Complications of Volar Plating of Distal Radius Fractures: A Systematic Review

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Abstract

Background In recent years, there has been an increased utilization of volar locking plate fixation of distal radius fractures (DRFs). However, reported long-term complication rates with this technique remain unclear.

Purpose The purpose of this systematic review was to investigate the pooled incidence of complications associated with volar locking plating of DRF.

Methods A search of the Scopus database was performed from 2006 through 2016. Studies were considered eligible if they had a diagnosis of a DRF and were treated with a volar locking plate with an average of 12 months or longer follow-up.

Results The literature search yielded 633 citations, with 55 eligible for inclusion in the review (total $n = 3{,}911$). An overall complication rate of 15% was identified, with 5% representing major complications requiring reoperation. The most common complication types identified included nerve dysfunction (5.7%), tendon injury (3.5%), and hardware-related issues (1.6%).

Conclusion Nerve complications were reportedly higher than tendon and hardware-related complications combined. However, despite varying complication rates in the literature, this systematic review reveals an overall low complication rate associated with volar locking plating of DRF.

Keywords
- ► distal radius fracture
- ► volar locking plate
- ► complications

Distal radius fractures remain one of the most common orthopaedic injuries.[1–3] However, despite this high incidence, there remains no consensus regarding the optimal treatment strategy. Common treatment options currently include closed reduction, closed reduction with percutaneous pinning, intramedullary fixation, external fixation, and various open reduction and internal fixation strategies.[4–7] Despite the various available treatment strategies, open reduction and internal fixation with dorsal and volar plates has seen a steady increase in use in recent years due to purported faster functional recovery and often improved radiographic alignment.[4,8,9] In particular, over the last decade there has been an increased utilization of volar locked plating of distal radius fractures.[5,8,10–12]

The most commonly reported complications with this technique can be divided into the following categories: nerve related, tendon related, and hardware related. Carpal tunnel syndrome is the most common nerve-related complication, although this frequently occurs with distal radius fracture regardless of treatment modality.[13] Vulnerable tendons with volar locking plates include both extensor tendons (extensor pollicis longus, extensor digitorum communis, extensor indicis)[14,15] and flexor tendons (flexor pollicis longus, flexor digitorum profundus),[16] with purportedly lower overall rates compared with dorsal plates.[17] Hardware-related complications include malunion, screw loosening, and loss of reduction, among others. In addition, complications such as infection, hematoma, and wound dehiscence can occur with

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any surgical procedure, as well as many other less frequently reported sequelae.

In spite of the rising utilization of this technique, our understanding of long-term complication rates associated with volar locking plating of distal radius fractures remains limited. Therefore, the purpose of this study was to perform a systematic review to investigate incidence of complications following volar locking plate fixation of distal radius fractures.

Methods

A search of the Scopus database, which incorporates PubMed and Medline, was performed from 2006 through 2016. This timeframe was selected to focus on a period where specifically locked, rather than nonlocked, volar plating was more ubiquitous. The database was searched using the following search terms: volar, palmar, Colles fracture, Barton fracture, Smith fracture, distal radius fracture, distal radial fracture, or fracture of distal radius. Only articles written in English were included.

Studies were considered eligible if they met the following criteria: (1) patients had a diagnosis of a distal radius fracture, irrespective of diagnostic criteria, etiology, associated pathology, sex, or age; (2) patients were treated with a volar locking plate. Studies were excluded if they were (1) case reports; (2) reviews; (3) animal studies; (4) cadaveric studies; (5) complication data unavailable or not presented; (6) inadequate plate-type information; (7) dorsal plate fixation; (8) additional percutaneous pin fixation augmentation; (9) nonlocking volar plates; and (10) follow-up less than 12 months (►**Fig. 1**).

Each included study was independently analyzed by two different authors (T.H.A. and A.M.I.). The following data were extracted and recorded: study characteristics (first author, year of publication, country of origin); fracture characteristics, implant type; sample size; mean age; sex distribution; duration of follow-up; study design; number of complications. A complication was defined as an adverse treatment event that was reported by the authors of the study. The main outcome measure of the systematic review was the overall rate of complications. Complications were divided into minor and major complications, with a major complication defined as any adverse event postoperatively requiring reoperation during the study follow-up period.

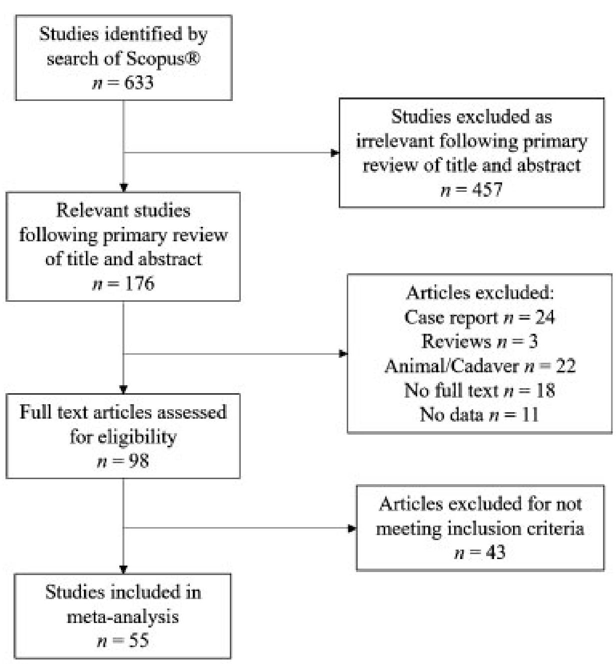

Fig. 1 Flow diagram indicating results of the literature search and study selection procedure.

Results

The literature search identified 633 citations, of which 55 were eligible for inclusion in the systematic review (total $n = 3{,}911$).[4,6,9,10,13,18–67] The average age was 57, with a range from 13 to 94. Men accounted for 36% of all patients. Average follow-up was 20.6 months, with a range from 6 to 90 months. The overall complication rate identified was 15%. Major complications requiring reoperation accounted for 5%, and minor complications consisted of 10% (►**Table 1**).

The most common complications included nerve dysfunction (5.7%), tendon injury (3.5%), and hardware problems (1.6%; ►**Table 2**). Other complications in descending order of incidence included infection, wound complications, and refracture or loss of reduction accounting for 3.9%. A major complication was defined as one requiring reoperation, with the exception of carpal tunnel syndrome, complex regional pain syndrome, and plate removal by patient request. The most common major complication was tendon rupture, with extensor being more common than flexor tendon rupture (►**Table 3**).

Nerve complications were most common with an overall rate of 5.7%, with postoperative carpal tunnel syndrome being the most common at 2%. Complex regional pain syndrome was reported in 1.4% of cases.

The overall tendon complication rate was 3.5% with extensor tendon rupture accounting for 1% and extensor tenosynovitis 0.6%. Flexor tendon tenosynovitis and rupture were reportedly lower at 0.7 and 0.3%, respectively. De Quervain's tenosynovitis, intersection syndrome, and trigger finger were equally low at 0.03% overall. The incidence of tendonitis and tendon rupture where the tendon was not specified was 0.7 and 0.1%, respectively.

Hardware complication rate was 1.6%, with malunion being the most common at 0.6%. Plate prominence was encountered in only 0.1% of patients, screw loosening in 0.3%, intra-articular screws in 0.2%, and prominent screws in 0.1%.

Discussion

The purpose of this study was to perform a systematic review to investigate incidence of complications following volar locking plate fixation of distal radius fractures. Despite the varying overall complication rates in the literature from 0 to 60%,[4,6,9,10,13,18–67] this systematic review reports an overall complication rate of 15% associated with volar locked plating of distal radius fractures, of which only 5% were considered

Table 1 Principal study characteristics with major and minor complication rates by study

Reference	Year	Journal	Study design	Male (%)	No. of patients	Mean age ± SD (range) (y)	Mean follow-up ± SD (range) (mo)	AO Class A (%)	AO Class B (%)	AO Class C (%)	Plate type	Complication rate	
												Minor (%)	Major[a] (%)
Arora et al[4]	2009	J Orthop Trauma	Retrospective	32	53	75.9 ± 4.8 (70–89)	51.5 (12–64)	53	0	47	Fixed	4	9
Arora et al[10]	2011	J Bone Joint Surg Am	Prospective	22	36	75.9 (65–88)	12	28	0	72	Fixed	8	28
Arora et al[18]	2007	J Orthop Trauma	Retrospective	18	114	57.4	14.9 ± 5.1 (12–27)	48	0	52	Fixed	12	15
Brennan et al[19]	2016	Injury	Retrospective	40	151	47.9	32.2 (12–60)	44	37	19	Fixed	8	7
Chung et al[20]	2008	J Hand Surg	Prospective	40	55	47.6 (20–83)	12	44	15	42	Fixed	18	2
Chung et al[21]	2006	J Bone Joint Surg Am	Prospective	43	87	48.9 ± 16.7 (18–83)	12	40	9	51	Fixed	10	0
Figl et al[22]	2010	J Trauma	Prospective	12	58	79 (75–92)	13 (12–15)	66	3	31	Variable angle	5	2
Figl et al[23]	2009	Arch Orthop Trauma Surg	Prospective	38	80	58.4 (23–88)	12 (12–24)	45	13	43	Variable angle	15	0
Gruber et al[24]	2008	J Orthop Trauma	Prospective	33	55	60 (20–92)	29 ± 7	0	0	100	Fixed	4	4
Gereli et al[25]	2014	Arch Orthop Trauma Surg	Prospective	55	31	44 (18–60)	32 (12–90)	100	0	0	Fixed	0	3
Gereli et al[26]	2010	Acta Orthop Traumatol Turc	Retrospective	69	16	49 ± 16	26.1 ± 6.1	0	0	100	Fixed	0	0
Goehre et al[27]	2014	J Hand Surg: Eur Vol	Prospective		21	71.3 ± 5.7	12	86	0	14	Fixed	14	0
Gogna et al[28]	2013	ChinJ Traumatol	Prospective	81	27	30.12 ± 11.48 (19–52)	26.8 (22–34)	26	0	74	Fixed	7	0
Gradl et al[29]	2014	Injury	Prospective	9	55	61.4 ± 14	24	100	0	0	Fixed	24	5
Gradl et al[30]	2013	Arch Orthop Trauma Surg	Prospective	15	52	63 (18–88)	12	56	0	44	Fixed	12	8
Grewal et al[31]	2011	J Hand Surg	Prospective	77	18	58.0 ± 9.9	12	65	0	35	Fixed	11	11
Gruber et al[32]	2010	J Bone Joint Surg Am	Prospective	50	54	63 ± 18	72	0	0	100	Fixed	4	4
Hakimi et al[9]	2010	J Hand Surg: Eur Vol	Retrospective	34	77	62 (18–94)	12 (10–15)	16	0	84	Mixed[b]	12	1
Hollevoet et al[33]	2011	Acta Orthop Belg	Prospective	11	20	67	19 (12–26)				Fixed	15	15
Karantana et al[34]	2013	J Bone Joint Surg Am	Prospective		64	(18–73)	12	41	56	3	Fixed	22	3
Kato et al[35]	2014	Nagoya J Med Sci	Prospective	50	100	56.7 (20–84)	18	16	0	84	Fixed	24	3
Kawasaki et al[36]	2014	J Orthop Traumatol	Retrospective	22	49	59.9 (23–85)	20.2 (12–56)	0	0	100	Variable angle	4	0
Khamaisy et al[37]	2011	Injury	Retrospective	46	91	52.7 (18–74)	12	3	15	81	Fixed	2	1
Knight et al[38]	2010	Injury	Prospective	13	40	59 (18–84)	13.6 (6–24)	43	0	58	Fixed	25	40
Konstantinidis et al[39]	2010	Arch Orthop Trauma Surg	Prospective	43	40	54.4 (19–86)	16.9 ± 5.2 (12–31)	0	0	100	Fixed	30	3
Kumbaraci et al[40]	2014	Eur J Orthop Surg Traumatol	Retrospective	75	34	48 ± 16	49.6 ± 20 (12–72)	0	0	100	Fixed	9	0
Kwan et al[41]	2011	Int Orthop	Prospective	55	75	51 (13–82)	24	18	7	75	Fixed	12	3
Lattmann et al[42]	2008	J Hand Surg	Prospective	20	91	64 ± 17 (24–91)	12	37	9	54	Fixed	9	4
Lattmann et al[43]	2011	J Trauma	Prospective	24	228	62 ± 18 (18–96)	12	42	5	53	Fixed	12	3
Lee et al[44]	2012	Int Orthop	Retrospective		31	50–70	19.2 ± 7.1	55	0	45	Fixed	3	0

(*Continued*)

Table 1 (*Continued*)

Reference	Year	Journal	Study design	Male (%)	No. of patients	Mean age ± SD (range) (y)	Mean follow-up ± SD (range) (mo)	AO Class A (%)	AO Class B (%)	AO Class C (%)	Plate type	Complication rate	
												Minor (%)	Major[a] (%)
Marlow et al[45]	2012	Acta Orthop Belg	Retrospective	24	65	57.7 (17.5–92)	17.2 (7–20)	23	8	69	Variable angle	5	3
					42	56.1 (18.6–87)	32.5 (14–54)	29	7	64	Fixed	0	12
Matschke et al[46]	2011	Injury	Prospective	31	118	57.1 (20–80)	24	34	8	58	Fixed	11	1
Matschke et al[47]	2011	J Orthop Trauma	Retrospective	33	266	54.3 ± 15.1	24	41	7	52	Fixed	12	4
Mellstrand Navarro et al[48]	2016	J Orthop Trauma	Prospective	10	70	63 (50–74)	12	43	0	57	Fixed	41	14
Minegishi et al[49]	2011	Ups J Med Sci	Retrospective	25	15	64.4 (34–76)	15.5 (12–24)	7	0	93	Fixed	13	7
Osada et al[50]	2008	J Hand Surg	Prospective	33	49	60 (17–86)	12	12	0	88	Fixed	0	2
Phadnis et al[51]	2012	J Orthop Surg	Retrospective	28	183	62.4 ± 17.9 (16–93)	30 (13–53)	51	10	39	Variable angle	13	2
Plate et al[52]	2015	J Hand Surg	Prospective	37	30	55 ± 16	24	100	0	0	Fixed	7	3
Rampoldi and Marsico[13]	2007	Acta Orthop Belg	Retrospective	46	90	44 (21–86)	12	31	3	66	Fixed	1	7
Rampoldi et al[53]	2011	J Orthop Traumatol	Prospective	71	21	41 (24–73)	13 (9–18)	57	0	43	Fixed	5	5
Roh et al[6]	2015	J Hand Surg	Prospective	67	36	54.4 ± 10.9	12	0	0	100	Mixed[b]	17	0
Rozental et al[54]	2009	J Bone Joint Surg Am	Prospective	30	23	51 (19–77)	11 ± 2	43	0	57	Fixed	9	0
Sonderegger et al[55]	2010	Arch Orthop Trauma Surg	Prospective	34	62	57.9 (20–89)	14.7 (12–14)	34	0	66	Variable angle	6	15
Souer et al[56]	2010	J Hand Surg	Retrospective	29	62	58 (23–78)	24	100	0	0	Fixed	6	2
Sügün et al[57]	2012	Acta Orthop Traumatol Turc	Retrospective	52	46	48.7 (24–87)	19 (6–43)	0	0	100		4	2[c]
Takada et al[58]	2012	Eur J Trauma Emerg Surg	Retrospective	30	20	48 (21–76)	13.8 (12–24)	20	15	65		0	0
Tarallo et al[59]	2013	J Orthop Trauma	Retrospective	39	303	56 (18–87)	56.4	10	31	59	Variable angle	1	5
Vlček et al[60]	2014	Bosn J Basic Med Sci	Retrospective	30	50	48.5 (22–77)	12	18	0	82	Variable angle	12	2
Wei et al[61]	2009	J Bone Joint Surg Am	Prospective	25	12	61 ± 18	12	25	0	75	Fixed	17	0
Wei et al[62]	2014	Indian J Orthop	Prospective	32	22	65 (37–80)	12 (10–18)	36	50	14	Fixed	18	0
Wichlas et al[63]	2014	J Orthop Traumatol	Retrospective	41	225	54.6 ± 17.4	33.2 ± 17.2	36	7	56	Fixed	1	2
Wilcke et al[64]	2011	Acta Orthop	Prospective	24	33	55 (20–69)	12	79	0	21	Fixed	12	9
Williksen et al[65]	2013	J Hand Surg	Prospective	20	52	54 (20–84)	12	29	0	71	Fixed	17	12
Yu et al[66]	2011	J Hand Surg	Retrospective	38	47	56 (19–84)	38 (12–72)	11	21	68	Fixed	19	11
Zenke et al[67]	2011	J Orthop Trauma	Retrospective	29	66	63.5 ± 16.8 (25–94)	22.7 ± 9.0 (12–41)	64	0	36	Fixed	5	2
				Total	**3,911**						**Total**	10	5

Abbreviations: AO, Arbeitsgemeinschaft für Osteosynthesefragen; CTS, Carpal Tunnel Syndrome; CRPS, Complex Regional Pain Syndrome.
[a]Complications requiring reoperation with the exception of CTS, CRPS, and patient request.
[b]Study characteristics and complication rates not separated by plate type.
[c]Eleven cases of extensor tenosynovitis were asymptomatic and detected only by ultrasound.[57]

Table 2 Most common complications

Complication type	Rate (%)
Nerve	5.70
Carpal Tunnel Syndrome (CTS)	2.05
Complex Regional Pain Syndrome (CRPS)	1.41
Median nerve sensitivity (no CTS)	1.25
Paresthesia (nonspecific)	0.38
Radial nerve neuropathy	0.20
Median nerve damage (thenar motor)	0.15
Paresthesia (thenar region)	0.13
Paresthesia (cutaneous branch)	0.10
Ulnar nerve neuropathy	0.03
Tendon	3.53
Extensor tendon rupture	1.02
Flexor tenosynovitis	0.69
Tendonitis (nonspecific)	0.69
Extensor tenosynovitis	0.59
Flexor tendon rupture	0.33
Tendon rupture (nonspecific)	0.13
Intersection syndrome	0.03
De Quervain	0.03
Trigger finger	0.03
Hardware	1.61
Malunion	0.61
Screw loosening	0.33
Loss of reduction	0.23
Intra-articular screw	0.20
Prominent screw	0.13
Prominent plate	0.05
Broken plate	0.05

Table 3 Major complications by complication type

Major complication type		No. of events	% of total patients
Tendon	Extensor tenosynovitis	19	0.49
	Extensor tendon rupture	40	1.02
	Flexor tenosynovitis	23	0.59
	Flexor tendon rupture	13	0.33
	Tendonitis (nonspecific)	8	0.20
	Tendon rupture (nonspecific)	1	0.03
	Tendon sheath fibroma	1	0.03
Hardware	Screw loosening	5	0.13
	Intra-articular screw	4	0.10
	Prominent screw	2	0.05
	Prominent plate	2	0.05
	Loss of reduction	5	0.13
	Malunion	2	0.05
	Radioulnar synostosis	1	0.03
	Plate break	1	0.03
Other	Pain/Discomfort/ Irritation	39	1.00
	Infection	1	0.03
	Nonspecific reoperations	21	0.54
Total		188	4.81

major complications by requiring a reoperation. Much of the discrepancy in the literature was surmised to be related to the varying definitions of a "complication," how stringent complications were reported by the authors, and how a major or minor complication was defined if at all. For instance, Mellstrand et al performed a randomized control trial comparing volar locked plating and external fixation with a high complication rate of 50.7% in the volar locking plate group and 44.6% in the external fixation group.[48] Although only one patient who underwent volar locked plating developed carpal tunnel syndrome that was treated operatively, 36.9% of patients reported some form of nerve dysfunction. However, this nerve dysfunction was most often transient requiring no additional treatment or surgery.

As illustrated in our review, several reported series identified nerve dysfunction and/or carpal tunnel syndrome as the most common complication following volar locking plate fixation. Arora et al performed a prospective randomized study between cast treatment and volar locked plating and reported an operative complication rate of 13%,[10] comparable to our review's rate. Further they found a 2.8% rate of carpal tunnel syndrome, similar to our combined 2%. Roh et al compared volar plating and external fixation and reported a complication rate following volar plating of 17%, with a rate of carpal tunnel syndrome also at 2.8%, both comparable to our reported rates.[6]

Carpal tunnel syndrome is common and endemic in the population at large, but it is also known to occur as a product of distal radius fractures in 7 to 15%[68] of cases in general, irrespective of treatment strategy. Typically, carpal tunnel syndrome following distal radius fracture is not assumed to be related to hardware, but more related to the trauma to the nerve from the fracture and/or subsequent healing with thickened bony anatomy and any residual malunion. Due to the endemic nature, we considered carpal tunnel syndrome to be a minor complication even in instances where carpal tunnel release was required. Additionally, plate removal by patient request was not considered a complication, major or minor. However, symptomatic hardware or tendon irritation due to hardware is directly related to the fixation and therefore considered a major complication if reoperation was required.

It has been hypothesized that the volar anatomy of the wrist is better suited to plating than the dorsal side due to the presence of more space and less contact between the distal radial cortex and tendons.[49] Our systematic review identified only 0.7% flexor tendon tenosynovitis and 0.3% flexor tendon rupture. While we did find low rates of flexor tendon involvement following volar locking plate fixation, there was an overall tendon complication rate of 3.8% with extensor tendon complications accounting for 1.9%. In a systematic review of tendon complications following open reduction and internal fixation of distal radius fractures, Azzi et al similarly found a low incidence of tendon complications following volar plating.[69] Their systematic review reported a 7.5 versus 4.5% tenosynovitis and 1.7 versus 1.4% tendon rupture rate following dorsal plating and volar locked plating, respectively.

Further comparison of complication rates between dorsal and volar locked plating by Wichlas et al found a low complication rate in both groups with 3.6% in the volar plate and 11.7% in the dorsal plate groups.[63] They reported a low incidence of carpal tunnel syndrome at 0.44% and no tendon complications following volar locked plating. Although they found no tendon complications, implant removal was performed in 6.7% of the volar locked plate group for patients with implant-associated pain, swelling, or patient request. Whether or not persistent pain and swelling in the volar group was related to tendon irritation or truly symptomatic hardware from another source is unclear.

We found a lower hardware complication rate than expected, with the majority of complications associated with screw loosening or prominent screws. Hardware complications are likely underreported in the literature, as many nerve and tendon complication may be related to symptomatic hardware even if not explicitly stated. Arora et al found a 27% complication rate following volar locked plating with tendon complications accounting for more than half and all patients with tenosynovitis underwent early hardware removal.[18] While all cases of tenosynovitis and tendon rupture may not be associated with hardware prominence, the two are likely related and may explain the lower than expected hardware complication rate in our systematic review.

The main limitation of our systematic review is the heterogeneity of the data. Different surgical approaches, implants, and techniques for volar locked plating were utilized in these studies. Further, surgeon experience likely varied. Also, the scrutiny with which complications were noted by the authors is inherently unpredictable. Despite these limitations, this meta-analysis highlights the overall complication rates associated with volar locked plating of distal radius fractures over the past 10 years.

In short, this systematic review provides an updated review of the literature demonstrating a low tendon and hardware complication rate supporting the increased utilization of volar plating, and it also identified that nerve dysfunction is prevalent. Further investigation regarding the different types of volar plates may help elucidate the reason for varying complication rates between studies.

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Conflict of Interest
None declared.

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