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SURGERY ARTICLES

The importance of pronator quadratus repair in the treatment of distal radius fractures with volar plating

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Abstract
Background Open reduction internal fixation (ORIF) of distal radius fractures via a volar approach involves surgical release of the overlying pronator quadratus (PQ) muscle. Complete repair of the PQ, defined as full and stable replacement of the periphery of the PQ back to its original anatomic location, is not always possible upon conclusion of the operation. Postoperative consequences of incomplete PQ repair with regards to range of motion (ROM), grip strength, and complications are not well documented. It was hypothesized that the completeness of PQ repair would yield no significant difference in the postoperative ROM, grip strength, and incidence of complications.
Methods A retrospective review was performed of 110 repairs of distal radius fractures with ORIF via placement of a volar locking plate. The following clinical data were extracted: complete or incomplete PQ repair, patient age, gender, follow-up ROM/grip strength, and incidence of postoperative complications.
Results and conclusions No significant difference in ROM, grip strength, and postoperative complications was detected between the complete and incomplete PQ repair groups. Complications consisted of two incidences of malunion requiring revision surgery and one occurrence of complex regional pain syndrome. There were no tendon ruptures. No statistical difference in ROM/grip strength or incidence of postoperative complications was detected between the complete and incomplete PQ repair groups. Regardless of the level of injury sustained by the PQ, surgeons should make an effort to cover the distal aspect of the volar plate during closure following distal radius fracture ORIF. Coverage of the distal aspect of the plate with the PQ (at a minimum) provides adequate results in ROM and grip strength, as well as protection against flexor tendon injury.
Level of evidence Therapeutic Level III: Retrospective Comparative Study.

Keywords Distal radius fracture · Pronator quadratus · Volar locking plate · Open reduction internal fixation

Introduction

Distal radius fractures constitute the most prevalent fracture of the upper extremity in the USA, with more than 600,000 cases per year [6]. Volar fixed-angle plating for the repair of distal radius fractures has become the technique of choice in recent years as it exhibits the potential for decreased functional disability and a lower complication rate than alternatives such as external fixation, dorsal plating, or closed reduction and casting/percutaneous pin fixation [14]. The volar plate stabilizes the fractured distal radius by distributing the load in the distal subchondral bone, thereby minimizing the load across the fracture site [4].

The volar approach required for plate placement necessitates the surgical release of the pronator quadratus muscle (PQ) for direct visualization of the distal radius. Due to circumstances beyond the surgeon's control, oftentimes full

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and stable replacement of the periphery of the PQ back to its original anatomic position (complete repair, Fig. 1) is not possible at the conclusion of the operative procedure. In these instances, the viable muscle tissue of the PQ is sutured to cover the most distal portion of the implanted volar plate along the watershed line. This is done to cover the area of the plate that is in closest contact with the overlying flexor tendons, as this is the location that these tendons are at the highest risk for attritional rupture along the plate. The scenario in which the distal plate alone is covered using PQ tissue with the remainder of the plate exposed is defined as an incomplete repair (Fig. 2). Previous studies have documented an approximate 21 % loss of pronation torque upon complete denervation of the PQ: a change that likely correlates with incomplete/non-anatomic PQ repair [12] and may not be clinically relevant. However, the question remains whether non-anatomic pronator quadratus repair following distal radius open reduction internal fixation (ORIF) may also reduce function with regards to range of motion, grip strength, and incidence of complications.

This retrospective study evaluates patients' postoperative outcomes following ORIF via volar plating with and without complete anatomic repair of the pronator quadratus muscle. The degree of pronator quadratus repair is dependent upon a multitude of factors: patient age, severity of fracture, intraoperative manipulation, and viability of the muscle tissue prior to surgery. Outcome measures were comprised of pronation, supination, flexion, extension, grip strength, and postoperative complications. Documented complications of distal radius fracture ORIF include tendon injury, nerve dysfunction, vascular compromise, skin problems, compartment syndrome, and complex regional pain syndrome (CRPS) [7].

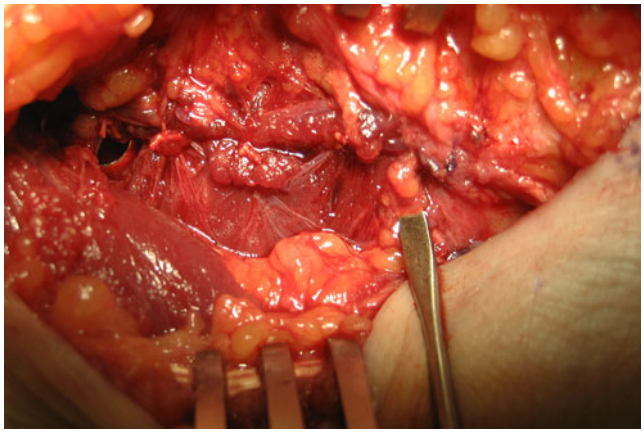

Fig. 1 Complete anatomic repair of the pronator quadratus muscle following fixed-angle volar plating of a distal radius fracture. The hand is to the *right* and the elbow to the *left*. Note the instrument is pointing at the "watershed line" indicating the distal aspect of the pronator quadratus, which is anatomically repaired

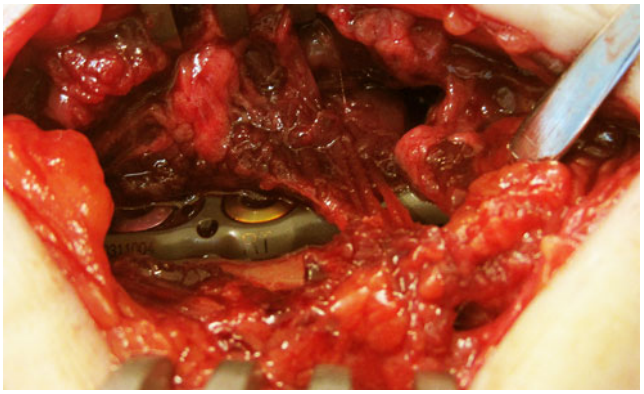

Fig. 2 Incomplete repair of the pronator quadratus muscle following fixed-angle volar plating of a distal radius fracture. The hand is to the *right* and the elbow to the *left*. Note the instrument is pointing at the "watershed line" indicating the distal aspect of the pronator quadratus. To help protect the overlying flexor tendons, the PQ has been mobilized to cover the most distal portion of the plate at a minimum. The more proximal portion of the pronator is not repairable and the proximal plate is incompletely covered

Materials and methods

Approval was obtained from our institutional review board prior to the commencement of this retrospective study. A retrospective review was performed identifying 121 patients with 124 repairs of AO/ASIF classification system type C2 and C3 distal radius fracture repair via ORIF volar plating at our institution from January 2008 to April 2011. This fracture classification was selected because it consisted of the most common fracture treated surgically at our institution via volar plating.

Of these 121 patients, 13 were lost to follow-up while the remainder had a mean follow-up of 3.1 months (range, 2–7 m). Fractures were coded under the Current Procedural Terminology code for distal radius fractures involving greater than three fragments. All of the surgical procedures were performed by the same fellowship-trained hand surgeon.

A two-stage classification system of PQ repairs was established in the operative reports by the surgeon performing the distal radius fracture surgery. Complete repair was defined as full and stable replacement of the periphery of the PQ back to its original anatomic position using 3-0 bioabsorbable braided suture (Fig. 1). Incomplete repair was defined as the suturing of viable PQ muscle tissue to cover the most distal portion of the implanted volar plate along the watershed line at a minimum (Fig. 2). If sufficient muscle tissue was not available to bridge the gap across the distal radius, the remaining PQ was released from its ulnar attachment proximally and rotated distally to cover the distal plate. The top priority was established to cover the implanted plate at the distal aspect where the flexor tendons are most susceptible to injury.

Postoperatively, all patients were treated in a volar wrist splint for 2 weeks. At the 2-week follow-up, the patients

were removed from their splints and therapy was begun to restore wrist flexion, wrist extension, and forearm rotation.

Using their respective operative reports, the patients were divided into two groups based upon the classification of the PQ repair. The complete PQ repair group (Fig. 1) was comprised of 69 patients (28 male, 41 female) with 70 repairs and a mean age of 52 years (range, 19–85). The incomplete PQ repair group (Fig. 2) consisted of 39 patients (11 male, 28 female) with 40 repairs and a mean age of 62 years (range, 24–89). Each group included one patient with bilateral distal radius fractures. Consequently, the corresponding contralateral grip strength ratios were omitted from the data.

During the time period of assessment for this study, volar locking plate from nine different plate manufacturers were used for the ORIF of distal radius fractures. Data were collected from hand therapy notes and follow-up appointments at one institution. Patient therapy was performed at our institution by a team of certified hand therapists. The therapists were not aware of complete versus incomplete PQ repair. Range of motion assessment (normal values included in parentheses) consisted of pronation (80°), supination (80°), flexion (70°), and extension (80°) [17] for the affected limb, and grip strength (JAMAR® Hydraulic hand dynamometer, North Coast Medical, Gilroy, CA, USA) was evaluated for both limbs.

Patient information regarding postoperative complications was also retrieved from the patient database. To assess the incidence of long-term complications not included in the database, patients in the incomplete and complete PQ repair groups were contacted via telephone with a mean postoperative interval of 18 and 24 months, respectively. The telephone interview questioned patients about subsequent hospital visits involving their distal radius surgery along with the occurrence of any complications since the last follow-up appointment.

Statistical methods

Unpaired Student's *t* tests with equal variance were used to determine significant differences of the means between the two groups in this study for range of motion and grip strength ratio values. For all analyses, two-sided tests were used and the level of significance was set at an α level of 0.05 ($p<0.05$) with associated 95 % confidence intervals. Pooled standard deviation, sample size, and minimum predicted difference were used to calculate statistical power.

Results

As outlined in Table 1, the group of patients with complete repair of the pronator quadratus, the average patient age was 52 years (range, 19–85) with an average follow-up duration of 3.2 months (range, 2–7). The mean active range of wrist motion was pronation of 76.9 ° (range, 30–80 °), supination of 72.9 ° (range, 20–80 °), flexion of 51.6 ° (range, 0–70 °), and extension of 55.5 ° (range, 10–80 °). Mean grip strength compared to the contralateral was 59 %.

In the group of patients with incomplete repair of the pronator quadratus, the average patient age was 62 years (range, 24–89) with an average follow-up duration of 3.1 months (range, 1–6). The mean active range of wrist motion was pronation of 74.8 ° (range, 20–80 °), supination of 72.6 ° (range, 50–80 °), flexion of 50.3 ° (range, 15–70 °), and extension of 56.7 ° (range, 24–80 °). Mean grip strength compared to the contralateral was 62 %.

Postoperative complications (Table 2) were assessed in the chart review, and telephone communication with all patients was attempted. Retrospective chart review revealed two cases of malunion of the distal radius, both in the complete repair group. In the incomplete pronator quadratus repair group, 29 patients were successfully contacted accounting for 30 of the 40 distal radius fractures with an average of 18 months since surgery; there were zero reports of postoperative complications. In the complete pronator quadratus repair group, 48 patients were contacted accounting for 49 of the 70 distal radius fractures with an average of 24 months since surgery; one case of CRPS was reported.

Discussion

Surgeons are routinely faced with a challenging repair of the pronator quadratus after volar plate fixation of the distal radius. The muscle tissue may not allow for complete repair due to traumatic displacement, poor anatomic viability, or the bulk of the implant and raises the question of what type of repair is adequate. Surgical repair of the pronator quadratus muscle offers protection to the flexor tendons that traverse the radiocarpal joint; it has also been suggested that this closure may contribute to increased stability of the distal radioulnar joint with the theoretical caveat of limited wrist pronation and supination [10, 16]. Our surgical technique for incomplete repair (Fig. 2), which involves coverage of the distal most aspect of the volar plate at a minimum, intends to provide protection to the flexor tendons from mechanical injury where they traverse the distal aspect of the plate. Although it is important to recognize that a binary system for classifying PQ repair is not completely accurate, the quality of muscle repair exists on a continuum as opposed to a two-stage classification. Ateschrang et al. conducted a study to identify the risk factors associated with flexor tendon irritation with the use of volar locking plates [2]. A careful reconstruction of the PQ was noted as more important than placement of the plate in reference to the

Table 1 Patient clinical assessment measures

Classification of PQ repair	Average patient age (years)	Average follow-up (months)	Pronation (°)	Supination (°)	Flexion (°)	Extension (°)	Jamar grip strength ratio to contralateral limb
Complete	52 (19–85)	3.1 (2–7)	76.9 (30–80)	72.9 (20–80)	51.6 (0–70)	55.5 (10–80)	0.59 (0.04–0.92)
Incomplete	62 (24–89)	3.2 (1–6)	74.8 (20–80)	72.6 (50–80)	50.3 (15–70)	56.7 (24–80)	0.62 (0.13–0.93)
p value	0.002	0.818	0.319	0.890	0.670	0.687	0.568

watershed line in the reduction of tendon irritation. A novel surgical technique which spares PQ release has been reported, and it relies on distal elevation of the PQ to allow for the volar plate to be slid underneath with screw placement involving perforation of the muscle belly [8].

The range of motion and grip strength values from the two groups were not significantly different at the 95 % confidence interval. This finding suggests functional equivalence between the complete and incomplete repair of the pronator quadratus muscle. A power analysis yielded >95 % power for the range of motion comparisons and >80 % for the grip strength comparison. The sample sizes between the two groups are not equivalent due to the retrospective nature of the study and the fact that incomplete repair of the PQ was only performed when a complete repair was not possible.

A variety of complications pertaining to volar plate fixation for the management of distal radius fractures have been reported. Incidence of flexor pollicis longus (FPL) rupture has been reported from 2 to 12 % [1, 4, 9, 15]. Plate prominence at the watershed line predisposes individuals to FPL rupture and may be avoided by thorough fluoroscopic evaluation from multiple angles [15]. FPL rupture has been reported from 4 to 68 months after volar plate placement [3, 4]. Our study presents follow-up data of 108 patients with up to 42 months after surgery without any FPL tendon ruptures, a discrepancy from the literature that may be attributed to incomplete follow-up, duration of follow-up, or vigilant surgical technique.

Complications other than tendon ruptures have been cited. Our data set included an instance of CRPS, which has been reported in 3–10 % of patients with a wide spectrum of symptoms [1, 4, 11, 13]. Possible causes include an excessive inflammatory response or local neuropathic disturbance. One patient in our data set was diagnosed with CRPS. Unfortunately, the cause of this incident cannot be directly traced as the operative note or follow-up appointments did not yield any supplementary information, and the patient sought treatment from another physician after the initial complaint of CRPS.

The limitations of this study are inherent to the retrospective nature of this analysis. There are a number of variables that impact the likelihood of tendon rupture injuries that are unable to be assessed. This includes the quality of the reduction and the location of the volar plate in reference to the watershed line. Additionally, the postoperative follow-up duration is limited. Patients typically do not have additional follow-up appointments after the 3-month visit for the assessment of functional outcomes since these patients have typically reached a state of stable recovery. Patients have been cited to have a mean activities of daily living score of 85, indicating excellent ability to perform daily tasks at 3 months postoperatively [5]. An 18–24-month long-term complication assessment is limited in reference to the cited duration required for tendon rupture of 4–68 months: patients that currently are may still develop future complications [4]. However, the majority of these patients were contacted via telephone and had the opportunity to indicate to us if any complications had been encountered, months to years following their last clinic follow-up appointment. Approximately 10 % of patients were lost to follow-up and were excluded from the study; additionally, only 72 % of the patients were available for contact to assess long-term complications. Efforts were made to collect data from all of the patients, but many were unreachable due to the dynamic nature of our study population.

No statistical difference in range of motion and grip strength was detected between complete and incomplete pronator quadratus repair following ORIF of distal radius fractures. Additionally, postoperative complications were

Table 2 Patient long-term complications assessment

Classification of PQ repair	Number of patients contacted	Total number of patients	Percentage of patients contacted	Average time since surgery (months)	Number of complications
Complete	48	69	70	24 (5–42)	3
Incomplete	29	39	75	18 (5–39)	0

not indicative of a distinction. We conclude that there is no difference in the quality of functional postoperative outcomes whether the pronator quadratus muscle is completely repaired to its anatomic orientation or not; however, it is strongly recommended that surgeons make an effort to cover at least the distal aspect of the volar plate with pronator tissue (incomplete repair) to protect the overlying flexor tendons at their most vulnerable location for hardware irritation.

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