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ORIGINAL STUDY

Removal of volar plate after open reduction internal fixation of distal radius fractures : clinical and radiographic analysis

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The operative treatment of distal radius fractures had evolved over the years. In the last two decades anatomic locking plates were introduced and are increasingly being used for this indication becoming the most common surgical fixation for distal radius fractures. This study investigated how often plate removal is related to preventable reasons such as plate and screw positioning, screw length, and quality of reduction.

All patients who underwent volar plate removal in our institution between the years 2006-2014 were included in this study. Patients' charts were retrospectively reviewed, and preoperative radiographs were analyzed including plate to volar rim distance (PVR), plate to critical line distance (PCR), Soong classification, implant position, and screw prominence.

A total of 50 patients (26 males, 24 females) were identified. Patients with subjective feeling of prominent implant were found to be younger than the rest of the cohort. In addition, this complaint was associated with ulnar prominence of the proximal part of the plate due to malposition on the coronal plane. Extensor tendon irritation was associated with prominence of the proximal screws. Only one case was associated with flexor tendon irritation and there was no association to the Soong grade or PCL and PVR measurements.

We believe that good fracture reduction, correct plate positioning, and appropriate screw location and length, can largely limit the need for volar plate removal.

Keywords : distal radius fracture ; volar plate ; implant removal ; implant prominence.

INTRODUCTION

Distal radius fractures are the most common upper extremity fractures with a reported incidence of over 640000 cases a year in the US alone *(1)*. Karl et al. *(2)* Reported a bimodal incidence of distal radius fractures with the highest rates in age groups under 18 y/o and over 65 y/o, and lower rates in the middle age groups. The operative treatment of distal radius fractures had evolved over the years. In

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the last two decades anatomic locking plates were introduced and are increasingly being used for this indication *(3,4)* becoming the most common surgical fixation for distal radius fractures *(5-7)*.

Although volar plate fixation provides reliable and reproducible results *(8,9)*, several complications have been associated with their use including carpal tunnel syndrome *(10)*,tendon injuries, both flexors *(11,12)* and extensors *(13)*, and intra-articular screw penetration *(14,15)*. Part of the complications appear to be implant related and therefore require its removal. The reasons for implant removal following distal radius open reduction internal fixation (ORIF) were not widely described in the literature *(8, 16-18)*. The goal of our study was to identify and analyze the reasons for volar plate removal following ORIF of distal radius fractures. Identifying preventable causes may potentially allow improving the surgical technique of implant application, and consequently decrease the need for subsequent removal.

METHODS

Following the approval of our institutional review board, we performed a retrospective study at a level I trauma center. All patients operated between 2006 and 2014 for volar plate removal after ORIF of distal radius fractures were identified. Exclusion criteria were children with open physis and the associated use of a dorsal plate. Patients' medical records were reviewed for age, gender, hand dominancy, side of fracture, mechanism of injury, time between injury to the operative fixation, reasons for implant removal, and time between the ORIF to implant removal. Radiographic analysis included review of two sets of radiographs for each patient, one taken after the initial trauma and the second taken before the removal of the implant. Each set included postero-anterior (PA) and lateral views. In five cases, patients underwent ORIF in other medical facilities, and consequently the radiographs after the initial trauma were not available. We reviewed the postoperative radiographs for : secondary displacement, intra articular screw penetration, prominence of the screws at the dorsal aspect of the radius, plate position on the coronal plane, distance from the plate to the volar rim (PVR), distance from the plate to the critical line(PCL) *(19)*), and Soong classification *(14)*. Statistical analysis of the data was carried out with Pearson Chi-Square test ($\chi 2$) for categorical variables and student t test for scaled variables at a significance level of 0.05.

RESULTS

Fifty patients were included in the study. There were 24 females and 26 males, with an average age at the time of implant removal of 46.7 years (range 17-82). The dominant hand was involved in 17 cases, seven patients had bilateral distal radius fractures and one patient had an open fracture. The mechanism of the fractures was a fall on an outstretched hand in 37 cases, car accident in 12 cases, and in one case this data was not available. Fourteen cases had been acknowledged as work compensation. The distribution of fractures type according to the AO Müller classification is presented in table 1. Seventy two percent of the fractures had an intra-articular involvement. The mean time from the occurrence of the fracture to ORIF was 9.6 days (range 0-29) and the mean time between ORIF and implant removal was 81.39 weeks (range 3-431). Of the 50 implants that were removed, Forty-two were locking and 8 were non-locking plates from different manufacturers.

Table 1. — AO Müller classification

Fracture Type	Fracture Group		
	1	**2**	**3**
23A	0	10	3
23B	1	1	12
23C	7	6	5

According to the AO Müller classification number 2 indicates Radius and Ulna, number 3 indicates distal segment, and the letters A,B,C indicate the fracture type (A – extra-articular, B – partial articular, C – complete articular), the fracture group in the upper row indicate the fracture comminution.

The reasons for implant removal (one or more per patient) are shown in table 2. Subjective feeling of prominent implant leading to its removal was significantly associated with younger age (39.3 years Vs 49.3 years ; P=0.05), and with ulnar prominence of the proximal part of the plate

Table 2. — Reasons for implant removal

Reason for implant removal		Number of patients (%)
Subjective reasons	Pain	38 (76)
	Stiffness	32 (64)
	Subjective prominent implant	13 (26)
Objective reasons	Articular collapse	12 (24)
	Malposition	11 (22)
	Tenosynovitis/tendon lesion	9 (18)
	Carpal tunnel syndrome (CTS)	2 (4)
	Infection	1 (2)
	Non-union	1 (2)

(p=0.037). Hand dominancy was not found to be significantly associated with any reason for implant removal (P>0.5). No correlation was found between any of the reasons for implant removal and the type of fracture according to the AO Müller classification or the type of plate (locking Vs Non-locking). Six patients had a prominent screw into the Distal Radio-Ulnar Joint (DRUJ) and eight into the Radio-Carpal joint. As expected, all patients with prominent screws into joints had wrist pain and stiffness.

There was a significant association between prominence of the most distal diaphyseal screw and the occurrence of extensor tenosynovitis that required implant removal (P=0.021). In cases of extensor tendon irritation the mean protrusion of the most distal diaphyseal screw was 1.7 mm compared to 0.688 mm in cases that did not demonstrate irritation of the extensor tendons. Soong grade, PCL and PVR evaluations are detailed in table 3. Those criteria were not found to be associated with any reason for implant removal. One patient (2%) had flexor pollicis longus tendon irritation. In that case the Soong grade was 1, PCL was 2.2mm, and PVR was 4.1mm.

Intraoperative difficulties and complications during the implant removal included 2 cases of iatrogenic injuries to the radial artery that were treated with immediate repair. In addition, in 3 cases the use of a reversed threaded screwdriver was required to remove damaged screws. There was no significant association between the occurrence of an intra operative complication and time between ORIF and implant removal, (p=0.936) the type of plate used(locking and not locking) (p=0.589), or patients' age (p=0.635). In 18 cases, additional procedures were performed during implant removal ; these procedures are detailed in table 4. Those cases were not associated with increased rate of intraoperative complication (p=0.642) or with any specific reason for implant removal (p>0.1).

DISCUSSION

Distal radius fractures are the most common upper extremity fractures with an increased incidence in recent years *(20,21)*. As the operative treatment, especially ORIF with volar plating, is

Table 3
Soong classification, PVR and PCL measurements

	Soong grade 0	Soong grade 1	Soong grade 2	Total
Number of patients	5	22	23	50
PVR	4.2 (SD1.98)	5.23 (SD2.79)	3.71 (SD4.1)	4.1 (SD3.43)
PCL	1.29 (SD1.01)	4.06 (SD2.24)	4.76 (SD3.53)	4.21 (SD2.4)

PVR (Plate to Volar Rim) and PCL (Plate to Critical Line) are measured in mm. Plate prominence greater than 2.0 mm beyond the volar critical line and plate position distal to 3.0 mm from the volar rim both were found by Kitay et al. to be highly sensitive and specific for flexor tendon rupture (19).

Table 4. — Additional procedures during implant removal surgery

Procedure	Number of patients
Neurectomy of PIN and AIN and adhesion release of the Median nerve	6
Osteotomy of osteophyte that limited range of motion	5
Carpal Tunnel Release	3
Extensor tendon tenolysis	3
Arthroscopy (including TFCC repair)	3 (2)
Debridement	1
Darach procedure	1

Figure 1. — Ulnar prominence of the proximal part of the plate indicate a rotation of the plate on the coronal axis.

Figure 2. — Dorsal prominence of screw in the diaphysis of the radius**.**

becoming more common *(5-7)*, plate removal rate increases as well. Our study aimed to analyze the reasons for plate removal, and to identify predictive parameters that could be adjusted to decrease plate removal rates.

The average patient age at implant removal in our series was 46.7y/o ,which is significantly younger than the mean reported age for ORIF of distal radius fractures *(6)*. This finding is in agreement with what has been reported by Snoddy et al. *(17)*. The mean age at implant removal in their series of 33 cases was 46y/o. It might be explained by the finding that subjective feeling of implant prominence, which was a common reason for implant removal in our series, was more common in younger patients. In addition there is a general reluctance of surgeons to re-operate on elderly patients with higher peri-operative morbidity *(22)*.

Subjective feeling of implant prominence was associated with ulnar prominence of the proximal part of the plate and was significantly more common in younger patients. To our knowledge, this reason for plate removal was not previously reported. Ulnar prominence of the proximal part of the plate is caused by a position which is not parallel to the coronal axis of the radius, and consequently may be associated with radial prominence of its distal part (figure 2), where the irritation is usually located. The distal prominence of the plate may be overlooked on plane radiographs due to the unique shape of the radial metaphysis, and proximal ulnar prominence is easier to identify. The association between this

Table 5. — Tendinous lesions reported in literature

	Number of cases	Number of tendinous lesions	Extensor lesions	flexor lesions
(17)	33	9	8	1
(18)	37	7	7	0
{Rampoldi, 2007 #75}	90	5	3	2
(31)	114	17	6	11 (2 FPL tears)
(16)	28	9	2	7 (FPL tear, 2 FDP tears)
(14)	165	6	0	6 (FPL tear, FDP tear, FDP+FDS tear)
(37)	22	5	5	0
Current study	50	9	8	1

reason for plate removal to younger patients age is probably related to their higher activity level. In an attempt to limit plate prominence in the coronal plane, we currently position the distal part of the plate on the ulnar aspect of the distal radius, and its proximal part parallel to the long axis of the bone. In addition, we choose the narrowest plate that will provide adequate stable fixation to the fracture. Although several studies reported no benefit in repairing the pronator quadratus *(23)* following volar plate fixation of distal radius fractures, in light of our current study, we believe that implementation of this technique for plate coverage should be considered in young patients with higher level of physical activity.

Tendon irritation and related problems are the leading complication following ORIF of distal radius fracture in almost all series *(10,17,18,24,25)*. In our series tenosynovitis was the reason for implant removal in 18% of the patients. In all but one, the extensor tendons were involved and there was no case of tendon rupture. These findings are similar to the findings of Lutsky et-al. *(18)* who reviewed 37 patients who underwent implant removal following volar plating of distal radius fractures and found 19% incidence of tenosynovitis or tendon lesion without any case of flexor tendon rupture. The most significant factor associated with extensor tendon irritation in our series was the amount of dorsal prominence of the most distal diaphysial screw (figure 1). Wall et-al. *(26)* recommended uni-cortical fixation of the epiphyseal screws to minimize extensor tendon complications, since the effect of grabbing the dorsal cortex has been proven to be negligible on construct strength. Pater et al. *(27)* in their study on cadaveric forearm model found that unicortical locked fixation and bicortical non-locked fixation both appear to afford adequate construct stability for a simple forearm fracture model in the immediate postoperative stage. In addition, Overtuf et al. *(28)* demonstrated biomechanical equivalence between bicortical and unicortical-abutting locking screw-plate fixation in radial diaphyses. In order to minimize tendon irritation, the use of unicortical abutting locking screws should be considered in proximal plate fixation, especially for the most distal diaphyseal screw.

Flexor tendon complications are reported less frequently than extensor tendon complications, their distribution are shown in table 5. Kitay et-al. *(19)* compared lateral radiographs of 8 patients with flexor tendon rupture to 17 matched control patients in an attempt to find an association between plate position and flexor tendon rupture. Based on their findings they recommended on elective implant removal for symptomatic patients with plate prominence greater than 2.0mm volar to the critical line (PCL) and plate position within 3mm of the volar rim (PVR). We found in the current study that PCL was higher or equal to 2mm in 42 patients (avg. 4.12 ± 2.4) and PVR was less than 3mm in 13 patients (Avg. 4.1 ± 3.43). Although PCL and PVR were high and low respectively in the only patient in our series with flexor tendon irritation, no statistically significant association was found between these criteria and the reason for implant removal.

Intra articular screw placement was diagnosed in 14 patients (6 DRUJ, 8 Radio-Carpal Joint), and all had pain and joint stiffness. In order to

maximally support the articular surface the most distal screws should ideally be inserted underneath the subchondral bone *(3)*. Consequently, very distal fractures with intra articular comminution pose the greatest risk for this complication and the most ulnar screw has the highest risk for intra articular penetration *(29)*. The incidence of intra-articular screw penetration is rarely reported in the literature. Both Marsland et al. *(30)* and Arora et al. *(31)* reported on one intra-articular screw penetration that was diagnosed and corrected intraoperatively. Soong et al. *(14)* reported on eight cases of intra-articular screw penetration out of 594 distal radius plating, and Pace et al. *(32)* reported on 8 intraarticular screw penetration out of 128 cases. In order to reduce the incidence of this unfortunate complication, several authors suggested multiple fluoroscopic views to better demonstrate the joint line *(32-34)*. Recently we started to use locking distal pegs (available in some distal radius plating systems) in questionable cases, in an attempt to reduce radiocarpal irritation.

Intraarticular screw penetration can also occur postoperatively due to secondary collapse of the subchondral bone which was originally supported by the stiff construct of the locking mechanism. Esenwein et al. *(15)* reported on 9 cases of secondary collapse out of 665 cases of distal radius fractures treated with fixed angle locking plates. This finding is similar to the results of Soong et al. *(14)* who reported 1.2 % loss of fixation (7 of 594 cases).

The Intraoperative complication rate in our series was 4% and 6% (respectively) and included two cases of arterial injury and three cases of damaged screws. Intraoperative complications during implant removal has been described by others. Bae et al. *(35)* described significant difficulties in screw removal due to stripping of hexagonal screw heads in 24 out of 279 3.5mm locking screws. Van Nortwick et al. *(36)* described 2 cases complicated by arduous removal of screws due to bone integration, welding and stripping of their heads. Gyuricza et al. *(16)* in their review of 28 cases of distal radius plate removal reported on 2 cases of damaged screw heads. Surprisingly, we did not find any report on other intraoperative complications including arterial injury as described in the current series.

Limitations

Our study has several limitations including its retrospective nature, and the fact that the study population only included patients that had their implant removed, without a comparison to the entire patient population who had distal radius fracture fixation with volar plates. Nevertheless, this is one of the few and largest series of volar plate removal. Since the popularity of volar plate fixation of distal radius fractures is constantly increasing, analyzing the reasons for its removal is of clinical importance.

CONCLUSIONS

Although the use of volar locking plates for the treatment of distal radius fractures is considered a reliable procedure, surgeons must be aware of the factors that are associated with the increased need for implant removal, especially those that can be adjusted. According to the current series, these factors included younger age, initial plate malpositioning in the coronal plane, and screw malpositioning (intra-articular penetration, or dorsal prominence). Based on our findings, in order to decrease the need for implant removal we suggest to position the plate parallel to the long axis of the radius with its distal part positioned as ulnar as possible on the metaphysis, to use the narrowest plate available without compromising fracture fixation stability, and to carefully position and measure the screws to avoid joint protrusion or screw prominence that may lead to tendon irritation. Finally, when locking and tightening the screws, care must be taken to avoid damage to their heads, that may lead to future difficulties in cases of need of implant removal.

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