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IS VOLAR PLATING IN DISTAL RADIUS FRACTURES SAFE REGARDING PRONATOR QUADRATUS?

O USO DE PLACAS VOLARES EM FRATURAS DISTAIS DO RÁDIO É SEGURO PARA O PRONADOR QUADRADO?

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ABSTRACT

Objective: This study aimed to investigate whether isokinetic strength decrease significantly after using volar plating for distal radius fractures and evaluate the pronator quadratus muscle regarding atrophy. Methods: This study took place between 2011 and 2015 and included 18 distal radius fracture patients (group 1) who were treated via volar plating at least one year prior and 14 healthy controls (group 2). All participants were tested isokinetically. Grip strength, radiological evaluation, wrist range of motion, disabilities of the arm, shoulder, and hand and visual analog scale scores were assessed for clinical and functional outcomes. Ultrasonography evaluated the pronator quadratus muscle thicknesses. Results: The peak supination torque (PT) and supination work per repetition (WPT) strength values significantly decreased (p:0.039, p:0.025, respectively). Although we determined an 11% pronation PT deficit and a 19% pronation WPT deficit, neither were significant. In group 1, the pronator quadratus muscle thickness decreased 5.9% ± 13.3 in the radial area and 9.7% ± 10.5 in the interosseous area according with ultrasonography; these results were not statistically significant compared to group 2. All clinical and functional outcomes were not statistically significant between the groups. Conclusion: The use of volar plating after distal radius fractures is a safe method regarding isokinetic strength and pronator quadratus muscle atrophy. ***Level of evidence III; Retrospective case-control study.***

Keywords: Muscle strength. Radius fractures. Open fracture reduction.

RESUMO

Objetivo: Este estudo teve como objetivo investigar se as forças isocinéticas diminuem significativamente após o uso de placa volar para tratamento de fraturas do rádio distal e avaliar o músculo pronador quadrado quanto à atrofia. Métodos: Este estudo realizado entre 2011 e 2015 incluiu 18 pacientes com fratura do rádio distal (grupo 1) que tenham sido tratadas com placa volar pelo menos um ano antes e 14 pessoas saudáveis como controle (grupo 2). Todos os participantes foram testados isocineticamente. Força de preensão, avaliação radiológica, amplitude de movimento do punho, deficiências do braço, ombro e mão e escores da escala visual analógica foram avaliados clinica e funcionalmente. A ultrassonografia avaliou a espessura do músculo pronador quadrado. Resultados: A força máxima do torque de supinação (TM) e do trabalho por repetição (ER) de supinação diminuíram significativamente (p: 0,039, p: 0,025, respectivamente). Embora tenhamos determinado um déficit de TM de pronação de 11% e um déficit de ER de pronação de 19%, nenhum dos dois foi significativo. No grupo 1, a espessura do músculo pronador quadrado diminuiu 5,9% ± 13,3 na área radial e 9,7% ± 10,5 na área interóssea, segundo ultrassonografia; estes resultados não foram estatisticamente significativos em comparação com o grupo 2. Nenhum resultados clínico ou funcional foi estatisticamente significativo entre os grupos. Conclusão: O uso de placa volar após fraturas do rádio distal é um método seguro em relação à força isocinética e atrofia do músculo pronador quadrado. ***Nível de evidência III; estudo retrospectivo de caso-controle.***

Descritores: *Força muscular. Fraturas do rádio. Redução aberta.*

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INTRODUCTION

Distal radius fractures - the most common among long bone fractures - constitute an orthopedic emergency due to trauma; they account for one-sixth of all fractures.[1] Distal radius fractures represent a significant public health problem given the increased life expectancy of the general population. While there has been a historical shift from conservative to surgical treatment [2] and many related studies have been conducted, there is still no clear consensus on the preferred treatment. Surgical treatment is applied either for unstable fractures or when adequate anatomical reduction

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is not achieved with conservative treatment.[3] The most commonly used surgical method is open reduction and internal fixation with volar plating.[4] In the volar approach, the pronator quadratus muscle is elevated from the radial side and is usually repaired at the end of the surgical procedure. However, after the implementation of this approach, it is not known exactly how dissection of the pronator quadratus muscle affects clinical and functional outcomes; therefore, research is ongoing on this subject.[5,6] The aims of this study were to determine any changes in isokinetic strengths after the use of volar plating for distal radius fractures and whether this could have a negative impact on functional clinical outcomes as well as a correlation with sonographic measurements of the pronator quadratus muscle.

MATERIALS AND METHODS

Study population

This retrospective case-control study was performed at a single Level 1 trauma centre after receiving approval from the ethics committee and written informed consent from each of the 32 participants. Initially, 41 patients who were treated with volar plating after a distal radius fracture in our department between 2011–2015 met the inclusion criteria. Of those 41 patients, 18 agreed to participate in this study (Group 1), and 14 healthy volunteers served as the control group (Group 2). (Table 1) The inclusion criteria included being between ages 18 and 65 years; having an AO type 23-C fracture; having undergone an open reduction via the volar approach; having at least a 12-month postoperative follow-up; and being operated on by the same surgeon with the same type of locking plate (Aculoc-Acumed). All included participants were mobile, sedentary, and cooperative. The exclusion criteria included the use of external fixation or pinning; the use of an additional dorsal incision for reduction or plating; an open fracture; an ipsilateral or contralateral upper extremity fracture; either non-union or malunion, and the inability to cooperate. Group 2 had similar baseline features to those of group 1, but they had no past upper extremity fractures or neurological diseases that could have negatively affected their muscle function.

The dominant sides of the patients and whether the fracture was on the dominant or non-dominant side were determined. The time from surgery until 2015 December was determined in months.

Surgical approach and rehabilitation protocol

A standard modified Henry approach was used by the same experienced surgeon. During this approach, the pronator quadratus muscle was cut with a longitudinal incision. It was carefully stripped from the radial side to the ulnar side, leaving 2-3 mm on the radial side to allow repair. The fractures were then reduced and fixed with an anatomical volar locking plate (Acu-Loc®, Acumed, Portland, OR, USA). The pronator quadratus muscles were repaired with a braided, absorbable, synthetic 3/0 polyglactin suture (Vicryl®, Ethicon, Somerville, NJ, USA) at the end of the operation. The goal was a complete repair, but the surgery reports noted a loose or partial) repair due to either a traumatic injury or disruption of the muscle in seven of the patients.

The rehabilitation protocol started after 5–7 days of plaster cast immobilization for pain and swelling subsidence. A removable splint was used for another five weeks, and active wrist exercises were started and advised for all patients during this period. Strengthening therapies for wrist musculature were initiated at the sixth week to improve the patients' functional status.

Table 1. Characteristics of included subjects.

		Study groups			
		Plating group		Control group	
		n	%	n	%
Sex	Female	3	16.7	3	21.4
	Male	15	83.3	11	78.6
Dominant side	Right	16	88.9	14	100.0
	Left	2	11.1	0	0
Injured side	Right	10	55.6	*	
	Left	8	44.4		
AO type	23C1	7	41.2	*	
	23C2	6	35.3		
	23C3	4	23.5		
Age (mean, SD)		43.8 10.2		38.8 13.2	
Weight (mean, SD)		79.3 12.1		74.9 13.1	
Time from surgery (months)		55.3 21.8		*	

SD: Standard derivation, *No data for the group.

Isokinetic test protocol

A computed dynamometer (Humac Norm II, CYBEX, Stoughton, MA, USA) was used for the isokinetic strength measurement of individuals by the same physiotherapist (TŞ). All measurements were performed at 10:00 and 13:00 to minimize the effect of day-to-day hormonal changes while the participants were tested. The test procedure was performed primarily after a five-minute warm-up of the Cybex Upper Body Ergometer. Two isokinetic tests were performed for each upper extremity of each participant: forearm pronation/supination and wrist extension/flexion. The patients were seated in an upright position with their hip joint at 90° flexion and their elbow joint at 90° flexion. Forearm pronation/supination and wrist flexion/extension movements were repeated four times to determine peak torque (PT) (N·m), work per repetition (WPT) (J), and PT deficit at a velocity of 90°/sec. PT is the maximum torque produced by any repetition of the test set, and WPT is the work done in each repetition. [7] The PT deficit is the percentage loss of the strength relative to either the dominant or the uninjured side.

We performed grip strength measurements using a Jamar dynamometer (Asimow Engineering, Los Angeles, CA, USA). The shoulders were kept in adduction and in neutral rotations. The elbow was flexed at 90°, and the forearm was in a neutral position. Power measurements of each side were successfully repeated three times. Kilogram-force was used as the measurement unit.

Sonographic evaluation

In total, 11 patients from group 1 and 11 members of group 2 agreed to participate in wrist ultrasound imaging. They were all evaluated for thickness of the pronator quadratus muscle. Scanning was done prior to the isokinetic testing to avoid affecting the results. The same senior radiologist performed all the examinations (FB). A General Electric LOGIQ P5 device was used for the imaging of all participants. Each participant's hand was laid comfortably on a rectangular flat table, and the shoulder was positioned in adduction and a neutral rotation while allowing the elbow to remain at 90°. Sagittal and axial images of the pronator quadratus muscle were provided by using a linear probe. Measurements were taken from the point where the muscle was its thickest.

The interosseous area measurement was taken at approximately 3 cm proximal of the radiocarpal joint in sagittal views (Figure 1). For the radial area measurement, the diameter of the pronator quadratus muscle was measured from 3 cm proximal to the radiocarpal joint and 5 mm lateral of the radius medial contour in axial views (Figure 2).

Clinical evaluation

The same physician measured the wrist range of motion (ROM). Each patient's functional status was evaluated for disabilities of the arm, shoulder, and hand (DASH) [8] outcome measure score,

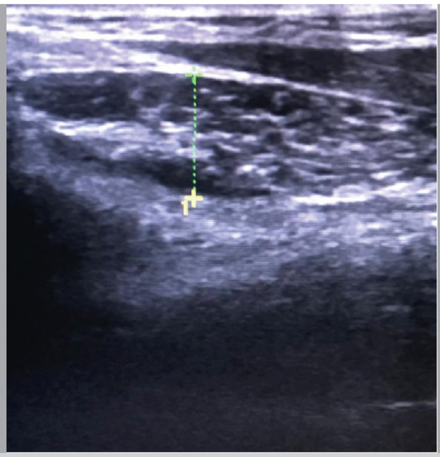
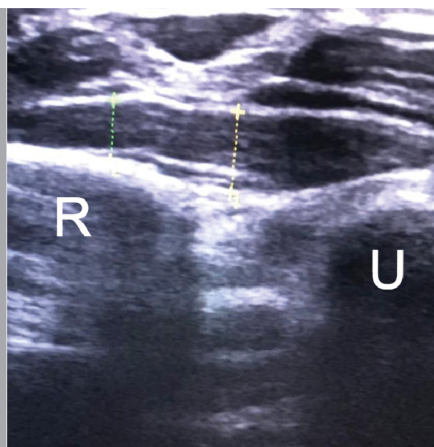


Figure 1. Measurement of pronator quadratus thickness in interosseous area in sagittal view.



R = radius, U = ulna. Yellow dotted line indicates pronator quadratus length in radial area.

Figure 2. Measurement of pronator quadratus thickness in axial view.

and their pain status was evaluated with the visual analog scale (VAS) score. Standard wrist anteroposterior and lateral radiographs of all patients were taken bilaterally and were examined for volar tilt, ulnar variance, radial inclination, and radial length. The measurements were taken by the same physician (NT) using computer software.

Statistical analysis

Descriptive characteristics were indicated by the appropriate number, percentage, average, and standard deviation values. To compare the measurements between the groups, a t-test in independent groups and a one-way ANOVA test were used in the parametric data. Chi-square and Fisher's exact tests were used to compare categorical data. For statistical significance, $p < 0.05$ was accepted. SPSS 20 for Windows (SPSS Inc., Chicago, IL, USA) was used in the analysis of the study.

RESULTS

This study included 18 patients (group 1) with a mean age of 43.8 ± 10.2 and 14 healthy volunteers (group 2) with a mean age of 38.8±13.2. The mean weight was 79.3 ± 12.1 kg in group 1 and 74.9 ± 13.1 kg in group 2. The mean follow-up was 55.3 ± 21.8 months. All participants had dominance in their right hand except two in group 1. There were no significant baseline characteristics, including mean age, weight, and follow-up between the groups ($p > 0.05$).

Isokinetic strength evaluation

Isokinetic PT and WPT values were compared within the groups. For group 1, the mean supinator PT and mean supinator WPT were significantly higher in the uninjured sides than they were in the injured sides (p: 0.039 and p: 0.025, respectively). The mean pronator PT values were 9.7 ± 2.9 N·m in the uninjured side and 8.4 ± 2.4 N·m in the injured side (p: 0.159). The mean pronator WPT values were 19.7 ± 5.2 N·m in the uninjured side and 16.8 ± 6.0 N·m in the injured side (p: 0.141). Although there was a trend toward decreased pronation strength, it was not statistically significant. (Table 2) Neither flexor nor extensor strength values were considered significant ($p > 0.05$).

For group 2, this study showed no difference between the dominant and nondominant upper extremities, except the pronator WPT (p: 0.041) in the mean PT and the mean WPT in group 2.

We observed no statistically significant difference between the groups when comparing the PT and the work deficits ($p > 0.05$). (Table 3)

Sonographic outcomes

For group 1, the radial area measurement was 5.6 ± 1.3 mm on the injured side, while it was 6.0 ± 1.1 mm on the uninjured side. The interosseous area measurement for group 1 was 7.6 ± 2.5 mm on the fractured side, while the uninjured side was 8.4 ± 2.4 mm. The percentage of thickness deficit was 5.9% in the radial area and 9.7% in the interosseous area in group 1, while the same variables for group 2 were 1.2% and 3.3%, respectively. There was no statistically significant difference between the groups. (Table 4)

Clinical outcomes

The clinical results (Table 4) were similar in both groups. There was no statistically significant difference in grip strength when comparing

Table 2. Results of isokinetic testing.

	Plating group		p [a]	Control group		p [a]
	Uninjured side	Injured side		Dominant side	Nondominant side	
	Mean and standard deviation			Mean and standard deviation		
Pronator PT	9.7 ± 2.9	8.4 ± 2.4	0.159	9.1 ±2.1	10.3 ±2.6	0.187
Pronator WPT	19.7 ± 5.2	16.8 ± 6.0	0.141	17.3 ±4.8	21.1 ± 4.7	0.041
Supinator PT	8.0 ± 2.9	6.3 ± 1.6	0.039	8.8 ±3.7	6.7 ± 2.0	0.076
Supinator WPT	16.3 ± 5.7	12.2 ± 4.5	0.025	15.2 ±6.0	13.5 ± 4.8	0.409
Extensor PT	10.9 ± 3.5	10.8 ± 5.2	0.916	11.4 ±3.3	12.2 ±3.9	0.533
Extensor WPT	9.6 ± 2.9	8.7 ± 4.4	0.525	12.1 ±3.9	13.1 ±4.5	0.535
Flexor PT	14.8±4.8	12.9±6.1	0.319	15.0 ±5.4	12.9 ±4.9	0.296
Flexor WPT	14.1±4.8	11.2±6.2	0.147	16.1 ± 5.5	14.1 ±5.4	0.343

SD: Standart deviation, PT: Peak torque, WPT: Work per repetition, [a] One way ANOVA test. PT values are Newton-metre (N·m), WPT values are joule (J).

Table 3. Peak torque deficit and work per repetition deficit between sides.

	Study groups	
	Plating group	Control group
	Mean and standard deviation	
Pronator PTD	11.5 ± 14.4	9.2 ± 17.0
Pronator WPTD	19.0 ± 22.2	16.0 ± 17.3
Supinator PTD	19.1 ± 25.8	16.4 ± 10.9
Supinator WPTD	25.1 ± 29.7	14.4 ± 17.0
Extensor PTD	9.7 ± 31.4	7.4 ± 17.6
Extensor WPTD	15.5 ± 35.7	9.6 ± 25.0
Flexor PTD	14.4 ± 29.8	16.1 ± 15.4
Flexor WPTD	18.2 ± 34.1	16.9 ± 14.8

PTD: Peak Torque Deficit, WPTD: Work Per Repetition Deficit, [a] One way ANOVA test. All numbers are percentage.

Table 4. Comparison of sonographic measurements, grip strength and functional outcomes.

	Study groups		P^a
	Plating group	Control group	
	Mean and standard deviation		
Injured side USG Radial area (mm)	5.6 1.3	5.6 0.9	0.957
Injured side USG interosseous area (mm)	7.6 2.5	7.3 0.9	0.709
Uninjured side USG Radial area (mm)	6.0 1.1	5.7 1.2	0.685
Uninjured side USG interosseous area (mm)	8.4 2.4	7.5 1.0	0.343
Injured side grip strength (kgf)	32.4 11.9	41.1 8.8	0.182
Uninjured side grip strength (kgf)	39.4 12.1	43.2 10.0	0.912
Grip strength deficit percentage	17.8 18.5	3.7 9.8	0.232
DASH score	5.4 5.4	11.6 11.5	0.066
VAS score	0.0 0.0	0.4 1.2	0.168
Flexion	68.6 9.7	70.5 8.2	0.653
Extension	59.7 8.1	62.5 8.1	0.262
Pronation	79.3 10.2	86.1 7.2	0.183
Supination	81.4 8.3	82.6 5.0	0.131

[a] One way ANOVA test, mm: milimeter, kgf: kilogram-force, USG: ultrasonography. Dominant side is chosen as uninjured side, nondominant side is chosen as injured side for control group.

the two groups. The percentage of grip strength difference between the sides was compared within and between the groups, and no statistically significant difference was found. We compared the injured sides of Group 1 and the non-dominant sides of Group 2 for ROM, DASH and VAS scores evaluation. The groups did not differ in their ROM and DASH scores. The mean ulnar variance was 0.0 ± 1.9 mm; the radial length was 11.6 ± 2.4 mm; the volar tilt was +3.8° ± 5.4; and the radial inclination was 22.4° ± 4.6. All acceptability criteria for distal radius fractures were achieved in group 1 regarding these parameters.

DISCUSSION

Pronation force is thought to be formed by combinations of muscle forces, with the pronator quadratus muscle being the primary contributor to pronator PT.[9] However, the pronator quadratus is dissected and elevated from its origin during volar plating. There is not enough data in the literature to determine whether pronator quadratus muscle dissection reduces this pronator force. Therefore, we sought to investigate isokinetic forearm strength after the occurrence of distal radius fractures.

McConkey et al. measured isometric pronation strengths both before and after they paralyzed the pronator quadratus muscle with lidocaine.[10] They reported a 21% decrease in pronation torque after inducing paralysis in their study. Huh et al. reported that they showed 8% pronation PT and 20% supination PT deficits after volar plating of a distal radius fracture at 12-month follow-up. Similar results were obtained in this study; the supinator PT and WPT deficits were greater than the pronator PT and WPT deficits. The deficits in pronation PT, pronation WPT, supination PT, and supination WPT were 11%, 19%, 22%, and 26%, respectively.

This study confirmed that volar plating of distal radius fractures did not change the pronation strength at mid- and long-term follow-ups, which it had in other studies; however, the supination torque and supination WPT strengths were significantly lower in group 1.[6,11] One study showed that the loss of supination strength in particular was correlated with worse Patient-Rated Wrist Evaluation scores.[12] Contrarily, this study and Huh et al.'s study showed that supination strength loss did not affect functional outcomes.[6] Here, patients in group 1 were evaluated via DASH scores (mean 5.4 ± 5.4); there was no significant difference between the groups regarding grip strength, DASH scores, wrist ROM. Functional impairment had improved for the surgery group at mid- and long-term follow-ups.

McConkey et al. emphasized that the pronator quadratus may heal in a lengthened position and may function at the same power that it had in the past.[10] When we performed postoperative ultrasonography to detect healing of the pronator quadratus, the data showed that the pronator quadratus muscle's thickness had improved after the surgery. Pronator quadratus thicknesses were measured on the radial side in the interosseous area, as mentioned previously, and there was no statistically significant difference compared to group 2, although the pronator quadratus was traumatized. The pronation strength's lack of significant change may have been because the muscle of the pronator quadratus had somehow healed.

The topic of whether the pronator quadratus should be repaired with the volar approach to plating is an interesting debate. Limited isokinetic research has been indecisive about this issue. When we repaired the pronator quadratus, no significant change in pronator strength resulted. Nho et al.'s study isokinetically and functionally supported the idea that the pronator quadratus has minimal impact on pronator strength and forearm rotation function.[11] They examined a repaired pronator quadratus muscle during hardware removal at the mean 9th month and found that 68% of the original muscle length was reached at that time; they found no significant differences in either the isokinetic or the functional outcomes. In another study, pronation strength after a repair showed no difference at the 6th and 12th weeks, but the authors stated that pronator repair might be better for pain control in the early postoperative period and for reducing complications.[13] Although the pronator quadratus was not repaired in Huh et al.'s study, they found that pronator strength had not diminished significantly.[6] On the contrary, Armangil et al. used a small-sized group and showed that the pronator quadratus muscle, which had been dissected and repaired after volar plating of distal radius fractures, resulted in a decrease in pronator strength.[5]

When Hershman et al. and Ahsan et al. investigated outcomes clinically and functionally, they found no advantages to repairing the pronator quadratus during the volar plating of distal radius fractures.[14,15] Similarly, researchers found no significant difference regarding functional outcomes, ROM, grip strength, post-operative pain, and complications between repair and no repair groups in a recent systematic review.[16] If we look at this issue from another perspective, pronator quadratus repair will also cover the plate; therefore, it will hypothetically reduce the risk of rupture by increasing the distance between the flexor tendons and the plate. In an ultrasound study, distance from the flexor pollicis longus tendon to the volar prominence of the plate decreased significantly when the pronator quadratus was not repaired, and the authors stated the importance of repair.[17]

This study has some notable limitations. Firstly, the included patients had undergone surgery at least one year prior; hence, early outcomes of surgery were not evaluated. In addition, the time since surgery was rather variable among patients, and the initial trauma characteristics and quality of the pronator repair changed among the patients.

CONCLUSION

This study showed that, although pronator strength does not significantly change after the volar plating of a distal radius fracture, supinator strength statistically significantly decreases. We believe that this phenomenon is not related to either the anatomical or functional results of the pronator quadratus muscle. In addition, the pronator quadratus muscle does heal, which we observed via ultrasonography, and it continues to contribute to pronation strength.

AUTHORS' CONTRIBUTION: Each author contributed individually and significantly to the development of this article. NT and TA: study conception and design and article writing; FB: sonographic evalutation and article writing. TŞ, AŞK, and ÖA: result interpretation and data collection. CŞ: conception and design and critical review of the article.

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