Of the 29 cases of flexor tendon rupture reported in various published studies after distal radius fracture, only 11 were attributed to the plate. Of these 11 cases, eight involved the flexor pollicis longus, two involved the flexor indicis profundus and one involved both the flexor indicis superficialis and profundus. We carefully analysed our two cases of flexor pollicis longus tendon rupture. Both surgeries were performed with the NEWCLIP plate. This plate is thicker than the other locking plates used. In both cases, the reduction was flawed and dorsal tipping persisted in the sagittal plane. It seems that the confluence of these factors (overly thick plate and poorly reduced fracture) results in a plate that projects anteriorly and eventually leads to flexor tendon rupture (Fig. 5).

As for the extensor mechanism, if one of the screws extends too far dorsally into Lister's tubercle, the extensor pollicis longus can rupture. In most of the plates, one screw hole requires drilling into the third extensor compartment; an overly long screw will protrude into this compartment [16]. In a cadaver study, the thickness of the radius at the third compartment was found to be 19.6 mm (range 16.4–23.4, SD 1.3 mm). This measurement suggests that only screws shorter than 20 mm should be used in this location [2]. The rate of extensor pollicis longus rupture without surgery is 3 % [17]. Thus, the rate of extensor pollicis longus ruptures with newer-generation plates reported here (3.4 % or four cases) seems insignificant, although screw length was implicated in certain cases upon intra-operative inspection.

In the current study, the rate of nerve-related complications was 2.6 %; these were exclusively median nerve compression cases. This rate falls within the 0–12 % range reported in various published studies. Distal radius fractures have an associated risk of median nerve injury. These injuries can occur due to either compression during fragment displacement or use of the volar surgical approach. No studies have been able to demonstrate a statistical relationship between volar displacement of fracture fragments, the magnitude of this displacement and secondary compression of the median nerve. In addition, intra-operative nerve release procedures are not always documented in published studies [18]. Involvement of the sensory branch of the radial nerve seems to be correlated with the type of surgical treatment performed. This complication almost never occurs with conservative treatment, but when the fracture is pinned (K-wires or external fixator), the rate is much higher [1].

The current study revealed that different complications occur with different types of plates. The locking screw concept (i.e. locking plates) was developed by the AO [19], with the goal of maintain the initial surgical reduction over time [20]. When the fracture is stabilized with non-locking screws, the friction forces between the plate and bone give

Table 3 Complications reported in published studies

	Follow-up (months)	No. patients	Age	CRPS	Median nerve compression	Tendon-related complications	Implant-related problems
Orbay and Fernandez [11]	12.5	N/R	54			4.5 % (irritations)	
Drobetz and Kutscha-Lissberg [12]	26	$N = 50$	62	6 %	2 %	14 %	–
Constantine et al. [13]	12	$N = 20$	41		5 %	10 % (irritations)	1 intra-articular screw
Kamano et al. [21]	14	N/R	54	–	–	0	–
Sakhaii et al. [5]	10	$N = 100$	63	–	–	–	1 intra-articular screw
Dumont et al. [22]	>18	$N = 166$	59	0.6 %	12 %	–	–
Schutz et al. [23]	6	$N = 24$		–	–	–	1 intra-articular screw
Orbay and Fernandez [24]	16	$N = 24$	>75	4.3 %	–	–	–
Krimmer et al. [25]	62	$N = 55$	62	1.6 %	–	–	–
Prokop et al. [26]	12	$N = 40$	49	2.5 %	4 %	–	–
Margaliot et al. [27]	23	$N = 603$	51	2.5 %	5.6 %	2.6 % (ruptures)	–
Meta-analysis						5.2 % (irritations)	
Gruber et al. [28]	15.6	$N = 102$	60	1 %	2 %	2 (ruptures)	–
Kreder et al. [29]	6	$N = 84$	39	–	–	–	–
Koshimune et al. [30]	12	$N = 22$	68	–	0	0	–
Ruch and Papadonikolakis [31]	22	$N = 14$	46	–	2 cases	1 (irritation)	–
Rozental and Blazar [32]	17	$N = 41$	53	–	–	3 (irritation)	–
Rampoldi and Marsico [33]		$N = 70$		–	1	3 extensors 2 flexors	–
Arora et al. [9]	15	$N = 140$	57	5	3	2 EPL ruptures 2 FPL ruptures 4 EPL irritations 9 FPL irritations	1
Current study		$N = 152$		7 (4.6 %)	4 (2.6 %)	6 (3.9 %)	7

CRPS complex regional pain syndrome, *EPL* extensor pollicis longus, *FPL* flexor pollicis longus, *N/R* not reported

the construct its strength. This system is suitable for good-quality bone with thick cortices, but in osteoporotic bone or comminuted fractures, these forces are quite low and the risk of secondary displacement is high. With locking plates, the plate and screws are interdependent. The hold of the fixation is independent of friction forces and thus independent of bone quality. The first commercialised locking plates were standard, straight or angled AO T-plates with 3.5-mm screws [4]. But these screws were fixed relative to the plate, the plates had to be shaped by the

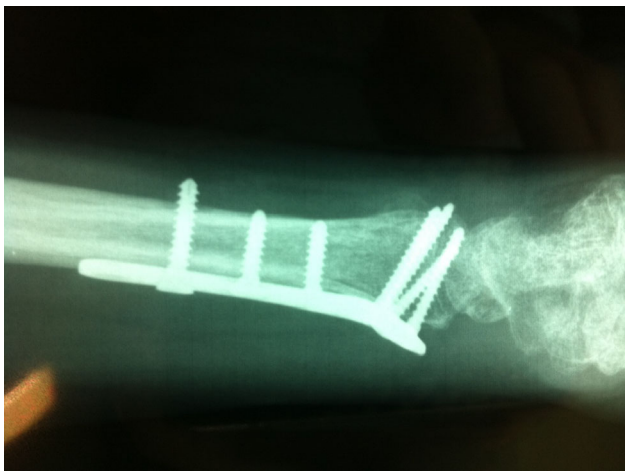

Fig. 5 Case with a thick plate that extends beyond the bone and incomplete reduction leading to flexor pollicis longus tendon rupture

surgeon to better fit on the radius and the size and limited number of epiphyseal screws made fixation difficult. This led to the introduction of newer (third- and fourth-generation) plates. These newer plates feature smaller screws, more epiphyseal screws, a larger locking cone (variable angle construct), a more anatomical shape and a lower profile. Compared with the older plates in the current study, the newer plates had the same overall complication rate (16.1 vs. 16.5 %), fewer implant-related problems (4.1 vs. 6.4 %) and more tendon ruptures (5 vs. 0 %). Ruptures of the flexor pollicis longer are generally related to the plate or screws extending too far on the volar side and styloid side. There were two cases of tendon ruptures with NEWCLIP plates. These were related to a confluence of factors, namely an overly thick plate and improper reduction.

Conclusion

Distal radius fractures can be treated effectively with volar plate fixation. Plates are a proven treatment option because of the stability they provide. However, this fixation method brings its share of complications, mainly related to the plate and screws themselves and tendon ruptures. There were also a few cases of carpal tunnel syndrome and complex regional pain syndrome, but these complications also occur when distal radius fractures are fixed with other methods. To minimise these complications, the surgeon must be sure to use a highly exacting technique. Plate manufacturers must also continue to develop new products that minimise the implant's thickness, while maintaining its strength.

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Conflict of interest L. Obert is Consultant for FX Solution, Zimmer, SBI, Synthes-Johnson&Johnson, Medartis, Evolutis, Biotech-Wright, Argo. Each author certifies that he has no commercial associations that might pose a conflict of interest in connection with the submitted article.

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