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 QUADRAO?

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

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.

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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. 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 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...
is not achieved with conservative treatment.\textsuperscript{3} The most commonly used surgical method is open reduction and internal fixation with volar plating.\textsuperscript{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.\textsuperscript{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 injury to 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\textsuperscript{®}, Acumed, Portland, OR, USA). The pronator quadratus muscles were repaired with a braided, absorbable, synthetic 3/0 polyglactin suture (Vicryl\textsuperscript{®}, 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.

**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.\textsuperscript{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)\textsuperscript{8} outcome measure score,

### Table 1. Characteristics of included subjects.

| Characteristic       | Study groups | Control group |
|----------------------|--------------|---------------|
|                      | 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 | 6 | 54.5 |
| 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.
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. 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 between the groups. (Table 4)

Table 2. Results of isokinetic testing.

| Study groups | Plating group | Control group |
|--------------|---------------|---------------|
| Uninjured side | Injured side | Uninjured side | Injured side |
| Mean and standard deviation | Mean and standard deviation | Mean and standard deviation | Mean and standard deviation |
| Pronator PT | 8.7 ± 2.9 | 9.1 ± 2.1 | 10.3 ± 2.6 | 10.5 ± 2.1 |
| Pronator WPT | 19.7 ± 5.2 | 17.3 ± 4.8 | 21.1 ± 4.7 | 20.2 ± 4.8 |
| Supinator PT | 7.0 ± 2.9 | 8.8 ± 3.7 | 6.7 ± 2.0 | 7.1 ± 2.5 |
| Supinator WPT | 16.3 ± 5.7 | 15.2 ± 6.0 | 13.5 ± 4.8 | 12.5 ± 4.7 |
| Extensor PT | 10.9 ± 3.5 | 11.4 ± 3.3 | 12.2 ± 3.9 | 12.2 ± 4.0 |
| Extensor WPT | 9.6 ± 2.9 | 12.1 ± 3.9 | 13.1 ± 4.5 | 13.2 ± 4.7 |
| Flexor PT | 14.8 ± 4.8 | 15.0 ± 5.4 | 12.9 ± 4.9 | 13.1 ± 5.1 |
| Flexor WPT | 14.1 ± 4.8 | 14.1 ± 5.4 | 14.1 ± 5.5 | 14.1 ± 5.6 |

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

| Study groups | Plating group | Control group |
|--------------|---------------|---------------|
| Mean and standard deviation | 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 | 15.3 ± 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. * One way ANOVA test. SD: Standard deviation, PT: Peak torque, WPT: Work per repetition.
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. 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. They reported a 21% decrease in pronation torque after inducing paralysis in their study. Huh et al. reported that they did not change the pronation strength at mid- and long-term follow-ups. However, 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 indicative 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. 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. Although the pronator quadratus was not repaired in Huh et al.’s study, they found that pronator strength had not diminished significantly. On the contrary, Armangl 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. 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. 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. 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.

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.
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REFERENCES

1. Owen RA, Melton LJ, Johnson KA, et al. Incidence of Colles’ fracture in a North American community. Am J Public Health. 1982;72(6):605-607.
2. Diaz-Garcia RJ, Chung KC. The Evolution of Distal Radius Fracture Management: A Historical Treatise. Hand Clin. 2012;28(2):105-111.
3. Chung KC, Shauver MJ, Birkmeyer JD. Trends in the United States in the treatment of distal radial fractures in the elderly. J Bone Jt Surg - Ser A. 2009;91(8):1868-1873.
4. Ruch DS, Papadonikolakis A. Volar versus dorsal plating in the management of intra-articular distal radius fractures. J Hand Surg Am. 2006;31(1):9-16.
5. Armangil M, Bezirgan U, Başarir K, et al. The pronator quadratus muscle after plating of distal radius fractures: Is the muscle still working? Eur J Orthop Surg Traumatol. 2014;24(3):335-339.
6. Huh JK, Lim JY, Song CH, et al. Isokinetic evaluation of pronation after volar plating of a distal radius fracture. Injury. 2012;43(2):200-204.
7. Wilkerson GB, Pinerola JJ, Caturano RW. Invertor vs. evertor peak torque and power deficiencies associated with lateral ankle ligament injury. J Orthop Sports Phys Ther. 1997;26(2):78-86.
8. Hudak PL, Amadio PC, Bombardier C, et al. Development of an upper extremity outcome measure: The DASH (disabilities of the arm, shoulder, and head). Am J Ind Med. 1996;29(6):602-608.
9. Gordon KD, Pardo RD, Johnson JA, et al. Electromyographic activity and strength during maximum isometric pronation and supination efforts in healthy adults. J Orthop Res. 2004;22(1):208-213.
10. McConkey MO, Schwab TD, Travlos A, et al. Quantification of Pronator Quadratus Contribution to Isometric Pronation Torque of the Forearm. J Hand Surg Am. 2009;34(9):1612-1617.
11. Jae-Hwi N, Hyun Sk G, Cheol Ho S, et al. Examination of the pronator quadratus muscle. CiOS Clin Orthop Surg. 2014;6(3):267-272.
12. Ploegmakers J, The B, Wang A, et al. Supination and Pronation Strength Deficits Persist at 2-4 Years after Treatment of Distal Radius Fractures. Hand Surg. 2015;20(3):430-434.
13. Häberle S, Sandmann GH, Deiler S, et al. Pronator quadratus repair after volar plating of distal radius fractures or not? Results of a prospective randomized trial. Eur J Med Res. 2015;20(1):93.
14. Hershman SH, Immerman I, Bechtel C, et al. The Effects of Pronator Quadratus Repair on Outcomes After Volar Plating of Distal Radius Fractures. J Orthop Trauma. 2013;27(3):130-133.
15. Ahsan ZS, Yao J. The importance of pronator quadratus repair in the treatment of distal radius fractures with volar plating. HAND. 2012;7(3):276-280.
16. Goslings JC, Mulders MAM, Waienkamp MMJ, et al. Repair of the pronator quadratus after volar plate fixation in distal radius fractures: a systematic review. Strateg Trauma Limb Reconstr. 2017;12(3):181-188.
17. Goonens CK, Van Royen K, Grijseels S, et al. Ultrasonographic evaluation of the distance between the flexor pollicis longus tendon and volar prominence of the plate as a function of volar plate positioning and pronator quadratus repair - A cadaver study. Hand Surg Rehabil. 2018;37(3):171-174.