Ultrasound Assessment and Clinical Correlation of the Pronator Quadratus Muscle After Its Repair in the Treatment of Distal Radius Fractures

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ABSTRACT

Introduction: Repair of the pronator quadratus in distal radius fractures treated with volar plates is controversial, particularly given its proposed protective role against implant-related complications. **Objective:** To assess, through ultrasound, the impact of pronator quadratus reinsertion in patients with distal radius fractures treated with volar plates. **Materials and Methods:** Forty-two patients were analyzed: 28 with pronator quadratus reinsertion (Group I) and 14 without reinsertion (Group II). Evaluations included friction between the flexor tendons and the plate, quality of the interposing tissue, changes in the flexor tendons, and clinical signs of friction. **Results:** The distance between the plate and the tendons was <2 mm in 42.9% of cases. In Group I, 45% exhibited tendon friction, 10% had fibrosis of the separating tissue, 80% had mild tendon attrition, and 20% severe attrition. In Group II, 71% exhibited friction, 36.4% had tissue fibrosis, 45.5% had mild attrition, and 54.5% severe attrition. The quality of the separating tissue was superior in Group I, with better preservation of contractile muscle and less fibrosis, findings associated with lower functional impairment and reduced tendon friction. Ultrasound abnormalities did not always correlate with clinical symptoms. **Conclusions:** Repair of the pronator quadratus improves the quality of the separating tissue between the flexor tendons and the volar plate, favoring preservation of contractile muscle. Although no differences were observed in tendon friction or rupture rates, the findings suggest a protective effect.

Keywords: Distal radius fracture; pronator quadratus repair; volar plate; open reduction and internal fixation; tendon friction; tendon rupture.
Level of Evidence: III

Evaluación ecográfica y correlación clínica del músculo pronador cuadrado luego de su reparación en el tratamiento de fracturas de radio distal

RESUMEN

Introducción: La reparación del pronador cuadrado en fracturas de radio distal tratadas con placas volares es controvertida por su supuesto efecto protector frente a complicaciones del implante. **Objetivo:** Evaluar ecográficamente el impacto de la reinserción del pronador cuadrado en pacientes con fractura de radio distal tratados con placas volares. **Materiales y Métodos:** Se analizó a 42 pacientes: 28 con reinserción (grupo I) y 14 sin reinserción (grupo II). Se evaluaron la fricción entre los tendones flexores y la placa, la calidad del tejido separador, los cambios en los tendones flexores y los signos clínicos de fricción. **Resultados:** La distancia entre la placa y los tendones fue <2 mm en el 42,9%. En el grupo I, el 45% tenía fricción tendinosa; el 10%, fibrosis del tejido separador; el 80%, atrición leve de los tendones y el 20%, severa. El 71% del grupo II tenía fricción; el 36,4%, fibrosis del tejido separador; el 45,5%, atrición leve y el 54,5%, severa. La calidad del tejido separador fue superior en el grupo I, con mejor preservación del tejido contráctil y menor fibrosis, asociado a menor deterioro funcional y fricción tendinosa. No siempre se correlacionaron las alteraciones ecográficas con la fricción clínica. **Conclusiones:** La reparación del pronador cuadrado mejora la calidad del tejido separador entre tendones y la placa, con predominio de músculo contráctil. Aunque no hubo diferencias en la fricción o rotura tendinosa, los resultados sugieren un efecto protector.

Palabras clave: Fractura de radio distal; reparación de pronador cuadrado; placa volar; reducción abierta con fijación interna; fricción tendinosa; rotura tendinosa.
Nivel de Evidencia: III

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INTRODUCTION

Distal radius fractures are the most common fractures of the upper limb and account for 18% of all fractures in adults older than 65 years.[1,2] Open reduction and internal fixation with a volar locking plate has become the preferred surgical treatment, as it provides better functional outcomes and lower complication rates compared with techniques such as external fixation or percutaneous fixation.[3,4] However, the traditional surgical approach requires detaching the pronator quadratus muscle from its radial insertion to optimize fracture exposure and facilitate plate placement.[5,6]

Complications associated with volar plates include neurovascular injury, infection, complex regional pain syndrome, fracture, and soft-tissue problems such as flexor tendon irritation or rupture.[7,8] Between 0.3% and 5.6% of patients develop tendon rupture, with an incidence of approximately 1.5% in some studies. The flexor pollicis longus tendon is most commonly affected, followed by the flexor digitorum profundus.[9-11] These injuries are associated with factors such as improper plate positioning, screw prominence, implant design, and loss of fracture reduction.[12]

Currently, there is controversy regarding the relevance of repairing the pronator quadratus muscle with respect to functional outcomes and complication rates. Although some authors suggest that pronator quadratus repair provides a protective layer between the flexor tendons and the plate, no comparative study to date has demonstrated a reduction in tendon rupture rates after repair.[4,13-15] Nevertheless, in a pilot study, Swigart et al. reported that up to 83% of North American hand surgeons routinely repair the pronator quadratus.[16]

Ultrasound studies have shown greater retraction and reduced length of the pronator quadratus muscle, along with a shorter distance between the flexor tendons and the plate, when the muscle is not repaired. These findings may reflect areas of tendon-implant conflict, supporting the need for further research to assess a potential protective effect.[17,18]

We hypothesized that patients undergoing open reduction and internal fixation with reinsertion of the pronator quadratus muscle would demonstrate significant ultrasound differences in flexor tendon quality and in the muscle tissue superficial to the plate compared with patients in whom the pronator quadratus was not reinserted.

The aim of this study was to evaluate ultrasound findings in patients treated at our center with open reduction and internal fixation for distal radius fractures, with specific emphasis on closure of the pronator quadratus muscle. A secondary objective was to compare these findings with those of a control group in which the pronator quadratus muscle was not repaired.

MATERIALS AND METHODS

This retrospective study began with a thorough review of the medical records in our hospital's database. Forty-two patients with extra-articular distal radius fractures classified as AO 23-A2 underwent open reduction and internal fixation using the same type of implant (volar plate) between March 2020 and March 2022.

All procedures were performed by the same surgical team at our center. Patients with a history of radiocarpal joint injections, neurological disorders, previous wrist infections, or <2 years of follow-up were excluded. The study design included two groups:

Group I: patients with extra-articular distal radius fractures treated with osteosynthesis using a volar distal radius plate, with reinsertion of the pronator quadratus using interrupted Vicryl® 3.0 sutures to ensure complete coverage of the volar plate.

Group II: patients with extra-articular distal radius fractures treated with osteosynthesis using a volar distal radius plate, without reinsertion of the pronator quadratus.

The decision to repair the pronator quadratus muscle was made intraoperatively based on muscle viability, structural integrity, and the feasibility of achieving a tension-free anatomical repair. If the muscle was torn, had tissue loss, or showed clear degenerative changes, repair was not performed.

Both groups followed a strict immobilization protocol with a forearm–palmar plaster splint for the first 2 weeks. After this period, and provided wound conditions allowed, sutures were removed. Patients were then protected for an additional 2 weeks using an intermittent rigid wrist immobilizer, which could be removed for rehabilitation

and personal hygiene. During this phase, patients were encouraged to perform active flexion-extension exercises of the fingers and metacarpophalangeal joints, as well as pinch-type grasping with all digits.

All patients completed an 8-week rehabilitation protocol supervised by upper-limb specialists. This included assisted passive wrist range of motion exercises during the first week, followed by active range of motion without resistance or weight bearing. All fractures were treated with the same implant: an anatomical titanium plate with a fixed-angle locking system (Pro-Anatomic®, South America Implants S.A., Canning, Buenos Aires, Argentina). Anatomical reduction was confirmed both in the immediate postoperative period and during late follow-up.

Analysis of Imaging Studies

Radiological evaluation included anteroposterior and lateral wrist projections obtained both in the immediate postoperative period and at 12-month follow-up. In all cases, acceptable fracture reduction was confirmed, defined as volar tilt 0°–11°, radial inclination >20°, and ulnar variance between –2 and +2 mm.[19-22] To assess volar implant prominence and its potential implications for flexor tendon friction, Soong's classification was applied in all postoperative radiographic assessments.

A Toshiba Xario 200 ultrasound system (18-MHz linear transducer) was used to evaluate the interaction between the flexor tendons and the implant. To ensure objectivity, initial ultrasound assessments were performed on the volar aspect of the wrist with the hand in anatomical position. Dynamic examinations were then conducted, asking patients to actively flex and extend their fingers to identify any areas of tendon conflict. All ultrasound studies were performed by a diagnostic imaging specialist who was not part of the surgical team and was blinded to whether pronator quadratus repair had been performed.

A standardized imaging protocol was applied to all patients, including the following parameters (Table 1):

Table 1. Diagnostic imaging protocol.

Ultrasound Operated side	**Flexor friction**	**Yes**		**No**	
	Quality of tissue separating plate from flexors	Contractile muscle		Fibrosis	
	Minimum plate-flexor distance (mm)	0	0-2	2-4	4 or more
	Flexor tendon quality	Normal		Mild Attrition	Severe Attrition
Ultrasound Non-operated side	**Flexor friction**	**Yes**		**No**	
	Quality of tissue separating radius from flexors	Contractile muscle		Fibrosis	
	Minimum radius–flexor distance (mm)	0	0-2	2-4	4 or more
	Flexor tendon quality	Normal		Mild Attrition	Severe Attrition

- Flexor friction: Yes / No
- Quality of the tissue interposed between the plate and the flexors: contractile muscle vs. fibrosis
- Minimum plate–flexor distance (mm): 0, 0–2, 2–4, or >4
- Flexor tendon quality: normal, mild degeneration, or severe degeneration. Mild degeneration was defined as the presence of atrophic tendon changes, quantified by measuring tendon thickness at the volar lip of the distal radius. Severe degeneration was defined as attritional changes associated with tendon thinning, fibrillation, focal intratendinous alterations, or tendon rupture.[23]

Ultrasound evaluation was performed in all patients in both groups, and findings were subsequently compared.

At completion of the rehabilitation protocol, functional outcomes were assessed using the *Disabilities of the Arm, Shoulder and Hand* (DASH) questionnaire. Scores for all patients were recorded as part of postoperative clinical follow-up.

Statistical Analysis

A descriptive and comparative study was conducted. The distribution of quantitative variables was assessed using the Shapiro–Wilk test. When variables showed normal distribution and homogeneity of variances (evaluated using Levene's test), they were expressed as mean ± standard deviation and compared using Student's *t* test for independent samples. When these assumptions were not met, variables were expressed as median and interquartile range and compared using the Mann-Whitney *U* test. For each variable, the measurement method used is specified.

Qualitative variables are expressed as absolute and relative frequencies (%). Given the small sample size, Fisher's exact test was used for all between-group comparisons. A p value <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics®, version 26.0.

Surgical Technique

All patients were operated on at our center by the same surgical team, under regional anesthesia and in the supine position, with the arm supported on a radiolucent table to facilitate intraoperative fluoroscopic assistance.

Using the modified Henry approach, the fracture site was exposed and the pronator quadratus muscle was carefully elevated in an "L"-shaped fashion.[24,25] After identifying the fracture, reduction was achieved (directly or indirectly) and temporarily stabilized using Kirschner wires under fluoroscopic control. In all cases, an anatomical titanium volar plate with a fixed-angle locking system (Pro-Anatomic®) was used, corresponding to the implant available at our institution during the study period. Although this type of plate does not allow for screw redirection, which may influence its placement relative to the watershed line, its design allowed adequate reduction of the fracture in all cases.

Based on treatment of the pronator quadratus, patients were divided into two groups: Group I: repair of the pronator quadratus muscle using interrupted Vicryl® 3-0 sutures, ensuring full coverage of the plate after fracture stabilization. Group II: no repair of the pronator quadratus muscle.

It is important to note that in some cases the pronator quadratus exhibited pre-existing injuries, such as partial tears or discontinuity, likely related to the initial trauma. Additionally, in older patients, signs of muscular degeneration with fatty infiltration were observed, which made repair difficult or unfeasible.

RESULTS

Forty-two patients were analyzed [mean age, 52.9 years (±19.4)]. Most were women (66.7%), and involvement was slightly more frequent in the right upper limb (52.4%). The most relevant finding was the significant difference in the quality of the tissue interposed between the radius and the flexor tendons (Table 2).

Table 2. Summary of patients included in the series.

Variables	(n = 42)
Age (n, SD)	52.9 ± 19.4
Sex (n, %)	
Male	14 (33,3)
Female	28 (66.7)
Side (n, %)	
Left	20 (47.6)
Right	22 (52.4)
Flexor friction (n, %)	
Yes	24 (57.1)
No	18 (42.9)
Quality of separating tissue (n, %)	
Contractile muscle	32 (76.2)
Fibrosis	10 (23.8)
Flexor tendon quality (n, %)	
Mild attrition	26 (61.9)
Severe attrition	16 (38.1)
Plate-tendon distance (n, %)	
0 mm	2 (4.7)
0-2 mm	18 (42.9)
2-4 mm	(38.1)
>4 mm	6 (14.3)
Pronator quadratus treatment (n, %)	
Reinsertion	28 (66.7)
No reinsertion	14 (33.3)

All patients in Group I (with repair) and only 29% of Group II had viable contractile tissue; the remaining 71% corresponded to fibrotic tissue ($p < 0.001$). Clinical flexor tendon friction was present in 45% of Group I and 71% of Group II, a difference that reached statistical significance ($p = 0.042$). In Group I, 77.5% showed no ultrasound abnormalities and only 22.5% showed mild friction. In Group II, mild friction was observed in 43% of patients, whereas 57% had no abnormalities. In no case were ultrasound abnormalities detected without a corresponding clinical manifestation. With respect to contact between the flexor tendons and the plate, 71% of Group II had direct contact, whereas 29% had interposed muscle tissue. No direct correlation was identified between clinical friction and the presence of tissue interposition. Overall, Group I demonstrated greater preservation of contractile tissue and a lower prevalence of fibrosis compared with Group II, in which fibrotic tissue predominated and a higher incidence of clinical friction was observed (Table 3).

Table 3. Comparative analysis between patients with and without pronator quadratus reinsertion

Variables	With repair (n = 28)	Without repair (n = 14)	p
Clinical flexor friction n (%)			
Yes	12 (45.0)	10 (71.0)	0.156
No	16 (55.0)	4 (29.0)	0.112
Ultrasound flexor friction (n, %)			
Yes	7 (25.0)	6 (43.0)	0.34
No	21 (77.5)	8 (57.0)	0.270
Quality of separating tissue (n, %)			
Contractile muscle	28 (100)	4 (29.0)	**0.011**
Fibrosis	0 (0)	10 (71)	**5.28×10^{-6}**
Flexor tendon quality (n, %)			
Mild attrition	6 (22.5)	6 (43,0)	0.20
Severe attrition	8 (28.6)	8 (57.1)	
Plate-tendon distance n (%)			
0 mm	0 (0)	1 (14.3)	0.36
0-2 mm	6 (42.9)	3 (42.9)	
2-4 mm	5 (35.7)	3 (42.9)	
>4 mm	3 (21.4)	0 (0)	

Although the plates used featured a fixed-angle locking system, which limits screw redirection, postoperative assessments showed that most implants were positioned proximal to the watershed line. Only four cases were classified as Soong 1 (three in Group I and one in Group II), and no cases were classified as Soong 2.

At clinical follow-up, the mean DASH score was 14.2 (SD ± 5.8), corresponding to a mild level of disability and consistent with a favorable clinical outcome. No significant differences were found between groups (p = 0.187). Most patients resumed their usual activities without major restrictions, and no reoperations were required.

DISCUSSION

In this study, we compared imaging findings in patients with distal radius fractures treated with open reduction and internal fixation, differentiating between those in whom the pronator quadratus was repaired and those in whom it was not. The main difference between the two cohorts was the quality of the tissue interposed between the radius and the flexor tendons, specifically regarding coverage of the volar plate. In the repair group, viable contractile tissue was significantly more frequent, a difference that reached statistical significance compared with the non-repair group. No significant differences were found in flexor tendon friction, structural tendon quality, or minimum plate-tendon distance.

The literature regarding pronator quadratus repair after volar plate fixation remains controversial. Some studies suggest potential benefits, whereas others do not support routine repair. In a recent meta-analysis by Shi and Ren, the authors concluded that pronator quadratus repair does not improve postoperative functional scores, grip strength, pronation strength, or range of motion following volar plate fixation for distal radius fractures.[14]

Among complications associated with volar distal radius plates, injury of the flexor pollicis longus tendon is one of the most significant. However, in a systematic review by Azzi et al., including a large patient cohort, the incidence of this complication was reported to be below 1%. Moreover, studies such as that by Brown et al. indicate that tendon ruptures can occur even when the pronator quadratus is repaired, despite the theorized protective effect against tendon-implant friction.[26]

Although the limited sample size of our study did not allow us to confirm a protective effect of pronator quadratus repair, it is worth noting that no tendon injuries were observed in any patient. Larger studies will be required to determine whether the contractile tissue identified overlying the plate after pronator quadratus repair contributes to a protective effect by reducing flexor tendon contact with the implant and lowering rupture rates.

This study has several limitations, including the small number of cases, limited follow-up, and the potential for information bias due to reliance on the accuracy of medical records. Nonetheless, it also has meaningful strengths: the inclusion of a control group allowed for more robust comparisons, and the use of a blinded sonographer, unaware of whether the pronator quadratus had been repaired, significantly reduced assessment bias.

CONCLUSIONS

In the postoperative ultrasound assessment, significant differences were observed between the groups. In Group I, the tissue interposed between the flexor tendons and the plate was of higher quality, with more viable contractile muscle and less fibrosis compared with Group II, a difference that reached statistical significance. Clinical flexor tendon friction was also lower in the repair group, supporting the potential protective role of the pronator quadratus.

Although no differences were identified in tendon rupture or functional outcomes (DASH scores), the preservation of viable contractile tissue may contribute to reducing tendon friction. However, this hypothesis could not be definitively confirmed due to the small sample size and limited follow-up period.

Future studies with larger cohorts, multivariate analyses, and eventually randomized controlled trials will be required to more accurately determine the clinical impact of pronator quadratus reinsertion on preventing implant-related complications and on functional wrist outcomes.

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