RESEARCH ARTICLE

Forearm Plate Fixation: Should Plates Be Removed?

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Abstract

Background: Refracture after both bone forearm fracture fixation may vary with or without plate removal. We tested the null hypothesis that there is no difference in the rate of refracture in patients who have undergone open reduction and internal fixation of a diaphyseal forearm bone who have retained implants versus removed implants. We also studied factors associated with plate removal.

Methods: We retrospectively identified 645 adult patients with a total of 925 primary fractures that underwent primary plate fixation of an ulnar or radial shaft fracture between 2002 and 2015 at a single institutional system. Patients with nonunion, pathological fracture or infection were excluded. Independent factors associated with refracture and plate removal were identified using multivariable analysis.

Results: Refractures occurred in 6.3% of the fractures that had forearm implant removal, compared to 2.1% of the fractures with retained plates. Refractures were independently associated with plate removal (OR: 3.7, 95% CI: 1.2-11.7, *P=0.023*) and was more frequent in the radius (OR: 2.4, 95% CI: 1.0-5.8, *P=0.06*). A refracture after implant removal occurred within 3 months after removal. Ulnar plates were removed more often compared to radial plates (OR: 2.6, 95% CI: 1.4-4.7, *P=0.002*) as were plates used for type A fractures compared to type C fractures (OR: 3.2, 95% CI: 1.1-9.2, *P=0.032*).

Conclusion: The rate of refracture is higher after plate removal compared to patients who did not have plates removed. Although uncommon, refractures of the radius tend to be more common than a refracture of the ulna. If the implant is symptomatic on the ulnar side, it may be preferable to remove the ulnar implant and retain the radius implant rather than remove both plates when possible. Furthermore, limiting strenuous activity for three months after implant removal is a consideration.

Level of evidence: III

Keywords: Forearm, Fracture, Implant removal, Osteosynthesis, Plate removal, Refracture

Introduction

Forearm fractures account for 10-14% of all fractures and usually occur due to high energy trauma(1). The majority of both bone forearm fractures are treated with plate fixation(1, 2).

After fracture healing some patients will request implant removal because of symptoms or patient preference(3, 4). In general, most surgeons wait at least 12 to 24 months after initial surgery before plate removal(5-7). The most frequent reason for implant removal is pain or discomfort and other indications include infection or restricted motion(3, 4). It is unclear whether routine implant removal in the forearm increases the risk of a refracture, which occurs at rates reported between 3.9% to 26% (1, 3-13).

When a patient has retained plates after open reduction and internal fixation (ORIF), refractures generally occur at the edge of the plate. In patients who have plates removed, refractures generally occur at a prior screw

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hole, but our understanding of refractures is limited (3, 14). We tested the null hypothesis that there is no difference in the rate of refracture in patients who have undergone ORIF of a diaphyseal forearm bone who have retained implants versus removed implants. Additionally, we studied the factors associated with plate removal.

Materials and Methods

We retrospectively identified all patients that underwent primary plate fixation of an ulnar or radial shaft fracture using the Current Procedural Terminology (CPT) codes: "25515", "25525", "25526", "25545", "25574" and "25575" and the International Classification of Diseases Ninth Edition (ICD-9) procedure code "79.32". All adult patients that were treated between 2002 and 2015 at five urban hospitals in the Northeastern United States were identified (n=4959). The coding query identified patients up to July 25, 2017. We used a data processing program (STATA 13.0, StataCorp LP, College Station, USA) to identify patients that had the word "radius", "radial", "ulnar", "ulna" or "forearm" in the operative notes. In these patients, we performed a manual chart review to verify the patients and to determine if they met inclusion criteria. We excluded 2837 patients with a distal radius fracture, 1416 patients who had either an elbow fracture, pathologic fracture, 19 patients with no radiograph available, four patients who were treated without plate, one patient without a fracture, nine patients were excluded because of implant removal due to infection and 28 patients were excluded because of implant replacement due to nonunion [Chart 1]. Inclusion criteria were adult patients, who had a surgical treatment of a mid-shaft forearm fracture. In total 645 patients were included for analysis, with 925 fractured bones, both bone forearm fractures counted as two fractures, sixteen patients had bilateral forearm fractures due to high energy trauma.

Medical charts were reviewed to collect data regarding demographics, fracture and treatment characteristics along with postoperative complications and indications for reoperation. Recognizing the limitations of the study, we did not specifically evaluate for plate or screw loosening. A refracture was defined as a fracture at the prior fracture site, at the screw holes, or at the edge of the plate. Fractures were classified according to the AO/OTA fracture classification by a fellowship trained orthopaedic hand surgeon. The follow-up was defined as the time from index surgery to the date of last clinical follow-up at one of our institutional hospitals.

Study population

We included 407 males and 238 females with a median age of 38.5 years (IQR: 26.2-53.5) [Table 1]. Sixteen patients (2.5%) had bilateral forearm fractures, while the rest had unilateral injuries. There were a total of 925 forearm fractures of which 524 (57%) were both bone fractures. For statistical reasons we counted both bone forearm fractures as two events: a radius fracture and an ulna fracture. According to the AO/OTA fracture

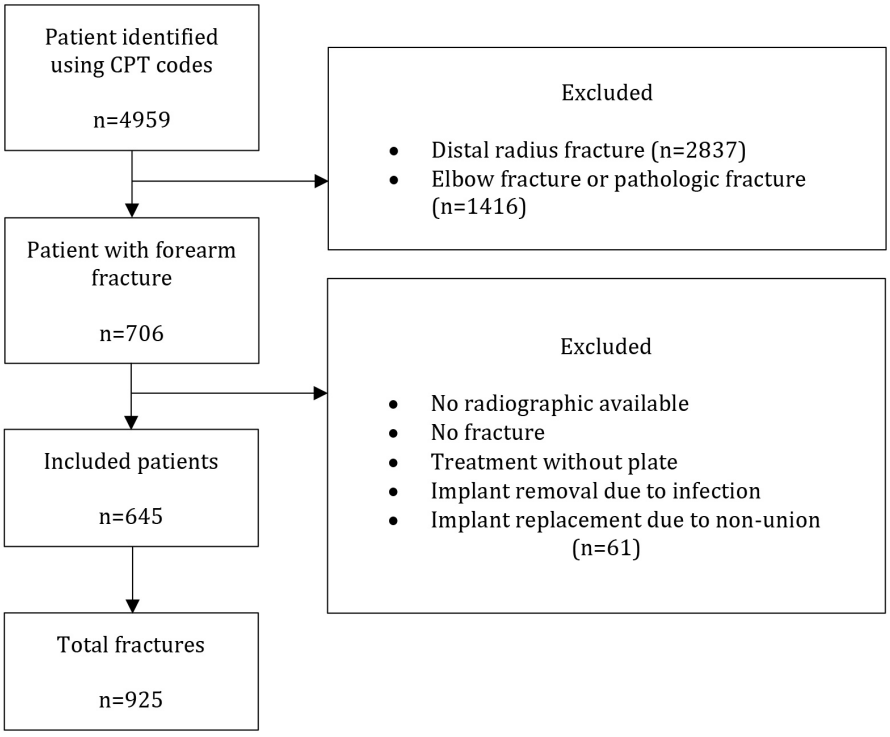

Chart 1. Flow chart for patient inclusion. For statistical reasons, both bone fractures were counted as two events.

Table 1: Study population	
Patient demographics (n=645)	
Age: years	
Median (IQR)	38.5 (26.2-53.5)
Gender, n(%)	
Male	407 (63.1)
Female	238 (36.9)
Unilateral or Bilateral, n(%)	
Unilateral forearm fracture	629 (97.5)
Bilateral forearm fracture	16 (2.5)
Fracture characteristics (n=925)	
Location - Bone, n(%)	
Radius	425 (45.9)
Ulna	500 (54.1)
Location - Characteristic, n(%)	
Isolated radius	161 (17.4)
Isolated ulna	240 (26.0)
Both bone	524 (56.6)
Open fracture, n(%)	
Open injury	310 (33.6)
Closed injury	615 (66.5)
AO/OTA classification, n(%)*	
Type A	319 (48.3)
Type B	203 (30.7)
Type C	103 (15.6)
No initial X-ray	36 (5.4)
Type of implant, n(%)	
Compression plate	677 (73.2)
Locking plate	239 (25.8)
Unknown	9 (1)

* Total number of forearms = 661 (16 Patients had bilateral injury)

classification there were 319 (48%) type A fractures, 203 (31%) type B fractures and 103 (16%) type C fractures. In 36 (5.4%) fractures no initial radiograph was available for review. A total of 310 (34%) fractures were an open fracture [Table 1]. A locking plate was used in 239 (26%) fractures and 677 (73%) fractures were stabilized using a compression plate, in 9 (1%) fractures there was no record of the implant type. When a locking plate was used surgeons used a combination of locking and non-locking screws. Plate removal was not routinely performed, only 50 patients (7.8%) underwent 64 (6.9%) plate removals at a median of 13.7 (IQR: 8.9-20.8) months after index surgery. In six patients the screw holes were curetted. Bone fillers or bone grafting for filling the screw holes were not used in

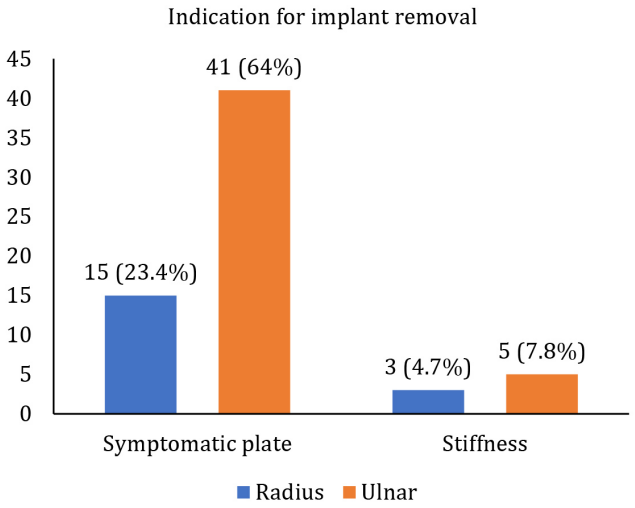

Chart 2. Diagram of indications for plate removal.

any patient. All fractures were radiographically united prior to implant removal.

The indication for plate removal was most commonly symptomatic implants (e.g. the patient or physician felt that the implant was bothering the patient) (n=56, 88%) and stiffness (n=8, 13%) [Chart 2]. There were 20 patients with the both forearm fractures who underwent symptomatic implant removal, both plates were removed in 12 patients, seven patients only had the ulnar plate removed and in one patient only the radial plate was removed.

Of the 64 fractures where the implant was removed, 32 (50%) were placed in soft dressing postoperatively, 19 (30%) were placed in a splint and one (1.6%) was placed in soft dressing followed by splinting at first postoperative visit, the remaining patients (n=12, 20%) did not have post-operative treatment recorded in medical charts. In the four refractures after plate removal, the postoperative protocol was a soft dressing without splint in three patients and with splint in another patient.

Statistical Analysis

To evaluate the factors associated with refracture and those associated with plate removal we used the Fisher's exact test for dichotomous and categorical variables and the Mann-Whitney U test for age. We included all variables with a *P<0.1* in bivariate analysis along with location of the plate because of differences in torsional forces through the ulna and radius in multivariable logistic regression analysis. A *P-value* of <0.05 was considered statistically significant.

Results

In the fractures where the implant was retained, refractures occurred in 18 forearm bones (2.1%). In fractures where the plate was removed, refracture occurred in 4 (6.3%) forearm bones 11 days to 2.7 months after plate removal. With a retained implant, a refracture

Table 2. Factors associated with refracture

	Refracture		*P-value*
	Yes (n=22)	No (n=903)	
Overall plate removal, n(%)			0.06*
Yes	4 (6.3)	60 (94)	
No	18 (2.1)	843 (98)	
Location, n(%)			0.13*
Radius	14 (3.3)	411 (97)	
Ulna	8 (1.6)	492 (98)	
Type of fracture, n(%)			0.36*
Open fracture	5(1.6)	305(98)	
Closed fracture	17(2.8)	598(97)	
AO/OTA classification, n(%)			0.24*
Type A	13(3.1)	409(97)	
Type B	6(1.9)	303(98)	
Type C	1(0.7)	151(99)	
Gender			>0.99*
Male	14(2.4)	577(98)	
Female	8(2.4)	326(98)	
Type of implant**			0.59*
Compression plate	12(1.9)	613(98)	
Locking plate	6(2.6)	221(97)	

* Using Fisher's Exact

** Only fracture with implant in-situ

Table 3. Multivariable logistic regression for refracture

Variable	OR	SE	95% CI	*P-value*
Plate removal	3.74	2.17	1.20 - 11.66	0.023
Location: (ref: Ulnar)				
Radius	2.35	1.07	0.96-5.76	0.06

OR= Odds ratio, SE= standard error, CI= confidence interval

occurred after a median of 21.5 (IQR: 9.7-38.9) months after index surgery and occurred at the location of either proximally or distally last screw holes most frequently [Supplementary 1]. Plate removal was independently associated with refracture (OR: 3.7: 95% CI: 1.2-11.7, *P=0.023*). There was a trend to higher refracture rates of the radius compared to the ulna (OR: 2.4, 95% CI: 1.0-5.8, *P=0.06*) [Table 2; 3].

Among the refractures where implants had been removed, three fractures occurred at the radial shaft and one in the ulnar shaft [Chart 3]. In these four refractures, two occurred at the screw hole while another two occurred at the old fracture site [Figure 1]. Three of the refractures were treated with ORIF and one patient was treated non-surgically with a splint.

Of the 18 refractures with a retained implant, 11 (61%) were fractures of the radius and 7 (39%) fractures of the ulnar shaft, of which one was a both bone refracture (Patient 14). Index fracture treatment was with a compression plate in 13 fractures and a locking plate in five fractures. Of those treated with a locking plate, two had locking screws at both the proximal and distal screw. Ten peri-implant fractures occurred at the distal end of the implant and eight occurred at the proximal end of the implant. Seventeen refractures occurred at the screw

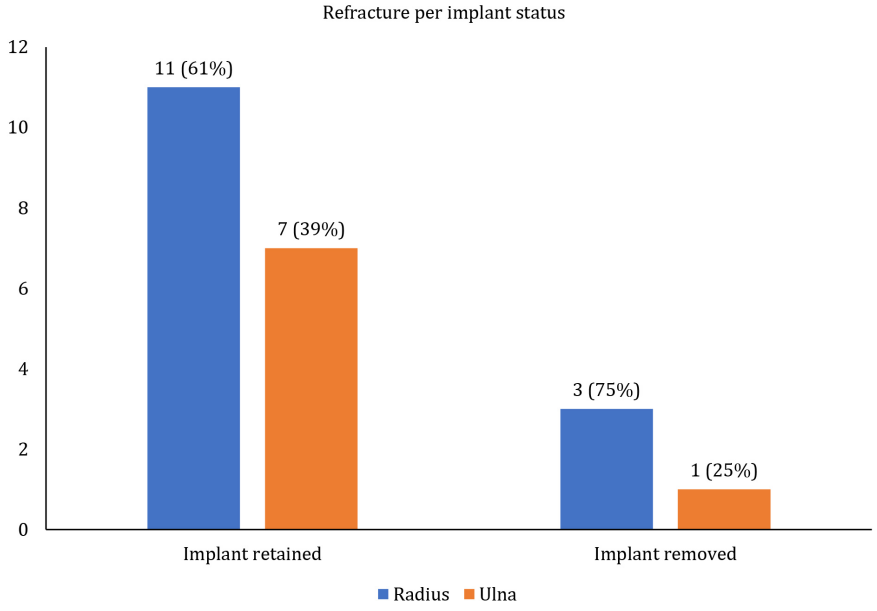

Chart 3. Diagram of refracture per implant status.

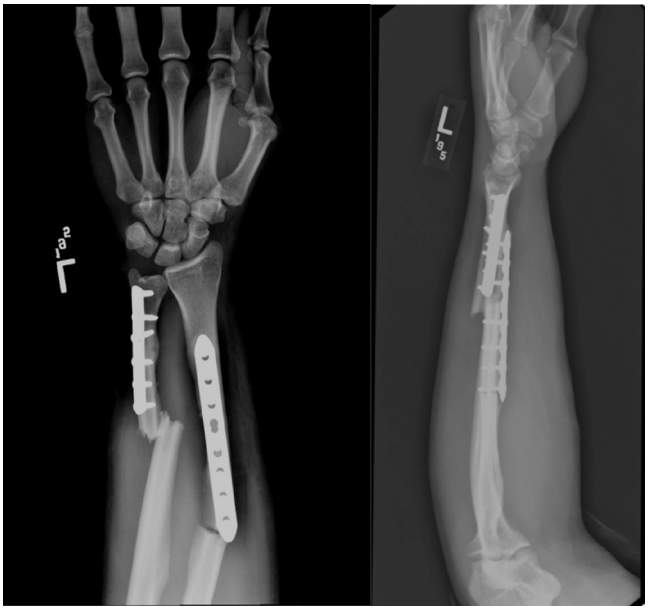

Figure 1. Radiographic studies of left forearm of 39-year-old male who had refracture which occurred at the screw hole 2 months after implant removal. We speculate that the enlarged hole was because of bone resorption or technical error at the time screw insertion.

Figure 3. Radiographic studies of left forearm of 38-year-old male who had refractures which occurred proximal to implant (ulna) and at the screw hole (radius) at 33 months after surgical fixation. Although the patient presented with an acute both-bone refracture, the radius fracture seems subacute because of the fracture pattern, blunted fracture edges with sclerosis, and periosteal reaction on the lateral view.

Figure 2. Radiographic studies of left forearm of 66-year-old female who had refracture of left radius at distal screw hole at 1.2 month after index surgery.

holes and only one occurred at the proximal plate edge [Figures 2; 3]. Of 18 refractures with retained implant, 15 refractures were treated surgically with revision ORIF and other three were treated non-surgically by means of splinting or casting.

Ulnar shaft plates were removed (46 of 64, 72%) more frequently compared to radial shaft plates (18 of 64, 28%) (OR: 2.6, 95% CI: 1.4-4.7, *P=0.002*). Of these plate removals, 26 (41%) fractures were a both forearm fracture and had both plates removed. Type A fractures underwent implant removal more frequent than type C fractures (OR: 3.2, 95% CI: 1.1-9.2, *P=0.032*) [Tables 4; 5].

Discussion

We compared the occurrence of refractures after plate removal versus plate retention in 925 forearm fractures. Sixty-four (6.9%) plates were removed at a median of 13.7 (IQR: 8.9-20.8) months after index surgery. When the plate was retained, refractures occurred in 18 (2.1%) forearm bones and when the plates were removed this occurred in four (6.3%) forearm bones. In the setting of plate removal, refractures occurred at the screw holes within three months after plate removal. With a retained plate a refracture occurred ranging between 1.1 and 169.3 months post-operatively and occurred at the screw holes most frequently. Plate removal was associated with

Table 5. Factors associated with plate removal

	Plate removal		*P-value*
	Yes (n=64)	No (n=861)	
Location, n(%)			0.004*
Radius	18(4.2)	407(96)	
Ulna	46(9.2)	454(91)	
Type of fracture, n(%)			0.17*
Open fracture	16(5.2)	294(95)	
Closed fracture	48(7.8)	567(92)	
AO/OTA classification, n(%)			0.034*
Type A	36(8.5)	386(91)	
Type B	19(6.1)	290(94)	
Type C	4(2.6)	148(97)	
Gender			0.35*
Male, n(%)	37(6.3)	554(94)	
Female, n(%)	27(8.1)	307(92)	
Age (year)			
Median (IQR)	39.3 (29.4-49.4)	38.5 (25.8-53.6)	0.80**

* Using Fisher's Exact

** Using Mann-Whitney U test

Table 6. Multivariable logistic regression for plate removal

Variable	OR	SE	95% CI	*P-value*
Location (ref: Radius)				
Ulna	2.57	0.78	1.42 - 4.65	0.002
AO/OTA (ref: Type C)				
Type A	3.19	1.17	1.10 - 9.17	0.032
Type B	2.35	1.32	0.78 - 7.08	0.128
Open fracture	0.55	0.17	0.29 - 1.04	0.06

OR= Odds ratio SE= standard error CI= confidence interval

refracture and so was a removal of plate from the radius compared to the ulna.

There are several limitations that need to be considered when interpreting the results of this study. First, patients were identified by procedure codes relying on correct coding, we aimed to address miscoding by using broad and inclusive codes. Second, implant removal was based on the patient's and surgeon's discretion. This may have led to selection bias. Third, we decided to use the number of fractures as denominator to calculate the number of refractures. Although this leads to double counting of patient characteristics in those with both forearm fractures, we believe this was the best approach because in some cases with both bone forearm fractures only one plate was removed. Additionally, the definition of a rate is not well established. It is possible that patients who had a plate removed may refracture several years after plate removal, despite most refractures occurring within 3 months.

Refracture rates after implant removal are reported between 3.9% to 26% and are mainly due to low energy trauma(1, 5-7, 9, 11-13). We had a refracture rate of 2.4%. In this study, implants were removed ranging from 3.9 to 93.0 months after primary surgery. We observed four refractures after implant removal, of which two were removed later than 12 months after surgery. Most prior studies advocate plate removal after a minimum of 12 months(5-7). A study by Hidaka et al. evaluated 23 patients that had forearm plate removal within 12 months after index surgery and reported a refracture rate of 22%(6). Additionally, it has been reported that refractures occur more often in patients that had plates removed after an average of 14.8 months compared to those that had plate removal after an average of 19 months(5). Implant removal after an interval of 18 months postoperatively was recommended, based on these clinical observations(5). Deluca et al. found an average time from fixation to plate removal of 16 months in patients with a refracture and 17.5 months in those who did not had a refracture(7). Plate removal after at least two years after surgical fixation was recommended(7).

Optimal timing for plate removal remains controversy, Uhthoff et al. showed changes in bone metabolism after bone plating in dogs(15). They reported a loss of bone mass, along with slower bone remodeling if plates were retained after fracture union has taken place(15). This could increase the risk for refracture after plate removal. This may be the reason why refractures occurred at the screw holes within 3 months after plate removal in this cohort, which is similar to previous work describing most refractures within the first three months after plate removal(7). Additionally, a study by Johnson et al. compared the maximum load of cadaver fibulas that were either plated or non-plated and found that after screw removal the bones lost half their strength(16). It may be worthwhile taking caution with activity in the period immediately after implant removal.

We observed that the radius refractured more frequently than the ulna. This may be related to the torsional strain experienced by the radius relative to the ulna during pronation and supination(17, 18). In general, symptomatic ulnar plates are the primary impetus for implant removal, and surgeons remove the radial implant too because of patient preference or to remove all of the implants during a single anesthetic administration. In light of our findings, it may be preferable to remove only the ulnar plate rather than both plates if the radial implant is asymptomatic.

We found that half of refractures after plate removal

occurred at the screw holes. Some surgeons elect to fill defects with screw holes with bone graft or bone void filler to improve bone strength and to decrease the chance of a refracture (19). This is an area for further investigation.

In conclusion, implant removal is associated with a higher rate of refracture. The radial shaft has a higher rate of refracture compared to the ulnar shaft. After implant removal, most refractures occurred within 3 months of plate removal. From these limited observations, it may be worthwhile to be cautious with immediate return to activity. In cases of symptomatic hardware of the ulna after both bone forearm fracture, it may judicious to remove only the ulnar plate, and limiting strenuous activity for three months after implant removal.

Patient consent: We have a waiver for informed consent by IRB. (IRB approval letter in electronic supplement material)

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