Significance of a Pronator Quadratus-Sparing Approach for Volar Locking Plate Fixation of Comminuted Intra-articular Fractures of the Distal Radius

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Abstract

Background: The preservation of the integrity of the pronator quadratus (PQ) muscle is expected to have many benefits, particularly in cases of highly comminuted intra-articular fractures of the distal radius. Therefore, we examined the significance of a PQ muscle-sparing approach for volar locking plate (VLP) fixation of these types of fractures. **Methods:** Sixty-five patients who sustained AO Foundation and Orthopaedic Trauma Association (AO/OTA) type C2 and C3 distal radius fractures were treated with VLP fixation using either a PQ muscle release and repair (PQ-releasing group, $n = 30$) or a PQ muscle-sparing approach (PQ-sparing group, $n = 35$). Radiographic parameters, active range of motion (ROM), percentage of the grip power of the injured hand compared with that of the opposite hand, wrist pain visual analog scale (VAS) score, and Quick Disability of the Arm, Shoulder, and Hand (DASH) score (disability/symptom) were evaluated monthly up to 12 months after surgery. **Results:** The mean VAS score was significantly lower in the PQ-sparing group at 2, 3, and 4 months postoperatively than in the PQ-releasing group. Furthermore, the mean Quick DASH score in the PQ-sparing group was significantly lower than that in the PQ-releasing group at 1 and 2 months postoperatively. There were no significant differences, however, in the other functional parameters in the groups through the observation period. **Conclusions:** The PQ muscle-sparing approach appears to achieve satisfactory results in patients undergoing VLP fixation of comminuted intra-articular fractures of the distal radius.

Keywords: distal radius fracture, comminuted intra-articular fracture, pronator quadratus muscle, surgical approach, volar locking plate

Introduction

Distal radius fractures frequently occur in the elderly and can easily become comminuted due to bone fragility in those with osteoporosis. Open reduction and internal fixation using a plate is a popular method for treating such distal radius fractures. As Orbay et al reported that dorsally displaced distal radius fractures can be reduced anatomically and fixed with volar locking plates,¹² these plates have replaced nonlocking plates for the management of unstable distal radius fractures. The authors proposed placement of a volar locking plate using fixed-angle screws to achieve subchondral support of the articular surface, prevent secondary dislocation, and allow early mobilization.¹³ Because volar locking plates are believed to secure an anatomical reduction, facilitate stabilization of the fracture, and allow early mobilization, these plates have recently been used even in highly comminuted intra-articular fractures of the distal

radius (AO/OTA type C2 and C3).¹⁰ The gold standard for fracture reduction and volar locking plate fixation has been to release the pronator quadratus (PQ) muscle along the radial border of the distal radius and repair it after the plate fixation was accomplished. However, PQ muscle repair is often difficult to achieve due to the friable tissue of the muscle belly and poor volume available to cover a thick plate, especially in aged patients. Because the PQ muscle might restore pronation strength, provide distal radioulnar joint stability, protect flexor tendons from friction and irritation that could lead to rupture, and supply blood to fragments of

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the fractured radius, preservation of the integrity of the PQ muscle is expected to have many benefits, particularly in cases of highly comminuted intra-articular fractures. A few recent reports, however, found no advantage in repairing the PQ muscle after the volar plating of distal radius fractures.^{8,17} Our goal in this study was to evaluate the effects of PQ muscle preservation on the recovery of postoperative function in severely comminuted intra-articular fractures of the distal radius.

Patients and Methods

Seventy-three patients who had sustained comminuted AO/OTA type C2 and C3 intra-articular fractures of the distal radius were treated with volar locking plate fixation. Patients with any other associated fractures including those of the ulnar head or shaft or previous fractures of the ipsilateral upper extremity were excluded. A polyaxial locking plate, the Aptus 2.5 (Medical Engineering System Co. Ltd., Tokyo, Japan), was used for volar plating. Between October 2011 and March 2013, patients were treated with a PQ muscle-releasing approach in which the dissected PQ muscle was repaired (PQ-releasing group). Subsequently, between April 2013 and March 2014, the fixation surgery was accomplished through a PQ muscle-sparing approach (PQ-sparing group). A team of orthopedic specialists performed all surgeries.

The PQ Muscle-Releasing Approach

After obtaining a degree of closed reduction with traction, the trans-flexor carpi radialis (FCR) approach, which involves opening the tendon sheath of the FCR,⁹ was performed. The PQ muscle was incised sharply along its proximal, radial, and distal borders along the distal radius using a rectangular-shaped incision (Figure 1a). After the fracture site was exposed carefully, preventing enlargement of the tear that has been caused by the fracture, an open reduction was performed with an elevator and confirmed under fluoroscopy. The reduction was temporarily stabilized with two 1.4- to 1.6-mm diameter K-wires driven into the radial styloid in a distal-to-proximal direction. A volar locking plate was then placed under fluoroscopic guidance to achieve subchondral support of the articular surface; 4 distal screws were inserted to support the central subchondral bone, and 3 screws were placed in the second row to support the dorsal region of the subchondral bone to provide double-tiered subchondral support¹³ (Figure 1c). We took care to cover the distal edge of the plate completely with the PQ repair. The temporary K-wires were removed after the operative wound was closed.

The PQ Muscle-Sparing Approach

All reduction and plate fixation procedures were conducted under fluoroscopic guidance. After the reduction was

Figure 1. Surgical approaches to the distal radius.

Note. (a) The PQ muscle-releasing approach: The PQ muscle is incised sharply along its proximal, radial, and distal borders along the distal radius using a rectangular-shaped incision. (b) The PQ muscle-sparing approach: Along with a subperiosteal retrograde release of the PQ muscle from its fibrous distal attachments to the distal radius, its muscle belly is carefully exfoliated to reduce any palmar protruded fragments with an elevator to form a path for the plate without enlarging the transverse tear caused by the fracture and a locking plate is slid underneath the PQ muscle in a retrograde direction. (c) Radiograph of volar locking plate fixation showing double-tiered subchondral support. Left = anteroposterior view; Right = lateral view; PQ, pronator quadratus.

completed using a modified Kapandji method,¹⁴ the reduction was maintained using a temporary stabilization with two or three 1.4- to 1.6-mm diameter K-wires. The PQ muscle was then exposed using the trans-FCR approach. Along with a subperiosteal retrograde release of the PQ muscle from its fibrous distal attachments to the distal radius, its muscle belly was carefully exfoliated to reduce any palmar protruded fragments with an elevator to form a path for the plate without enlarging the transverse tear caused by the fracture (Figure 1b).³ The locking plate was slid underneath the PQ muscle in a retrograde direction. The longitudinal limb of the plate was aligned with the radial shaft and locking screws were inserted through mini-incisions in the PQ muscle from a central slot to fit the plate's transverse limb on the distal fragments. Locking screws were then inserted into the holes of 2 distal rows to achieve subchondral support of the articular surface; screws were subsequently placed into the proximal holes. The distal border and rupture of the PQ muscle were repaired, and the temporary K-wires were removed.

Posttreatment

Patients in both groups were allowed to perform active range of motion (ROM) exercises including pronation and supination on the day after the operation; active assisted exercise began as allowed by wrist pain as early as 1 to 2

Table 1. The Number of Patients Enrolled in This Study Classified by the AO/OTA Classification of the Fracture Type.

	C2	C3	C2 and C3
PQ releasing	17/19	13/15	30/34
PQ sparing	17/18	18/21	35/39

Note. PQ, pronator quadratus.

weeks after surgery. In the patients with an accompanying base fracture of the ulnar styloid, however, a postoperative volar splint in extension allowing full digit flexion was applied for 2 to 3 weeks. ROM and grip exercises were continued under the observation of occupational therapists until bone healing was verified by radiographs and their functional improvement plateaued.

Postoperative Evaluation

The radiographic parameters of radial length (RL), radial inclination (RI), and palmar tilt (PT) were measured to analyze the reduced position in each group.⁶ The absolute values of the differences between the values at 12 months and immediately postoperatively (Δ value) were determined using these radiographic parameters to compare the diminution in reduced position. Active ROM including wrist extension (ext) and flexion (flex), forearm pronation (pro), and supination (sup), percentage of the grip power of the injured hand compared with that of the opposite hand (grip power %), wrist pain visual analog scale (VAS) score, and Quick Disability of the Arm, Shoulder, and Hand (DASH) score (disability/symptom) were evaluated monthly after surgery for 12 months.

The number of patients with AO/OTA type C2 and C3 fractures in each group was statistically compared using chi-square tests. The number of cases with an associated ulnar styloid fracture at the base or less than 1/2 site, the dominant hand as the affected side, and gender in each group were also statistically compared using chi-square tests. The immediate postoperative radiographic parameters, their Δ values, patient age, ROM, grip power %, VAS score, and Quick DASH score in each group were compared using the Mann-Whitney *U* test. The differences were considered statistically significant when $P < .05$.

Results

Of the 34 and 39 patients in the PQ-releasing group and the PQ-sparing group, respectively, 4 cases had a PQ muscle belly that was too severely lacerated and friable to repair or spare and were excluded from analysis in each group (Table 1). There were no differences in the distribution of patients by AO/OTA classification of the fracture type or the number of

Table 2. The Background Data of Patients Enrolled in This Study.

	Age, years	Gender female/ male	Dominant/ nondominant hand	Ulnar styloid fracture base/ less than 1/2
PQ releasing	70.7 $\pm$ 8.6	26/4	10/20	8/12
PQ sparing	71.0 $\pm$ 8.8	28/7	13/22	6/11

Note. Age is shown as means $\pm$ SDs. PQ, pronator quadratus.

Table 3. The Radiographic Parameters Measured Immediately Postoperatively in the PQ-Releasing Group and the PQ-Sparing Group.

	RL (mm)	RI (degree)	PT (degree)
PQ releasing	-0.7 $\pm$ 2.1	20.0 $\pm$ 4.6	7.2 $\pm$ 6.0
PQ sparing	-0.8 $\pm$ 2.1	20.9 $\pm$ 4.6	5.7 $\pm$ 6.2

Note. The data are shown as means $\pm$ SDs. PQ, pronator quadratus; RL, radial length; RI, radial inclination; PT, palmar tilt.

Table 4. The Absolute Values of the Differences Between the Values at 12 Months and Immediately Postoperatively (Δ Value) Determined Using the Radiographic Parameters.

	RL (mm)	RI (degree)	PT (degree)
PQ releasing	1.7 $\pm$ 1.5	0.2 $\pm$ 3.4	1.2 $\pm$ 4.6
PQ sparing	1.4 $\pm$ 1.4	0.2 $\pm$ 2.7	1.4 $\pm$ 4.0

Note. The data are shown as means $\pm$ SDs. RL, radial length; RI, radial inclination; PT, palmar tilt; PQ, pronator quadratus.

cases associated with ulnar styloid fracture between the groups. The background data of patients enrolled in this study including average age, gender, and the number of dominant hands affected in each group are summarized in Table 2. There were no differences in these data between the study groups. No major adverse events including tendon rupture or complex regional pain syndrome (CRPS) were reported in either group. There were no differences in the radiographic parameters measured immediately postoperatively (Table 3) and their Δ value at 12 months postoperatively (Table 4) between the PQ-releasing group and the PQ-sparing group. The results including ROM, grip power %, VAS score, and Quick DASH score are summarized in Table 5. The mean value of the Quick DASH score in the PQ-sparing group was significantly lower than that in the PQ-releasing group at 1 and 2 months postoperatively ($P < .05$). Furthermore, the mean value of the VAS score was significantly lower in the PQ-sparing group at 2, 3, and 4 months postoperatively than in the PQ-releasing group ($P < .05$, $P < .05$, and $P < .01$, respectively). There were no significant differences, however, in the other functional parameters between the groups throughout the observation periods.

Table 5. ROM, Grip Power %, VAS Score, and Quick DASH Score in the PQ-Releasing Group and the PQ-Sparing Group Evaluated Monthly After Surgery for 12 Months.

	Ext (degree)	Flex (degree)	Pro (degree)	Sup (degree)	Grip power %	Quick DASH	VAS
1 month							
PQ releasing	41.1 ± 8.4	42.7 ± 7.8	62.0 ± 18.2	72.5 ± 12.6	33.5 ± 18.0	43.2 ± 9.6*	25.0 ± 7.1
PQ sparing	40.7 ± 9.8	36.9 ± 9.2	72.4 ± 15.7	71.4 ± 8.2	44.8 ± 17.2	33.6 ± 9.2*	21.7 ± 13.9
2 months							
PQ releasing	51.1 ± 12.4	53.2 ± 10.5	78.1 ± 10.7	77.5 ± 8.7	63.0 ± 17.4	28.9 ± 18.9*	24.0 ± 9.6*
PQ sparing	54.4 ± 11.0	48.2 ± 12.3	84.8 ± 8.1	83.8 ± 6.7	64.7 ± 15.2	16.0 ± 9.2*	14.0 ± 12.7*
3 months							
PQ releasing	60.0 ± 10.0	58.6 ± 13.4	84.6 ± 10.8	86.7 ± 4.4	70.7 ± 2.2	17.1 ± 12.1	25.8 ± 13.6*
PQ sparing	56.9 ± 8.0	52.3 ± 9.3	86.9 ± 5.9	80.6 ± 7.7	70.7 ± 9.2	15.6 ± 13.9	9.3 ± 11.1*
4 months							
PQ releasing	61.7 ± 8.3	58.0 ± 7.1	86.7 ± 8.6	82.1 ± 6.2	71.4 ± 12.5	14.5 ± 8.1	17.0 ± 9.5**
PQ sparing	60.6 ± 8.9	54.2 ± 11.9	89.7 ± 1.2	86.6 ± 4.7	72.0 ± 9.5	6.0 ± 6.3	4.3 ± 4.6**
6 months							
PQ releasing	61.3 ± 7.5	56.3 ± 8.5	87.5 ± 5.0	87.1 ± 3.9	74.5 ± 13.8	5.6 ± 5.6	3.3 ± 5.8
PQ sparing	61.7 ± 6.1	55.5 ± 6.9	89.4 ± 1.7	86.5 ± 4.1	75.8 ± 4.0	2.5 ± 4.2	4.0 ± 5.2
12 months							
PQ releasing	61.8 ± 8.2	58.9 ± 10.9	89.5 ± 2.1	84.8 ± 7.5	86.1 ± 16.4	8.3 ± 5.3	2.4 ± 6.2
PQ sparing	62.5 ± 10.8	57.0 ± 12.2	89.2 ± 2.0	85.5 ± 4.1	74.1 ± 12.4	4.1 ± 6.9	1.8 ± 4.5

Note. The data are shown as means ± SDs. ROM, range of motion; VAS, visual analog scale; DASH, Disability of the Arm, Shoulder, and Hand; PQ, pronator quadratus; Ext, extension; Flex, flexion; Pro, pronation; Sup, supination.

* $P < .05$. ** $P < .01$.

Discussion

Preservation of the integrity of the PQ muscle has many benefits, including preservation of a sliding surface for flexor tendons, particularly the flexor pollicis longus (FPL), which protects against the friction and irritation that lead to tendon rupture, restoration of pronation strength and stability of the distal radioulnar joint, and conservation of blood supply to the fragments of the fractured radius. Therefore, some reports have recommended sparing the PQ muscle when using volar plating to treat distal radius fractures.^{7,15} We changed our operative procedure for distal radius fractures from the PQ-releasing to the PQ-sparing approach for these reasons. The distal fragments of these fractures are too comminuted to use the common technique of indirect fracture reduction using a plate. By fixing the transverse limb of the plate to the distal fracture fragments and then reducing the plate onto the radial shaft to reduce the distal articular fragments onto the diaphysis, we accomplished plate fixation after reduction and temporary fixation by percutaneous pinning in AO/OTA type C2 and C3 intra-articular fractures of the distal radius. There were no differences in the radiographic parameters measured immediately postoperatively; they show accuracy of reduction, and their Δ values 12 months postoperatively show retention of the reduced position when comparing the PQ-releasing group with the PQ-sparing group. These results suggest that sufficient reduction and rigid fixation of the fracture fragments can be

achieved by each approach regardless of the differences in access to the fracture.

Postoperative FPL tendon rupture has been reported at a rate as high as 12%.^{1,4,16} Placement of volar locking plates over the watershed line is recognized as a major cause of FPL rupture.¹⁶ Our study presents follow-up data for 65 patients with AO/OTA type C2 and C3 fractures up to 12 months after surgery without any FPL tendon ruptures or major complications. These results may be attributable to the preservation of a protective layer between the plate and the flexor tendons by careful reconstruction or sparing of the PQ muscle.² Furthermore, the PQ-sparing group in this study had a mean VAS score that was significantly lower after 2, 3, and 4 months and a Quick DASH score that was significantly lower at 1 and 2 months postoperatively than in the PQ-releasing group. These results may be due to the previously cited positive effects of the PQ muscle-sparing approach that safely enables early postoperative mobilization.

Fan et al compared the results of volar locking plate fixation between a PQ muscle cut and repaired group and a PQ muscle spared group for AO/OTA type A through C distal radius fractures.⁵ They reported significant postoperative differences with respect to ROM, grip power, wrist function, and wrist pain until 6 weeks after operation but not after 6 months. In our research on more severe cases, the mean value of VAS score was superior until 4 months, and Quick DASH score was superior until

2 months postoperatively in the PQ-sparing group compared with those of the PQ-releasing group; however, there were no significant differences between the groups in these parameters after 6 months, which is consistent with the findings of Fan et al. Meanwhile, there were no significant differences between the groups in any other functional parameters including ROM and grip power, through the observed period. Considering that approximately 21% of pronation torque is lost upon complete denervation of the PQ muscle,¹¹ it is predicted that power may not fully recover even after complete repair due to muscle atrophy and postoperative scarring, which may limit pronation and supination. However, in our study there was no difference in the mean value of pronation or supination between the groups. The difference between our results and the research of Fan et al may be due to not only the fracture type but also the age of participants; the mean patient age was 70.9 and 42.5 years, respectively, that is, the age-related atrophied PQ muscle may have little effect on functional recovery even though its muscle belly is well preserved. If the PQ muscle is repaired properly to cover the distal edge of the implanted volar plate in the PQ-releasing group, improvement in the injured wrist function may be observed in the relatively early postoperative period, as a result. However, postoperative scar formation around the injured PQ muscle followed by contracture may be inevitable, resulting in wrist pain and indefinite complaints in this group. Therefore, we would advocate that the PQ muscle-sparing approach is effective to achieve satisfactory results in patients requiring palmar plate fixation of comminuted intra-articular fractures of the distal radius, although this approach may not improve functional recovery in aged patients.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures in this study were in accordance with the ethical standards of the responsible committee on human experimentation of the authors' institution and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed written consent was obtained from all patients.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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